



EUROPEAN COMMISSION
Directorate-General for Research and Innovation
RTD.C – Clean Planet
C.4 – Euratom Research

AMENDMENT Reference No AMD-847593-35

Grant Agreement number: 847593 — European Joint Programme on Radioactive Waste Management (EURAD)

The parties agree to amend the Grant Agreement as follows ('**Amendment**')

1 . Addition of a linked third party

The following new linked third parties are added:

- UNIVERSITE PAUL SABATIER TOULOUSE III (UT3/LMDC), affiliated or linked to ANDRA — as from 1 June 2021
- EIDGENOESSISCHE TECHNISCHE HOCHSCHULE ZUERICH (ETH), affiliated or linked to NAGRA — as from 1 June 2021
- Jacobs Clean Energy Limited (Jacobs), affiliated or linked to NAGRA — as from 1 June 2021
- HELMHOLTZ ZENTRUM POTSDAM DEUTSCHESGEOFORSCHUNGSZENTRUM GFZ (GFZ), affiliated or linked to JUELICH — as from 1 June 2021
- INSTITUT MINES-TELECOM (IMT/EMSE), affiliated or linked to ANDRA — as from 1 June 2021
- UNIVERSIDAD DE GRANADA (UGR), affiliated or linked to CIEMAT — as from 1 June 2021
- UNIVERSITE JEAN MONNET SAINT-ETIENNE (UJean Monnet), affiliated or linked to CNRS — as from 1 June 2021
- THE UNIVERSITY OF MANCHESTER (UNIMAN), affiliated or linked to RWM — as from 1 June 2021

This implies the **following changes** to the Grant Agreement:

- The new linked third parties and the 'starting date of participation' are added to **Article 14.1**:

"UNIVERSITE PAUL SABATIER TOULOUSE III (UT3/LMDC), affiliated or linked to ANDRA — as from 1 June 2021"

"EIDGENOESSISCHE TECHNISCHE HOCHSCHULE ZUERICH (ETH), affiliated or linked to NAGRA — as from 1 June 2021"

"Jacobs Clean Energy Limited (Jacobs), affiliated or linked to NAGRA — as from 1 June 2021"

“HELMHOLTZ ZENTRUM POTSDAM DEUTSCHESGEOFORSCHUNGSZENTRUM GFZ (GFZ), affiliated or linked to JUELICH — as from 1 June 2021”

“INSTITUT MINES-TELECOM (IMT/EMSE), affiliated or linked to ANDRA — as from 1 June 2021”

“UNIVERSIDAD DE GRANADA (UGR), affiliated or linked to CIEMAT — as from 1 June 2021”

“UNIVERSITE JEAN MONNET SAINT-ETIENNE (UJean Monnet), affiliated or linked to CNRS — as from 1 June 2021”

“THE UNIVERSITY OF MANCHESTER (UNIMAN), affiliated or linked to RWM — as from 1 June 2021”

2 . Addition of an international partner

The following new international partners are added:

- COMMONWEALTH SCIENTIFIC AND INDUSTRIAL RESEARCH ORGANISATION (CSIRO), international partner of NAGRA — as from 1 June 2021
- Nuclear Waste Management Organization of Japan (NUMO), international partner of NAGRA — as from 1 June 2021
- Nuclear Waste Management Organization (NWMO), international partner of NAGRA — as from 1 June 2021

This implies the **following changes** to the Grant Agreement:

- **Article 14a** becomes applicable.

The new international partners and the ‘starting date of participation’ are added to **Article 14a.1** :

"COMMONWEALTH SCIENTIFIC AND INDUSTRIAL RESEARCH ORGANISATION(CSIRO), international partner to NAGRA — as from 1 June 2021"

"Nuclear Waste Management Organization of Japan(NUMO), international partner to NAGRA — as from 1 June 2021"

"Nuclear Waste Management Organization(NWMO), international partner to NAGRA — as from 1 June 2021"

The other options for international partners:

- are added (**Article 4.1**) and
- become applicable (**Article 50.3.1(n)**)

3. Change of Annex 1 (description of the action)

Annex 1 is changed and replaced by the Annex 1 attached to this Amendment.

4 . Changes of Annex 2 (estimated budget)

Annex 2 is changed and replaced by the Annex 2 attached to this Amendment.

5. Change of the estimated eligible costs

The estimated eligible costs of the action set out in **Article 5.2** are changed to:

“**EUR 59 801 442.89** (fifty nine million eight hundred and one thousand four hundred and forty two EURO and eighty nine eurocents)”.

All other provisions of the Grant Agreement and its Annexes remain unchanged.

This Amendment **enters into force** on the day of the last signature.

This Amendment **takes effect** on the date on which the amendment enters into force, except where a different date has been agreed by the parties (for one or more changes).

Please inform the other members of the consortium of the Amendment.

SIGNATURES

For the coordinator

For the Commission

Pierre-Marie ABADIE with ECAS id nabadipi signed in the Participant Portal on 12/10/2021 at 14:08:57 (transaction id SigId-99322-98lew WOmFEZGk7rvbViFhDDvpzJe05l8xyxnrClFeehRufPGCcExU3y0ZjcCD uO7GB8bHkYEzZsNv1Sm7zYA1Gm-yntOf97TTHq7ktbp37lfAm-zLjx2 9SUme4jDCf2h8EGxulSu7uizVCFZjrAvqAKsxzQO7DrcvIhZwtY9yTrgk A0KQqbY24VyygCefjZqXN3dyG). Timestamp by third party at 2021.10.12 15:09:27 CEST

Signed by Yves DEJAEGERE with ECAS id dejaeyv as an authorised representative on 03-11-2021 09:12:27 (transaction id SigId-68857-we3tzykxzPmah4kZDawUZ40c7lbdCCiN1VgPW9xmtjglMTSAzPWtQudz jceE0XeVFOdzoDzjSZOOUU6opvA7qclG-jpJZscgsw0Kj0B2uQKXbFu-C zIBjNopSH2bdHWDVCMXn0OpFbcKGPdFw0pdQYfrzLhLxmbgut9H hx7zLCVfrks0RflzcjSyZDfKuGHwzZEPOg) 2021.11.03 09:12:32 CET

Enclosures:

Annex 2

Annex 1



EUROPEAN COMMISSION

Directorate-General for Research and Innovation

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ANNEX 1 (part A)

COFUND (European Joint Programme)

NUMBER — 847593 — EURAD

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1.1. The project summary

Project Number ¹	847593	Project Acronym ²	EURAD

One form per project

General information

Project title ³	European Joint Programme on Radioactive Waste Management
Starting date ⁴	The first day of the month after the signature by the Commission
Duration in months ⁵	60
Call (part) identifier ⁶	NFRP-2018
Topic	NFRP-2018-6 European Joint Research Programme in the management and disposal of radioactive waste
Fixed EC Keywords	Nuclear
Free keywords	Radioactive Waste Management; Disposal Solutions; Geological Disposal; Science and Technology ; Safety

Abstract ⁷

Following decades of RD&D in support of the safe management and disposal of radioactive waste, and building on the preparatory work of the recent EC JOPRAD project, a European Joint Programme on Radioactive Waste Management (EURAD) is now proposed to coordinate activities on agreed priorities of common interest between European Waste Management Organisations (WMOs), Technical Support Organisations (TSOs) and Research Entities (REs).

Such Joint Programming will complement National RD&D Programmes, by jointly establishing and carrying out activities jointly where there is added value at the European level. It is the logical next step in deepening collaboration between European actors in the field of radioactive waste management (RWM). It builds on existing and emerging networks of European actors (IGD-TP, SITEX and REs network), preceding coordination and support actions (in particular, SecIGD2, SITEX-II project and JOPRAD).

The Joint Programme will generate and manage knowledge to support EU Member States with their implementation of the Directive 2011/70/Euratom (Waste Directive), taking into account the different magnitudes and stages of advancement of Member State National Programmes. This will encompass:

- Supporting Member-States in developing and implementing their national RD&D programmes for the safe long-term management of their full range of different types of radioactive waste through participation in the RWM Joint Programme; in particular:
- Consolidating existing knowledge for the safe start of operation of the first geological disposal facilities for spent fuel, high-level waste, and other long-lived radioactive waste, and supporting optimization linked with the stepwise implementation of geological disposal; and
- Enhancing knowledge management and transfer between organisations, Member-States and generations.

1.2. List of Beneficiaries

Project Number ¹	847593	Project Acronym ²	EURAD

List of Beneficiaries

No	Name	Short name	Country	Project entry date ⁸	Project exit date
1	AGENCE NATIONALE POUR LA GESTION DES DECHETS RADIOACTIFS	ANDRA	France		
2	ARAO-AGENCIJA ZA RADIOAKTIVNE ODPADKE LJUBLJANA ZAVOD	ARAO	Slovenia		
3	BEL V	BEL V	Belgium		
4	BUNDES-GESELLSCHAFT FUR ENDLAGERUNGMBH (BGE)	BGE	Germany		
5	COMMISSARIAT A L ENERGIE ATOMIQUE ET AUX ENERGIES ALTERNATIVES	CEA	France		
6	CENTRO DE INVESTIGACIONES ENERGETICAS, MEDIOAMBIENTALES Y TECNOLOGICAS-CIEMAT	CIEMAT	Spain		
7	PUBLIC UNION CHORNOBYL RESEARCH AND DEVELOPMENT INSTITUTE	ChRDI	Ukraine		
8	CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE CNRS	CNRS	France		
9	CENTRALE ORGANISATIE VOOR RADIOACTIEF AFVAL NV	COVRA	Netherlands		
10	VALSTYBINIS MOKSLINIU TYRIMU INSTITUTAS FIZINIU IR TECHNOLOGIJOS MOKSLU CENTRAS	FTMC	Lithuania		
11	CENTRUM VYZKUMU REZ SRO	CV REZ	Czech Republic		
12	DANSK DEKOMMISSIONERING	Dekom	Denmark		
13	ELLINIKI EPITROPI ATOMIKIS ENERGEIAS	EEAE	Greece		
14	EMPRESA NACIONAL DE RESIDUOS RADIATIVOS S.A.	ENRESA	Spain		
15	FORSCHUNGSZENTRUM JULICH GMBH	JUELICH	Germany		
16	GESELLSCHAFT FUR ANLAGEN UND REAKTORSICHERHEIT (GRS) gGmbH	GRS	Germany		
17	VALSTYBES IMONE IGNALINOS ATOMINE ELEKTRINE	IAE	Lithuania		
18	INSTYTUT CHEMII I TECHNIKI JADROWEJ	INCT	Poland		

1.2. List of Beneficiaries

No	Name	Short name	Country	Project entry date ⁸	Project exit date
19	INSTITUT DE RADIOPROTECTION ET DE SURETE NUCLEAIRE	IRSN	France		
20	INSTITUTO SUPERIOR TECNICO	IST	Portugal		
21	ASSOCIACAO DO INSTITUTO SUPERIOR TECNICO PARA A INVESTIGACAO E DESENVOLVIMENTO	IST ID	Portugal		
22	INSTITUT JOZEF STEFAN	JSI	Slovenia		
23	JRC -JOINT RESEARCH CENTRE- EUROPEAN COMMISSION	JRC	Belgium		
24	KARLSRUHER INSTITUT FUER TECHNOLOGIE	KIT	Germany		
25	LIETUVOS ENERGETIKOS INSTITUTAS	LEI	Lithuania		
26	ENERGIATUDOMANYI KUTATOKOZPONT	MTA EK	Hungary		
27	NATIONALE GENOSSENSCHAFT FUER DIE LAGERUNG RADIOAKTIVER ABFAELLE	NAGRA	Switzerland		
28	NATIONAL CENTER FOR SCIENTIFIC RESEARCH "DEMOKRITOS"	NCSR	Greece		
29	NUCLEAR ENGINEERING SEIBERSDORF GMBH	NES	Austria		
30	NARODNY JADROVY FOND	NJF	Slovakia		
31	NUCLEAR RESEARCH AND CONSULTANCY GROUP	NRG	Netherlands		
32	NATIONALE INSTELLING VOOR RADIOACTIEF AFVAL EN VERRIJKTE SPLIJSTOFFEN	ONDRAF/NIRAS	Belgium		
33	POSIVA OY	POSIVA	Finland		
34	PAUL SCHERRER INSTITUT	PSI	Switzerland		
35	RADIOAKTIV HULLADEKOKAT KEZELO KOZHASZNU NONPROFIT KORLATOLT FELELOSSEGU TARSASAG	PURAM	Hungary		
36	REGIA AUTONOMA TEHNOLOGII PENTRU ENERGIA NUCLEARA - RATEN	RATEN	Romania		
37	RADIOACTIVE WASTE MANAGEMENT LIMITED	RWM	United Kingdom		
38	STUDIECENTRUM VOOR KERNENERGIE / CENTRE	SCK•CEN	Belgium		

1.2. List of Beneficiaries

No	Name	Short name	Country	Project entry date ⁸	Project exit date
	D'ETUDE DE L'ENERGIE NUCLEAIRE				
39	SVENSK KARNBRANSLEHANTERING AKTIEBOLAG	SKB	Sweden		
40	STATE ENTERPRISE STATE SCIENTIFIC AND TECHNICAL CENTER FOR NUCLEAR AND RADIATION SAFETY	SSTC NRS	Ukraine		
41	SLOVENSKA TECHNICKA UNIVERZITA V BRATISLAVE	STUBA	Slovakia		
42	Radioactive Waste Repository Authority	SÚRAO	Czech Republic		
43	STATNI USTAV RADIACNI OCHRANY v.v.i.	SURO	Czech Republic		
44	NEDERLANDSE ORGANISATIE VOOR TOEGEPAST NATUURWETENSCHAPPELIJK ONDERZOEK TNO	TNO	Netherlands		
45	TS ENERCON MERNOKIRODA KFT	TS Enercon	Hungary		
46	TECHNICAL UNIVERSITY OF SOFIA	TUS	Bulgaria		
47	UNIVERSITY OF CYPRUS	UCyprus	Cyprus		
48	HELSINGIN YLIOPISTO	UHelsinki	Finland		
49	UNITED KINGDOM RESEARCH AND INNOVATION	UKRI	United Kingdom		
50	TEKNOLOGIAN TUTKIMUSKESKUS VTT OY	VTT	Finland		
51	VUJE AS	VUJE	Slovakia		

1.3. Workplan Tables - Detailed implementation

1.3.1. WT1 List of work packages

WP Number ⁹	WP Title	Lead beneficiary ¹⁰	Person-months ¹¹	Start month ¹²	End month ¹³
WP1	Programme Management Office	1 - ANDRA	176.30	1	60
WP2	Assessment of Chemical Evolution of ILW and HLW Disposal Cells (ACED)	38 - SCK•CEN	515.70	1	48
WP3	Cement-Organic-Radionuclide-Interactions (CORI)	24 - KIT	534.20	1	48
WP4	Development and Improvement Of NUMerical methods and Tools for modelling coupled processes (DONUT)	1 - ANDRA	517.65	1	48
WP5	Fundamental understanding of radionuclide retention (FUTuRE)	15 - JUELICH	595.10	1	48
WP6	Mechanistic understanding of gas transport in clay materials (GAS)	32 - ONDRAF/NIRAS	667.59	1	60
WP7	Influence of temperature on clay-based material behaviour (HITEC)	50 - VTT	693.20	1	48
WP8	Spent Fuel Characterization and Evolution Until Disposal (SFC)	39 - SKB	652.65	1	48
WP9	Waste management routes in Europe from cradle to grave (ROUTES)	19 - IRSN	172.36	1	60
WP10	Uncertainty Management multi-Actor Network (UMAN)	3 - BEL V	157.59	1	60
WP11	State-of-Knowledge	4 - BGE	126.55	1	60
WP12	Guidance	42 - SÚRAO	100.30	1	60
WP13	Training & Mobility	38 - SCK•CEN	95.67	1	60
WP14	Ethics requirements	1 - ANDRA	N/A	1	60
WP15	CONtainer CORrosion under Disposal conditions (ConCorD)	27 - NAGRA	574.50	25	60
WP16	Chemo-Mechanical AGIng of Cementitious materials (MAGIC)	19 - IRSN	511.33	25	60
WP17	MONitoring equipment and DATA Treatment for Safe repository operation and staged closure (MODATS)	1 - ANDRA	417.70	25	60
Total			6 508.39		

1.3.2. WT2 list of deliverables

Deliverable Number¹⁴	Deliverable Title	WP number⁹	Lead beneficiary	Type¹⁵	Dissemination level¹⁶	Due Date (in months)¹⁷
D1.1	2nd Annual Work Plan	WP1	1 - ANDRA	Report	Confidential, only for members of the consortium (including the Commission Services)	9
D1.2	3rd Annual Work Plan	WP1	1 - ANDRA	Report	Confidential, only for members of the consortium (including the Commission Services)	21
D1.3	4th Annual Work Plan	WP1	1 - ANDRA	Report	Confidential, only for members of the consortium (including the Commission Services)	33
D1.4	5th Annual Work Plan	WP1	1 - ANDRA	Report	Confidential, only for members of the consortium (including the Commission Services)	45
D1.5	PMO - EURAD Quality Management Plan	WP1	1 - ANDRA	Report	Public	3
D1.6	EURAD Data Management Plan	WP1	1 - ANDRA	ORDP: Open Research Data Pilot	Confidential, only for members of the consortium (including the Commission Services)	12
D1.7	EURAD Roadmap, extended with Competence Matrix	WP1	1 - ANDRA	Report	Public	12
D1.8	Process for the extensive update of the EURAD SRA/ Roadmap	WP1	1 - ANDRA	Report	Public	26
D1.9	‘Extensive’ update of the SRA/Roadmap	WP1	1 - ANDRA	Report	Public	44
D1.10	- Identification of Subject Matter/Theme Experts from EURAD Colleges	WP1	1 - ANDRA	Report	Public	12

Deliverable Number¹⁴	Deliverable Title	WP number⁹	Lead beneficiary	Type¹⁵	Dissemination level¹⁶	Due Date (in months)¹⁷
D1.11	EURAD Dissemination strategy	WP1	1 - ANDRA	Report	Public	3
D1.12	EURAD website	WP1	1 - ANDRA	Websites, patents filing, etc.	Public	3
D1.13	List of members of the CS group	WP1	19 - IRSN	Report	Public	6
D1.14	Mid-term evaluation of the ICS activities and experimental model of interaction between EURAD participants and Civil Society	WP1	19 - IRSN	Report	Public	30
D1.15	Integrated review of the ICS activities in EURAD	WP1	19 - IRSN	Report	Public	58
D1.16	Evaluation of experimental model of interaction between EURAD participants and Civil Society	WP1	19 - IRSN	Report	Public	58
D1.17	Evaluation of the impacts of EURAD first implementation phase	WP1	1 - ANDRA	Report	Public	60
D2.1	ACED - State-of-the-art report	WP2	9 - COVRA	Report	Public	6
D2.2	ACED - Updated State-of-the-art report & Summary of major conclusions from the work package	WP2	9 - COVRA	Report	Public	48
D2.3	ACED - Training materials	WP2	38 - SCK•CEN	Report	Public	36
D2.4	ACED - Treatment of chemical evolution in national programmes	WP2	9 - COVRA	Report	Public	5
D2.5	ACED - Experiments and numerical model studies on interfaces	WP2	15 - JUELICH	Report	Public	5
D2.6	ACED Task 2.1 - Technical report on the modelling approach proposed	WP2	27 - NAGRA	Report	Public	15
D2.7	ACED Task 2.1 - Final technical report on the	WP2	19 - IRSN	Report	Public	46

Deliverable Number¹⁴	Deliverable Title	WP number⁹	Lead beneficiary	Type¹⁵	Dissemination level¹⁶	Due Date (in months)¹⁷
	steel/cement material interactions					
D2.8	ACED Task 2.2 - Technical report on the modelling approach proposed	WP2	19 - IRSN	Report	Public	15
D2.9	ACED Task 2.2 - Final technical report on the steel/clay material interactions	WP2	19 - IRSN	Report	Public	46
D2.10	ACED Task 3.1 - HLW: Report describing the selected experiments and the existing/ expected experimental results	WP2	26 - MTA EK	Report	Public	7
D2.11	ACED Task 3.1 - ILW: Report describing the selected experiments and the existing/ expected experimental results	WP2	22 - JSI	Report	Public	7
D2.12	ACED Task 3.1 - HLW: Report describing the results of characterization performed during the project	WP2	5 - CEA	Report	Public	31
D2.13	ACED Task 3.1 - ILW: Report describing the results of characterization performed during the project	WP2	22 - JSI	Report	Public	31
D2.14	ACED Task 3.2 - Report describing the results of modelling, and the recommendations for future experimental and numerical work	WP2	38 - SCK•CEN	Report	Public	46
D2.15	ACED Task 3.3 - Report describing the results of modelling, and the recommendations for future experimental and numerical work	WP2	1 - ANDRA	Report	Public	46

Deliverable Number¹⁴	Deliverable Title	WP number⁹	Lead beneficiary	Type¹⁵	Dissemination level¹⁶	Due Date (in months)¹⁷
D2.16	ACED Task 4.1 - Report on the conceptual model formulation for a mechanistic based model on implementing the initial SOTA knowledge on models and parameters in existing numerical tools	WP2	14 - ENRESA	Report	Public	12
D2.17	ACED Task 4.1 - Report on the integrated model for assessing the chemical evolution in a disposal cell on the simulations with a reactive transport model of the chemical evolution at the disposal cell scale	WP2	19 - IRSN	Report	Public	30
D2.18	ACED Task 4.2 - Report on the conceptualization of upscaling including upscaling & model abstraction methods for the integration of process-level knowledge to disposal cell scale knowledge	WP2	38 - SCK•CEN	Report	Public	24
D2.19	ACED Task 4.2 - Report on comparison of model abstraction results	WP2	15 - JUELICH	Report	Public	45
D2.20	ACED Task 4.3 - Integration report of the work on disposal cell scale chemical evolution	WP2	14 - ENRESA	Report	Public	45
D3.1	CORI - SOTA on cement-organic-radionuclide-interactions in the content of L/ILW disposal	WP3	24 - KIT	Report	Public	6
D3.2	CORI - SOTA UPDATE on cement-organic-radionuclide-interactions in the	WP3	24 - KIT	Report	Public	48

Deliverable Number¹⁴	Deliverable Title	WP number⁹	Lead beneficiary	Type¹⁵	Dissemination level¹⁶	Due Date (in months)¹⁷
	content of L/ILW disposal					
D3.3	CORI - Training Materials	WP3	24 - KIT	Report	Public	8
D3.4	CORI - Training Materials UPDATE	WP3	24 - KIT	Report	Public	48
D3.5	CORI - Final Report integrating the RD&D performed in CORI, including application to the Safety Case	WP3	24 - KIT	Report	Public	48
D3.6	CORI - Final Report on results generated in Task 2 of CORI	WP3	8 - CNRS	Report	Public	44
D3.7	CORI - Final Report on organic retention in cementitious systems	WP3	1 - ANDRA	Report	Public	44
D3.8	CORI - Final Report on radionuclide mobility in cementitious materials in the presence of organics	WP3	5 - CEA	Report	Public	46
D4.1	DONUT - State-of-the-art in the fields of numerical analysis and scientific computing	WP4	1 - ANDRA	Report	Public	6
D4.2	DONUT - Updated State-of-the-art in the fields of numerical analysis and scientific computing	WP4	1 - ANDRA	Report	Public	48
D4.3	DONUT - Training materials	WP4	1 - ANDRA	Report	Public	36
D4.4	DONUT - Report describing the benchmarks to be carried out during the WP	WP4	1 - ANDRA	Report	Public	24
D4.5	DONUT - Technical report describing numerical method improvement and their transferability in numerical tools as well as benchmarks realization	WP4	8 - CNRS	Report	Public	46
D4.6	DONUT - Final report describing	WP4	1 - ANDRA	Report	Public	46

Deliverable Number¹⁴	Deliverable Title	WP number⁹	Lead beneficiary	Type¹⁵	Dissemination level¹⁶	Due Date (in months)¹⁷
	improvement and implementation of scale transition methods to model coupled processes					
D4.7	DONUT - Report describing numerical improvement and developments and their application to treat uncertainty when dealing with coupled processes	WP4	1 - ANDRA	Report	Public	46
D4.8	DONUT - Final report describing benchmark realisations and (i) influence of the development carried out in other tasks on the quantification of improvement (ii) comparison, when possible, of tools on which numerical methods have been implemented	WP4	1 - ANDRA	Report	Public	46
D5.1	FUTuRE - Initial State-of-the-art report on the understanding of radionuclide retention in clay and crystalline rocks	WP5	38 - SCK•CEN	Report	Public	6
D5.2	FUTuRE - Updated State-of-the-art on the understanding of radionuclide retention in clay and crystalline rocks	WP5	38 - SCK•CEN	Report	Public	48
D5.3	FUTuRE - Related deliverable: D5.4 Training materials	WP5	15 - JUELICH	Report	Public	36
D5.4	FUTuRE - Final technical report on radionuclide mobility in compacted clay systems	WP5	34 - PSI	Report	Public	48
D5.5	FUTuRE - Final technical report on radionuclide mobility in crystalline systems	WP5	15 - JUELICH	Report	Public	48

Deliverable Number¹⁴	Deliverable Title	WP number⁹	Lead beneficiary	Type¹⁵	Dissemination level¹⁶	Due Date (in months)¹⁷
D5.6	FUTuRE - Final report on reversibility of sorption	WP5	34 - PSI	Report	Public	48
D5.7	FUTuRE - Final technical report on redox reactivity of radionuclides on mineral surfaces	WP5	1 - ANDRA	Report	Public	48
D6.1	GAS - Initial State-of-the-art (SOTA) report on gas transport through clay materials	WP6	32 - ONDRAF/NIRAS	Report	Public	18
D6.2	GAS - Updated State-of-the-art (SOTA) report on gas transport through clay materials	WP6	32 - ONDRAF/NIRAS	Report	Public	60
D6.3	GAS - Training materials of the 1st GAS/HITEC Joint training course (copy of the presentations of each doctoral school organised during the course of the project)	WP6	32 - ONDRAF/NIRAS	Report	Public	3
D6.4	GAS - Training materials of the 2nd GAS/HITEC Joint training course (copy of the presentations of each doctoral school organised during the course of the project)	WP6	32 - ONDRAF/NIRAS	Report	Public	48
D6.5	GAS - Book of proceedings of the final GAS workshop	WP6	32 - ONDRAF/NIRAS	Report	Public	60
D6.6	GAS - Technical report of the GAS WP	WP6	32 - ONDRAF/NIRAS	Report	Public	60
D6.7	GAS - Technical report Gas Transport Mechanisms including diffusion, retention and advective processes in clay	WP6	49 - UKRI	Report	Public	57
D6.8	GAS - Technical report on barrier integrity	WP6	27 - NAGRA	Report	Public	57
D6.9	GAS - Technical report on conceptualisation	WP6	1 - ANDRA	Report	Public	57

Deliverable Number¹⁴	Deliverable Title	WP number⁹	Lead beneficiary	Type¹⁵	Dissemination level¹⁶	Due Date (in months)¹⁷
	and evaluation at the repository scale					
D7.1	HITEC - Initial State-of-the-art on THM behaviour of i) buffer clay materials and of ii) host clay materials	WP7	6 - CIEMAT	Report	Public	6
D7.2	HITEC -Updated State-of-the-art on THM behaviour of i) buffer clay materials and of ii) host clay materials	WP7	6 - CIEMAT	Report	Public	48
D7.3	HITEC -Final technical report on thermal effects on near field properties	WP7	8 - CNRS	Report	Public	46
D7.4	HITEC -Specific GAS/HITEC technical report on self-sealing processes	WP7	1 - ANDRA	Report	Public	46
D7.5	HITEC -Final technical report on effect of temperature on far field properties	WP7	8 - CNRS	Report	Public	46
D7.6	HITEC - Final modelling report on effect of temperature on near field properties	WP7	1 - ANDRA	Report	Public	46
D7.7	HITEC - technical report on Material characterisation – Task 3.1 final results	WP7	39 - SKB	Report	Public	46
D7.8	HITEC - HITEC technical report on test at high temperature – Task 3.2 final results	WP7	49 - UKRI	Report	Public	46
D7.9	HITEC - Experimental works (small and mid-scale laboratory experiments) – final report (Results of the experimental works of T3.3)	WP7	6 - CIEMAT	Report	Public	46
D7.10	HITEC - Modelling – final report (Results of all modelling task carried in T3.3 in	WP7	6 - CIEMAT	Report	Public	46

Deliverable Number¹⁴	Deliverable Title	WP number⁹	Lead beneficiary	Type¹⁵	Dissemination level¹⁶	Due Date (in months)¹⁷
	cooperation with DONUT					
D7.11	HITEC - Guidance for safety case development and repository optimization	WP7	27 - NAGRA	Report	Public	46
D7.12	HITEC - Final report on Influence of temperature on clay-based material behaviour	WP7	50 - VTT	Report	Public	48
D8.1	SFC - State-of-the-art report	WP8	27 - NAGRA	Report	Public	6
D8.2	SFC - Updated State-of-the-art report	WP8	27 - NAGRA	Report	Public	48
D8.3	SFC - Summary of training materials produced during the SFC WP	WP8	6 - CIEMAT	Report	Public	48
D8.4	SFC - principles and performance of NDA systems and innovative detection techniques used for the characterisation of SNF samples and assemblies	WP8	23 - JRC	Report	Public	36
D8.5	SFC - results of the characterisation of SNF samples by NDA and radiochemical analysis: results from subtasks 2.2 and 2.3	WP8	38 - SCK•CEN	Report	Public	48
D8.6	SFC - performance of “sophisticated” and “best-practice industry” codes based on SKB-50 data and data produced in subtask 2.2 and 2.3	WP8	34 - PSI	Report	Public	48
D8.7	SFC - recommended procedures to determine the SNF source terms	WP8	39 - SKB	Report	Public	48
D8.8	SFC - Thermo-mechanical-chemical properties of unirradiated and irradiated samples of spent nuclear fuel rod segments and cladding	WP8	24 - KIT	Report	Public	48

Deliverable Number¹⁴	Deliverable Title	WP number⁹	Lead beneficiary	Type¹⁵	Dissemination level¹⁶	Due Date (in months)¹⁷
D8.9	SFC - Influence of oxygen and fission products on microstructure of UO ₂ fuel and He within the UO ₂ matrix	WP8	15 - JUELICH	Report	Public	48
D8.10	SFC - Chemical and structural / crystallographic properties of simulated fuel pellets and irradiated fuel pellets at the cladding/fuel interface	WP8	24 - KIT	Report	Public	48
D8.11	SFC - Identification and analysis of potential accident scenarios for fuel assembly damage and fuel material release during fuel handling in an interim storage and/or packaging facility	WP8	27 - NAGRA	Report	Public	36
D8.12	SFC - Assessment of fuel performances for a postulated accident scenario under storage conditions: re-criticality, integrity under mechanical loads and container degradation studies	WP8	6 - CIEMAT	Report	Public	48
D8.13	SFC - Analysis of the dynamics of the state-of-emergency radioactive waste packages from the Chernobyl catastrophe	WP8	7 - ChRDI	Report	Public	36
D9.1	ROUTES - Training materials	WP9	19 - IRSN	Report	Public	60
D9.2	ROUTES - Recommendations for future RD&D, strategic study and KM activities for the 2nd wave of EURAD-1	WP9	19 - IRSN	Report	Public	18
D9.3	ROUTES - Recommendations for future RD&D, strategic study and KM activities	WP9	19 - IRSN	Report	Public	58

Deliverable Number¹⁴	Deliverable Title	WP number⁹	Lead beneficiary	Type¹⁵	Dissemination level¹⁶	Due Date (in months)¹⁷
	for future European collaboration					
D9.4	ROUTES - Overview of existing work on categorization/ classification of RWs in participating states	WP9	1 - ANDRA	Report	Public	10
D9.5	ROUTES - Overview of issues related to challenging wastes	WP9	1 - ANDRA	Report	Public	24
D9.6	ROUTES - Common understanding of the practical issues on waste management routes	WP9	1 - ANDRA	Report	Public	48
D9.7	ROUTES - Review of radioanalytical characterisation of selected radioactive wastes and wastes with complex chemical and toxic properties	WP9	15 - JUELICH	Report	Public	24
D9.8	ROUTES - Review of characterization of legacy and historical wastes	WP9	15 - JUELICH	Report	Public	33
D9.9	ROUTES - Report suggestions for the management of challenging wastes while maintaining compatibility with the option(s) for disposal	WP9	50 - VTT	Report	Public	40
D9.10	ROUTES - Report about the knowledge for existing and potential disposal options for SIMS	WP9	28 - NCSR	Report	Public	24
D9.11	ROUTES - Report presenting the results of the workshop dealing with possible conditioning routes for SIMS	WP9	29 - NES	Report	Public	36
D9.12	ROUTES - Studies and plans for developing shared solutions for radioactive waste management in Europe	WP9	9 - COVRA	Report	Public	12

Deliverable Number¹⁴	Deliverable Title	WP number⁹	Lead beneficiary	Type¹⁵	Dissemination level¹⁶	Due Date (in months)¹⁷
D9.13	ROUTES - Case studies of shared development and use of technologies and facilities	WP9	5 - CEA	Report	Public	24
D9.14	ROUTES - Report on the feasibility of developing further European shared solutions for waste management from cradle to grave	WP9	9 - COVRA	Report	Public	42
D9.15	Scoping of ROUTES, initial CS input and ICS action plan (task 7.1)	WP9	22 - JSI	Report	Public	11
D9.16	Implementation of the ROUTES ICS action plan first phase - CS discussion and input focused on the first topic identified in the ICS action plan (task 7.2)	WP9	19 - IRSN	Report	Public	23
D9.17	Implementation of the ROUTES ICS action plan second phase - CS discussion and input focused on the second topic identified in the ICS action plan (task 7.2)	WP9	19 - IRSN	Report	Public	35
D9.18	Implementation of the ROUTES ICS action plan third phase - CS discussion and input focused on the third topic identified in the ICS action plan (task 7.2)	WP9	19 - IRSN	Report	Public	47
D9.19	Final synthesis ROUTES report of the work and results of task 7 including the documentation of the interaction framework developed, including recommendations for future CS interaction	WP9	22 - JSI	Report	Public	60
D9.20	Contribution to ROUTES factsheet presenting the results	WP9	19 - IRSN	Report	Public	60

Deliverable Number¹⁴	Deliverable Title	WP number⁹	Lead beneficiary	Type¹⁵	Dissemination level¹⁶	Due Date (in months)¹⁷
	and outcomes of ROUTES and in a larger context					
D9.21	ROUTES - Report on Evaluation of existing predisposal routes for SIMS with regard to disposal options. The final report is an updated version of the milestone MS289	WP9	28 - NCSR	Report	Public	44
D9.22	ROUTES - Summary report on analysis, assessment and evaluation of disposal options for SIMS (taking into account both potential disposal options and predisposal routes) including Annex: C case studies on typical waste pathways. The final report is an update	WP9	28 - NCSR	Report	Public	55
D10.1	UMAN - Training materials	WP10	3 - BEL V	Report	Public	48
D10.2	UMAN - Strategies for managing uncertainties	WP10	50 - VTT	Report	Public	36
D10.3	UMAN - Uncertainty identification, classification and quantification	WP10	15 - JUELICH	Report	Public	36
D10.4	UMAN - Methodological approaches to uncertainty and sensitivity analysis	WP10	24 - KIT	Report	Public	48
D10.5	UMAN - Uncertainties relevant to the safety case	WP10	8 - CNRS	Report	Public	36
D10.6	UMAN - Views of the different actors on the identification, characterization and potential significance of uncertainties on waste inventory and on the impact of predisposal steps	WP10	38 - SCK•CEN	Report	Public	36

Deliverable Number¹⁴	Deliverable Title	WP number⁹	Lead beneficiary	Type¹⁵	Dissemination level¹⁶	Due Date (in months)¹⁷
D10.7	UMAN - Views of the different actors on the identification, characterization and potential significance of uncertainties on site and geosphere	WP10	36 - RATEN	Report	Public	36
D10.8	UMAN - Views of the different actors on the identification, characterization and potential significance of uncertainties on human aspects	WP10	1 - ANDRA	Report	Public	36
D10.9	UMAN - Views of the different actors on the identification, characterization and potential significance of uncertainties associated with spent fuel	WP10	6 - CIEMAT	Report	Public	48
D10.10	UMAN - Analysis and description of groups of different actors	WP10	4 - BGE	Report	Public	12
D10.11	UMAN - Study on management options for different types of uncertainties and programme phases	WP10	27 - NAGRA	Report	Public	42
D10.12	UMAN - Identification, analysis and description of preferences of different actors on uncertainty management options	WP10	31 - NRG	Report	Public	48
D10.13	UMAN - Understanding of uncertainty management by the various stakeholders	WP10	24 - KIT	Report	Public	40
D10.14	UMAN - Pluralistic analysis of uncertainty pictures	WP10	19 - IRSN	Report	Public	40
D10.15	UMAN - Pluralistic analysis of uncertainty management options and preferences of stakeholders vis-	WP10	1 - ANDRA	Report	Public	48

Deliverable Number¹⁴	Deliverable Title	WP number⁹	Lead beneficiary	Type¹⁵	Dissemination level¹⁶	Due Date (in months)¹⁷
	à-vis uncertainty management					
D10.16	UMAN - Methods for a pluralistic assessment of uncertainties and their management along the disposal programme	WP10	19 - IRSN	Report	Public	48
D10.17	UMAN - Synthetic mapping of the stakes related to WP UMAN outcomes from a civil society point of view	WP10	19 - IRSN	Report	Public	48
D10.18	UMAN - Views of the different actors on the identification, characterization and potential significance of uncertainties on the near-field.	WP10	34 - PSI	Report	Public	57
D10.19	UMAN - Identification, analysis and description of preferences of different actors on options for managing uncertainties related to the near field	WP10	16 - GRS	Report	Public	57
D10.20	UMAN - Application of the methods for a pluralistic assessment of uncertainties and their management to near-field uncertainties.	WP10	19 - IRSN	Report	Public	60
D11.1	Screening and review of existing/ available knowledge management approaches and/or tools	WP11	15 - JUELICH	Report	Public	13
D11.2	List of selected demonstration cases, criteria for final selection, proposal and estimation of effort and resources	WP11	4 - BGE	Report	Public	9
D11.3	Outcomes of the demonstration cases	WP11	4 - BGE	Report	Public	22
D11.4	Procedures to Involve Knowledge providers	WP11	4 - BGE	Report	Public	13

Deliverable Number¹⁴	Deliverable Title	WP number⁹	Lead beneficiary	Type¹⁵	Dissemination level¹⁶	Due Date (in months)¹⁷
D11.5	QA procedures for the generation of SoK demonstration cases	WP11	40 - SSTC NRS	Report	Public	4
D11.6	revised QA procedures	WP11	40 - SSTC NRS	Report	Public	19
D11.7	Contribute to establishment of the initial SoK Roadmap Mapping and Gap Analysis led by WP1 (PMO)	WP11	4 - BGE	Report	Public	24
D11.8	KM SoK - Authors Guidance & Template	WP11	4 - BGE	Report	Public	24
D11.9	KM SoK - Specification of the EURAD KM platform	WP11	15 - JUELICH	Report	Public	36
D11.10	KM SoK - Feedback mechanism for Domain Insights, SoK documents and KM Systems –Methods and results	WP11	40 - SSTC NRS	Report	Public	36
D12.1	KM Guidance - PLANMAN Guide - Updated version of the PLANDIS Guide consistent with the EJP Roadmap and including perspectives of the TSOs needs (PLANMAN Guide)	WP12	42 - SÚRAO	Report	Public	12
D12.2	KM Guidance - Quality management procedure for PLANMAN development (incl. review and approval procedure)	WP12	42 - SÚRAO	Report	Public	12
D12.3	KM Guidance - approved list of prioritized topics for fourther guidance documents and selection of one topic for the development of a pilot guide	WP12	42 - SÚRAO	Report	Public	22
D12.4	KM Guidance - Development of the Pilot Guide	WP12	42 - SÚRAO	Report	Public	29

Deliverable Number¹⁴	Deliverable Title	WP number⁹	Lead beneficiary	Type¹⁵	Dissemination level¹⁶	Due Date (in months)¹⁷
D12.5	KM Guidance - Updated list of prioritized topics for future guidance documents	WP12	42 - SÚRAO	Report	Public	29
D12.6	KM Guidance - Final report on the PLANMAN Guide and the subsequent detailed Guidance, overall conclusions and recommendations	WP12	42 - SÚRAO	Report	Public	60
D12.7	KM Guidance - Contribution to the EURAD Roadmap Gap Analyses – Identifying Existing and Missing Guidance Documents	WP12	42 - SÚRAO	Report	Public	25
D13.1	KM Training - List of training needs from the RD&D and SS WPs	WP13	38 - SCK•CEN	Report	Public	3
D13.2	KM Training - Mapping of available course material	WP13	38 - SCK•CEN	Report	Public	8
D13.3	KM Training - Alignment of the available course material with the Roadmap	WP13	38 - SCK•CEN	Report	Public	12
D13.4	KM Training - Priority list and schedule for training/mobility	WP13	38 - SCK•CEN	Report	Public	12
D13.5	KM Training - Quality criteria and training specification as a reference guide of requirements and expectations of the training courses to be developed	WP13	38 - SCK•CEN	Report	Public	9
D13.6	KM Training - Implementation of first training courses developed and implemented depending on the priorities identified and approved within the EJP	WP13	38 - SCK•CEN	Report	Public	13

Deliverable Number¹⁴	Deliverable Title	WP number⁹	Lead beneficiary	Type¹⁵	Dissemination level¹⁶	Due Date (in months)¹⁷
D13.7	KM Training - Specification document of the content, material, and learning outcomes of mobility training e.g. in relation with a curricular of S/T knowledge acquisition targets	WP13	43 - SURO	Report	Public	12
D13.8	KM Training - Development of mobility programme	WP13	43 - SURO	Report	Public	13
D13.9	KM Training - Update on training courses organized by EURAD	WP13	38 - SCK•CEN	Report	Public	36
D13.10	KM Training - Update on mobility actions organized by EURAD	WP13	43 - SURO	Report	Public	36
D13.11	KM Training - Overview of webinars organized in the first three years of EURAD	WP13	38 - SCK•CEN	Report	Public	38
D13.12	KM Training - Update on the website of the School of RWM	WP13	38 - SCK•CEN	Websites, patents filing, etc.	Public	32
D13.13	KM Training - Overview of School of RWM training and mobility activities in EURAD-1	WP13	38 - SCK•CEN	Report	Public	60
D14.1	EPQ - Requirement No. 1	WP14	1 - ANDRA	Ethics	Confidential, only for members of the consortium (including the Commission Services)	12
D14.2	EPQ - Requirement No. 2	WP14	1 - ANDRA	Ethics	Confidential, only for members of the consortium (including the Commission Services)	12
D14.3	EPQ - Requirement No. 3	WP14	1 - ANDRA	Ethics	Confidential, only for members of the consortium (including the Commission Services)	12

Deliverable Number¹⁴	Deliverable Title	WP number⁹	Lead beneficiary	Type¹⁵	Dissemination level¹⁶	Due Date (in months)¹⁷
D15.1	ConCorD - State-of-the-Art	WP15	16 - GRS	Report	Public	30
D15.2	ConCorD - SOTA update	WP15	16 - GRS	Report	Public	59
D15.3	ConCorD - Training materials	WP15	38 - SCK•CEN	Report	Public	35
D15.4	ConCorD - Updated training materials	WP15	38 - SCK•CEN	Report	Public	59
D15.5	ConCorD - Report on novel material choices for HLW/ SF containers	WP15	1 - ANDRA	Report	Public	36
D15.6	ConCorD - Report on novel materials properties: corrosion/durability and mechanical performance	WP15	50 - VTT	Report	Public	59
D15.7	ConCorD - Elucidation of critical irradiation parameter	WP15	27 - NAGRA	Report	Public	52
D15.8	ConCorD - Synthesis of irradiation results under repository conditions	WP15	8 - CNRS	Report	Public	55
D15.9	ConCorD - Experimental set-up and first results on the impact of irradiation, dry density, particle size and O2 on the microbial community	WP15	42 - SÚRAO	Report	Public	42
D15.10	ConCorD - Integration of the findings on the impact of irradiation, dry density, particle size, and O2 on the microbial community	WP15	15 - JUELICH	Report	Public	59
D15.11	ConCorD - Designation of boundary conditions and experimental approach	WP15	42 - SÚRAO	Report	Confidential, only for members of the consortium (including the Commission Services)	30
D15.12	ConCorD - Identification of the effect of transient processes on corrosion	WP15	42 - SÚRAO	Report	Public	57

Deliverable Number¹⁴	Deliverable Title	WP number⁹	Lead beneficiary	Type¹⁵	Dissemination level¹⁶	Due Date (in months)¹⁷
D15.13	ConCorD - Task 6 report on modelling at the disposal scale and the implications for performance assessment	WP15	15 - JUELICH	Report	Public	59
D15.14	ConCorD - ConCorD final synthesis report	WP15	27 - NAGRA	Report	Public	60
D16.1	MAGIC - T1- Initial State of the Art on the chemo-mechanical evolution of cementitious materials in disposal conditions	WP16	19 - IRSN	Report	Public	36
D16.2	MAGIC - T1- Updated State-of-the-art report & Summary of major conclusions from the work package	WP16	19 - IRSN	Report	Public	58
D16.3	MAGIC - T2- Report on selected experiments for assessing the evolution of concrete, their mechanical safety functions and performance targets	WP16	9 - COVRA	Report	Public	30
D16.4	MAGIC - T2 – Technical report on the results of the selected experiments for assessing the evolution of the studied types of concrete	WP16	1 - ANDRA	Report	Public	55
D16.5	MAGIC - S/T 3-4 - Initial synthesis of experimental data for calibration and validation of macroscopic models in Task 4.	WP16	8 - CNRS	Report	Public	53
D16.6	MAGIC - S/T 3-3 - Report on Bio-Chemical processes controlling microstructural evolution and mechanical strength	WP16	38 - SCK•CEN	Report	Public	56
D16.7	MAGIC - T3 - Report on micro scale chemo-mechanical modelling	WP16	34 - PSI	Report	Public	56

Deliverable Number¹⁴	Deliverable Title	WP number⁹	Lead beneficiary	Type¹⁵	Dissemination level¹⁶	Due Date (in months)¹⁷
	of leaching and carbonation and parameters upscaling					
D16.8	MAGIC - S/T 4-1 – 4/2 -Chemo-mechanical numerical coupling development and up-scaling methods	WP16	15 - JUELICH	Report	Public	44
D16.9	MAGIC - S/T 4-3 Chemo-mechanical processes in safety structures	WP16	1 - ANDRA	Report	Public	56
D17.1	MODATS – Initial State-of-the-art	WP17	1 - ANDRA	Report	Public	32
D17.2	MODATS – Final State-of-the-art	WP17	1 - ANDRA	Report	Public	58
D17.3	MODATS - Lessons from URL Experiments	WP17	50 - VTT	Report	Public	36
D17.4	MODATS - Guidance on Quality Assurance Project Plans (QAPPs)	WP17	50 - VTT	Report	Public	48
D17.5	MODATS - Enhanced System Understanding, Multi-Party Dialogue	WP17	19 - IRSN	Report	Public	57
D17.6	MODATS - Task 2 Integrated Report: Data Treatment for Increased Confidence in Repository Monitoring	WP17	50 - VTT	Report	Public	58
D17.7	MODATS - Synthesis Report on Innovative and Enhanced Equipment for Repository Monitoring	WP17	1 - ANDRA	Report	Public	57
D17.8	MODATS - Interaction of the MODATS WP with EURAD Knowledge Management Work Packages – Synthesis Report	WP17	40 - SSTC NRS	Report	Public	58
D17.9	MODATS - Final report Monitoring Equipment and Data Treatment for Safe Repository Operation and Staged Closure	WP17	50 - VTT	Report	Public	60

1.3.3. WT3 Work package descriptions

Work package number ⁹	WP1	Lead beneficiary ¹⁰	1 - ANDRA
Work package title	Programme Management Office		
Start month	1	End month	60

Objectives

The 'Programme Management Office' (PMO) has a strategic role in ensuring the overall coordination of the deployment of EURAD. More specifically, the PMO ensures:

- Day-to-day management of the administrative, legal and financial aspects;
- Internal communication between EURAD Beneficiaries (Mandated Actors);
- Reporting to and interfaces with EC;
- Overall scientific and technical coordination/ integration/ evaluation of impacts (RD&D, Strategic Studies and KM, interaction with Civil Society)
- Interfaces with third parties;
- Dissemination of EURAD progress and overall results (of RD&D WPs, Strategic Studies WPs and KM WPs) and outreach activities.

Description of work and role of partners

WP1 - Programme Management Office [Months: 1-60]

ANDRA, BEL V, CNRS, IRSN, JSI, JRC, RWM

Description of work

Task 1 - Management and coordination of the administrative, legal and financial aspects

Start Date: Month 1 – End Date: Month 60

Task Leader: [Andra]

The PMO is in charge of the day-to-day management of the administrative, legal and financial aspects of EURAD. This includes:

- Developing a Quality Management Plan (D1.5) that will describe all the procedures for a smooth coordination and fulfilment of obligations as stated in the Grant Agreement and the Consortium Agreement (this includes procedures for assuring reporting standards, check of industrial or intellectual property rights, risk management, respect of ethical EU standards etc.)
- Managing any update of the Consortium Agreement and Grant Agreement;
- Coordinating the preparation and submission to EC of the Annual Periodic Reports (administrative and financial aspects);
- Coordinating the preparation and submission to EC of the Annual Work Plans (D1.1, D1.2, D1.3 and D1.4);
- Monitoring of the budget, ensure that the overall budget is in line with the commitment and in case of significant changes propose to the General Assembly adequate amendments.
- Assistance to the Consortium for administrative and financial aspects;
- Intellectual Property Rights rules establishment and follow-up, development of the EURAD Data Management Plan (D1.6)

Task 2 – Overall scientific and technical coordination/integration/evaluation of impacts (RD&D, Strategic Studies and KM)

Start Date: Month 1 – End Date: Month 60

Task contributors [CNRS] [RWM] [IRSN] [JRC] [Andra]

At WP level, it is reminded that the scientific and technical coordination of a WP is done by the WP Board. At EURAD level, and as a permanent mission, the PMO shall ensure appropriate coordination and integration of the overall programme of activities (RD&D, Strategic Studies and Knowledge Management) for an effective deployment of the objectives, in line with EURAD SRA and Roadmap.

The PMO shall :

- Establish monitoring and evaluation criteria to assess EURAD outputs, early affects and long-term impacts constructed (this will be integrated in the Quality Management Plan). This will serve as the basis for the development of a set of key performance indicators (KPI) and shall be in alignment with the Strategic Research Agenda and the Roadmap in order to analyse the impacts of EURAD work on strategies for RWM. Such KPIs shall help measuring outcomes

and impacts towards the phases of the Roadmap and in terms which can also be assessed by decision makers (EC, Programme Owners). The list of KPIs will be annually assessed and revised and sent for review to EC in the framework of EC annual reviews of the EJP. As part of this task, and towards the end of the action the PMO shall prepare a tool (e.g. questionnaire aligned to the Waste Directive) for getting the views from national programme owners on EURAD impacts during phase 1.

- In addition to KPIs, the PMO will actively maintain and monitor a Risk Register to document those risks identified within each Work Package that may impact the overall performance of the EJP. With respect to the DONUT Work Package (and other WPs that require significant coordination and strategic oversight to ensure consistency and continued support by each College), it is anticipated that a key risk will be raised that relates to meeting the needs of safety assessment end-users with a focus on generic methodologies (exact wording to be agreed). This risk will be managed through identified mitigation measures to be developed and continuously monitored together with the WP Leader, Key WP Contributors from each College, and the PMO.

- Propose and ensure the implementation of a set of criteria for monitoring the performance of each Work Package and regularly update the report on the evolution of the implementation;

- Ensure, in liaison with the WP Leaders that quality control and quality assurance practice is applied.

- Ensure that the quality of the scientific/technical reporting from each WP is adequate and that uniform standards are applied;

- Coordinate the preparation of the scientific/technical aspects of the Annual Reports based on the inputs provided by the WP Boards;

- Coordinate the preparation of the Annual Work Plans (scientific/technical aspects) based on the inputs provided by the WP Boards;

- Ensure and enhance that activities at interfaces among WPs are properly implemented and developed by the WP Boards (e.g. joint workshops between WPs, identification of clear experimental boundary conditions, which allow better exchange between model and experimental teams, development of KPI to monitor the performance of these exchanges);

- Ensure effective internal scientific/technical communication and transfer of results from WPs to WPs, and effective coordination of the communities of practice.

Task 3 – Support the Bureau/General Assembly in the extension/update of the SRA and the Roadmap

Start Date: Month 1 – End Date: Month 60

Task contributors [CNRS] [RWM] [IRSN] [JRC] [Andra]

The SRA and the Roadmap form the backbone for handling and visualizing the overall situation with respect to the scientific-technical state-of-the-art, the state of knowledge, research needs, needs for and access to guidance, competence needs and tools for knowledge transfer, along with the different phases of a RWM programme. The SRA/Roadmap is also an important input for identifying future work programme priorities (RD&D, Strategic Studies and KM) and up-dating the work programme. It is also the tool for identifying and structuring expert support and the activities of Communities of Practice for different field (see WP1-Task 4). Finally, the SRA/Roadmap is a valuable tool for visualizing EURAD progress, i.e. fields where needs are met and the overall RWM situation thus has improved.

The PMO shall support the Bureau/General Assembly in the exercise that consists of extending/updating the SRA and the Roadmap. During EURAD-1, the following exercises are anticipated:

- [Year 1] Roadmap Extension - Complete EURAD Roadmap with a Competency Matrix, to identify competencies for different Actors (WMOs, TSOs and REs) and to map existing/available SoK, Guidance and Training material (open access) against Themes of EURAD SRA for different phases of implementation of a RWM programme. This shall support identification of the key need-gaps, which will then be used to prioritise the scope of each of the main KM WPs. This task will be undertaken by the PMO, with inputs from participants of the KM WPs and with oversight and guidance by the appointed Joint Programme Fellows/Experts (Deliverable 1.7)

- [Year 2] Process for the extensive update of the SRA / Roadmap including comments that could have been part of the soft update, e.g. assessing the level of common interest of topics that emerged lately in the process of developing the SRA; identification of emerging RD&D needs and assess level of common interest. (Deliverable 1.8)

- [Year 4-5] ‘Extensive’ update of the SRA/Roadmap (exact timing to be adjusted in order to be in line with Euratom work programme) to coincide with preparation and prioritisation of the scope of the potential EURAD2. During this extensive update, it is anticipated that significant changes may result to take account of learning from EURAD-1 and align the Vision, SRA, Roadmap and RD&D, Strategic Studies and KM Work Packages scope and methodologies with how things evolve, particularly with respect to the JP governance scheme and how the criteria used to identify needs of the WMOs, TSOs and REs. (Deliverable 1.9)

Task 4 –Identification of Subject Matter/Theme Experts from EURAD Colleges

Start Date: Month 1 – End Date: Month 60

Task contributors [CNRS] [RWM] [IRSN] [JRC] [Andra] [Bel V]

Recognising that good Knowledge Management is as much about people, as it is about documentation, the PMO at initiation will issue invitations to WMO, TSO and RE Colleges to identify subject matter experts against each of the Roadmap Sub-themes/topics (Deliverable 1.9) as well as experts having a broad overview of a RWM programme. Those identified experts will be able to provide adhoc technical support for a set term (possibly be reviewed/updated annually). The approach is that we utilise those identified to guide Roadmap updates and Joint Programme Knowledge Management Activities, to oversee and direct (with limited effort) SoK (WP11), Guidance (WP12) and Training (WP13) efforts in collaboration with the KM Work Package Leaders. Our ambition is that by identifying experts upfront, we have a clear and transparent framework while reducing the administrative efforts for the PMO and Colleges for technical review and the oversight activities.

Candidates would be colleagues that those working in the RWM community can turn to for their insights and experience and with a set allocation of volunteered hours dedicated to providing input and advice. Committed to passing on their knowledge, appointed experts would focus purely on the science of developing documents or organisation of the State of Knowledge for their given field, and only at the request of the KM WPs.

Task 5 – Internal communication and meetings of the Consortium

Task contributors [CNRS] [RWM] [IRSN] [JRC] [Andra] [Bel V]

Start Date: Month 1 – End Date: Month 60

The PMO shall coordinate the organisation of EURAD Consortium meetings, as described in the Governance section (section 3.5.1), Kick-off meeting, General Assemblies, EURAD Annual Meetings, Bureau meetings and PMO/WP Boards meetings.

In addition to these regular meetings, the PMO shall ensure the internal communication through:

- Management of a private Intranet section only accessible by EURAD Participants (Beneficiaries and Linked Third Parties) in order to facilitate exchanges between them. Specific access rights will be provided individually depending on the role of each contributor;
- Regularly updated distribution/contact lists;
- Regular transfer of information about EURAD implementation

Task 6 – Dissemination

Task contributors [CNRS] [RWM] [IRSN] [JRC] [Andra]

Start Date: Month 1 – End Date: Month 60

Subtask 6.1 - Dissemination Strategy

Given the wide scope and objectives of EURAD, it will be of high value to come up with a cohesive, consistent and concise dissemination strategy that highlights both methodological and technical/scientific achievements made within EURAD. More specifically, a Dissemination Strategy (D1.11) will be developed at the PMO level to identify the key messages to be delivered, the target audiences to be addressed, the method/channels to address them, and the timing and process of dissemination.

A first version of this strategy shall be available in its first version at month 3. It will be then updated periodically after each annual periodic report (at month 14, 26, 38, 50 and 60+2) and validated by the GA.

Subtask 6.2 - Tools to deploy the Dissemination Strategy

Dissemination tools will be developed which help in the raising of awareness concerning the Joint Programme goals and results/achievements. These tools will include a website, annual EURAD meetings, newsletters, etc.

a) Development, update and maintenance of a website

As a communication tool with the broader community, a public website (D1.12) will be developed and maintained for disseminating the Joint Programme objectives, main results and achievements, as well as main open events and workshops.

b) Newsletters

EURAD newsletters will be issued on a quarterly basis in order to keep all interested parties informed on EURAD activities. This newsletter will be sent by email to all interested parties, and will also be made available on EURAD website.

c) Briefs and news papers

EURAD will be a step change in the visibility of European research on RWM. The voice of EURAD shall therefore be solicited on key research findings for example for press statements, newspaper articles, public hearings etc.

d) EURAD Annual Meetings

EURAD Meetings will be organised on an annual basis with the main objectives to i) disseminate EURAD on-going activities, results and achievements to the large RWM community ii) explore new ideas that may be developed in the framework of EURAD-1 (2nd wave of RD&D/Strategic Studies, annual work programme of the KM activities) iii) organise sessions in the framework the Interactions with Civil Society activities; iv) initiate or deepen collaborations with organisations such as IAEA, NEA, NUGENIA, ENEN, etc.

e) Presentation of EURAD in international/European/national events/forums.

Personal contacts and presentations through attendance at relevant workshops, conferences, and events are important channels for the dissemination of EURAD results. Networking remains a crucial way to exchange, give information about EURAD, and keep informed about the latest developments and outcomes. Non-exhaustive list of external events related to RWM: IGD-TP events, SITEX events, IAEA events, NEA events, NUGENIA events, ENEF Forum, EURADWASTE, Clay Conference, Annual Waste Management Conference, national and local events, etc.

Task 7 - EURAD in the international arena

Task Leader: [Andra]

Start Date: Month 1 – End Date: Month 60

The size and the inclusiveness of EURAD consortium as well as its large generic RD&D/Strategic Studies programme and KM activities will make it a key player in European and worldwide RWM. Exchange with other international actors is essential for increasing the impact of EURAD in the international landscape. EURAD will as well be solicited by various partner organisations and programme owners in their National Programme dissemination. The PMO will ensure interfaces and interactions at EURAD level with IGD-TP, SITEX, EuradSciences, IAEA, NEA, third country organisations (DOE...) and any other relevant organisations. This can include the formulation of MoU or any other joint agreements, to be validated at the GA and in agreement with EC rules.

Task 8 - Coordination, organisation and reporting on Interactions with CS Task 8 –

Start Date: Month 1 – End Date: Month 60

Task [IRSN (MUTADIS)]

This task is dedicated to the coordination of CS interactions within EURAD. It is organizing the attendance of the CS members of the CS group to EURAD workshops and will ensure the integration of the results of the participants of the CS teams involved in the different scientific/technical WPs, as well as methodological support for interactions between CS and stakeholders.

Finalizing the composition of the CS group

The composition of the CS group will be finalised during the inception phase of the JP according to a selection procedure open to Civil Society applicants from the EU (D1.13). The CS group includes several categories of participants such as representatives of European or national Civil Society Organisations, members of local communities having interest in RWM, be they representatives of local groups such as local association, local Committee of Information, local partnership (or having participated to such groups) .

A call for expression of interest will be sent to identify potential members in the first quarter of the first year of EURAD-1 with the perspective to finalize the CS group by the end of the first semester of the project. In order to select the members of the CS group, a list of criteria will be established and after receiving all the applications, they will be assessed through this list of criteria. According to the evaluation, the applicants will receive a formal confirmation of their participation or a formal answer explaining why they do not fulfil the criteria of the CS group. It will be still possible to enter the CS group after and the applicants will be assessed on the same basis.

Organizing yearly a workshop (as part of EURAD Annual Meeting) involving the participants of the CS group, the CS Experts together with a panel of WMOs, TSOS and REs participants in EURAD

Task 8 will organize each year a workshop that will be divided in one general session on the overall progress of EURAD scientific and technical activities and topical sessions (for the 1st wave: ROUTES & UMAN WPs), this includes elaboration of material, methodologies, processes and sessions to prepare EURAD participants and CS representatives in order facilitate fruitful interactions. The topical sessions will each be prepared and animated by the dedicated CS experts team involved in ROUTES and UMAN WPs. Each CS Experts team will gather CS views on the activities of their WP. In order to organize the general session of its annual workshop in the frame of the EURAD Annual meetings, Task 8 will collect results from the work of the different scientific/technical WPs, ensure the translation of results to the CS group during the session and gather CS advices and comments on the activities of the scientific and technical WPs. A small team of CS experts will be dedicated to this task and will work together with representatives from WMOs, TSOS and REs from the different WPs.

Assessment of the experimental model of Interaction between EURAD participants and Civil Society.

Evaluation of the experimental model of Interaction between EURAD participants and Civil Society will be carried out at mid-term (Month 30) and at the end of EURAD-1 (Month 60) under the supervision of the PMO. It will be performed by integrating the views of EURAD consortium (through the 3 colleges WMOs, TSOS and REs), CS Experts and CS group. It shall make sure the scheme for interactions is evolving positively, and if felt necessary as a conclusion of the evaluation, adapt and revise it in order to improve it. (D1.14, D1.15 and D1.16).

Partner number and short name	WP1 effort
1 - ANDRA	100.00
3 - BEL V	6.00
8 - CNRS	14.00
19 - IRSN	7.20
MUTADIS	4.10
NTW	13.80
22 - JSI	0.00
EIMV	2.20
23 - JRC	15.00
37 - RWM	14.00
Total	176.30

List of deliverables

Deliverable Number ¹⁴	Deliverable Title	Lead beneficiary	Type ¹⁵	Dissemination level ¹⁶	Due Date (in months) ¹⁷
D1.1	2nd Annual Work Plan	1 - ANDRA	Report	Confidential, only for members of the consortium (including the Commission Services)	9
D1.2	3rd Annual Work Plan	1 - ANDRA	Report	Confidential, only for members of the consortium (including the Commission Services)	21
D1.3	4th Annual Work Plan	1 - ANDRA	Report	Confidential, only for members of the consortium (including the Commission Services)	33
D1.4	5th Annual Work Plan	1 - ANDRA	Report	Confidential, only for members of the consortium (including the Commission Services)	45
D1.5	PMO - EURAD Quality Management Plan	1 - ANDRA	Report	Public	3
D1.6	EURAD Data Management Plan	1 - ANDRA	ORDP: Open Research Data Pilot	Confidential, only for members of the consortium (including the Commission Services)	12

List of deliverables

Deliverable Number¹⁴	Deliverable Title	Lead beneficiary	Type¹⁵	Dissemination level¹⁶	Due Date (in months)¹⁷
D1.7	EURAD Roadmap, extended with Competence Matrix	1 - ANDRA	Report	Public	12
D1.8	Process for the extensive update of the EURAD SRA/Roadmap	1 - ANDRA	Report	Public	26
D1.9	‘Extensive’ update of the SRA/Roadmap	1 - ANDRA	Report	Public	44
D1.10	- Identification of Subject Matter/Theme Experts from EURAD Colleges	1 - ANDRA	Report	Public	12
D1.11	EURAD Dissemination strategy	1 - ANDRA	Report	Public	3
D1.12	EURAD website	1 - ANDRA	Websites, patents filing, etc.	Public	3
D1.13	List of members of the CS group	19 - IRSN	Report	Public	6
D1.14	Mid-term evaluation of the ICS activities and experimental model of interaction between EURAD participants and Civil Society	19 - IRSN	Report	Public	30
D1.15	Integrated review of the ICS activities in EURAD	19 - IRSN	Report	Public	58
D1.16	Evaluation of experimental model of interaction between EURAD participants and Civil Society	19 - IRSN	Report	Public	58
D1.17	Evaluation of the impacts of EURAD first implementation phase	1 - ANDRA	Report	Public	60

Description of deliverables

- D1.1 – Second Annual Work Plan [Month 9] – Lead: [Andra]
- D1.2 – Third Annual Work Plan [Month 21] – Lead: [Andra]
- D1.3 – Fourth Annual Work Plan [Month 33] – Lead: [Andra]
- D1.4 – Fifth Annual Work Plan [Month 45] – Lead: [Andra]
- D1.5 – EURAD Quality Management Plan [Month 3] + its annual update - Lead: [Andra]
- D1.6 – EURAD Data Management Plan [Month 12] – Lead [Andra]
- D1.7 - EURAD Roadmap, extended with Competence Matrix and mapping exercise on related SoK, Guidance, and Training/Mobility Resource input from D1.9 [Month 12] - Lead: [Andra]
- D1.8 - Process for the extensive update of the SRA/Roadmap – [Month 26] - Lead: [Andra]
- D1.9 - ‘Extensive’ update of the EURAD SRA/Roadmap – [Month 44] - Lead: [Andra]

- D1.10 - Identification of Subject Matter/Theme Experts from EURAD Colleges [Month 12] + its update - Lead: [Andra]
- D1.11 - EURAD Dissemination strategy [Month 3] + annual update - Lead: [Andra]
- D1.12- EURAD website [Month 3] - Lead: [Andra]
- D1.13 List of members of the CS group [Month 6] + its annual update Lead [IRSN (Mutadis)]
- D1.14– Mid-term evaluation of the ICS activities and experimental model of interaction between EURAD participants and Civil Society [Month 30] Lead [IRSN (Mutadis)]
- D1.15 - Integrated review of the ICS activities in EURAD [Month 58] Lead [IRSN (Mutadis)]
- D1.16 - Evaluation of experimental model of interaction between EURAD participants and Civil Society [Month 58] Lead [IRSN (Mutadis)]
- D1.17 – Evaluation of the impacts of EURAD first implementation phase [Month 60] – Lead: [Andra]

D1.1 : 2nd Annual Work Plan [9]

2nd Annual Work Plan

D1.2 : 3rd Annual Work Plan [21]

3rd Annual Work Plan

D1.3 : 4th Annual Work Plan [33]

3rd Annual Work Plan

D1.4 : 5th Annual Work Plan [45]

5th Annual Work Plan

D1.5 : PMO - EURAD Quality Management Plan [3]

EURAD Quality Management Plan

D1.6 : EURAD Data Management Plan [12]

EURAD DMP specifies how research data will be handled both during and after EURAD projects. It identifies key actions and strategies to ensure that research data are of a high quality, safe, sustainable and – where possible – accessible and reusable.

D1.7 : EURAD Roadmap, extended with Competence Matrix [12]

EURAD Roadmap, extended with Competence Matrix and mapping exercise on related SoK, Guidance, and Training/ Mobility Resource input from D1.9

D1.8 : Process for the extensive update of the EURAD SRA/Roadmap [26]

Change of the title: "Soft" Update of the EURAD SRA/Roadmap into "Process for the extensive update of the EURAD SRA/Roadmap". Report describing the process that will be put in place for the extensive update of the SRA/ Roadmap

D1.9 : 'Extensive' update of the SRA/Roadmap [44]

'Extensive' update of the SRA/Roadmap (exact timing to be adjusted in order to be in line with Euratom work programme) to coincide with preparation and prioritisation of the scope of the potential EURAD2. During this extensive update, it is anticipated that significant changes may result to take account of learning from EURAD-1 and align the Vision, SRA, Roadmap and RD&D, Strategic Studies and KM Work Packages scope and methodologies with how things evolve, particularly with respect to the JP governance scheme and how the criteria used to identify needs of the WMOs, TSOs and REs

D1.10 : - Identification of Subject Matter/Theme Experts from EURAD Colleges [12]

identification of subject matter experts against each of the Roadmap Sub-themes/topics as well as experts having a broad overview of a RWM programme who experts will be able to provide adhoc technical support for a set term (possibly be reviewed/updated annually) in order to guide Roadmap updates and Joint Programme Knowledge Management Activities

D1.11 : EURAD Dissemination strategy [3]

a Dissemination Strategy will be developed to identify the key messages to be delivered, the target audiences to be addressed, the method/channels to address them, and the timing and process of dissemination.

D1.12 : EURAD website [3]

EURAD website

D1.13 : List of members of the CS group [6]

List of members of the CS group

D1.14 : Mid-term evaluation of the ICS activities and experimental model of interaction between EURAD participants and Civil Society [30]

Mid-term evaluation of the ICS activities and experimental model of interaction between EURAD participants and Civil Society

D1.15 : Integrated review of the ICS activities in EURAD [58]

Integrated review of the ICS activities in EURAD

D1.16 : Evaluation of experimental model of interaction between EURAD participants and Civil Society [58]

Evaluation of experimental model of interaction between EURAD participants and Civil Society

D1.17 : Evaluation of the impacts of EURAD first implementation phase [60]

Evaluation of the impacts of EURAD first implementation phase

Schedule of relevant Milestones

Milestone number ¹⁸	Milestone title	Lead beneficiary	Due Date (in months)	Means of verification
MS1	EURAD Kick-off meeting (General Assembly n°1)	1 - ANDRA	1	EURAD Kick-off meeting (General Assembly n°1)
MS12	EURAD EJP Newsletters	1 - ANDRA	3	EURAD EJP Newsletters (Due date : M3 and then every quarter)
MS30	EURAD General Assembly n°2	1 - ANDRA	7	EURAD General Assembly n°2
MS42	EURAD Annual Work Plan 2	1 - ANDRA	9	EURAD Annual Work Plan 2
MS71	Methodology for ICS activities assessment	19 - IRSN	12	Methodology for ICS activities assessment
MS81	EURAD General Assembly n°3 + EURAD Annual Meeting 1	1 - ANDRA	13	EURAD General Assembly n°3 + EURAD Annual Meeting 1
MS82	ICS Workshop 1	19 - IRSN	13	ICS Workshop 1
MS85	EURAD Periodic Report 1	1 - ANDRA	14	EURAD Periodic Report 1
MS103	EURAD General Assembly n°4	1 - ANDRA	19	EURAD General Assembly n°4
MS112	EURAD Annual Work Plan 3	1 - ANDRA	21	EURAD Annual Work Plan 3
MS136	EURAD General Assembly n°5 + EURAD Annual Meeting 2	1 - ANDRA	25	EURAD General Assembly n°5 + EURAD Annual Meeting 2
MS137	ICS Workshop 2	19 - IRSN	25	ICS Workshop 2
MS140	EURAD Periodic Report 2	1 - ANDRA	26	EURAD Periodic Report 2
MS153	EURAD General Assembly n°6	1 - ANDRA	31	EURAD General Assembly n°6
MS162	EURAD Annual Work Plan 4	1 - ANDRA	33	EURAD Annual Work Plan 4

Schedule of relevant Milestones

Milestone number¹⁸	Milestone title	Lead beneficiary	Due Date (in months)	Means of verification
MS185	EURAD General Assembly n°7 + EURAD Annual Meeting 3	1 - ANDRA	37	EURAD General Assembly n°7 + EURAD Annual Meeting 3
MS186	ICS Workshop 3	19 - IRSN	37	ICS Workshop 3
MS189	EURAD Periodic Report 3	1 - ANDRA	38	EURAD Periodic Report 3
MS199	EURAD General Assembly n°8	1 - ANDRA	43	EURAD General Assembly n°8
MS206	EURAD Annual Work Plan 5	1 - ANDRA	45	EURAD Annual Work Plan 5
MS222	EURAD General Assembly n°9 + EURAD Annual Meeting 4	1 - ANDRA	49	EURAD General Assembly n°9 + EURAD Annual Meeting 4
MS223	ICS Workshop 4	19 - IRSN	49	ICS Workshop 4
MS224	EURAD Periodic Report 4	1 - ANDRA	50	EURAD Periodic Report 4
MS234	EURAD General Assembly n°10	1 - ANDRA	55	EURAD General Assembly n°10
MS235	ICS Workshop 5	19 - IRSN	55	ICS Workshop 5
MS240	EURAD General Assembly n°11 + EURAD Annual Meeting 5	1 - ANDRA	60	EURAD General Assembly n°11 + EURAD Annual Meeting 5
MS241	EURAD Periodic Report 5	1 - ANDRA	60	EURAD Periodic Report 5 (Due date: 60+2)

Work package number ⁹	WP2	Lead beneficiary ¹⁰	38 - SCK•CEN
Work package title	Assessment of Chemical Evolution of ILW and HLW Disposal Cells (ACED)		
Start month	1	End month	48

Objectives

Objectives

The broader scope of this work package is the assessment of the chemical evolution at the disposal cell scale involving interacting components/materials and thermal, hydraulic and/or chemical gradients by considering ILW and HLW disposal concepts representative for different concepts throughout Europe. To increase the attention towards relevant materials and processes, the work package addresses ILW and HLW components up to the disposal cell scale. The study of the disposal cell in this WP ranges from microscale processes at interfaces between different materials up to interactions of waste packages with their immediate surrounding near field environment and the host rock.

The main objective is to improve methodologies to obtain multi-scale quantitative models for the chemical model at cell disposal scale based on existing and new experimental data and process knowledge and to improve the description of the most relevant processes driving the chemical evolution into robust mathematical frameworks. This is done for four selected representative disposal cell designs by analysing and combining information from available experimental studies, new targeted experimental studies developed within this WP and modelling exercises at both process and system levels. Applications will lead to integrated process understanding at larger temporal and spatial scales compared to individual process scale studies. The outcomes will impact the safety case in different ways such as with respect to material specifications and establishment of requirements for deposition scenarios. The representative designs are set for ILW and HLW in both crystalline and sedimentary rock types, representing prevailing designs of the WMOs as end-users.

More specifically, the WP seeks to:

- Compile and integrate the process level knowledge and description of reactivity at the interfaces between materials relevant for ILW and HLW disposal cells
- Develop and evaluate methodologies to integrate available process-level knowledge and processes into a multi-process and multi-scale modelling framework for assessing chemical evolution at the disposal cell level
- Propose and apply a step-wise scale-up process-based approach to identify (i) processes and features which control the chemical evolution for representative HLW and ILW disposal cells and (ii) to which detail and complexity these processes should be incorporated in models for different type of safety and performance related studies. The information gained through study of the more generic but European representative HLW and ILW disposal cells can later be used and adapted for more specific, national disposal cell designs.

Expected impacts

Regarding RWM implementation needs

The WP evaluates how process level knowledge can be incorporated in models describing chemical evolution between the waste form (glass, cemented waste) and the near field materials to assess the evolution of the buffer, container and waste matrix accounting for transport of reactive species and/or other drivers for geochemical alterations. The methodologies are important to obtain a holistic view of the effect of interacting processes on the geochemical evolution at relevant spatial and temporal scales, which help in understanding the evolution of such systems. For example, a number of chemical perturbations by considering different materials (glass, steel, clay, cement, granite) under relevant hydraulic and thermal gradients are integrated at relevant spatial and temporal scales. The interaction of metallic and cement materials with each other is studied with experimental characterization and through modelling at different scales. The performance of the improved models is evaluated using experimental data. Such integrated models can then be used in process and parameter sensitivity studies to identify key features, processes and parameters to describe the chemical evolution at the relevant space and timescales

A good understanding and assessment of the geochemical evolution forms also the basis for other aspects. The WP studies degradation/corrosion of different waste immobilisation matrices (vitrified waste, cemented waste) and metallic wastes as function of the evolving conditions imposed by different materials and geometrical features. The experimental and modelling studies concerning waste form alteration considered in this WP provide essential information on geochemical boundary conditions affecting the mechanisms and kinetics of radionuclide release. The impact of geochemical transformations at the interfaces will induce an evolution of porosity (including clogging phenomena) which is a critical parameter as porosity represents the primary affected physical variable determining radionuclide migration and fluid flow.

The process of model simplification at the system level basis, allows for the identification of the most relevant processes, features and parameters determining the chemical evolution at the cell disposal scale. This will provide inputs to how chemical evolution should be handled in a safety case for the repository level.

Building model capacity for assessing chemical evolution with benchmarked simplified models at the system level allows for model calculations for program-specific disposal cell geometries and analyses for optimization, sensitivity and uncertainties. The systematic approach for model abstraction developed in the work package will increase the confidence in the different models with different model complexity.

Assessment of the chemical evolution at the cell disposal scale will give input to identify critical features in the design of a disposal cell. The model capacity and benchmarked simplified models will help in the engineering and design of immediate surroundings of waste packages.

Regarding safety

The methodological developments and applications for assessing the chemical evolution at a cell disposal scale will allow for better representation of interactive and complex processes, with emphasis on chemical processes, within ILW or HLW disposal cell systems. The chemical evolution forms the basis for the evolution and the assessment of many safety- and performance-related aspects such as waste form degradation, material alteration, source term (radionuclide release), and radionuclide speciation, fate and transport. This better representation of expected evolutions will help:

- To assess and quantify the generic safety functions isolation of waste and immobility of the waste. The chemical conditions induce geochemical alteration of different barriers. These alterations may lead to change in lifetime of a barrier, including the waste package container (isolation), and change in mobility of radionuclides, including both solubility and sorption. The methodologies developed and evaluated in this work package contributes to the assessment of these generic safety functions as they will describe the change in chemical conditions over time when different materials, waste packages and disposal cells interact with each other.
- To further reduce conservatism and uncertainty, and to quantify the safety margin.
- To define the requirements on materials, including the robustness of allowable tolerances. The specifications, including dimensioning, of the packages and disposal cell(s) can be influenced based on the WP outcomes. Acceptance criteria for varying wastes and stabilization materials can also be influenced by the WP achievements towards understanding material evolution and impact sensitivity.

Both methodological routes can be applied in different steps in a safety case. A good approach for the integration of process knowledge helps to build scientific-based models for understanding system behaviour and evolution and for identifying key processes determining chemical evolution. The abstraction methodology provides guidelines about how to assess which level of process or system representation is needed to assess the chemical evolution in an acceptable way, or to quantify the level of conservatism when a specific simplification is used. Although the methodological routes are applied in this work package for the assessment of the chemical evolution, information and recommendations will also be relevant for other processes to be considered within a safety case such as those studied in some of the other work packages in this project.

Relevance for European National Programmes

As mentioned above, both ILW and HLW disposal cells will be studied. On one side, there are a number of elements, especially at the interface scale, which are common for both disposal cell types. On the other hand, the disposal cells for ILW and HLW also have specific elements only relevant for either one of the two such as involved processes, features, etc. Therefore, having both the ILW and HLW as separate study objects in the evaluation of the methodologies for process integration and model abstraction will allow for a much broader application of the outcomes of this work package for the different national programs. ILW and HLW studies are included in the waste package (Task 3) and disposal cell scale (Task 4). For the interface scale (task 2), the studies on the steel-clay interface are relevant for the HLW disposal cell in many European national programs, whereas the steel-cement interface, beside in HLW disposal cell in a limited number of European national programs, is present in many, if not all, waste packages in ILW disposal cells. The weight between the amount of effort devoted specifically to ILW compared to HLW studies has been partially influenced by the needs and associated co-funding.

Description of work and role of partners

WP2 - Assessment of Chemical Evolution of ILW and HLW Disposal Cells (ACED) [Months: 1-48]

SCK•CEN, ANDRA, BEL V, CEA, CIEMAT, CNRS, COVRA, ENRESA, JUELICH, IRSN, JSI, LEI, MTA EK, NAGRA, PSI, SÚRAO, VTT

Task 1 – S/T coordination, State-of-the-art and training material

Start: Month 1 – End: Month 48 - Task Leader: [SCK•CEN] Co-Task Leaders [COVRA] [JUELICH]

Task contributors: [Andra] [CIEMAT] [COVRA] [ENRESA] [JUELICH] [LEI] [SÚRAO] [SCK•CEN] [VTT]

Total PM: 32,6

Task Objectives:

- S/T coordination of the WP
- Developing/updating State-of-the-art
- Developing training materials as an input to KM
- In-depth analysis of the current handling of the chemical evolution in Europe
- Building blocks (experimental studies, conceptual and mathematical models, parameters, etc.) for Task 2, 3, and 4

Subtask 1.1 – S/T coordination

Start: Month 1 – End: Month 48 – Subtask Leader: [SCK•CEN]

Total PM: 2

The scientific and technical coordination of ACED will be performed by the WP Leader [SCK•CEN]. The WP Leader will be supported by the Task leaders and co-leaders: [IRSN] [PSI] [Andra] [VTT] [COVRA] [JUELICH] [SÚRAO (UJV)] which together with [SCK•CEN] constitute the WP Board of ACED. The WP Leader will make sure that EURAD rule are followed by all partners, that the scientific milestones and deliverables are reached timely, and that the results are disseminated efficiently inside and outside the project. It includes also participation to PMO meetings twice a year. Subtask 1.1 consists of ensuring information transfer between different (sub)tasks. This is accomplished by a number of WP meetings, workshops and general milestones.

The following WP meetings (WPM) are planned :

- Kick-off meeting (WPM1) at the start of the WP including a discussion on the specifications of the representative systems and discussion between experimentalists and modellers on requirements for modelling approaches and expected experimental input (input to MS8) (Month 1)
- WPM 2 - including task meetings and a first workshop (Month 7)
- WPM 3 - including task meetings (Month 19)
- WPM 4 - including task meetings and MS155 (Month 31)
- WPM 5 - including task meetings and workshop 6 (Month 43)
- Closure meeting (WPM 6) at the end of the WP (Month 48)

Following workshops (WS) or interaction meetings are planned :

- WS1 (Month 7) (adjacent to work package meeting) – workshop on data, model concepts, and parameters based on expected experimental results for interface and waste package scales (input from D2.1, MS16, D2.10), on coordination of information exchange between experiments and models within and between scales and on scale transitions of data, model approaches and model results (leading to MS31, MS43 and D2.18)
- WS2 (Month 13-18) – Joint workshop with GAS and DONUT on (i) possible benchmark studies for DONUT (input from D2.14, D2.15 and D2.16), (ii) numerical challenges, and (iii) abstraction methodologies.
- WS3 (Month 31) (adjacent to WP meeting) – workshop on status of experiments and models for the different scales and information exchange of preliminary data between experiments and models within scales and update of model concepts and parameters based on these preliminary data towards information exchange between scales and upscaling (Milestone 1.1.4).
- WS4 (Month 30-37) – Joint workshop with GAS and DONUT on intermediate results of (i) benchmark studies, (ii) numerical developments, and (iii) application of abstraction methodologies.
- WS5: (Month 37) (adjacent to project meeting) – workshop on information exchange of data between experiments and models within scale and information exchange towards upscaling with update of model concepts and parameters (MS180)
- WS6: (Month 43) (adjacent to WP meeting) – workshop on how to use the different methodologies applied and evaluated in the work package in safety assessment methodologies for geological disposal of radioactive waste (as input to D2.2)

Subtask 1.2 – State-of-the-art

Start: Month 1 – End: Month 48 – Subtask Leader: [COVRA] Sub-Task Contributors: [SCK•CEN] [JUELICH] [COVRA]

Total PM: 6

This sub-task compiles and evaluates the state-of-the-art regarding relevant processes that influence the long-term chemical evolution in disposal cells for vitrified HLW and for cemented ILW (D2.1). Besides information from integrated experiments, other alternative routes to study the long-term chemical evolution are included as well such as evidence from natural or archaeological analogues. Also, current practices of integration are reviewed. These desktop studies will provide:

- Description of relevant processes and transients that influence the chemical evolution in the disposal cells (e.g. with respect to pH, redox, temperature, chemistry of near field water, etc.) and at the following six interfaces glass-steel,

cement/mortar granite, cement/concrete-clay, steel/iron bentonite, steel/iron-cement/concrete and steel/iron-granite (e.g. formation of new phases, porosity/permeability changes influencing fluid/gas transport, etc.)

- Overview about which conceptual and mathematical models have been and are used to describe these processes and the chemical evolution; how are these models parameterized (e.g. sources of data to parameterize long-term processes, e.g. application of data/insight from experiments, natural/archaeological analogues, etc.)

Integration of the results of WP tasks 2 to 4 by updating the state-of-the-art pertaining to chemical evolution process understanding and model capacity. It furthermore addresses questions related to methodological aspects of integration of knowledge and addressing complexity of chemical evolution in a disposal cell taking into account interaction between components and processes. (D2.2)

Subtask 1.3 – Training materials

Start: Month 24 – End: Month 48 – Subtask Leader: [SCK•CEN]

Total PM: 2

Experience on methodological and practical aspects for developing, implementing and interpreting models for the assessment of the chemical evolution at the disposal cell scale will be obtained in this WP. Based on the expertise gained during the first two years of the project, different tools for learning material will be developed in close cooperation with the training/mobility KM WP. The tools envisaged are theoretical lectures/tutors, demonstration of simulation tools used within this WP, tutorials and practical exercises for some example simulation tools. The practical exercises will be based on the simulations performed in the tasks 2 – 4 and will cover the three scales envisaged in this WP. Possible topics includes principle and approaches in reactive transport modelling at different scales and model abstraction, sensitivity and uncertainty analysis. A training workshop (level doctoral school) is organised during the third year on one of these topics. Collaboration with other WPs, especially DONUT, in development of the training materials will be investigated. [SCK•CEN] will coordinate and assemble training material for the work package on the assessment of the chemical evolution at cell disposal scale. (D2.3)

Subtask 1.4 – Current handling of the chemical evolution

Start: Month 1 – End: Month 5 – Subtask Leader: [COVRA] Subtask Contributors: [SCK•CEN] [JUELICH] [Andra] [VTT] [SÚRAO] [ENRESA] [LEI] [COVRA]

Total PM: 11

There may be current European practices why the chemical evolutions for disposal are included and how the chemical evolution at the disposal cell scale has been treated e.g. in safety cases. The conceptualisations of the chemical evolutions and which parts have been modelled in Europe will be collected. For countries not participating in Task 1, teleconferences with authors of safety cases will be held to get the conceptualisations, model descriptions and sources of data at a sufficient detail from the other National Programmes. (D2.4)

Subtask 1.5 – Analysis of experiments and numerical model studies on interfaces

Start: Month 1 – End: Month 4 – Subtask Leader: [JUELICH] Subtask Contributors: [SCK•CEN] [Andra] [VTT] [SÚRAO] [COVRA] [CIEMAT] [JUELICH]

Total PM: 11,6

In a pre-project phase, the existing/running and proposed experiments have been reviewed with the 5 selection criteria to have experiments for task 2: chemical evidence for model validation, solid-solid interfaces, not a clay-cement interface due to the running EU project Cebama, preference for running experiments and more than one country should have interest in the specific interface. The following interfaces with steel were selected for task 2 after application of these selection criteria: steel-bentonite, steel-concrete, steel-granite. The benefit of these steel interfaces is that they all three contain another distinctly different parameter value i.e. (initial) pH of pore water and process i.e. transport of degraded corrosion products. This set is therefore expected to provide process understanding of the chemical evolution at these interfaces. Within task 3 and 4 also additional interfaces not included in the experimental work in task 2 will be relevant, such as glass-steel, concrete-clay, and concrete-granite. Therefore, desk-based studies will be performed to provide a structured overview of existing (experimental) data on relevant processes occurring at the following six interfaces: glass-steel, cement/mortar-granite, cement/concrete-clay, steel/iron-bentonite, steel/iron-cement/concrete and steel/iron-granite. The overviews includes also natural/ archaeological analogues that may provide insight/data for long-term processes relevant to the chemical evolution of the disposal cells not accessible in short-term (laboratory) experiments. In addition, the desk-based studies will also provide an overview on the conceptual models used to describe the processes at the interface. This overview forms the basis for conceptualisation of the chemical evolution at these interfaces in the other tasks and will be used to support model validation and parametrization of models (D2.5)

Task 2 - Interface scale: Reactivity of Steel/Material Interfaces

Start: Month 1 – End: Month 48 - Task Leader: [IRSN]

Task contributors: [BEL V] [CIEMAT (UAM)] [CNRS-SUBATECH (IMT Atlantique)] [ENRESA] [IRSN (Mines ParisTech)] [JSI [ZAG]] [MTA EK] [NAGRA (UBERN)] [PSI] [SÚRAO (UJV)] [VTT]

Total PM: 239

Task objectives:

The general task objective is to provide geochemical and coupled reactive transport models for assessing the geochemical evolution at steel/clay material and steel/cement material interfaces in terms of corrosion rates, geochemical alterations and physical alterations. These models will provide the bases of the up-scaling to waste package (Task 3) and disposal cell (Task 4) modelling.

More specifically, the combined modeling-experimental approach will result in an increased confidence and decreased uncertainty of model simulations of:

- the corrosion rates of steel in contact with clay or cement materials under different environmental conditions as temperature, redox conditions, chemistry of solutions or quality of the interface;
- the fate of corrosion products (Fe(II)) in the cement or clay material;
- the physical-chemical evolution at the interface;
- the evolution of transport properties.

The experimental studies ultimately lead to a consistent input and validation data set for geochemical and reactive transport modelling of the interface evolution by obtaining information on:

- the geochemical reactions and transport properties controlling the corrosion and the interaction of corrosion products with bentonite and cement materials;
- the corrosion type and the corrosion rate in function to the environmental variables;
- specifically for the steel/clay material interface, the diffusivity of Fe(II) in bentonite;
- specifically for the steel/cement material interface, effects of temperature and alkalinity of the environment, of chemistry of relevant waters (granite groundwater or clayey pore waters), and of the presence of heterogeneities at the interface.

The model studies will:

- use this data to validate modelling approaches including geochemical models for corrosion products, corrosion rates, corrosion type, redox processes, fate of Fe, and evolution of the materials in contact with steel;
- analyze the effect of different environmental conditions on the chemical evolution at the steel-clay and steel-cement interface;
- provide the base for up-scale to waste package (Task 3) and disposal cell (Task 4) scale by a significant reduction in the uncertainties of reactive transport models.

To ensure interactions between modelling and experimental work, a workshop will be organized by each subtask leader each year (to define, adapt and synthesize the modelling approach (interaction modelling teams) and to optimize experiments and characterization for model validation (interaction modelling and experimental teams). This results in following work plan for each subtask:

- Workshop 1 (Month 3)
- Milestone MS16 (M6) – A note on the specific experimental conditions at the steel/clay or steel/cement material interface and parameters and the modelling approaches with detailed information on set-ups and work flow, variables to measure and a dismantling and characterization plan. It will also define the link between the experiments and the model approaches (also input to general workshop 1, and M1.1.2).
- Workshop 2 (Month 19)
- Workshop 3 (Month 31)
- Workshop 4 (Month 43)

Subtask 2.1 – Steel/clay material interface reactivity

Start: Month 1 – End: Month 48 – Subtask Leader: [IRSN]

Subtask Contributors: [SÚRAO (UJV)] [CIEMAT (UAM)] [ENRESA] [NAGRA (UBERN)] [MTA EK] [SCK CEN] [CNRS-SUBATECH (IMT Atlantique)]

Total PM: 150,5 PM

Interactions between a modeling and an experimental group will identify the critical elements to improve the conceptual description of steel/clay material interactions in reactive transport models and the crucial variables to measure for model validation and predictions of corrosion rates and clay alterations. Corrosion rates, physico-chemical evolution, mineralogical evolution at the interface or porosity evolution, amongst others, are measured on existing and two new experimental set-ups for a range of environmental conditions as redox state, aggressive anions (chloride concentration from few mg/L to 35 g/L), temperature (from 20°C to 80°C), close to neutral pH.

The experimental group [SÚRAO (UJV)] [NAGRA (UBERN)] [CNRS-SUBATECH (IMT Atlantique)] [CIEMAT (UAM)] [MTA EK] designs, manages and characterizes a number of experiments that forms the basis for the modelling group (Figure 19). The experimental programme combines two approaches: i/ two existing experiments with a steel

(or iron)/clay material interface during a few months (EE2-1/2) [SÚRAO (UJV)] to several years (EE2-1/1) [CIEMAT (UAM)] and [NAGRA (UBERN)] ii/ two new experiments, a first one to understand the FeII reactivity with bentonite in a simplified approach (porous iron steel/smectite interface) (NE2-1/1) [U. Bern] and second one to understand the evolution of a steel/clayey material interface [MTA EK] at different temperature (NE2-1/2). Several partners [CNRS-SUBATECH (IMT Atlantique)] [CIEMAT(UAM)] contribute to the characterization of the interface experiments.

The modelling group [ENRESA] [NAGRA (UBERN)] [SCK CEN] and [SÚRAO (UJV)] will perform geochemical and coupled reactive transport calculations on the selected experiments with these modelling features:

New experiment that studies the impact of FeII release on smectite (NE2-1/1). [NAGRA –UBERN] improve the modeling of the iron reactivity in smectite. This model will provide input to long-term model and for models at waste package and disposal cell scale.

The experiments EE2-1/1 and NE2-1/2. [SCK CEN] implements a kinetic steel corrosion model into a reactive transport model to model the existing (EE2-1/1) and new experiments (NE2-1/2).

- The short term existing experiment (EE2-1/2). [SÚRAO (UJV)] will simulate the main reactive pathways with geochemical modeling to describe the experiment.
- The long term experiments (EE2-1/1). [NAGRA (UBERN)] and [ENRESA] collaborate to improve the comprehensiveness of the reactive transport modelling to reproduce the physico-chemical evolution (e.g. saturated and unsaturated conditions) of the steel/bentonite interfaces and the extension of the perturbations.

Related deliverables are D2.6 and D2.7.

Subtask 2.2 – Steel/cement material interface reactivity

Start: Month 1 – End: Month 48 – Subtask Leader: [BEL-V]

Subtask Contributors: [BEL V] [IRSN (Mines ParisTech)] [MTA EK] [PSI] [CNRS-SUBATECH (IMT Atlantique)] [VTT] [JSI (ZAG)]

Total PM: 88,5

As for the subtask 2-1, interactions between a modeling and an experimental group will identify the critical elements to improve the conceptual description of steel/cement material interactions in reactive transport models and the crucial variables to measure for model validation and predictions of corrosion rates and cement alteration products (e.g. physico-chemical evolution, mineralogical and porosity evolution of the interface). These parameters, amongst others, are measured on two existing and two new experimental set-ups for a range of environmental conditions as redox state (essentially in anoxic conditions), aggressive anions with chloride concentration from few mg/L to 35 g/L (e.g. clayey solution in EE2-2/1 and NE2-2/1 to sea water in NE2-2/2), temperature from ambient conditions (EE2-2/1, EE2-2/2) to 80°C (NE2-2/1, NE2-2/2), high pH range starting from neutral (EE2-2/2) to high pH (EE2-2/1, EE2-2/2, NE2-2/1, NE2-2/2) (see Fig. 2).

The experimental work [IRSN] [VTT] [BELV] [CNRS-SUBATECH (IMT Atlantique)] [MTA EK] [JSI (ZAG)] is starting with characterizations of existing experiments (EE2-2/1, EE2-2/2) [IRSN] [VTT] along the needs for model validation and continue with a number of new dedicated experiments (NE2-2/1, NE2-2/2), identified as critical for process understanding and model validation [IRSN] [MTA EK]. Mainly in situ experiments are planned to be characterized or started [IRSN, VTT]. Existing experiments with Portland cement or grout cement (low alkaline cement) in contact with steel in saturated conditions in ambient temperature will be characterized by several organizations [IRSN] [CNRS (SUBATECH)] [VTT]. The new experiments in situ [IRSN] and in laboratory [MTA EK] will be focused on the interface reactivity at 80°C (NE2-2/1, NE2-2/2). The role of heterogeneities (e.g. non-perfect interface or presence of voids) at the interface will be also treated to identify a potential local influence on the corrosion type and rate.

The modelling group [IRSN (Mines ParisTech)] [PSI] and [IRSN (Mines ParisTech)] reformulate an existing solid/solution model for C- S-H, AFm and AFt phases to describe Fe uptake in the cementitious material exposed to steel corrosion [PSI]. Reactive transport models will then be evaluated to describe the ageing of the steel/cement interface for different conditions (low or high temperature, in contact with low or high alkaline cement/concrete) [IRSN (Mines Paris Tech)]. And if successful also incorporate the solid/solution approach [PSI].

Related deliverables are D2.8 and D2.9.

Task 3 - Waste package scale (conditioned waste, disposal container, overpack)

Start: Month 1 – End: Month 48 - Task Leader: [PSI] - Co-Leader: [Andra]

Task contributors: [Andra (BRGM)] [CEA (EDF)] [CNRS-SUBATECH (IMT Atlantique) (ULorraine)] [COVRA] [JUELICH] [JSI (ZAG)] [MTA EK] [PSI] [SCK•CEN] [JUELICH (UFZ)]

Total PM: 178,6

Task Objectives:

This subtask concerns the first upscaling step from the relatively isolated processes at interfaces (studied in Task 2) to repository sub-systems, representative for HL/IL waste packages, where chemical and physical processes might be closely intertwined. As the long term evolution of such systems by laboratory experiments is not easily available,

or cannot be obtained within the timeframe of this project, the investigations will be based largely on (i) existing datasets, or on (ii) using some ‘running’ datasets complemented by limited additional measurements, or on (iii) new measurements on ‘analogues’ (existing waste packages, existing infrastructure), or on (iv) a limited and targeted set of new experiment(s) to provide data which could be analysed during this WP.

Numerical modelling of the coupling between chemistry, transport processes and material alterations will be a major effort in this task. The modelling work will concentrate on describing the evolution of important chemical properties (redox pH, ionic strength) and other (geochemical) variables (e.g., mineralogy, porosity). This includes the evaluation and comparison of different conceptual and modelling approaches. The goal will be to investigate to what extent abstraction in terms of process de-coupling or scale separations (spatial and temporal) are possible and appropriate: this analysis will be shared with Task 4. For models that describe complex interactions between materials and processes it is absolutely necessary to evaluate not only single process couplings with experimental data but also to compare with experiments with more complex interactions of materials and processes, preferably, if possible, at relevant space and time scales.

This main objectives of this task are:

- To evaluate how adequate available phenomenological concepts and models describe the chemical evolution of typical materials at an intermediate scale – i.e., parts of a repository composed of several materials in a fixed geometry (representative for ILW or HLW waste packages) well below the disposal cell scale.
- To identify critical processes and features driving and controlling the chemical evolution at the waste package scale.
- To provide information on relevance and influence of processes for implementation at disposal cell scale and for model abstraction (task 4).

For ILW waste we concentrate on the two most common types of cemented waste, a metallic waste form containing contaminated/activated steel/iron and an organic waste form:

- Anoxic metal corrosion and degradation of organic matter are depending on the pH of the aqueous phase, which in turn depends on the degradation state of cement materials. Most metals incl. steel and iron will be subject to anoxic corrosion which produces H₂ while water is consumed. The corrosion rates in contact with different cement materials and at different pH are investigated with experiments in task 2 at interface level and in task 3.1 on waste package level.
- Similarly, it is expected that during degradation of organic matter CH₄ and CO₂ are released and water is consumed. Degradation of organic matter is investigated in WP CORI and will be integrated via BRGM, which participates in both WP.
- The long term degradation of concrete has a major influence on metal corrosion and degradation of organic matter. There is a feedback loop between concrete degradation, metal corrosion and organic matter degradation, and associated processes like gas production or liquid saturation on waste package scale and on disposal cell scale. Experimental data on long term internal concrete degradation due to reactive aggregates and externally driven degradation due to ingress of formation waters will be collected in task 3.1 and will help to constrain the waste package models scale models in task 3.3.

For HLW waste, we concentrate on existing HLW concepts in Europe through the study of three systems: « Glass/steel/clay » to « Glass/steel/cement » with an intermediate case « Glass/steel/cement buffer/clay ». The glass alteration rate highly depends on the chemistry (pH, concentrations in silica, calcium and magnesium in solution) of the aqueous phase in the buffer material, and on the nature of corrosion products formed during the corrosion of the overpack before its breaking. Experimental data on glass/steel interactions in different environments will be collected in task 3.1 and combined with the experiments performed in Task 2 dedicated to steel/clay and steel/cement interface will help to constrain the waste package models scale models in task 3.2.

Subtask 3.1 – Experimental analysis

Start: Month 1 – End: Month 31 – Subtask Leader: [CEA]

Sub-Task Contributors: [CEA (EDF)] [CNRS-SUBATECH (IMT Atlantique) (ULorraine)] [SCK•CEN] [MTA EK] [VTT] [Covra] [JUELICH] [JSI (ZAG)] [PSI] [SCK•CEN] [VTT]

Total PM: 113,5

This subtask concerns experimental investigations that will generate data (characterization of HL/IL interfaces), which can be analysed within the duration of the WP and allow for model verification, or complement datasets which are used as input to different modelling teams (Subtask 3.2 and Subtask 3.3).

The analysis of currently running experiments highlighted that most of them are related to existing HLW concepts. The different systems are consistent with both the interfaces studied in Task 2 and the different existing HLW concepts. They will allow getting information about the chemical evolution at glass/steel/buffer interfaces, mainly the nature of newly formed phases, the glass alteration rate and the corrosion rate, according to the temperature, the nature of buffer (clay or cement). These systems from « Glass/steel/clay » to « Glass/steel/cement » with an intermediate case « Glass/steel/cement buffer/clay » are selected.

- An on-going experiment Glass/steel/clay (5 year, 50°C) that will be dismantled and characterized by [CEA] with the support of [CNRS-SUBATECH (IMT Atlantique)].
- A Glass/steel/cement buffer/clay experiment that is launched at 70°C in April 2018 by EDF. The characterization of the different interfaces at different steps is planned during the project by [CEA (EDF)] with the support of [CEA].
- Mock-up tests have been performed at SCK•CEN in which the evolution of a water saturated glass/steel/cement system was monitored for 30 months, for 2 reference waste glass types (SON68, SM539), at room temperature. The cells have already been dismantled and partially characterized: Samples are available for further characterization that will be performed by [SCK•CEN] with the support [CNRS-SUBATECH (IMT Atlantique) (ULorraine)].
- In parallel, a limited series of specific experiments will be performed by [MTA EK] in order to study the chemical evolution of a system borosilicate glass/steel/Boda-claystone formation (BCF) and compare it with these HLW-characteristic systems.

For ILW conditions, following experimental data will be used as input:

- [VTT] provides access to long-term experimental data collected since 21 years on ILW waste package evolution. There is an ongoing experiment of full scale steel drums filled with waste which are deposited in a concrete vault saturated with anoxic water. The experiment setup allows sampling for gas and pore water chemistry analyses. This data will allow calibrating long term degradation of waste package components, specifically gas generation due to metal corrosion and degradation of organic matter.
- [COVRA] has running experiments on backfill and functional concrete degradation due to contact with saline water. Properties of the water are observed over time. Concrete samples will be analysed by Jülich and [JSI (ZAG)] to give indication of long term progress of reaction fronts in high porosity backfill and high strength concrete. This data will be used to test and calibrate reactive transport models in Task 3.3. [JUELICH] [JSI (ZAG)] [COVRA].
- [JSI (ZAG)] will investigate 70 to 100 years old concretes from water saturated parts of hydroelectric power plant dams. Cores will be extracted and analysed by [JUELICH] and [JSI (ZAG)] specifically to get information on long-term reactivity of silica (carbonate) aggregates. Such data is essential to assess scenarios for ILW and HLW that consider internal degradation of concretes/mortars due to long-term aggregate reactivity. [JUELICH] [JSI (ZAG)].

The work will be organized as follows:

- (M3) Interaction with T3.2 T3.3, T4 on existing and expected experimental data for modelling.
- Milestone MS31 (M7) information on existing data for inclusion in T3.2 and T3.3. Describing the selected experiments and existing experimental results D2.10 and D2.11. Some data sets (identical experiment dismantled and characterized after shorter alteration times) will be already available at the beginning of the project as input data for the T3.2 and T3.3.
- Collection and preparation of samples
- Milestone MS55 (M12): distribution of experimental samples to partners
- Analysis of samples and interpretation of results
- (M31): Data freeze: Communication of interpreted experimental data for inclusion in T3.2 and T3.3
- Final reporting D2.12 and D2.13 as input for MS155 and task 1.2

Subtask 3.2 – Modelling of chemical evolution of HLW waste package scale

Start: Month 6 – End: Month 48 – Subtask Leader: [SCK•CEN]

Subtask Contributors: [CEA] [COVRA] [Andra (BRGM)] [MTA EK] [SCK•CEN]

Total PM: 33,3

This subtask concentrates on modelling the selected reference experiments studied in subtask 3.1 and the evolution of a HLW waste package for vitrified waste consisting of a glass core encapsulated in an iron/steel canister and in contact with a cement or cement/clay backfill.

It will involve testing and comparing different conceptual models including different features (description of heterogeneities, e.g. voids) and processes, and/or waste alteration models and/or different corrosion models and/or degradation of concrete materials models and/or different reactive transport codes (PhreeqC, Hytec, Crunch, OpenGeoSys-GEM, etc.).

The modelling of experiments will involve [MTA EK] [CEA] and [Andra (BRGM)]. First (m6), modelling will use the datasets already available at the beginning of the WP (Deliverable D2.10) and will progressively integrate the results of characterization (annual meetings + deliverable D2.11). [Andra (BRGM)] [COVRA] and [Andra] and [SCK•CEN] will model a reference HLW waste package by taking into account different representations: perfect interfaces, presence of voids and/or heterogeneities.... The definition and the conceptualization of this reference HLW waste package will be done during the first year of the project by taking into account existing HLW concepts, the experiments studied in Subtask 3.1 and systems studied in Task 4.

The following steps are planned:

- Milestone MS8 (M1) Specifications of waste package model concepts and links with and between model approaches and expected experimental results from T2 and T3.1
- Milestone MS31 (M7): First input from experiments and information exchange with T4 on expected results

- Implementation in numerical model and first simulations
- Milestone MS155 (M31) Data freeze: Update of model parameters and conceptual model based on input from T2 on T3.1
- Update implementation in numerical model and update of simulation results with final experimental data.
- Milestone MS167 (M36): Synthesis note on concepts and effective parameters for approximation of chemical evolution of waste packages on disposal cell scale (input to MS180) (Lead: SCK•CEN)
- Milestone MS180 (M37): Data freeze: Update of upscaling concepts and parameter for T4
- D2.14 (M46): Description of modelling results, upscaling concepts and recommendations for future experimental and numerical work.

Subtask 3.3 – Modelling of chemical evolution of ILW waste package scale

Start: Month 6 – End: Month 48 – Subtask Leader: [UFZ]

Sub-Task Contributors: [Andra (BRGM)] [COVRA] [VTT] [PSI] [JUELICH (UFZ)] [SCK CEN]

Total PM: 31,8

This sub-task focus on modelling the long-term chemical evolution of ILW waste packages and to provide upscaled effective parameters for usage in disposal cell scale reactive transport models (Task 4).

All modelling teams [Andra (BRGM)] [JUELICH (UFZ)] [SCK CEN] [COVRA] [VTT] [PSI] work on the same waste types, but will investigate the chemical evolution considering different scenarios and different processes. This task will involve testing and comparing different models, including different features and processes, like waste alteration models, corrosion models or concrete degradation models with different reactive transport codes. The choice of scenarios and processes has to be coordinated with task 4 in order to avoid inconsistencies between waste package and disposal cell scale. The planned scenarios are related to intermediate storage of waste packages (important for definition of initial state at emplacement), after emplacement the evolution under fully liquid saturated conditions and the evolution under partially saturated conditions.

A major goal of this task is to define and provide – in close cooperation with task 4 - concepts and effective parameters for approximation of chemical evolution of waste packages on cell disposal scale.

The following steps are planned:

- Milestone MS8 (M2) Specifications of waste package model concepts and links with and between model approaches and expected experimental results from T2 and T3.1
- Milestone MS31 (M7): First input from experiments and information exchange with T4 on expected results
- Implementation in numerical model and first simulations
- Milestone MS158 (M31) Data freeze: Update of model parameters and conceptual model based on input from T2 on T3.1
- Update implementation in numerical model and update of simulation results with final experimental data.
- Milestone MS168 (M36): Synthesis note on concepts and effective parameters for approximation of chemical evolution of waste packages on disposal cell scale (input to MS180) (Lead: UFZ, M36)
- Milestone MS180 (M37): Data freeze: Update of upscaling concepts and parameter for T4
- D2.15 (M46): Description of modelling results, upscaling concepts and recommendations for future experimental and numerical work.

Task 4 - Disposal cell scale

Start: Month 6 – End: Month 48 - Task Leader: [VTT] - Co-Leader: [SCK•CEN]

Task contributors: [Andra] [COVRA] [ENRESA] [JUELICH (UFZ)] [IRSN (Mines ParisTech)] [LEI] [SCK•CEN] [VTT]

Total PM: 65,5

Task Objectives

This task will look at the scale of a disposal cell simulating the interactions of the waste packages with each other and with the immediate surrounding near field environment and the host rock within the frame of the ILW or HLW disposal concepts. The objectives of this task are to:

- Integrate available knowledge on critical processes and features (from Tasks1-3) into a conceptual, mathematical and numerical model to simulate the chemical evolution at the disposal cell scale for representative ILW and HLW disposal concepts
- Apply model abstraction techniques in order to describe key features of the chemical evolution with more robust and manageable models
- Identify interactive processes, parameters and features affecting chemical evolution at the disposal cell scale By doing this, this task will answer the following questions:
- How to upscale experimental degradation processes to the scale of a disposal cell?
- How the chemical deterioration processes interact with each other?

- How to transform this knowledge into a robust and manageable numerical model, which reflects the current state-of-the-art?

Subtask 4.1 – Conceptual and mathematical formulation for a mechanistic based model (reactive transport model) to simulate the chemical evolution at the disposal cell scale.

Start: Month 6 – End: Month 30 – Subtask Leader: [JUELICH (UFZ)]

Sub-Task Contributors: [Andra] [LEI] [COVRA] [JUELICH (UFZ)] [SCK•CEN] [ENRESA] [VTT] [IRSN (MINES ParisTech)]

Total PM: 31

The formulation of the model will be initiated by the initial SOTA knowledge (T1.2 and T1.5) on models and parameters. The resulting complexity of this model and the associated numerical limitations can serve as triggers for new developments in the WP Modelling or for abstraction methodologies in sub-task 4.2.

The complex model will subsequently be redefined based on current capabilities of the existing numerical tools. Then, the implementation into these tools, using the highest level of complexity as possible at that point in time, and interpretation of the results follows. In a second step, an update of the model is foreseen based on knowledge developed in T2 and T3 (and possible in other WPs) and numerical methods/tools in WP Modelling. This two-step approach guarantees an early start of T4.2 and T4.3. Related deliverables: D2.16 and D2.17.

List of Actions and Milestones:

- Description of conceptual models for reference ILW and HLW cell (M6-9)
- Implementation in baseline numerical model (M9-18)
- Simulation results as basis for T4.2 and T4.3 (M18) (MS96)
- Update of conceptual model based on T2, T3 (other WPs) (M24)
- Refinement of numerical model (M24-30)
- Simulation results as a basis for T4.2 and T4.3 (30) (MS149)

It is envisioned that all partners will collaborate to achieve the milestones listed above.

Subtask 4.2 – Model abstraction methodologies

Start: Month 13 – End: Month 45 - Task Leader: [ENRESA]

Sub-Task Contributors: [LEI] [COVRA] [JUELICH (UFZ)] [SCK•CEN] [VTT][ENRESA] [IRSN (MINES ParisTech)]

Total PM: 20

This subtask will develop and evaluate robust and manageable models in order to efficiently represent complex and coupled processes at the disposal cell scale. Model abstraction methodologies will be tested to represent the complex interacting processes in the full 2D/3D geometry with more simple descriptions such as geometrical simplification, process simplification of equilibrium or kinetic processes, look-up tables etc. An important element in model abstraction is that the simplified models will still be able to simulate the key features of chemical evolution of a disposal cell as predicted by the complex model. This will allow for quantitative predictions of the chemical evolution as boundary conditions for radionuclide release/mobility and estimation of durability of barriers with less complex and computational demanding models applicable for other geometries, for optimization, or for sensitivity calculations. Different levels of model abstraction (ranging from “as realistic or detailed as possible” to “as simple as possible”) will be evaluated. The benefits and limitations of the resulting models will be described in order to assess the added-value of complex modelling in a safety case.

List of Actions and Milestones:

- Identification of key macroscale and up-scaling processes for which the methods will be applied (M13-18)
- Description of abstraction and simplification methods (M12-24)
- Integration of abstraction and simplification methods into models (M24-36)
- Demonstration of simulation results with abstracted models (M36) (MS169)
- Update of methods and model based on T2, T3 (other WPs) (M36-42)
- Updated simulation results with abstracted models (M42) (MS194)

It is envisioned that all partners will collaborate to achieve the milestones listed above. Related deliverables: D2.18 and D2.19

Subtask 4.3 – Application of the model for a wide range of conditions and parameter values

Start: Month 18 – End: Month 48 – Subtask Leader: [SCK•CEN]

Sub-Task Contributors: [VTT] [JUELICH (UFZ)] [ENRESA] [LEI] [Andra] [SCK•CEN]

Total PM: 14,5

In this subtask, the abstracted models developed in T4.2 are applied to a wide range of conditions encountered in the disposal concepts, which result in a number of different chemical evolutions of the disposal cell. In order to apply the model for a wide range of conditions and parameter values, large number of model realizations has to be simulated within a limited time frame. This work also includes sensitivity analyses of the model parameters, mapping

of critical parameters to performance targets (e.g. pH, permeability...) and/or risks (loss of containment...), as well as analysing the response of the system to different environmental conditions. These are believed to be essential input for safety case. Partners have high-performance computing platforms are available for massive parallelized simulation of parameterization, model calibration and sensitivity analysis.

The subtask includes number of simulations with the developed model in safety case relevant conditions for the ILW/HLW disposal cell. Partners will work in close co-operation with operating companies/end-user groups to implement the knowledge gained in this WP to their safety case analyses and evaluate the full performance of the developed model. The collaboration will also provide repository performance targets that will be used in sensitivity analysis of them to the model parameters.

This task has also interaction with WP Modelling Task3 (sensitivity methods) via workshop 2 and workshop 3 defined in T1.1.

List of Actions and Milestones:

- Interactions with the end-users group in co-operation with Task 1.1 in form of a workshop (M19-24)
- Definition of calculation cases and parameter ranges (lead: Andra) (M24)
- Summary of calculation cases and parameter ranges from national HLW/ILW representative cases (M24-30)
- Performing simulations and sensitivity analyses from the models from Task 4.2 (M36-48)
- Simulation results and integration towards T1.2 (M42) MS195

It is envisioned that all partners will collaborate to achieve the milestones listed above. Related deliverables: D2.20

Participation per Partner

Partner number and short name	WP2 effort
1 - ANDRA	11.80
BRGM	19.60
3 - BEL V	5.00
5 - CEA	56.00
EDF	6.50
6 - CIEMAT	19.50
UAM	31.00
8 - CNRS	14.00
ULorraine	6.00
IMT Atlantique	12.00
9 - COVRA	10.50
14 - ENRESA	1.00
15 - JUELICH	10.80
UFZ	29.00
19 - IRSN	26.00
MINES ParisTech	26.00
22 - JSI	0.00
ZAG	38.00
25 - LEI	11.00
26 - MTA EK	11.00
27 - NAGRA	0.00
UBERN	54.00

Partner number and short name	WP2 effort
34 - PSI	18.00
38 - SCK•CEN	41.50
42 - SÚRAO	1.50
ÚJV	29.00
50 - VTT	27.00
Total	515.70

List of deliverables

Deliverable Number ¹⁴	Deliverable Title	Lead beneficiary	Type ¹⁵	Dissemination level ¹⁶	Due Date (in months) ¹⁷
D2.1	ACED - State-of-the-art report	9 - COVRA	Report	Public	6
D2.2	ACED - Updated State-of-the-art report & Summary of major conclusions from the work package	9 - COVRA	Report	Public	48
D2.3	ACED - Training materials	38 - SCK•CEN	Report	Public	36
D2.4	ACED - Treatment of chemical evolution in national programmes	9 - COVRA	Report	Public	5
D2.5	ACED - Experiments and numerical model studies on interfaces	15 - JUELICH	Report	Public	5
D2.6	ACED Task 2.1 - Technical report on the modelling approach proposed	27 - NAGRA	Report	Public	15
D2.7	ACED Task 2.1 - Final technical report on the steel/cement material interactions	19 - IRSN	Report	Public	46
D2.8	ACED Task 2.2 - Technical report on the modelling approach proposed	19 - IRSN	Report	Public	15
D2.9	ACED Task 2.2 - Final technical report on the steel/clay material interactions	19 - IRSN	Report	Public	46
D2.10	ACED Task 3.1 - HLW: Report describing the selected experiments and	26 - MTA EK	Report	Public	7

List of deliverables

Deliverable Number¹⁴	Deliverable Title	Lead beneficiary	Type¹⁵	Dissemination level¹⁶	Due Date (in months)¹⁷
	the existing/expected experimental results				
D2.11	ACED Task 3.1 - ILW: Report describing the selected experiments and the existing/expected experimental results	22 - JSI	Report	Public	7
D2.12	ACED Task 3.1 - HLW: Report describing the results of characterization performed during the project	5 - CEA	Report	Public	31
D2.13	ACED Task 3.1 - ILW: Report describing the results of characterization performed during the project	22 - JSI	Report	Public	31
D2.14	ACED Task 3.2 - Report describing the results of modelling, and the recommendations for future experimental and numerical work	38 - SCK•CEN	Report	Public	46
D2.15	ACED Task 3.3 - Report describing the results of modelling, and the recommendations for future experimental and numerical work	1 - ANDRA	Report	Public	46
D2.16	ACED Task 4.1 - Report on the conceptual model formulation for a mechanistic based model on implementing the initial SOTA knowledge on models and parameters in existing numerical tools	14 - ENRESA	Report	Public	12
D2.17	ACED Task 4.1 - Report on the integrated model for assessing the chemical evolution in a disposal cell on the simulations with a reactive transport model of the chemical evolution at the disposal cell scale	19 - IRSN	Report	Public	30

List of deliverables

Deliverable Number ¹⁴	Deliverable Title	Lead beneficiary	Type ¹⁵	Dissemination level ¹⁶	Due Date (in months) ¹⁷
D2.18	ACED Task 4.2 - Report on the conceptualization of upscaling including upscaling & model abstraction methods for the integration of process-level knowledge to disposal cell scale knowledge	38 - SCK•CEN	Report	Public	24
D2.19	ACED Task 4.2 -Report on comparison of model abstraction results	15 - JUELICH	Report	Public	45
D2.20	ACED Task 4.3 - Integration report of the work on disposal cell scale chemical evolution	14 - ENRESA	Report	Public	45

Description of deliverables

D2.1 - ACED - State-of-the-art report – SOTA of model and experiment with identification of knowledge gaps of experimental data – Lead: [COVRA] (Month 6)

D2.2 - ACED - Updated State-of-the-art report & Summary of major conclusions from the work package – Lead: [COVRA] a final synthesis report that brings together all the work done and interprets it and [SCK•CEN]: Summary of major conclusions (Month 48)

D2.3 - ACED - Training materials – Lead: [SCK•CEN] (Month 36)

D2.4 - ACED - Treatment of chemical evolution in National Programmes – Lead: [COVRA] (Month 5)

D2.5 - Experiments and numerical model studies on interfaces – Lead: [JUELICH] Month 5

D2.6 - ACED Task 2.1 - Technical report on the modelling approach proposed –This report will provide the first modelling results and refinement of the model approach. It will identify the missing data for model validation. Lead: [NAGRA (UBERN)] Month 15)

D2.7 - ACED Task 2.1 - Final technical report on the steel/cement material interactions –This report will synthesize the key results, identifying the difficulties/differences between the model and the experimental results, and proposing detailed outlooks in terms of experimental and modelling approaches to overpass the remaining gaps. Lead: [IRSN] (Month 46).

D2.8 - ACED Task 2.2 - Technical report on the modelling approach proposed –This report will provide the first modelling results and refinement of the model approach. It will identify the missing data for model validation. Lead: [IRSN (Mines ParisTech)] (Month 15)

D2.9 - ACED Task 2.2 - Final technical report on the steel/clay material interactions. This report will synthesize the key results, identifying the difficulties/differences between the model and the experimental results, and propose detailed outlooks in terms of experimental and modelling approaches to fill the remaining gaps. Lead: [IRSN] (Month 46).

D2.10 - ACED Task 3.1 - HLW: Report describing the selected experiments and the existing/expected experimental results as input for MS31 – Lead: [MTA EK] (Month 7)

D2.11 - ACED Task 3.1 - ILW: Report describing the selected experiments and the existing/expected experimental results as input for MS31– Lead: [JSI (ZAG)] (Month 7)

D2.12 - ACED Task 3.1 - HLW: Report describing the results of characterization performed during the project as input for MS152 and task 1.2 – Lead: [CEA] (Month 31)

D2.13 - ACED Task 3.1 - ILW: Report describing the results of characterization performed during the project as input for MS152 and task 1.2 – Lead: [JSI (ZAG)] (Month 31)

D2.14 - ACED Task 3.2 - Report describing the results of modelling, and the recommendations for future experimental and numerical work as input for task 1.2 – Lead: [SCK•CEN] (Month 46)

D2.15 - ACED Task 3.3 - Report describing the results of modelling, and the recommendations for future experimental and numerical work as input for task 1.2 - Lead: [Andra (BRGM)] (Month 46)

D2.16 - ACED Task 4.1 - Report on the conceptual model formulation for a mechanistic based model on implementing the initial SOTA knowledge on models and parameters (link to T1&T3) in existing numerical tools – Lead: [ENRESA] (Month 12)

D2.17 - ACED Task 4.1 - Report on the integrated model for assessing the chemical evolution in a disposal cell on the simulations with a reactive transport model of the chemical evolution at the disposal cell scale – Lead: [IRSN (MINES ParisTech)] (Month 30)

D2.18 - ACED Task 4.2 - Report on the conceptualization of upscaling including upscaling & model abstraction methods for the integration of process-level knowledge to disposal cell scale knowledge – Lead: [SCK•CEN] (Month 24)

D2.19 - ACED Task 4.2 -Report on comparison of model abstraction results obtained with different methods and best practice of methodology for model abstraction, recommendation of upscaling and model abstraction methodologies– Lead: [JUELICH (UFZ)] (Month 45)

D2.20 - ACED Task 4.3 - Integration report of the work on disposal cell scale chemical evolution performed in subtask 4.3 as input for task 1.2. Lead: [ENRESA] (Month 45)

D2.1 : ACED - State-of-the-art report [6]
ACED - State-of-the-art report

D2.2 : ACED - Updated State-of-the-art report & Summary of major conclusions from the work package [48]
ACED - Updated State-of-the-art report & Summary of major conclusions from the work package

D2.3 : ACED - Training materials [36]
ACED - Training materials

D2.4 : ACED - Treatment of chemical evolution in national programmes [5]
ACED - Treatment of chemical evolution in national programmes

D2.5 : ACED - Experiments and numerical model studies on interfaces [5]
ACED - Experiments and numerical model studies on interfaces

D2.6 : ACED Task 2.1 - Technical report on the modelling approach proposed [15]
ACED Task 2.1 - Technical report on the modelling approach proposed. CHANGE OF LEAD

D2.7 : ACED Task 2.1 - Final technical report on the steel/cement material interactions [46]
ACED Task 2.1 - Final technical report on the steel/cement material interactions

D2.8 : ACED Task 2.2 - Technical report on the modelling approach proposed [15]
ACED Task 2.2 - Technical report on the modelling approach proposed. CHANGE OF LEAD

D2.9 : ACED Task 2.2 - Final technical report on the steel/clay material interactions [46]
ACED Task 2.2 - Final technical report on the steel/clay material interactions

D2.10 : ACED Task 3.1 - HLW: Report describing the selected experiments and the existing/expected experimental results [7]
ACED Task 3.1 - HLW: Report describing the selected experiments and the existing/expected experimental results

D2.11 : ACED Task 3.1 - ILW: Report describing the selected experiments and the existing/expected experimental results [7]
ACED Task 3.1 - ILW: Report describing the selected experiments and the existing/expected experimental results

D2.12 : ACED Task 3.1 - HLW: Report describing the results of characterization performed during the project [31]
ACED Task 3.1 - HLW: Report describing the results of characterization performed during the project

D2.13 : ACED Task 3.1 - ILW: Report describing the results of characterization performed during the project [31]
ACED Task 3.1 - ILW: Report describing the results of characterization performed during the project

D2.14 : ACED Task 3.2 - Report describing the results of modelling, and the recommendations for future experimental and numerical work [46]
ACED Task 3.2 - Report describing the results of modelling, and the recommendations for future experimental and numerical work

D2.15 : ACED Task 3.3 - Report describing the results of modelling, and the recommendations for future experimental and numerical work [46]
ACED Task 3.3 - Report describing the results of modelling, and the recommendations for future experimental and numerical work

D2.16 : ACED Task 4.1 - Report on the conceptual model formulation for a mechanistic based model on implementing the initial SOTA knowledge on models and parameters in existing numerical tools [12]
ACED Task 4.1 - Report on the conceptual model formulation for a mechanistic based model on implementing the initial SOTA knowledge on models and parameters in existing numerical tools

D2.17 : ACED Task 4.1 - Report on the integrated model for assessing the chemical evolution in a disposal cell on the simulations with a reactive transport model of the chemical evolution at the disposal cell scale [30]
ACED Task 4.1 - Report on the integrated model for assessing the chemical evolution in a disposal cell on the simulations with a reactive transport model of the chemical evolution at the disposal cell scale

D2.18 : ACED Task 4.2 - Report on the conceptualization of upscaling including upscaling & model abstraction methods for the integration of process-level knowledge to disposal cell scale knowledge [24]
ACED Task 4.2 - Report on the conceptualization of upscaling including upscaling & model abstraction methods for the integration of process-level knowledge to disposal cell scale knowledge

D2.19 : ACED Task 4.2 -Report on comparison of model abstraction results [45]
ACED Task 4.2 -Report on comparison of model abstraction results

D2.20 : ACED Task 4.3 - Integration report of the work on disposal cell scale chemical evolution [45]
ACED Task 4.3 - Integration report of the work on disposal cell scale chemical evolution

Schedule of relevant Milestones

Milestone number ¹⁸	Milestone title	Lead beneficiary	Due Date (in months)	Means of verification
MS1	EURAD Kick-off meeting (General Assembly n°1)	1 - ANDRA	1	EURAD Kick-off meeting (General Assembly n°1)
MS2	ACED Kick-off meeting (WPM1)	38 - SCK•CEN	1	ACED Kick-off meeting (WPM1)
MS8	ACED Specifications of representative disposal cell systems and links with and between model approaches and expected experimental results M1.1.1	38 - SCK•CEN	2	ACED Specifications of representative disposal cell systems and links with and between model approaches and expected experimental results M1.1.1
MS11	ACED Task 2 workshop 1	38 - SCK•CEN	3	ACED Task 2 workshop 1
MS12	EURAD EJP Newsletters	1 - ANDRA	3	EURAD EJP Newsletters (Due date : M3 and then every quarter)
MS16	ACED - note on the specific experimental conditions at the steel/clay material interface, parameters and modelling approaches	38 - SCK•CEN	6	ACED - note on the specific experimental conditions at the steel/clay material interface, parameters and modelling approaches with detailed information on set-ups and work flow, variables to measure and a dismantling and characterization plan. It will also define the link

Schedule of relevant Milestones

Milestone number ¹⁸	Milestone title	Lead beneficiary	Due Date (in months)	Means of verification
				between the experiments and the model approaches (also input to general workshop 1, and MS31)
MS30	EURAD General Assembly n°2	1 - ANDRA	7	EURAD General Assembly n°2
MS31	ACED Experimental data as a first input for modelling and information exchange towards other scales M1.1.2	38 - SCK•CEN	7	ACED Experimental data as a first input for modelling and information exchange towards other scales M1.1.2
MS32	ACED WP meeting 2 + Workshop 1	38 - SCK•CEN	7	ACED WP meeting 2 + Workshop 1
MS42	EURAD Annual Work Plan 2	1 - ANDRA	9	EURAD Annual Work Plan 2
MS43	ACED Identification of integration and upscaling strategies M1.1.3	38 - SCK•CEN	9	ACED Identification of integration and upscaling strategies M1.1.3
MS55	ACED T3.1 - distribution of experimental samples to partners	38 - SCK•CEN	12	ACED T3.1 - distribution of experimental samples to partners
MS72	ACED Workshop 2 – Joint workshop with GAS and DONUT	38 - SCK•CEN	13	ACED Workshop 2 – Joint workshop with GAS and DONUT (Month 13 - 18)
MS81	EURAD General Assembly n°3 + EURAD Annual Meeting 1	1 - ANDRA	13	EURAD General Assembly n°3 + EURAD Annual Meeting 1
MS85	EURAD Periodic Report 1	1 - ANDRA	14	EURAD Periodic Report 1
MS94	ACED - GAS - DONUT Joint Workshop - 1	32 - ONDRAF/NIRAS	16	ACED - GAS - DONUT Joint Workshop
MS95	ACED Task 2 workshop 2	38 - SCK•CEN	18	ACED Task 2 workshop 2
MS96	ACED T4.1 - Simulation results as basis for ACED T4.2 and T4.3	38 - SCK•CEN	18	ACED T4.1 - Simulation results as basis for ACED T4.2 and T4.3
MS103	EURAD General Assembly n°4	1 - ANDRA	19	EURAD General Assembly n°4
MS104	ACED WP meeting 3	38 - SCK•CEN	19	ACED WP meeting 3
MS112	EURAD Annual Work Plan 3	1 - ANDRA	21	EURAD Annual Work Plan 3
MS119	ACED T4.3 - Definition of calculation cases and parameter ranges	38 - SCK•CEN	24	ACED T4.3 - Definition of calculation cases and parameter ranges
MS136	EURAD General Assembly n°5 + EURAD Annual Meeting 2	1 - ANDRA	25	EURAD General Assembly n°5 + EURAD Annual Meeting 2

Schedule of relevant Milestones

Milestone number¹⁸	Milestone title	Lead beneficiary	Due Date (in months)	Means of verification
MS140	EURAD Periodic Report 2	1 - ANDRA	26	EURAD Periodic Report 2
MS148	ACED Task 2 workshop 3	38 - SCK•CEN	30	ACED Task 2 workshop 3
MS149	ACED T4.1 - Simulation results as a basis for ACED T4.2 and T4.4	38 - SCK•CEN	30	ACED T4.1 - Simulation results as a basis for ACED T4.2 and T4.4
MS150	ACED Workshop 4 – Joint workshop with GAS and DONUT	38 - SCK•CEN	30	ACED Workshop 4 – Joint workshop with GAS and DONUT (Month 30 - 37)
MS153	EURAD General Assembly n°6	1 - ANDRA	31	EURAD General Assembly n°6
MS154	ACED WP meeting 4 + Workshop 3	38 - SCK•CEN	31	ACED WP meeting 4 + Workshop 3
MS155	ACED Updated experimental data, model concepts and parameters as input for modelling and for information transfer towards other scales including update upscaling approach M1.1.4	38 - SCK•CEN	31	ACED Updated experimental data, model concepts and parameters as input for modelling and for information transfer towards other scales including update upscaling approach M1.1.4
MS162	EURAD Annual Work Plan 4	1 - ANDRA	33	EURAD Annual Work Plan 4
MS165	ACED - GAS - DONUT Joint Workshop	32 - ONDRAF/NIRAS	33	ACED - GAS - DONUT Joint Workshop
MS167	ACED T3.2 - Synthesis note on concepts and effective parameters for approximation of chemical evolution of waste packages on disposal cell scale (input to milestone M1.1.5)	38 - SCK•CEN	36	ACED T3.2 - Synthesis note on concepts and effective parameters for approximation of chemical evolution of waste packages on disposal cell scale (input to milestone M1.1.5)
MS168	ACED T3.3 - Synthesis note on concepts and effective parameters for approximation of chemical evolution of waste packages on disposal cell scale (input to milestone M1.1.5)	38 - SCK•CEN	36	ACED T3.3 - Synthesis note on concepts and effective parameters for approximation of chemical evolution of waste packages on disposal cell scale (input to milestone M1.1.5)
MS169	ACED T4.2 - Demonstration of simulation results with abstracted models	38 - SCK•CEN	36	ACED T4.2 - Demonstration of simulation results with abstracted models
MS180	ACED Final freeze of data and models mainly for transfer towards other scales M1.1.5	38 - SCK•CEN	37	ACED Final freeze of data and models mainly for transfer towards other scales M1.1.5

Schedule of relevant Milestones

Milestone number¹⁸	Milestone title	Lead beneficiary	Due Date (in months)	Means of verification
MS185	EURAD General Assembly n°7 + EURAD Annual Meeting 3	1 - ANDRA	37	EURAD General Assembly n°7 + EURAD Annual Meeting 3
MS189	EURAD Periodic Report 3	1 - ANDRA	38	EURAD Periodic Report 3
MS193	ACED Task 2 workshop 4	38 - SCK•CEN	42	ACED Task 2 workshop 4
MS194	ACED T4.2 - Updated simulation results with abstracted models	38 - SCK•CEN	42	ACED T4.2 - Updated simulation results with abstracted models
MS195	ACED T4.3 - Simulation results and integration towards T1.2	38 - SCK•CEN	42	ACED T4.3 - Simulation results and integration towards T1.2
MS199	EURAD General Assembly n°8	1 - ANDRA	43	EURAD General Assembly n°8
MS200	ACED WP meeting 5 + Workshop 6	38 - SCK•CEN	43	ACED WP meeting 5 + Workshop 6
MS206	EURAD Annual Work Plan 5	1 - ANDRA	45	EURAD Annual Work Plan 5
MS210	ACED Closure meeting	38 - SCK•CEN	48	ACED Closure meeting
MS222	EURAD General Assembly n°9 + EURAD Annual Meeting 4	1 - ANDRA	49	EURAD General Assembly n°9 + EURAD Annual Meeting 4
MS224	EURAD Periodic Report 4	1 - ANDRA	50	EURAD Periodic Report 4
MS234	EURAD General Assembly n°10	1 - ANDRA	55	EURAD General Assembly n°10
MS240	EURAD General Assembly n°11 + EURAD Annual Meeting 5	1 - ANDRA	60	EURAD General Assembly n°11 + EURAD Annual Meeting 5
MS241	EURAD Periodic Report 5	1 - ANDRA	60	EURAD Periodic Report 5 (Due date: 60+2)

Work package number ⁹	WP3	Lead beneficiary ¹⁰	24 - KIT
Work package title	Cement-Organic-Radionuclide-Interactions (CORI)		
Start month	1	End month	48

Objectives

Objectives

CORI aims to improve the knowledge on the organic release issues which can accelerate the radionuclide migration in the context of the post closure phase of geological repositories for ILW and LLW/VLLW, including surface/shallow disposal. The RD&D in CORI is expected to extend the current state-of-the-art, contribute to optimized disposal solutions and consider questions of regulatory concern. CORI will help Member-States to further develop their national RD&D programmes and support programmes at an early implementation stage. Enhancing cooperation between the different participating beneficiaries and countries is an important objective in CORI. Knowledge transfer and training of young researchers in view of future demands for qualified staff is likewise a key aspect of CORI.

CORI objectives are addressing topics in the context of cement-organic-radionuclide-interactions. Organic materials are present in some nuclear waste and as admixtures in cement-based materials and can potentially influence the performance of a geological disposal system, especially in the context of low and intermediate level waste disposal. This potential effect of organic molecules is related to the formation of complexes in solution with some radionuclides of interest (actinides and lanthanides) which can (i) increase the radionuclide solubility and (ii) decrease the radionuclide sorption. Organic substances require increased attention since a significant quantity exists in the waste and in the cementitious materials, with a large degree of chemical diversity. Cement-based materials will be degraded with time in the context of waste disposal inducing a large range of alkaline pH conditions according to their degradation state. Alkaline pH provides specific conditions under which the organics can degrade, which contributes to increasing their impact on repository performance. The most critical open topics and data needs required to better assess and quantify cement-organic-radionuclide-interactions are reflected in the three R&D oriented CORI Tasks:

- Organic Degradation
- Organic-Cement-Interactions
- Radionuclide-Organic-Cement-Interactions

Expected impacts of the WP

Predicting and assessing radionuclide transport is a key topic in nuclear waste disposal. For radionuclide behaviour in cementitious environments where large inventories of organic materials may be present, CORI has identified that the present knowledge can be significantly improved. An improved quantification of radionuclide solubility and sorption phenomena in cementitious environments can provide important input into predicting radionuclide transport. Against this general motivation in CORI, specific benefits in terms of impacting implementation or safety are described below. Regarding Radioactive Waste Management (RWM) implementation needs

Issues of interest at the repository scale are identified:

- o Improved scientific basis for the Safety Case for L/ILW waste repositories featuring high organic content.
- o Co-storage of waste: support decisions regarding the question whether or not a mix of various wastes (organics, soluble salts, exothermic waste) can be foreseen.
- o Optimization of vault design: limitations of interactions between the vaults regarding their content. CORI will provide information on the organic plume by characterizing the transfer behaviour in cement-based materials.
- o Optimization of concrete formulations as regards the potential effect of superplasticizers on radionuclide transfer properties.

The WP is linked to the Roadmap Theme 3 (EBS properties, function and long-term performance) phases 2 -4 and Theme 4 (Geoscience to understand rock properties, radionuclide transport and long-term geological evolution) phases 1 and 2.

Regarding safety

- o Characterizing the effect of the organic plume on the behavior of radionuclides in terms of:
 - (i) Solubility (limitation of solubility increase), and
 - (ii) Sorption (limitation of retention decrease) in terms of K_d values.
 - (iii) The retention of potentially ¹⁴C-bearing organic molecules (determined in CAST project) in cementitious environments in the case of specific waste.
- o This project aims to:
 - (i) Reduce the uncertainties on the current knowledge, which is mainly based on K_d values,

(ii) Improve the knowledge on the known organic molecules present in degradation solutions (not considered so far) with their complexing properties: better definition of the organic inventory regarding the waste and the concrete vault (geological and surface repositories).

Description of work and role of partners

WP3 - Cement-Organic-Radionuclide-Interactions (CORI) [Months: 1-48]

KIT, ANDRA, CEA, CIEMAT, CNRS, FTMC, CV REZ, JUELICH, JSI, PSI, RATEN, SCK•CEN, SÚRAO, UCyprus

Task 1 – S/T coordination, State-of-the-art and training material

Start: Month 1 – End: Month 48 - Task Leader: [KIT] (WP Leader)

Task contributors: [Andra] [CEA] [CIEMAT] [CNRS-SUBATECH] [KIT (Amphos 21)]

Total PM: 9,9

Subtask 1.1 – S/T coordination

Start: Month 1 – End: Month 48 – Subtask Leader: [KIT]

Subtask contributors: [Andra] [CEA] [CIEMAT] [CNRS-SUBATECH] [KIT (Amphos 21)]

Total PM: 3,6

The S/T coordination of CORI will be performed by the WP Leader [KIT]. The WP Leader will be supported by the Sub-Task leaders [Andra] and [CNRS-SUBATECH] for Task 2, [KIT (Amphos21)] and [Andra] for Task 3, and [CEA] and [CIEMAT] for Task 4, which together constitute the WP Board of CORI.

The WP leader will ensure that the WP is progressing according to the agreed planning, milestones and deliverables. All meetings will be documented in minutes prepared by [KIT]. The WP Leader is also responsible to report the work progress, any WP deliverables and eventual modifications of the WP work plan to the Programme Management Office (PMO). This will be done in close consultation with WP Board. The CORI WP Board will also be responsible to communicate CORI to other WPs and stakeholders in EURAD-1.

In order to reach these aims, the CORI WP Board will have regular meetings every 6 month, which will be captured in minutes to be distributed to CORI partners and the PMO. These meetings can be organised by specific side-meetings during the Annual CORI WP Meetings at Month 12, 24, 36 and 48 (see below). The additional meetings of the CORI WP Board at Months 1, 6, 18, 30 and 42 can be arranged as meetings in person and using video conferencing options whenever required.

The Annual CORI Work Package Meetings (WPM) are key events in CORI which will be arranged as cluster meetings with all partners to allow for information exchange, monitoring of work progress, dissemination of results, interaction with End Users and other stakeholders, amongst others. To ensure effective meetings, the Annual CORI WP Meetings will be prepared on the basis of a synthesis report prepared by the Task leaders after exchanging with all the partners prior to the workshop. Plenary meetings highlighting main RD&D results from CORI participants will constitute a key part of the meetings, which also will allow sufficient time for exchange and detailed discussions with interested WMOs, TSOs or REs not part of CORI). These activities will be complemented by dedicated technical meetings on Task level, topical sessions focussing on specific aspects of general interest in CORI, poster sessions or sessions focusing specifically on young researchers, as required. Integration at Task level will thus be organized at the Annual CORI WP Meetings. The Annual CORI WP Meetings will be documented in Proceedings which will summarize overall R&D progress, also by featuring selected S&T contributions from the CORI partners, in addition to the technical deliverables defined in the individual Tasks. [KIT] with the support of local organizers will organize The Annual CORI WP Meetings.

The foreseen Annual CORI WP Meetings and the Meetings of the CORI WP Board are

- WP Board Meeting 1 (Month 1)
- WP Board Meeting 2 (Month 6)
- First Annual CORI WP Meeting (including technical meetings on Task Level) with WP Board Meeting 3 (Month 12). Task technical meetings focus on:
 - Organic retention studies onto cementitious material (task 3)
 - Radionuclide retention studies onto cementitious material in presence of organics (task 4)
- WP Board Meeting 4 (Month 18)
- Second Annual CORI WP Meeting (including technical meetings on Task Level) with WP Board Meeting 5 (Month 24), Task technical meetings focus on:
 - Radionuclide speciation in cementitious media in presence of organics. (Task 2).
 - Studies on the role of iron (and/or calcium) on organic retention in cementitious media (Task 3)
 - Radionuclide speciation in cementitious media in presence of organics. (Task 4).

- WP Board Meeting 6 (Month 30)
- Third Annual CORI WP Meeting (including technical meetings on Task Level) with WP Board Meeting 7 (Month 36), Task technical meetings mainly focus on:
 - Transport of organic molecules in cementitious material. (Task 3)
 - Radionuclide transport in cementitious material in presence of organics. (Task 4).
- WP Board Meeting 8 (Month 42)
- Fourth and Final CORI WP Meeting (including technical meetings on Task Level) with WP Board meeting 9 (Month 48), Focus on technical deliverables preparation

[KIT] will establish an electronic data deposit to make the experimental data generated in Task 2, 3, 4 of CORI available in electronic form for use in later upscaling/PA related modelling activities. During the development of CORI, it was decided that a comprehensive modelling of the generated results will not be performed within CORI. However, it was clarified that this aspect is important and could be integrated in potential follow up activities focused on modelling. The data deposit will mainly be based on easily accessible Excel-type data tables in formats commonly used.

As Coordinator, [KIT] will be responsible for preparing the Deliverable D3.5, which is the Final Report on the RD&D results, main outcome and conclusions in CORI. This Deliverable will integrate the information from Task 2, 3, and 4, and highlight potential applications to the Safety Case arising from the work in CORI.

Subtask 1.2 – State-of-the-art

Start: Month 1 – End: Month 48 – Subtask Leader: [KIT]

Subtask contributors: [Andra] [CEA] [CIEMAT] [CNRS-SUBATECH] [KIT (Amphos21)]

Total PM: 3,1

The WP CORI will prepare an initial state-of-the-art report (SOTA) at Month 6 (D3.1) with updating at Month 48 (D3.2) which will feed into Knowledge Management in EURAD-1 and is communicated to other WPs in EURAD for information exchange. The writing of the SOTA reports will be led by the respective CORI Task leaders (meaning in teams of 2 partners), with support by the Coordinator. Information exchange with the respective Task partners will be organised at Task level.

The content of the SOTA will mainly reflect the content of the three R&D Tasks defined in CORI and build up on technical documents prepared on the Task level (M.2.1, M.3.1, M.4.1). Consequently, sub-chapters of the SOTA will address (i) organic degradation by hydrolytic and radiolytic processes, (ii) cement-organic-interactions, and (iii) cement-organic-radionuclide-interactions. Considering that the general context of the studies is related to cementitious environments, CORI D3.1 and D3.2 will also include a critical summary on “fundamental cement chemistry” to provide basic information relevant in this particular context, which is expected to be a valuable part of the training materials developed in Subtask 1.3 of CORI. The updating of the SOTA at Month 48 will reflect the improved knowledge base generated in CORI on these topics and implement the new information in the SOTA (D3.2) document.

Subtask 1.3 – Training materials

Start: Month 1– End: Month 48 – Subtask Leader: [KIT]

Subtask contributors: [Andra] [CEA] [CIEMAT] [CNRS-SUBATECH] [KIT (Amphos21)]

Total PM: 3,1

CORI will contribute to Training activities in EURAD-1 in close interactions with Training/Mobility KM WP. For this reason, specific training materials on topics addressed in CORI will be prepared. The approach to prepare training materials will follow two lines of activity.

First, it is planned to develop material for tutorials based on the information detailed in the SOTA reports generated in CORI Task 1.2 (D3.1 and D3.2). This Training material will be made available in the form of ppt-files or pdf-files (from about two months after the respective SOTA) and will eventually be presented at EURAD Training activities by CORI WP Board members. D3.3 will be updated at Month 48 as D3.4.

Second, depending on the specific focus of future Training activities in EURAD, CORI WP Board is also willing to contribute more detailed technical training material (for example considering PhD courses, e.g. on analytical tools and techniques, data treatment, ...), which however will later need to be developed in direct exchange with the future Training Event organisers. There is no Deliverable or Milestone formally placed for this highly flexible activity.

The preparation of the Training material will be led by the respective CORI Task leaders (meaning in teams of 2 partners), with support by the Coordinator. Information exchange with the respective Task partners will be organised at Task level.

Task 2 - ORGANIC DEGRADATION

Start: Month 1 – End: Month 48 - Task Leader: [CNRS-SUBATECH] [Andra]

Task Contributors: [Andra (BRGM)] [CNRS-SUBATECH (UOrléans)] [FTMC] [JSI] [JUELICH] [KIT] [PSI] [SÚRAO (CTU) (UVV)] [CV REZ] [SCK•CEN]

Total PM: 155,1

Task objectives:

- Improve knowledge of degradation of organic wastes in conditions representative of disposal facilities.
- Improve understanding of radiolytic/hydrolytic degradation of organic materials.
- Provide characterization and quantification of soluble organic species generated by degradation.

Task description

This Task aims to improve the knowledge about soluble organic species released due to the degradation of organic materials under disposal conditions and better describe their chemical characteristics. The available literature data concern the degradation of polymers and its impact on the structural and mechanical properties. Only very few publications consider the identification and characterisation of soluble organic species in solution. The two important degradation processes to be studied in Task 2 are radiolysis and hydrolysis. The organic materials considered in CORI are polyvinylchloride (PVC), cellulose, ion exchange resins (IER), and superplasticizers (as poly-carboxylate-ether). These materials have been selected by CORI partners with support of WMOs, considering that these are abundant organics in national waste inventories and can be expected to generate species with potentially high complexing properties. In order to be representative of the materials actually present in the waste inventories, the organic degradation studies will also consider selected industrial materials (formulated materials). Task 2 of CORI will provide a comprehensive summary report on the outcome of the RD&D studies as D3.6. This Deliverable will also feed into the integrated Final Report including application to the Safety Case, defined as D3.5.

The Technical document prepared under MS17 will provide an overview on organic degradation under hydrolytic and radiolytic conditions and discuss the related release of soluble organic species. This report will also be used as input to the SOTA D3.1 and D3.3. The description will cover the organic materials considered by partners in the Task 2 of CORI and also reflect the different experimental systems used for degradation studies.

The degradation studies performed in CORI will focus on two main experimental conditions and include detailed analysis of the degradation products.

(i) Radiolytic degradation: Irradiation of organic materials will be performed under dry conditions and in basic solution (alkaline media pH > 12) in order to be representative of different national disposal conditions. All organic materials (PVC, cellulose, IER and superplasticizers) will be irradiated by gamma irradiation; superplasticizers will be also degraded by using alpha particles (He-particles). Different irradiation conditions (regarding total dose, dose rate and atmosphere) will be investigated in order to identify specific effects of the irradiation conditions on organic degradation. [BRGM/ISTO] [CTU/CV REZ/UJV/SÚRAO] [JSI] [JUELICH] [SCK•CEN] [CNRS-SUBATECH].

(ii) Hydrolytic degradation: For materials irradiated under dry conditions, hydrolysis will be carried out after irradiation. Hydrolysis of pre-irradiated materials will be performed in basic solution characteristic for cementitious environments (alkaline media pH > 12 and under both oxic and anoxic atmosphere). For materials irradiated in solution, radiolysis and hydrolysis occurs simultaneously as both processes are coupled. Hydrolysis will be also performed on initial materials (non-irradiated materials) for purposes of results comparison. Hydrolysis of pre-irradiated materials will be studied by [Andra (BRGM)] [CNRS-SUBATECH (UOrléans)] [JUELICH] [SCK•CEN]. Hydrolysis of non-irradiated materials will be investigated by [Andra] [FTMC] [CV REZ] [KIT] [PSI] [SÚRAO (CTU)] [SÚRAO (UJV)]. Organic material will include superplasticizers, PVC, IER and cellulose.

(iii) Characterisation and quantification of soluble organic species in solution will be performed via complementary analytical techniques for the following solutions generated in CORI Task 2 containing degraded organic material: (i) solutions obtained by hydrolysis of pre-irradiated samples, (ii) solution obtained by simultaneous radiolysis/hydrolysis (irradiation of materials in solution), and (iii) simple hydrolysis without any irradiation. Partners intend to use TOC analysis, ionic/liquid chromatography, AES-OES or induced-coupled-plasma techniques, GC/ICP/LC mass spectrometry, UV-Vis or IR spectrometry, amongst others [all partners].

(iv) Gas measurements will be performed by some partners in order to determine radiolytic gas yields (H₂, HCl, CO₂...) by using gas-chromatography. Organic materials will include superplasticizer, PVC, IER and cellulose. [Andra] [Andra (BRGM)] [CNRS (UOrléans)] [CNRS-SUBATECH] [CV REZ] [JUELICH] [SCK•CEN].

Task 3 - ORGANIC-CEMENT-INTERACTIONS

Start: Month 1 – End: Month 48 - Task Leader: [KIT (Amphos21)] [Andra]

Task Contributors: [CEA] [CIEMAT (CSIC)] [CV REZ] [JSI] [KIT (Amphos 21)] [PSI (EMPA)] [RATEN] [SCK•CEN] [SÚRAO (CTU) (UJV)] [Andra]

Total PM: 163,5

Task objectives:

- Improve the understanding of the behaviour of anthropogenic organic molecules within cementitious systems.
- Study the sorption and transfer properties of organic molecules that might be released from the organics inventories (including polymers and superplasticizers) present in cement-based materials.

Task description

CORI Task 3 will investigate the sorption and diffusion processes of different organic molecules onto cement-based materials. The investigated organic molecules were defined to include (i) main degradation products such as ISA, phthalates [Andra] [CEA] [CIEMAT (CSIC)] [KIT (Amphos21)] [SCK•CEN] (ii) C14-bearing molecules identified in the European project CAST [RATEN] and (iii) degradation products resulting from Task 2 (during the second part of the project) [KIT (Amphos21)] [RATEN]. (iv) EDTA will be also studied as strong complexing molecule [CEA] [CIEMAT (CSIC)] [SÚRAO (CTU)] CTU as well as low molecular weight molecules [Andra] [KIT (Amphos21)].

Regarding the investigated cementitious materials, CORI partners will investigate selected systems of high interest. CEM I [JSI] [KIT] [RATEN] [SCK•CEN] [UCY] and CEM V [CEA] [CIEMAT (CSIC)] [JSI] [RATEN] will be used at various degradation states (including altered/carbonated states) according to the requirements by WMOs, as well as pure solid phases such as C-(A)-S-H KIT (Amphos21)] [PSI (EMPA)] and AFm-phases/ettringite [CIEMAT] [PSI (EMPA)] to allow for improved process understanding. Additionally, [CIEMAT] will study cement CEM IV.

Two prominent cations present in cementitious systems will be included in some of the Task 3 investigations, (i) iron, which is present in both, cement phases and steel corrosion phases generated by the corrosion of iron-based materials, and (ii) calcium, which is one of the main elements in cement components. The aim of including Fe and Ca systems is to elucidate their potential role as competitors of radionuclides (investigated in Task 4) for complexing organics. [CIEMAT (CSIC)] [KIT (Amphos21)] [RATEN] [SÚRAO (UJV)]. Some specific efforts will be made to integrate the experimental results with adequate models [Andra].

All contributors of this task have considered the priorities defined in Task 3 in terms of relevant organic molecules and cementitious materials to be studied in order to reduce and optimize the number of systems. Thus, dedicated experimental work combining batch sorption, diffusion, column systems, speciation, solubility and spectroscopic studies to allow fundamental model development and application oriented analyses is proposed. In particular, batch and diffusion experiments investigating the behavior in cement-based materials can lead to significant differences regarding K_d values. CORI has the objective to provide understanding on this experimental observation on the basis of spectroscopic techniques and phenomenological models such as reactive transfer and double layer models. Consequently, conceptual models will be derived within CORI Task 3 to serve as a basis for the more complex systems studied in Task 4. Overall, the work proposed by the partners enrolled in this Task will aim to produce a robust understanding of cement-organic interactions in cement-based systems. Task 3 of CORI will prepare a comprehensive summary report on the main results as D3.7. This Deliverable will also feed into the integrated Final Report including application to the Safety Case, defined as D3.5.

Task 4 - RADIONUCLIDE-ORGANIC-CEMENT-INTERACTIONS

Start: Month 1 – End: Month 48 - Task Leader: [CEA] [CIEMAT]

Task Contributors [Andra] [CNRS-SUBATECH] [FTMC] [JUELICH (HZDR)] [KIT (Amphos21)] [JGU-INC] (UPOTSDAM)] [SÚRAO (CTU) (UJV)] [RATEN] [SCK•CEN] [UCY] [CEA] [CIEMAT]

Total PM: 205,7

Task objectives:

- Improving the knowledge on organic-radionuclide complexes mobility in cement-based systems.
- Studying the competition or synergetic effect in ternary systems (i.e. organic/ radionuclide/ cement).
- Providing a mechanistic understanding of radionuclide interactions and quantitative transfer data in cementitious environments.

Task description

CORI Task 4 aims to improve the knowledge on organic-radionuclide complexes mobility in cement-based systems by providing mechanistic understanding of radionuclide interactions and detailed experimental data to quantitatively assess the impact of organics on radionuclide transport in the cementitious environment. CORI Task 4 will prepare a comprehensive summary report on the main results as D3.8. This Deliverable will also feed into the integrated Final Report including application to the Safety Case, defined as D3.5.

All contributors have considered the priorities defined in Task 4 in terms of critical radionuclides (or toxic heavy metals), relevant organic molecules and cementitious materials to be studied.

The main radionuclides that will be studied in Task 4 of CORI are: Nickel isotopes [CEA] [CIEMAT] [KIT (Amphos21)] [RATEN] [SÚRAO (UJV)] [SCK•CEN] Uranium isotopes [CEA] [CIEMAT] [CNRS-SUBATECH] [JUELICH (HZDR)] [KIT (Amphos21)] (UPOTSDAM)] [SÚRAO (CTU) (UJV)] [SCK•CEN] [UCY] Actinides(III/ IV) and/or homologues [CIEMAT] [FTMC] [JUELICH] [JUELICH (HZDR)] [KIT (Amphos21)] [KIT (JGU INC)] [KIT (UPOTSDAM)] [UCY].

The organic and cementitious materials are consistent with those analyzed in Task 2 and Task 3 of CORI. In particular, ISA will be studied by [CIEMAT] [CNRS-SUBATECH] [JUELICH (HZDR)] [KIT (Amphos21)] (JGU INC)] (UPOTSDAM)] [SCK•CEN] EDTA by [CEA] [JUELICH (HZDR)] [KIT (JGU INC)] [KIT (UPOTSDAM)] [SÚRAO

(CTU)] [UCY] PAN degradation products by [KIT] adipate, phthalate or short-chained carboxylic acid by [CEA] [FTMC] [JUELICH] [KIT (Amphos21) (JGU INC)] (UPOTSDAM)] [RATEN] [SÚRAO (CTU)].

CEM I [CIEMAT] [FTMC] [KIT (JGU INC)] [SÚRAO (UJV)] [SCK•CEN] and CEM V [CEA] [CIEMAT] [CNRS-SUBATECH] [JUELICH] [FTMC] [KIT (JGU INC)] [RATEN] will be the main cementitious material analyzed considering different degradation states (mainly II and III). Amongst the main mineral phases considered in CORI, CSH and CASH [CIEMAT] [CNRS-SUBATECH] [JUELICH (HZDR)] [KIT (Amphos21)] (JGU INC)] (UPOTSDAM)] [UCY] will be studied considering different C/S ratios.

A dedicated experimental work has been proposed combining batch sorption (on powder and small blocks), diffusion, column, speciation, solubility and advanced spectroscopic studies to allow fundamental model development and application-oriented analyses. The wide possibility of combinations of radionuclide /organic/ cementitious material / chemical conditions and experimental techniques resulted in a very limited overlap on the system studied by the different partners.

Numerical interpretation and conceptual modelling of experimental data and observations are included in Task 4. All partners' contributions will aim to give a complete and consistent set of data and therefore will contribute to update the state-of-art for organic-radionuclide complexes mobility in cement-based systems D3.3.

The Task leaders will ensure that the work programme is progressing accordingly to the agreed milestones and deliverables planning. They will be responsible to communicate to all Task 4 partners important information coming from CORI Tasks 1, 2 and 3, which is required as input for the detailed work programme.

Participation per Partner

Partner number and short name	WP3 effort
1 - ANDRA	10.40
BRGM	13.40
5 - CEA	35.40
6 - CIEMAT	44.40
CSIC	30.00
8 - CNRS	44.00
UOrléans	16.00
10 - FTMC	20.00
11 - CV REZ	12.00
15 - JUELICH	19.00
HZDR	8.00
22 - JSI	26.40
24 - KIT	47.90
Uni Mainz	24.00
AMPHOS 21	21.40
Uni Potsdam	12.00
34 - PSI	13.00
EMPA	11.00
36 - RATEN	17.00
38 - SCK•CEN	18.30
42 - SÚRAO	4.60
CTU	40.00

Partner number and short name	WP3 effort
ÚJV	42.00
47 - UCyprus	4.00
Total	534.20

List of deliverables

Deliverable Number ¹⁴	Deliverable Title	Lead beneficiary	Type ¹⁵	Dissemination level ¹⁶	Due Date (in months) ¹⁷
D3.1	CORI - SOTA on cement-organic-radionuclide-interactions in the content of L/ILW disposal	24 - KIT	Report	Public	6
D3.2	CORI - SOTA UPDATE on cement-organic-radionuclide-interactions in the content of L/ILW disposal	24 - KIT	Report	Public	48
D3.3	CORI - Training Materials	24 - KIT	Report	Public	8
D3.4	CORI - Training Materials UPDATE	24 - KIT	Report	Public	48
D3.5	CORI - Final Report integrating the RD&D performed in CORI, including application to the Safety Case	24 - KIT	Report	Public	48
D3.6	CORI - Final Report on results generated in Task 2 of CORI	8 - CNRS	Report	Public	44
D3.7	CORI - Final Report on organic retention in cementitious systems	1 - ANDRA	Report	Public	44
D3.8	CORI - Final Report on radionuclide mobility in cementitious materials in the presence of organics	5 - CEA	Report	Public	46

Description of deliverables

D3.1 CORI - SOTA on cement-organic-radionuclide-interactions in the content of L/ILW disposal. Chapters to include: (i) Organic degradation by hydrolytic and radiolytic processes; (ii) Organic-cement-interactions; (iii) Radionuclide-organic-cement-interactions; (iv) Fundamental Cement Chemistry. [KIT] (Months 6)

D3.2 CORI - SOTA UPDATE on cement-organic-radionuclide-interactions in the content of L/ILW disposal. Chapters to include: (i) Organic degradation by hydrolytic and radiolytic processes; (ii) Organic-cement-interactions; (iii) Radionuclide-organic-cement-interactions; (iv) Fundamental Cement Chemistry . [KIT] (Months 48).

D3.3 CORI - Training Materials. [KIT] (Month 8).

D3.4 CORI - Training Materials UPDATE. [KIT] Month 48).

D3.5 CORI - Final Report integrating the RD&D performed in CORI, including application to the Safety Case. [KIT] (Month 48).

D3.6 CORI - Final Report on results generated in Task 2 of CORI on (i) Degradation of organic materials by hydrolytic and radiolytic processes, and (ii) identification and quantification of degradation products. [CNRS-SUBATECH] (Month 44).

D3.7 CORI - Final Report on organic retention in cementitious systems. [Andra] and [KIT (Amphos21)] (Month 44).

D3.8 CORI - Final Report on radionuclide mobility in cementitious materials in the presence of organics, including (i) Radionuclide speciation under alkaline conditions in presence of organics, and (ii) Evaluation of radionuclide mobility in cementitious materials in the presence of organics. [CEA] and [CIEMAT] (Month 46).

D3.1 : CORI - SOTA on cement-organic-radionuclide-interactions in the content of L/ILW disposal [6]
CORI - SOTA on cement-organic-radionuclide-interactions in the content of L/ILW disposal

D3.2 : CORI - SOTA UPDATE on cement-organic-radionuclide-interactions in the content of L/ILW disposal [48]
CORI - SOTA UPDATE on cement-organic-radionuclide-interactions in the content of L/ILW disposal

D3.3 : CORI - Training Materials [8]
CORI - Training Materials

D3.4 : CORI - Training Materials UPDATE [48]
CORI - Training Materials UPDATE

D3.5 : CORI - Final Report integrating the RD&D performed in CORI, including application to the Safety Case [48]
CORI - Final Report integrating the RD&D performed in CORI, including application to the Safety Case

D3.6 : CORI - Final Report on results generated in Task 2 of CORI [44]
CORI - Final Report on results generated in Task 2 of CORI

D3.7 : CORI - Final Report on organic retention in cementitious systems [44]
CORI - Final Report on organic retention in cementitious systems

D3.8 : CORI - Final Report on radionuclide mobility in cementitious materials in the presence of organics [46]
CORI - Final Report on radionuclide mobility in cementitious materials in the presence of organics

Schedule of relevant Milestones

Milestone number ¹⁸	Milestone title	Lead beneficiary	Due Date (in months)	Means of verification
MS1	EURAD Kick-off meeting (General Assembly n°1)	1 - ANDRA	1	EURAD Kick-off meeting (General Assembly n°1)
MS12	EURAD EJP Newsletters	1 - ANDRA	3	EURAD EJP Newsletters (Due date : M3 and then every quarter)
MS17	CORI Technical Report - Task 2 State-of-art report on organic degradation by radiolytic and hydrolytic processes	24 - KIT	6	CORI Technical Report - Task 2 State-of-art report on organic degradation by radiolytic and hydrolytic processes.
MS18	CORI Technical Report- Task 3 with (i) Final documentation of the systems to be studied and (ii) State-of-art summary on organic-cement-interactions	24 - KIT	6	CORI Technical Report- Task 3 with (i) Final documentation of the systems to be studied and (ii) State-of-art summary on organic-cement-interactions.

Schedule of relevant Milestones

Milestone number ¹⁸	Milestone title	Lead beneficiary	Due Date (in months)	Means of verification
MS19	CORI Technical Report- Task 4 with (i) Final documentation of the systems to be studied and (ii) State-of-art summary on organic-cement-interactions	24 - KIT	6	CORI Technical Report- Task 4 with (i) Final documentation of the systems to be studied and (ii) State-of-art summary on organic-cement-interactions
MS26	SOTA from RD&D CORI WP as input to UMAN T3.2	24 - KIT	6	SOTA from RD&D CORI WP as input to UMAN T3.2
MS30	EURAD General Assembly n°2	1 - ANDRA	7	EURAD General Assembly n°2
MS33	CORI Start of experimental RD&D programme (task 2, 3 and 4)	24 - KIT	7	CORI Start of experimental RD&D programme (task 2, 3 and 4)
MS42	EURAD Annual Work Plan 2	1 - ANDRA	9	EURAD Annual Work Plan 2
MS56	CORI First Annual WP Meeting (including technical meetings on Task level)	24 - KIT	12	CORI First Annual WP Meeting (including technical meetings on Task level)
MS57	CORI Technical Report- Task 4 (i) Radionuclide retention on CSH or CASH or AFm/AFt in the presence of organics, (ii) Radionuclide retention on HCP in the presence of organics	24 - KIT	12	CORI Technical Report- Task 4 (i) Radionuclide retention on CSH or CASH or AFm/AFt in the presence of organics, (ii) Radionuclide retention on HCP in the presence of organics.
MS81	EURAD General Assembly n°3 + EURAD Annual Meeting 1	1 - ANDRA	13	EURAD General Assembly n°3 + EURAD Annual Meeting 1
MS85	EURAD Periodic Report 1	1 - ANDRA	14	EURAD Periodic Report 1
MS86	CORI Technical Report- Task 3 (i) Organic retention on cement hydrates (AFm, AFt, CSH/CASH), (ii) Organic retention on hardened cement pastes (HCP), (iii) Effect of iron on organic sorption in cementitious systems	24 - KIT	14	CORI Technical Report- Task 3 (i) Organic retention on cement hydrates (AFm, AFt, CSH/CASH), (ii) Organic retention on hardened cement pastes (HCP), (iii) Effect of iron on organic sorption in cementitious systems
MS97	CORI Technical Report - Task 2 Hydrolytic/radiolytic degradation of organics: description of first results on hydrolytic and radiolytic organic degradation and identification of released species	24 - KIT	18	CORI Technical Report - Task 2 Hydrolytic/radiolytic degradation of organics: description of first results on hydrolytic and radiolytic organic degradation and identification of released species
MS98	CORI Technical Report- Task 4 (i) Radionuclide transport	24 - KIT	18	CORI Technical Report- Task 4 (i) Radionuclide transport

Schedule of relevant Milestones

Milestone number¹⁸	Milestone title	Lead beneficiary	Due Date (in months)	Means of verification
	in HCP in the presence of organics, (ii) Radionuclide speciation under alkaline conditions in presence of organics			in HCP in the presence of organics, (ii) Radionuclide speciation under alkaline conditions in presence of organics.
MS103	EURAD General Assembly n °4	1 - ANDRA	19	EURAD General Assembly n °4
MS112	EURAD Annual Work Plan 3	1 - ANDRA	21	EURAD Annual Work Plan 3
MS120	CORI Second Annual WP Meeting (including technical meetings on Task level)	24 - KIT	24	CORI Second Annual WP Meeting (including technical meetings on Task level)
MS121	CORI Technical Report - Task 2 Identification/quantification of soluble organic species generated by degradation of organic matter	24 - KIT	24	CORI Technical Report - Task 2 Identification/quantification of soluble organic species generated by degradation of organic matter: description and discussion of results acquired about identification of soluble species generated by radiolysis/hydrolysis.
MS136	EURAD General Assembly n °5 + EURAD Annual Meeting 2	1 - ANDRA	25	EURAD General Assembly n °5 + EURAD Annual Meeting 2
MS140	EURAD Periodic Report 2	1 - ANDRA	26	EURAD Periodic Report 2
MS141	CORI Technical Report-Task 3 (i) Organic transport in HCP, (ii) Update on organic retention studies on cementitious materials including iron/calcium effect	24 - KIT	26	CORI Technical Report-Task 3 (i) Organic transport in HCP, (ii) Update on organic retention studies on cementitious materials including iron/calcium effect
MS142	CORI Technical Report. Update on radionuclide retention studies on cementitious materials in the presence of organics	24 - KIT	26	CORI Technical Report. Update on radionuclide retention studies on cementitious materials in the presence of organics.
MS153	EURAD General Assembly n °6	1 - ANDRA	31	EURAD General Assembly n °6
MS162	EURAD Annual Work Plan 4	1 - ANDRA	33	EURAD Annual Work Plan 4
MS170	CORI Third Annual WP Meeting (including technical meetings on Task level)	24 - KIT	36	CORI Third Annual WP Meeting (including technical meetings on Task level)
MS171	CORI Technical Report - Task 2 Update of soluble organics species generated by degradation of organic matter: update of results on	24 - KIT	36	CORI Technical Report - Task 2 Update of soluble organics species generated by degradation of organic matter: update of results on

Schedule of relevant Milestones

Milestone number¹⁸	Milestone title	Lead beneficiary	Due Date (in months)	Means of verification
	the identification of soluble organic species generated by radiolysis/hydrolysis			the identification of soluble organic species generated by radiolysis/hydrolysis
MS185	EURAD General Assembly n°7 + EURAD Annual Meeting 3	1 - ANDRA	37	EURAD General Assembly n°7 + EURAD Annual Meeting 3
MS189	EURAD Periodic Report 3	1 - ANDRA	38	EURAD Periodic Report 3
MS190	CORI Technical Report- Task 3Update on organic transport studies in HCP	24 - KIT	38	CORI Technical Report- Task 3Update on organic transport studies in HCP
MS191	CORI Technical Report. Update on radionuclide transport studies in HCP in the presence of organics.	24 - KIT	38	CORI Technical Report. Update on radionuclide transport studies in HCP in the presence of organics
MS196	CORI End of experimental RD&D programme (Task 2, 3 and 4)	24 - KIT	42	CORI End of experimental RD&D programme (Task 2, 3 and 4)
MS199	EURAD General Assembly n°8	1 - ANDRA	43	EURAD General Assembly n°8
MS206	EURAD Annual Work Plan 5	1 - ANDRA	45	EURAD Annual Work Plan 5
MS211	CORI Fourth and Final WP Meeting (including technical meetings on Task level)	24 - KIT	48	CORI Fourth and Final WP Meeting (including technical meetings on Task level)
MS212	CORI Electronic data deposit	24 - KIT	48	CORI Electronic data deposit
MS213	CORI Conclusive Technical Meeting of Task 2 (integrated into the Fourth Annual CORI WP Meeting). Preparation of technical	24 - KIT	48	CORI Conclusive Technical Meeting of Task 2 (integrated into the Fourth Annual CORI WP Meeting). Preparation of technical
MS214	CORI Conclusive Technical Meeting on Task 3 (integrated into the Fourth Annual CORI WP Meeting). Preparation of technical Deliverable	24 - KIT	48	CORI Conclusive Technical Meeting on Task 3 (integrated into the Fourth Annual CORI WP Meeting). Preparation of technical Deliverable. (48).
MS222	EURAD General Assembly n°9 + EURAD Annual Meeting 4	1 - ANDRA	49	EURAD General Assembly n°9 + EURAD Annual Meeting 4
MS224	EURAD Periodic Report 4	1 - ANDRA	50	EURAD Periodic Report 4
MS234	EURAD General Assembly n°10	1 - ANDRA	55	EURAD General Assembly n°10
MS240	EURAD General Assembly n°11 + EURAD Annual Meeting 5	1 - ANDRA	60	EURAD General Assembly n°11 + EURAD Annual Meeting 5

Schedule of relevant Milestones

Milestone number¹⁸	Milestone title	Lead beneficiary	Due Date (in months)	Means of verification
MS241	EURAD Periodic Report 5	1 - ANDRA	60	EURAD Periodic Report 5 (Due date: 60+2)

Work package number ⁹	WP4	Lead beneficiary ¹⁰	1 - ANDRA
Work package title	Development and Improvement Of NUmberical methods and Tools for modelling coupled processes (DONUT)		
Start month	1	End month	48

Objectives

Objectives

Improvement of numerical methods and tools for modelling multi-physical Thermo-Hydro-Mechanical-Chemical coupled processes (THMC) occurring in radioactive waste disposal is a major and permanent issue to support its optimization of design. It is worth noticing that the R&D objectives, later described in the document, are a not direct input of safety case, but contributes to improve scientific knowledge, which could if appropriate support safety case abstraction.

Numerical simulations are necessary to make predictive multi-physical assessments, at time frames and space scales larger than experiments can cover. These numerical simulations require integrating, in a consistent framework, an increasing scientific knowledge acquired for each of the individual components of a system for radioactive waste disposal. This implies to consider couplings of different and non-linear processes, applied to a wide range of materials with contrasting properties as a function of time and space in ever-larger systems.

The development of cutting-edge and efficient numerical methods is thus necessary, in the scope of development and use of powerful and relevant numerical tools for assessments. In parallel, it is also necessary to manage the uncertainties associated to the input data that feed the models, and to the representation of the processes, in order to assess the range of variability of the results and to identify the main parameters and processes that drive the behaviour of the systems of interest. Managing uncertainties in these complex systems requires the improvement and the development of innovative, appropriate and efficient methods.

According to the needs described previously, main objectives of this WP are:

- The development of relevant, performant and cutting-edge numerical methods that can easily be implemented in existing or new tools, in order to carry out high-performance computing to facilitate the study of highly coupled processes in large systems. These methods and their implementation in tools will be mainly applied to reactive transport, 2-phase flow, and THM modelling in porous and fractured media;
- The development of numerical scale transition schemes for coupled processes (meso to macro scale), supporting the study of specific multi-scale couplings such as chemo-mechanics;
- The development of innovative numerical methods to carry out uncertainty and sensitivity analyses;
- The set-up and the achievement of benchmark exercises, on representative test cases, to test the efficiency of developed methods (robustness, accuracy, time computational) on relevant tools.

Expected impacts

- Regarding RWM implementation needs

The understanding of couplings between thermal, hydraulic, mechanical and chemical processes of a radioactive waste disposal is based on the scientific and technical knowledge gained by combining both experimental approaches at different scales (from the sample to the underground research laboratory) and numerical simulations, which allow access at space and time scales out of range for experiments. Hence, the improvement of numerical methods and tools that are able to manage multi-physicals couplings appears to be necessary to support and to optimize the design of a nuclear waste repository. The work conducted in this WP is both relevant for design optimization of deep geological disposal of nuclear waste and near surface repository systems. The WP is linked to the Roadmap Theme 7 (performance assessment, safety case development, safety analyses) phases 2 -4.

- Regarding safety

DONUT will, by providing numerical means for analysis, contribute to:

- increase the multi-physical description of processes within radioactive waste disposal, and thus, ability to manage integrated scientific knowledge in the scope of safety assessment abstraction,
- (Understand the consequence of coupled processes and qualify long-term expected safety functions of components.

Description of work and role of partners

WP4 - Development and Improvement Of NUmberical methods and Tools for modelling coupled processes (DONUT) [Months: 1-48]

ANDRA, CEA, CNRS, COVRA, ENRESA, JUELICH, GRS, IRSN, LEI, MTA EK, NRG, PSI, SCK•CEN, SÚRAO, TS Enercon, TUS, UHelsinki

Task 1 – S/T coordination, State-of-the-art and training material

Start: Month 1 – End: Month 48 - Task Leader: [Andra (BRGM)]

Task contributors: [Andra (BRGM)] [CNRS (ULille)] [JUELICH (UFZ)] [SÚRAO] [TS ENERCON]

Total PM: 8,5

Task Objectives:

- S/T coordination of the WP
- Developing/updating State-of-the-art
- Developing training materials as an input to KM

Subtask 1.1 – S/T coordination

Start: Month 1 – End: Month 48 Subtask Leader: [Andra (BRGM)]

Subtask Contributors: [Andra (BRGM)] [CNRS (ULille)] [JUELICH (UFZ)] [SÚRAO] [TS Enercon]

Total PM: 3,5

The scientific and technical coordination of DONUT will be performed by the WP Leader [Andra (BRGM)]. The WP Leader will be supported by the Task leaders and co-leaders: [CNRS (ULille)] [JUELICH (UFZ)] [PSI] [TS Enercon] [SÚRAO] [Andra] [GRS] and [PSI] which together with [Andra (BRGM)] constitute the WP Board of DONUT. The WP Leader will make sure that EURAD rule are followed by all partners, that the scientific milestones and deliverables are reached timely, and that the results are disseminated efficiently inside and outside the project. It includes also participation to PMO meetings twice a year. Subtask 1.1 consists of ensuring information transfer between different (sub)tasks. This is accomplished by a number of WP meetings, workshops and general milestones.

Subtask 1.2 – State-of-the-art

Start: Month 1 – End: Month 48 Subtask Leader: [Andra (BRGM)]

Subtask Contributors: [Andra (BRGM)] [CNRS (ULille)] [JUELICH (UFZ)] [SÚRAO] [TS Enercon]. All WP participants will contribute to this subtask.

Total PM: 2,5

State-of-the-art will demonstrate the novelty of the research results gathered within DONUT. Besides demonstrating the novelty of the research conducted in DONUT, the state-of-the-art will be a direct input to EURAD KM programme. Indeed, it will inform interested scientists, engineers, student, etc. about the research problems that we try to solve, and about the developed approaches.

All organizations involved in task 1, 2 and 3 will contribute to the state-of-the-art (initial and updated) reports (D4.1 and D4.2). Self-consistency of the state-of the art report will be ensured by the coordination team. State-of-the-art report will also describe the representative experimental data that are needed for upscaling.

Subtask 1.3 – Training materials

Start: Month 24 – End: Month 48 Subtask Leader: [Andra (BRGM)]

Subtask Contributors: [Andra (BRGM)] [CNRS (ULille)] [JUELICH (UFZ)] [SÚRAO] [TS Enercon]

Total PM: 2,5

A series of Network meetings and scientific workshops are planned. The WP Board will organize sessions on the topics tackled within the project, e.g. at the Goldschmidt and Interpore conferences. The DONUT results will be at the heart of the topics explored by the Subsurface Environmental Simulation Benchmarking Initiative (Steeffel et al., 2015; Dwivedi et al., 2016). The participation of world-leading researchers in the domain of RTM also ensures an efficient dissemination of the outcome of the project in the scientific community of numerical modelling.

In order to promote the improved and developed methods and tools, a transferable skills seminar will be organized in close collaboration with the KM WP Training/Mobility. This will involve lectures by partners, presentations by stakeholders, exchange on modelling approaches and tools demonstration, both at the workshop and benchmark levels and discussion groups. Finally, these events, as well as major results, will be advertised using generic and specialized ‘social media’, in order to increase the visibility of the WP results (D4.3)

Within task 1, a report describing the benchmarks to be carried out during the project (in each task) will be delivered at Month 24. This deliverable will be coordinated by the WP Coordinator [Andra (BRGM)] in cooperation with all tasks (D.4.4). It is worth noticing that prior to benchmarks definition a workshop will be organized with other WP to set up and defined relevant benchmarks.

Task 2 - Numerical methods for high performance computing of coupled processes

Start: Month 1 – End: Month 48 - Task Leader: [CNRS (ULille)]

Task Contributors: [CNRS-LJAD (ULille) (UNice)] [PSI] [SÚRAO (CTU) (CU) (IGN) (TUL)] [CEA (EDF)] [MTA EK (SORC)] [Andra (BRGM)] [IRSN] [NRG]

Total PM: 262

The goal of task 2 is to design and implement efficient numerical algorithms taking advantage of the latest research achievements for solving complex coupled problems. In particular, the following axes play a central role in this task:

- numerical algorithms for parallel computing (e.g., linear solvers, domain decomposition, ...)
- efficient multiscale numerical methods for coupled problems
- grid adaptivity and adaptive stopping criteria based on a posteriori error estimates

The aimed applications are reactive multiphase porous media flows, the coupling of porous media flows with poromechanics, THGas couplings at repository scales, coupling of free flows in the galleries with flows in the surrounding porous medium, and the simulation of reactive processes like for instance corrosion.

At last but not least, the methods and tools that are developed will be made available within the other tasks of the WP to benchmark their efficiency and to the whole community (others WP and beyond) thanks to scientific publications, versatile codes development associated to a thorough documentation.

This task focuses on several axes of great importance in the strongly nonlinear and coupled processes occurring in the context of nuclear waste repository management. Getting mathematically founded results is one of the priority of this task, as well as the development of efficient tools taking advantage of the last advances in HPC.

Some contributions [CNRS (ULille)] [Andra (BRGM)] [NRG] will focus on reactive processes where electrical interactions with self-consistent potential occur. This encompasses corrosion and reactive transport in nanoporous materials.

A great effort will be devoted to the numerical modelling and simulation for Thermo-Hydro-Mechanics (THM). This includes modelling issues on the material constitutive laws [SÚRAO (CU)] as well as HPC issues related to parallelism based on domain decomposition [SÚRAO (CTU) (IGN)].

Taking chemistry into account is also fundamental in our context. Open access massively parallel numerical tools will be developed [CNRS-LMAP] for coupling thermo-hydro with chemistry.

In close relation to Task 3 on upscaling, the design of numerical methods taking pore size mechanical effects into account in THMC modelling will be realized [PSI]. This will yield bulk coupling effects, in opposition to physical phenomena occurring at different places and that should be coupled spatially. This is for instance the case of the free flow in the ventilation galleries and the surrounding porous matrix [CNRS-LJAD]. Fractures play a major role in transport phenomena, motivating the development of tools [SÚRAO (TUL)] where complex flows may occur in lower dimension structures. Still related to heterogeneity hydro-mechanical behaviour of interfaces between seal materials might play a role on gas transport and this issue need to be tackled [IRSN].

The development of efficient a posteriori error estimators is of paramount interest in order to better allocate the computational effort. Contributions on this topic [CEA (EDF)] will be addressed for porous media flow problems.

The results and outcomes of this task will be documented in D4.5.

Task 3 – Scale transition schemes for coupled processes

Start: Month 1 – End: Month 48 - Task Leaders : [JUELICH (UFZ)] [PSI]

Task Contributors : [SÚRAO (TUL)] [Andra (BRGM)] [JUELICH (UFZ)] [PSI]

Total PM: 73

Many coupled processes in fractured porous media are inherently multi-scale due to dynamic localization effects of, e.g., flow and deformation in narrow bands or faults. Their description requires special constitutive models and numerical methods. Secondly, individual processes are often best described on different scales depending on their specific phenomenology and the scales of their experimental characterization. Consequently, different process codes and scientific communities have evolved for, e.g., reactive transport and geomechanics. As a result, such couplings (e.g. chemo-mechanical couplings) are most often neglected despite their importance, not for scientific reasons but due to a lack of technical capabilities and of interaction/collaboration between experts in the relevant distinct fields.

This task aims at collecting, improving and developing numerical methods and tools that close this capability gap and address the described issues. Examples include numerical homogenization approaches, multi-scale simulation frameworks, coupling of scale-disparate numerical simulators, methods to represent material or phase interfaces across scales, etc. Developed methods and tools will be made available to the wider community for European added value. Specifically, main objectives of this task are to:

- Provide numerical methods to bridge spatial scales
- Provide tools that enable the consideration of chemo-mechanical process couplings

Task 3 studies the coupling between hydraulic, mechanical and chemical processes. Activities of this task are coordinated by [UFZ] and [PSI]. The different partners address this topic with complementary emphasis. The description is split into three parts:

H-M processes in with localized transport (multiscale simulations in fractured porous media):

Fractures represent an inherently multi-scale problem with strongly localized flow and therefore different transport properties. [SÚRAO (TUL)] develops methods to couple fracture flow to continuum (matrix) flow including HM couplings like fracture opening/closure, channelling, etc. Based on numerical methods developed in Task 2 (Fig.1) for Flow123 (<http://flow123d.github.io/>), here transport experiments performed at different scales incl. fracture borehole pressure tests, inter-borehole fracture tracer tests, etc., will be simulated. Different numerical concepts (dual porosity, co-dimensional entities) will be compared in their effectiveness to describe multi-scale transport phenomena and to transfer data from detailed models to repository scale models.

H-C processes from pore-scale to Darcy-scale (including electrochemical transport) [Andra (BRGM)] will use real pore-scale geometries by assimilating 3D image datasets of nanoporous materials, already available, into a simulation framework for flow and electrochemical transport. Pore scale models using the open-source framework OpenFoam (www.openfoam.com) and micro-continuum models developed in Task 2 by [Andra (BRGM)] will be used to derive macroscopic coupling terms for (large) Darcy-scale calculations. This upscaling of pore-scale to continuum transport will inform the methods used in the HMC section.

Multiscale HMC processes (coupling precipitation/dissolution processes to fracture mechanics):

[JUELICH] will provide available experimental data stemming from plug-flow column and tank experiments that feature dissolution/precipitation processes leading to clogging and eventually fracturing. Changing pathways will be visualized by tracers, by live monitoring of pore-connectivity changes using different imaging techniques at different scales (i.e. MRI, SEM). They will then model reactive transport processes separately on the pore-scale and the continuum scale with state-of-the-art tools (e.g. OpenGeoSys-GEM) and highlight where these existing approaches fail and where the parameterization between different experiments becomes inconsistent. These reactive transport models motivate the developments on chemo-mechanical coupling in this task and serve as test cases to show improvements brought by the new methods developed by [PSI] and [JUELICH (UFZ)].

To link the scale-separate simulations, [JUELICH (UFZ)] will develop and implement in OpenGeoSys (www.opengeosys.org) the FE² method for coupled processes to perform explicitly multi-scale simulations of heterogeneous materials. While the method will be set up using OGS, it will be implemented as a control scheme such that it can link different numerical tools for each scale. Due to the characteristics of the FE² scheme, the method can be parallelized efficiently. This will be demonstrated on in-house HPC infrastructure.

[PSI] in conjunction with the Lattice-Boltzmann Finite-Element coupling they developed in Task 2, will apply the method to the data provided by [JUELICH]. In analysing HMC coupled processes, the scientific expertise on thermo-hydro-mechanical processes (incl. fracture mechanics) of [JUELICH (UFZ)] and the geochemical expertise of [PSI] the developed tools will be applied to existing experimental data and benchmark with continuous FE codes coupled with geochemical solvers (i.e. OpenGeoSys-PHREEQC, OpenGeoSys – GEMS, FENICS, MCOTAC).

The results and outcomes of this task will be documented in D4.6.

Task 4 - Tools and methods to quantify/derive uncertainties induce by coupled processes

Start: Month 1 – End: Month 48 Task Leader: [TS Enercon]

Contributors: [SCK•CEN] [SÚRAO (IGN) (TUL) (ÚJV Řež)] [Andra (BRGM)] [GRS] [UHelsinki (TUT)] [ENRESA] [JUELICH (HZDR)] [TS Enercon]

Total PM: 140,3

Simulations of THMC process couplings of radioactive waste disposal involves many input models and data whose level of couplings vary in space and time and could be weak and strong. Effects of uncertainties of input data and models on final indicators are difficult to take into account as there are strong non-linearities, and classical methods have thus some limitations. Relevant methods and tools should be defined and set up to assess (i) effect of all kinds of uncertainties on uncertainty of results indicators (uncertainty analysis) and (ii) relevant input data and models which manage the result (sensitivity analysis).

Task 4 will focus on:

- Developments of innovating numerical methods to treat uncertainty and sensitivity analysis on complex coupled representative cases (big system, many media and input data) with strong non-linearities: global/local sensitivity analysis with specific tools (surrogate/metamodels such Chaos polynomia, neural network, adjoin state methods, ...)
- Developments of mathematical representations of uncertain parameters applied for coupled processes (correlations, ...)

In order to fulfil objective to carry out uncertainty and sensitivity analyses on problems involving coupled processes that required high CPU time-consuming because both nonlinearities and big size grid have to be managed, R&D development of surrogates models and metamodels are proposed (including models reduction). They will be applied in the field of local and global sensitivity, and will be tested on relevant test-cases (reactive transport, THGas, THM).

[SCK•CEN] aims to develop a novel, robust and accurate emulation-based method to make sensitivity analysis and uncertainty propagation of CPU-demanding reactive transport models (machine learning (ML) algorithms for nonlinear

regression, with last generation Gaussian processes (GP), random forest and (extreme) gradient boosting). [Andra (BRGM)] aims to develop surrogates time-space-parametric models (such as polynomial chaos expansions (PCEs)), adapted method to sensitivity analysis with dependent parameters, and test it to THM test-case including applications to inverse problems. [SÚRAO (IGN) (TUL)] [UHelsinki (TUT)] [GRS] will develop techniques to variance reduction techniques, and surrogate models construction, and contribute to test their efficiency with relevant global sensitivity indicators (Sobal, EFAST, etc.).

We intend to compare efficiency of some developed methods by partners (especially accuracy and range of applications) by benchmarking surrogate methods in the scope of non-intrusive global sensitivity, and examine ability to perform local sensitivity.

To complete this large R&D development on numerical methods, [TS-Enercon] plans to carry out understanding nonlinearities and inter-dependencies of uncertain parameters in coupled processes, and [ENRESA] contributes with innovative numerical methods for adjoint-state methods and Uncertainty quantification.

About developments of mathematical representations of uncertain parameters applied for coupled processes, a joint programme is outlined, since [SÚRAO [ÚJV Řež]] [GRS] [JUELICH (HZDR)] plan to collaborate to carry out a complex uncertainty treatment and sensitivity analysis effort based on a coordinated data collection, uncertainty quantification and testing sensitivity analysis methods, applied to geochemical application.

The results and outcomes of this task will be documented in D4.7.

Task 5 - Benchmarks of methods and tools for coupled processes

Start: Month 18 – End: Month 48 Task Leader: [SÚRAO]

Contributors: [COVRA] [ENRESA] [LEI] [SÚRAO (TUL)] [TUS] [Andra] [GRS]

Total PM : 33,9

The main objective of the Task 5 is to test efficiency of numerical methods developed in tasks 2, 3 and 4, on relevant test-cases defined in concertation with other WPs. This task will thus focus on :

- development of suitable benchmarks, mainly derived from THGas, THM, and reactive transport test-cases at large time and space scales (porous/fractured and free media),
- implementation of numerical methods developed at task 2, 3 and 4 in existing tools used by each involved partner,
- benchmarks of methods and tools to quantify efficiency and added-value in terms of :
 - o increase of knowledge (better physical representation, more integrated systems, ...)
 - o accuracy, robustness, computational cost,
 - o robustness of scale-transition approaches
 - o ability to manage uncertainty and sensitivity analyses

All the involved partners in this task will contribute supporting the development of benchmarks for the evaluation of the methods and numerical tools described in the other tasks considering their relevance in the scope of multi-physical assessment. Regarding the different partner's contribution in the different tasks, THM, THC (reactive transfer) and THGas benchmarks are considered being the most relevant and their exact setting up will be defined in close collaboration with the concerned WPs through a workshop.

[COVRA] [ENRESA] [SÚRAO] [Andra] and [GRS TSO] will prepare benchmarks from the point of view of the implementers and evaluators. These organisations and their partners participate in most of other work-packages, and the work will be carried out in close cooperation with the linked WPs and the RE involved in this WP. The prepared benchmarks will help to quantify how (e.g. among others accuracy and time calculation improvements) numerical methods developed in DONUT are relevant regarding current used methods, and to compare tools in which these methods are implemented. In order to make the benchmarks relevant for a large community they will address coupled processes representative in different kind host rocks (e.g. clay, crystalline rocks, salt).

The results and outcomes of this task will be documented in D4.8.

Participation per Partner

Partner number and short name	WP4 effort
1 - ANDRA	2.50
BRGM	34.50
5 - CEA	0.00
EDF	9.50
8 - CNRS	39.00

Partner number and short name	WP4 effort
ULille	31.00
UNice	6.00
9 - COVRA	0.60
14 - ENRESA	4.80
15 - JUELICH	17.00
HZDR	14.50
UFZ	27.50
16 - GRS	18.70
19 - IRSN	24.00
25 - LEI	5.00
26 - MTA EK	0.00
SORC	12.00
31 - NRG	5.00
34 - PSI	18.00
38 - SCK•CEN	26.00
42 - SÚRAO	6.50
CTU	35.00
TUL	45.00
IGN	64.00
ÚJV	10.00
CU	19.00
45 - TS Enercon	18.55
46 - TUS	4.00
48 - UHelsinki	0.00
TUT	20.00
Total	517.65

List of deliverables

Deliverable Number ¹⁴	Deliverable Title	Lead beneficiary	Type ¹⁵	Dissemination level ¹⁶	Due Date (in months) ¹⁷
D4.1	DONUT - State-of-the-art in the fields of numerical analysis and scientific computing	1 - ANDRA	Report	Public	6
D4.2	DONUT - Updated State-of-the-art in the fields of	1 - ANDRA	Report	Public	48

List of deliverables

Deliverable Number¹⁴	Deliverable Title	Lead beneficiary	Type¹⁵	Dissemination level¹⁶	Due Date (in months)¹⁷
	numerical analysis and scientific computing				
D4.3	DONUT - Training materials	1 - ANDRA	Report	Public	36
D4.4	DONUT - Report describing the benchmarks to be carried out during the WP	1 - ANDRA	Report	Public	24
D4.5	DONUT - Technical report describing numerical method improvement and their transferability in numerical tools as well as benchmarks realization	8 - CNRS	Report	Public	46
D4.6	DONUT - Final report describing improvement and implementation of scale transition methods to model coupled processes	1 - ANDRA	Report	Public	46
D4.7	DONUT - Report describing numerical improvement and developments and their application to treat uncertainty when dealing with coupled processes	1 - ANDRA	Report	Public	46
D4.8	DONUT - Final report describing benchmark realisations and (i) influence of the development carried out in other tasks on the quantification of improvement (ii) comparison, when possible, of tools on which numerical methods have been implemented	1 - ANDRA	Report	Public	46

Description of deliverables

Deliverables (brief description and month of delivery)

Deliverable 4.1 - State-of-the-art in the fields of numerical analysis and scientific computing

It will identify numerical solutions taking advantage of the recent breakthrough in the fields of numerical analysis and scientific computing. It will also describe representative experimental data needed for the upscaling procedure.

[Andra (BRGM)] –Month 6

Deliverable 4.2 - Updated State-of-the-art in the fields of numerical analysis and scientific computing [Andra (BRGM)] – Month 48

Deliverable 4.3 - Training materials (Month 36) [Andra (BRGM)]

Deliverable 4.4 - Report describing the benchmarks to be carried out during the WP (with inputs from all tasks) [Andra (BRGM)] – Month 24

Deliverable 4.5 – Technical report describing numerical method improvement and their transferability in numerical tools as well as benchmarks realization will describe how the developments can be linked and implemented in existing tools used by partners and it will document input/output interface. All partners involved in this task will contribute to this report. All partners including in task 2 will contribute to this report. [CNRS (Lille University)] - Month 46

Deliverable 4.6 - Final report describing improvement and implementation of scale transition methods to model coupled processes [Task leaders] – Month 46. All partners involved in this task will contribute to this report.

Deliverable 4.7 - Report describing numerical improvement and developments and their application to treat uncertainty when dealing with coupled processes. [TS Enercon] -Month 46. All partners including in this task will contribute to this report.

Deliverable 4.8 - Final report describing benchmark realisations and (i) influence of the development carried out in other tasks on the quantification of improvement (ii) comparison, when possible, of tools on which numerical methods have been implemented [SÚRAO] -Month 46. All partners involved in this task will contribute to this report.

D4.1 : DONUT - State-of-the-art in the fields of numerical analysis and scientific computing [6]
DONUT - State-of-the-art in the fields of numerical analysis and scientific computing

D4.2 : DONUT - Updated State-of-the-art in the fields of numerical analysis and scientific computing [48]
DONUT - Updated State-of-the-art in the fields of numerical analysis and scientific computing

D4.3 : DONUT - Training materials [36]
DONUT - Training materials

D4.4 : DONUT - Report describing the benchmarks to be carried out during the WP [24]
DONUT - Report describing the benchmarks to be carried out during the WP

D4.5 : DONUT - Technical report describing numerical method improvement and their transferability in numerical tools as well as benchmarks realization [46]
DONUT - Technical report describing numerical method improvement and their transferability in numerical tools as well as benchmarks realization

D4.6 : DONUT - Final report describing improvement and implementation of scale transition methods to model coupled processes [46]
DONUT - Final report describing improvement and implementation of scale transition methods to model coupled processes

D4.7 : DONUT - Report describing numerical improvement and developments and their application to treat uncertainty when dealing with coupled processes [46]
DONUT - Report describing numerical improvement and developments and their application to treat uncertainty when dealing with coupled processes

D4.8 : DONUT - Final report describing benchmark realisations and (i) influence of the development carried out in other tasks on the quantification of improvement (ii) comparison, when possible, of tools on which numerical methods have been implemented [46]
DONUT - Final report describing benchmark realisations and (i) influence of the development carried out in other tasks on the quantification of improvement (ii) comparison, when possible, of tools on which numerical methods have been implemented

Schedule of relevant Milestones

Milestone number¹⁸	Milestone title	Lead beneficiary	Due Date (in months)	Means of verification
MS1	EURAD Kick-off meeting (General Assembly n°1)	1 - ANDRA	1	EURAD Kick-off meeting (General Assembly n°1)
MS3	DONUT Kick off - WP Meeting 1	1 - ANDRA	1	DONUT Kick off - WP Meeting 1
MS12	EURAD EJP Newsletters	1 - ANDRA	3	EURAD EJP Newsletters (Due date : M3 and then every quarter)
MS30	EURAD General Assembly n°2	1 - ANDRA	7	EURAD General Assembly n°2
MS34	DONUT WP Meeting 2	1 - ANDRA	7	DONUT WP Meeting 2
MS42	EURAD Annual Work Plan 2	1 - ANDRA	9	EURAD Annual Work Plan 2
MS81	EURAD General Assembly n°3 + EURAD Annual Meeting 1	1 - ANDRA	13	EURAD General Assembly n°3 + EURAD Annual Meeting 1
MS85	EURAD Periodic Report 1	1 - ANDRA	14	EURAD Periodic Report 1
MS94	ACED - GAS - DONUT Joint Workshop - 1	32 - ONDRAF/NIRAS	16	ACED - GAS - DONUT Joint Workshop
MS103	EURAD General Assembly n°4	1 - ANDRA	19	EURAD General Assembly n°4
MS105	DONUT WP Meeting 3	1 - ANDRA	19	DONUT WP Meeting 3
MS112	EURAD Annual Work Plan 3	1 - ANDRA	21	EURAD Annual Work Plan 3
MS114	DONUT Intermediate report describing numerical method improvement and their transferability in numerical tools	1 - ANDRA	22	DONUT Intermediate report describing numerical method improvement and their transferability in numerical tools
MS116	DONUT Intermediate report describing improvement and implementation of scale transition methods improvement and their application for multiscale simulations	1 - ANDRA	22	DONUT Intermediate report describing improvement and implementation of scale transition methods improvement and their application for multiscale simulations
MS117	DONUT Intermediate report describing numerical developments realized to treat uncertainty	1 - ANDRA	22	DONUT Intermediate report describing numerical developments realized to treat uncertainty
MS130	HITEC Task 3.3 -Modelling benchmarks – description (Description of calibration case, verification cases and benchmarks selected for T3.3 in cooperation with DONUT	50 - VTT	24	HITEC Task 3.3 -Modelling benchmarks – description (Description of calibration case, verification cases and benchmarks selected for T3.3 in cooperation with DONUT

Schedule of relevant Milestones

Milestone number¹⁸	Milestone title	Lead beneficiary	Due Date (in months)	Means of verification
MS136	EURAD General Assembly n°5 + EURAD Annual Meeting 2	1 - ANDRA	25	EURAD General Assembly n°5 + EURAD Annual Meeting 2
MS140	EURAD Periodic Report 2	1 - ANDRA	26	EURAD Periodic Report 2
MS153	EURAD General Assembly n°6	1 - ANDRA	31	EURAD General Assembly n°6
MS156	DONUT WP Meeting 4	1 - ANDRA	31	DONUT WP Meeting 4
MS162	EURAD Annual Work Plan 4	1 - ANDRA	33	EURAD Annual Work Plan 4
MS165	ACED - GAS - DONUT Joint Workshop	32 - ONDRAF/NIRAS	33	ACED - GAS - DONUT Joint Workshop
MS185	EURAD General Assembly n°7 + EURAD Annual Meeting 3	1 - ANDRA	37	EURAD General Assembly n°7 + EURAD Annual Meeting 3
MS189	EURAD Periodic Report 3	1 - ANDRA	38	EURAD Periodic Report 3
MS199	EURAD General Assembly n°8	1 - ANDRA	43	EURAD General Assembly n°8
MS201	DONUT WP Meeting 5	1 - ANDRA	43	DONUT WP Meeting 5
MS206	EURAD Annual Work Plan 5	1 - ANDRA	45	EURAD Annual Work Plan 5
MS222	EURAD General Assembly n°9 + EURAD Annual Meeting 4	1 - ANDRA	49	EURAD General Assembly n°9 + EURAD Annual Meeting 4
MS224	EURAD Periodic Report 4	1 - ANDRA	50	EURAD Periodic Report 4
MS234	EURAD General Assembly n°10	1 - ANDRA	55	EURAD General Assembly n°10
MS240	EURAD General Assembly n°11 + EURAD Annual Meeting 5	1 - ANDRA	60	EURAD General Assembly n°11 + EURAD Annual Meeting 5
MS241	EURAD Periodic Report 5	1 - ANDRA	60	EURAD Periodic Report 5 (Due date: 60+2)

Work package number ⁹	WP5	Lead beneficiary ¹⁰	15 - JUELICH
Work package title	Fundamental understanding of radionuclide retention (FUTuRE)		
Start month	1	End month	48

Objectives

Objectives

- Fundamental insights into the impact of chemical boundary conditions and the role of microstructures on radionuclide speciation and mobility in “real” clay rocks as well as crystalline rocks
- Enhance the quantitative and mechanistic understanding of the impact of (i) specific surface properties of materials (diffusive double layer, surface potential), (ii) the role of grain boundaries, (iii) the effect of water saturation, content and chemistry (pH, ionic strength) as well as (iv) the impact of pore size variability and heterogeneity on the mobility of chemical species
- Refined understanding of the relation between fracture/ pore structures and transport as well as the feedback of mineral reactions (dissolution/precipitation, clogging) on pore structure and connectivity
- Closing knowledge gaps regarding sorption reversibility, uptake mechanisms (adsorption vs. incorporation, precipitation), sorption competition and surface diffusion which have not been addressed sufficiently in previous European projects (e.g. FUNMIG, SKIN).
- Fundamental understanding and thus reducing uncertainties of surface induced (heterogeneous) redox processes with regard to coupled sorption and electron transfer interface reactions governing the retention of redox-sensitive radionuclides at Fe(II)/Fe(III) bearing minerals surfaces – going beyond previous European projects (e.g. RECOSY).

Expected impacts

- Regarding RWM implementation needs

The WP will provide the scientific basis needed to bound the applicability range and to estimate uncertainties in the simplistic concepts used in the current safety assessment (SA) studies. The development of multicomponent mechanistic sorption models and pore scale simulations of radionuclides transport will allow validation of the concepts used in SA and ensure that all relevant processes are sufficiently understood and are taken in to account in SA at an appropriate level, e.g. surface diffusion, sorption mechanisms, competition and reversibility in clay rocks. Moreover, the proposed research will contribute to the understanding of transport of radionuclides in the crystalline rock environment by properly identifying relevant properties and species involved in sorption and transport processes, altogether with description of fractured rock environment. The combined analysis of reactivity, structure, flow field, and RN mobility/ retention would provide a unique dataset that would enable to include local boundary driven transport processes into safety assessment models.

The R&D in this work package covers a substantial fraction of the sub-domains addressed in domain 1.6 Radionuclide and Chemical Species Migration of the SRA regarding knowledge gaps related to sorption process, heterogeneous redox processes and in particular overall radionuclide mobility in “real” systems.

The WP is linked to the Roadmap Theme 4 (geoscience to understand rock properties, radionuclide transport and long-term geological evolution) phases 2-4,

- Regarding safety

Improvement of the scientific basis for the safety case of deep geological disposal in clay rock and crystalline rock. Reduction of uncertainties and potential reduction of conservatisms in more realistic descriptions of repository system evolution.

Description of work and role of partners

WP5 - Fundamental understanding of radionuclide retention (FUTuRE) [Months: 1-48]

JUELICH, ANDRA, CEA, CIEMAT, CNRS, GRS, KIT, MTA EK, PSI, RATEN, SCK•CEN, SÚRAO, TNO, UHelsinki

Description of work (where appropriate, broken down into tasks), lead partner and role of participants

Task 1 – S/T coordination, State-of-the-art and training material

Start: Month 1 – End: Month 48 - Task Leader: [JUELICH]

Task contributors: [Andra] [CEA] [JUELICH] [PSI] [SCK•CEN] [TNO]

Total PM: 8,3

Subtask 1.1 – S/T coordination

Start: Month 1 – End: Month 48 Subtask Leader: [JUELICH]

Subtask Contributors: [Andra] [JUELICH]

Total PM: 3

The scientific and technical coordination of WP5-FUTuRE will be performed by the WP Leader [JUELICH]. The WP Leader will be supported by the Task leaders and co-leaders: [PSI] [SÚRAO (UJV)] [JUELICH (HZDR)] [SCK•CEN] [Andra (BRGM)] which together with [JUELICH] constitute the WP Board of FUTuRE. The WP Leader will make sure that EURAD rules are followed by all partners, that the scientific milestones and deliverables are reached timely, and that the results are disseminated efficiently inside and outside the project. The WP Leader will ensure the interface between the WP Board, between the participants of WP5-FUTuRE, and with the Programme Management Office and the other EURAD WPs.

This subtask consists of ensuring information transfer between different (sub)tasks. This is accomplished by one WP meeting (WPM) per year involving Task 2 and 3, in addition to the kick-off meeting (WPM1).

Subtask 1.2 – State-of-the-art

Start: Month 1 – End: Month 48 Subtask Leader: [SCK•CEN]

Subtask Contributors: [CEA] [PSI] [SCK•CEN] [TNO]

Total PM: 4,3

In order to set a “baseline” and also as input to WP11-KM SoK, a state-of-the-art report will be drafted at the start of the project (Month 6) with the aim to provide a comprehensive overview of the available knowledge on the understanding of radionuclide retention in clay and crystalline rocks (D5.1). Emphasis will be on the current available knowledge with respect to i) transferability of sorption phenomena to compacted/realistic systems and sorption reversibility and, ii) surface induced (heterogeneous) redox processes.

At the end of the project (Month 48), this report will be updated incorporating the newly acquired knowledge (D5.2). A team of 4 research groups will compile these status report [SCK•CEN] [TNO] [PSI] and [CEA] at month 6 and month 48.

Subtask 1.3 – Training Materials

Start: Month 24 – End: Month 48 Subtask Leader: [JUELICH]

Subtask Contributor: [JUELICH]

Total PM: 1

Learning materials will be generated in order to:

- Provide the possibility for independent checks of an interested person that the SoK is well understood, and
- Request trainees for face-to-face training at the corresponding training modules of the “EURATOM RWM school” to prepare for the lectures so that a high level can be kept with the expected prominent training outcome.

The details of such material will be developed together with the WP13- KM Training/Mobility in view of different levels of learning ambition for different communities. As the training programme develops, amongst others questions on learning outcome from previously held training sessions and videos of such lectures can be added. The training materials developed within this subtask will be delivered under D5.3.

Task 2 - Mobility

Start: Month 1 – End: Month 48 - Task Leader: [PSI] – Co-Leaders: [JUELICH (HZDR)] and [SCK•CEN]

Task Contributors: [Andra (BRGM)] [CEA] [CIEMAT] [CNRS-SUBATECH/IC2MP/IPHC (UPoitiers)] [JUELICH]

Total PM: 349,7

Task objectives:

- Experimental studies on RN mobility in compacted clay with strongly sorbing RN: actinides, intermediate sorbing RN: Fe, Ra, weakly sorbing RN: I/Se) and a limited number of clay systems: pure clay systems (illite, montmorillonite) and clay rocks (in particular Opalinus clay and COx)
- Experimental studies on RN mobility in crystalline rock with strongly sorbing RNs: actinides, intermediate sorbing RNs: Ra, weakly sorbing: I/Se): Identification of the impact of structure (connected pore network and surface topography of fractured crystalline rock samples and mineral infills) on RN mobility; impact of flow velocity; providing an interface to the WP4-DONUT (smart Kd approach) by using the quantitative information about parameter variability (surface charge, nanotopography, flow velocity anisotropy) that reflect the complexity of natural materials.
- Sorption studies (excluding redox processes) with a focus on reversibility to close specific knowledge gaps with Ni and Ra in support of mobility studies

Subtask 2.1 - Mobility of radionuclides in compacted clay

Start: Month 1 – End: Month 48 - Task Leader: [PSI]

Subtask contributors: [Andra] [CEA] [CIEMAT] [CNRS-IC2MP/SUBATECH/IPHC (UPoitiers)]

[KIT (JGU)] [JUELICH] [MTA EK] [PSI] [SCK•CEN]

Total PM: 174,7

Diffusion studies on well-defined clay systems [SCK•CEN] [PSI] [CIEMAT] and on intact clay rocks [PSI] [CIEMAT] [JUELICH] [KIT (JGU)] [MTA EK] will be performed and the tracer profiles analysed with state-of-the art analytical tools such as Mass Accelerated Spectroscopy, Attenuated Total Reflection Fourier Transform Infrared Spectroscopy, micro-XAS and laser ablation with HR-ICP-MS in order to get better information on the speciation of the different nuclides on the surface of the solid phase. The diffusion profiles will be described with reactive transport codes containing state-of-the art adsorption and solid solution models as well as state-of-the art surface mobility models [PSI] [SCK•CEN] [KIT (JGU)] [JUELICH] [CNRS-SUBATECH]. This will give indication on whether the models derived from batch sorption experiments can be applied to compact systems. Pure clay samples of illite and kaolinite with well-defined characteristics such as porosity, clay particle size distribution and particle orientation will be provided by IC2MP for diffusion studies [CNRS-IC2MP] [CEA] [PSI]. Complementary to the diffusion studies, also batch sorption studies on compact clay systems will be performed [CNRS-SUBATECH], [CIEMAT].

The radiotracers that will be used in the diffusion and sorption studies are i) moderately sorbing tracers such as Fe, Mn, Zn, Ni, Ra [CIEMAT] [JUELICH] [SCK•CEN] [MTA EK] [CNRS-SUBATECH] and ii) strongly sorbing tracers such as Eu, Np, Pu, U and other actinides [KIT (JGU)] [CNRS-SUBATECH] [PSI] [CNRS-IPHC] [MTA EK]. Also a few weakly sorbing anionic tracers such as I and Se will be studied [SCK•CEN] [MTA EK] [CIEMAT] to decipher how simultaneous anion exclusion, sorption and surface induced mobility can be consistently described.

The results and outputs of Task 2.1, including statements on future research needs, will be compiled in a final report (D5.4).

Subtask 2.2 - Mobility of radionuclides in crystalline rock

Start: Month 1 – End: Month 48 - Task Leader: [JUELICH (HZDR)]

Subtask contributors: [JUELICH (HZDR)] [GRS] [KIT] [POSIVA] [SÚRAO (UJV)] [UHelsinki]

Total PM: 73,9

The work will be performed by a team out of [GRS] [JUELICH (HZDR)] [KIT] [UHelsinki] UJV, [POSIVA] and [SÚRAO]. The connected pore network and surface topography of fractured crystalline rock samples and mineral infills (provided by [SÚRAO] and [POSIVA]) are analyzed using μ CT [UHelsinki] [JUELICH (HZDR)] and interferometry microscopy (HZDR) prior to flow, diffusion, and sorption experiments. After transport experiments, post mortem analyses are performed using C-14-PMMA autoradiography technique [UHelsinki] interferometry [JUELICH (HZDR)], and AFM [GRS]. Batch type and flow through sorption experiments utilize reference pore water of the specific host rock [GRS] [JUELICH (HZDR)] [SÚRAO (UJV)]. We analyze the impact of surface potential variability, the role of grain boundaries [JUELICH (HZDR)] the effect of water chemistry (Eh, pH, ionic strength: [GRS] [SÚRAO (UJV)] as well as the impact of pore size variability of fracture infills and intact rock (nanometer to micron scale) [GRS] [SÚRAO (UJV)] [UHelsinki] [JUELICH (HZDR)]. Additional objectives include the analysis of the fluid velocity field (diffusive vs. advective transport) in and close to fractures by using PET techniques [JUELICH (HZDR)]. We utilize flow-through tracer tests to analyse the mobility of non-sorbing, intermediate, and strongly sorbing radionuclides (HTO, I, Ba/Eu) within rock fractures that covered with mineral infills [SÚRAO (UJV)]. Strongly, intermediate, and weakly sorbing radionuclides (Eu, Ra, Ba, Sr, Se (IV), and I) are used for sorption experiments focusing on the impact of porosity heterogeneities at the micron scale [SÚRAO (UJV)] [GRS] [UHelsinki] [JUELICH (HZDR)]. The laboratory experiments will be complemented by results of quantification of speciation and transport of radionuclides (Se, Am, Pu, Np, U, Tc) under natural crystalline fracture conditions under natural shear zone in Grimsel Test site. The experimental and analytical results will provide a basis for rigorous uncertainty and sensitivity studies thus providing an interface to WP DONUT. Generally, the results contribute to a realistic view on radionuclide migration in complex systems in order to overcome the current over-conservative consideration of heterogeneities, such as fracture planes, mineral infills, and porosity networks. The activities will be performed under close cooperation of all participating institutions.

The results and outputs of Task 2.2, including statements on future research needs, will be compiled in a final report (D5.5).

Subtask 2.3 - Reversibility of sorption

Start: Month 1 – End: Month 48 - Task Leader:[PSI]

Subtask contributors: [Andra (BRGM)] [CIEMAT] [CNRS-IPHC] [JUELICH] [MTA EK] [PSI] [SCK•CEN]

Total PM: 101,1

The sorption of radionuclides on clay minerals in engineered and geological barrier systems is a key safety function in deep geological disposal of radioactive waste. Reliable sorption data (K_d -values) and a mechanistic understanding of adsorption processes are mandatory for a proper evaluation of this safety function. Current models used in SA assume reversibility of the sorption. There are strong experimental evidences that the adsorption process is not fully reversible for a number of radionuclides.

The main aim of this subtask is to address open questions with respect to the adsorption reversibility and the nature of mechanism controlling the retention in the long-term (e.g. adsorption vs incorporation (surface precipitation, neoformation)). The degree of adsorption/desorption (reversibility), will be investigated over a relevant range of geochemical conditions (i.e., pH, I, nuclide concentration, competing nuclide or ligand, time scales) by macroscopic batch type experiments on (i) pure 2:1 type clay minerals [PSI] [Andra (BRGM)] [CNRS-IPHC] [CIEMAT] [JUELICH] [SCK•CEN] (ii) Fe mixed oxides [Andra (BRGM)] [CNRS-IPHC] and (iii) complex rock systems, primarily Opalinus Clay [JUELICH] [CNRS-IPHC] and Callovo-Oxfordian Clay [CNRS-IPHC] [CIEMAT] with a limited activity on Boda Claystone [MTA EK].

To obtain information on the molecular scale structure of the formed surface complexes, spectroscopic methods such as X-ray absorption spectroscopy [PSI] [CIEMAT] high resolution scanning transmission electron microscopy [Andra (BRGM)] Pair Distribution Function [Andra (BRGM)] transmission electron microscopy, micro-spectroscopy [MTA EK] and Attenuated Total Reflectance Fourier Transformed Infrared spectroscopy [CNRS-IPHC] will be applied.

Raman microscopy will be used to monitor the uptake of Ra during (Ba,Ra)SO₄ co-precipitation. It is the intention to implement the existing thermodynamic models to account for surface precipitation [PSI] [MTA EK] or sulphate co-precipitation of Ra [JUELICH] [PSI]. Following radiotracers will be used: weakly sorbing Se [SCK•CEN] [CIEMAT] [MTA EK] and moderately sorbing Ni [PSI] [Andra (BRGM)] [CIEMAT] [SCK], Ra [JUELICH] [CIEMAT] [MTA EK] and U(VI) [CNRS-IPHC]. The partners [PSI] [CNRS-IPHC] [CIEMAT] [JUELICH] [SCK•CEN] and [MTA EK] are also participating in subtask 2.1 where the aim is to evaluate whether adsorption processes and adsorption models developed on clays and clay rocks in diluted systems can be transferred as such to the real, compacted clays and clay rocks.

The results and outputs of Task 2.3, including statements on future research needs, will be compiled in a final report (D5.6).

Task 3 - Redox reactivity of radionuclides on mineral surfaces

Start: Month 1 – End: Month 48 - Task Leader: BRGM

Task Contributors: [Andra (BRGM)] [CEA] [CIEMAT] [CNRS (UGrenoble)] [JUELICH (HZDR)] [KIT] [PSI] [RATEN] [TNO]

Total PM: 237,2

Task objectives:

The overarching goal of task 3 “Redox” is to contribute to a better understanding of the coupled sorption and electron transfer interface reactions governing the retention of redox-sensitive radionuclides on Fe(II)/Fe(III) bearing minerals so as to improve our capacity to model, and thus predict, the fate of these elements within the safety assessment of radioactive waste storage. To address this issue, the interaction between different redox-sensitive radionuclides (or their non-radioactive analogues), including U, Pu, Tc, Np and Se, and purified relevant Fe-containing minerals and, to a minor extent, with rock envisioned as potential host-rocks (e.g., Callovian-Oxfordian) will be systematically investigated. Mineral properties with respect to its redox reactive iron content (structural/adsorbed) (i.e. abundance, location in the crystal structure, and oxidation state(s)) will be correlated to the degree of radionuclides retention (K_d) and molecular scale surface speciation. The transferability of the knowledge gained on dispersed pure phases (batch experiments) to the description and understanding of diffusion processes of radionuclides in compacted systems will be verified.

In a first part, pure clays and iron oxides (including magnetite) and, to a minor extent, argillaceous rocks (e.g., Callovian-Oxfordian rock or red clay), will be prepared and characterized for subsequent use in the different experiments [Andra (BRGM)] [PSI] [JUELICH (HZDR)] [CIEMAT] [TNO] [Andra] [RATEN]. HZDR will prepare magnetite samples with varying characteristics (i.e. Fe(II)/Fe(III), dopants, SSA, structural defects). Clay minerals with different Fe(II)/Fe(III) ratios will be prepared by reducing to different degrees the structural Fe(III) or by sorbing Fe(II) [Andra (BRGM)] [TNO] [PSI].

Complementary techniques (wet chemistry, Mossbauer spectrometry, electrochemistry, microscopy, and synchrotron-based X-ray techniques) will be employed to characterize the samples and the contacting solutions [RATEN] [Andra (BRGM)] [PSI] [JUELICH (HZDR)] [CIEMAT]. The iron oxides and clay samples obtained in this way will differ in their Fe characteristics (i.e., content, speciation and structural location), thus allowing to investigate the impact of each of these parameters on the extent and type of the redox interaction between minerals and radionuclides.

The second part of this task will focus on the understanding of the retention mechanisms of redox-sensitive radionuclides (e.g., U, Pu, Tc, Np, Se) on/in these Fe(II)/Fe(III) bearing minerals and of the associated electron transfer reactions [RATEN] [KIT] [PSI] [TNO] [CIEMAT] [JUELICH (HZDR)] [CNRS (UGrenoble)] [CEA]. Batch-type sorption experiments under different experimental conditions (e.g., pH, Eh, [RNs] dopants, solid concentration, time, presence of organics or H₂, etc.) and under controlled atmosphere will be carried out to quantify the retention and type of surface reaction (adsorption, reduction, oxidation, (co)-precipitation etc.). Competitive sorption experiments and reversibility tests will also be carried out. These experiments will guide the choice in the samples dedicated to structural speciation

measurements and provide sufficient experimental data to develop reliable surface reactivity models able to describe the retention of the chosen radionuclides under a relatively large range of conditions.

Molecular scale speciation techniques (e.g., XANES, EXAFS) and microscopy will be employed to identify the oxidation state(s) as well as the structural environment (adsorption, precipitation - e.g. nanoparticles, location of the surface complex - e.g. association with Fe) of the chosen radionuclides in the presence of above-mentioned mineral samples.

Additional experiments carried out with samples representative of host-rocks (compacted and intact argillaceous rocks), and in particular diffusion experiments, will enable to transfer the knowledge gained on isolated minerals to the characterization of the properties of actual materials present in radioactive waste repositories (including the mobility of the elements of interest in these materials).

The results and outputs of Task 3, including statements on future research needs, will be compiled in a final report (D5.7).

Participation per Partner

Partner number and short name	WP5 effort
1 - ANDRA	2.00
BRGM	30.50
5 - CEA	23.00
6 - CIEMAT	53.00
8 - CNRS	86.00
UGrenoble	31.00
UPoitiers	7.00
15 - JUELICH	31.00
HZDR	48.00
16 - GRS	10.40
24 - KIT	47.00
Uni Mainz	25.00
26 - MTA EK	21.00
34 - PSI	81.95
36 - RATEN	22.00
38 - SCK•CEN	12.25
42 - SÚRAO	1.00
ÚJV	31.00
44 - TNO	14.00
48 - UHelsinki	18.00
Total	595.10

List of deliverables

Deliverable Number¹⁴	Deliverable Title	Lead beneficiary	Type¹⁵	Dissemination level¹⁶	Due Date (in months)¹⁷
D5.1	FUTuRE - Initial State-of-the-art report on the understanding of radionuclide retention in clay and crystalline rocks	38 - SCK•CEN	Report	Public	6
D5.2	FUTuRE - Updated State-of-the-art on the understanding of radionuclide retention in clay and crystalline rocks	38 - SCK•CEN	Report	Public	48
D5.3	FUTuRE - Related deliverable: D5.4 Training materials	15 - JUELICH	Report	Public	36
D5.4	FUTuRE - Final technical report on radionuclide mobility in compacted clay systems	34 - PSI	Report	Public	48
D5.5	FUTuRE - Final technical report on radionuclide mobility in crystalline systems	15 - JUELICH	Report	Public	48
D5.6	FUTuRE - Final report on reversibility of sorption	34 - PSI	Report	Public	48
D5.7	FUTuRE - Final technical report on redox reactivity of radionuclides on mineral surfaces	1 - ANDRA	Report	Public	48

Description of deliverables

D5.1 State-of-the-art report on the understanding of radionuclide retention in clay and crystalline rocks. Emphasis will be on the current available knowledge with respect to i) transferability of sorption phenomena to compacted/ realistic systems and sorption reversibility and, ii) surface induced (heterogeneous) redox processes. Lead: [SCK•CEN] Month 6

D5.2 State-of-the-art report on the understanding of radionuclide retention in clay and crystalline rocks. Emphasis will be on the current available knowledge with respect to i) transferability of sorption phenomena to compacted/ realistic systems and sorption reversibility and, ii) surface induced (heterogeneous) redox processes. Lead: [SCK•CEN] Month 48

D5.3 Training materials Lead: [JUELICH] Month 36)

D5.4 WP5-FUTuRE Final technical report on radionuclide mobility in compacted clay systems This deliverable will describe results and outputs of Task 2.1, including statements on future research needs Lead: [PSI] Month 48.

D5.5 WP5-FUTuRE Final technical report on radionuclide mobility in crystalline systems - This deliverable will describe results and outputs of Task 2.2, including statements on future research needs Lead: [JUELICH (HZDR)] Month 48

D5.6 WP5-FUTuRE Final report on reversibility of sorption - This deliverable will describe results and outputs of Task 2.3, including statements on future research needs Lead: [PSI] Month 48.

D5.7 WP5-FUTuRE Final technical report on redox reactivity of radionuclides on mineral surfaces - This deliverable will describe results and outputs of Task 3, including statements on future research needs Lead: [Andra (BRGM)] Month 48

D5.1 : FUTuRE - Initial State-of-the-art report on the understanding of radionuclide retention in clay and crystalline rocks [6]

FUTuRE - Initial State-of-the-art report on the understanding of radionuclide retention in clay and crystalline rocks

D5.2 : FUTuRE - Updated State-of-the-art on the understanding of radionuclide retention in clay and crystalline rocks [48]

FUTuRE - Updated State-of-the-art on the understanding of radionuclide retention in clay and crystalline rocks

D5.3 : FUTuRE - Related deliverable: D5.4 Training materials [36]

FUTuRE - Related deliverable: D5.4 Training materials

D5.4 : FUTuRE - Final technical report on radionuclide mobility in compacted clay systems [48]

FUTuRE - Final technical report on radionuclide mobility in compacted clay systems

D5.5 : FUTuRE - Final technical report on radionuclide mobility in crystalline systems [48]

FUTuRE - Final technical report on radionuclide mobility in crystalline systems

D5.6 : FUTuRE - Final report on reversibility of sorption [48]

FUTuRE - Final report on reversibility of sorption

D5.7 : FUTuRE - Final technical report on redox reactivity of radionuclides on mineral surfaces [48]

FUTuRE - Final technical report on redox reactivity of radionuclides on mineral surfaces

Schedule of relevant Milestones

Milestone number ¹⁸	Milestone title	Lead beneficiary	Due Date (in months)	Means of verification
MS1	EURAD Kick-off meeting (General Assembly n°1)	1 - ANDRA	1	EURAD Kick-off meeting (General Assembly n°1)
MS4	FUTuRE Kick-off meeting (WPM1)	15 - JUELICH	1	FUTuRE Kick-off meeting (WPM1)
MS12	EURAD EJP Newsletters	1 - ANDRA	3	EURAD EJP Newsletters (Due date : M3 and then every quarter)
MS27	SOTA from RD&D FUTuRE WP as input to UMAN T3.3	15 - JUELICH	6	SOTA from RD&D FUTuRE WP as input to UMAN T3.3
MS30	EURAD General Assembly n°2	1 - ANDRA	7	EURAD General Assembly n°2
MS42	EURAD Annual Work Plan 2	1 - ANDRA	9	EURAD Annual Work Plan 2
MS50	FUTuRE Report on set-up of experiments – Task 2.1	15 - JUELICH	10	FUTuRE Report on set-up of experiments – Task 2.1
MS51	FUTuRE Report on set-up of experiments – Task 2.2	15 - JUELICH	10	FUTuRE Report on set-up of experiments – Task 2.2
MS52	FUTuRE Report on set-up of experiments – Task 2.3	15 - JUELICH	10	FUTuRE Report on set-up of experiments – Task 2.3
MS53	FUTuRE Report on set-up of experiments – Task 3	15 - JUELICH	10	FUTuRE Report on set-up of experiments – Task 3

Schedule of relevant Milestones

Milestone number ¹⁸	Milestone title	Lead beneficiary	Due Date (in months)	Means of verification
MS73	FUTuRE WPM2	34 - PSI	13	FUTuRE WPM2 - Change of Lead: 34 - PSI (instead of 15. JUELICH)
MS81	EURAD General Assembly n°3 + EURAD Annual Meeting 1	1 - ANDRA	13	EURAD General Assembly n°3 + EURAD Annual Meeting 1
MS85	EURAD Periodic Report 1	1 - ANDRA	14	EURAD Periodic Report 1
MS103	EURAD General Assembly n°4	1 - ANDRA	19	EURAD General Assembly n°4
MS112	EURAD Annual Work Plan 3	1 - ANDRA	21	EURAD Annual Work Plan 3
MS131	FUTuRE WPM3	34 - PSI	25	FUTuRE WPM3 - Change of Lead Beneficiary: 34. PSI (instead of 15. JUELICH)
MS136	EURAD General Assembly n°5 + EURAD Annual Meeting 2	1 - ANDRA	25	EURAD General Assembly n°5 + EURAD Annual Meeting 2
MS140	EURAD Periodic Report 2	1 - ANDRA	26	EURAD Periodic Report 2
MS153	EURAD General Assembly n°6	1 - ANDRA	31	EURAD General Assembly n°6
MS162	EURAD Annual Work Plan 4	1 - ANDRA	33	EURAD Annual Work Plan 4
MS181	FUTuRE WPM4	34 - PSI	37	FUTuRE WPM4 - Change of Lead Beneficiary: 34. PSI (instead of 15. JUELICH)
MS185	EURAD General Assembly n°7 + EURAD Annual Meeting 3	1 - ANDRA	37	EURAD General Assembly n°7 + EURAD Annual Meeting 3
MS189	EURAD Periodic Report 3	1 - ANDRA	38	EURAD Periodic Report 3
MS199	EURAD General Assembly n°8	1 - ANDRA	43	EURAD General Assembly n°8
MS206	EURAD Annual Work Plan 5	1 - ANDRA	45	EURAD Annual Work Plan 5
MS215	FUTuRE WPM5	34 - PSI	48	FUTuRE WPM5 - Change of Lead Beneficiary: 34. PSI (instead of 24. KIT)
MS222	EURAD General Assembly n°9 + EURAD Annual Meeting 4	1 - ANDRA	49	EURAD General Assembly n°9 + EURAD Annual Meeting 4
MS224	EURAD Periodic Report 4	1 - ANDRA	50	EURAD Periodic Report 4
MS234	EURAD General Assembly n°10	1 - ANDRA	55	EURAD General Assembly n°10
MS240	EURAD General Assembly n°11 + EURAD Annual Meeting 5	1 - ANDRA	60	EURAD General Assembly n°11 + EURAD Annual Meeting 5

Schedule of relevant Milestones

Milestone number ¹⁸	Milestone title	Lead beneficiary	Due Date (in months)	Means of verification
MS241	EURAD Periodic Report 5	1 - ANDRA	60	EURAD Periodic Report 5 (Due date: 60+2)

Work package number ⁹	WP6	Lead beneficiary ¹⁰	32 - ONDRAF/NIRAS
Work package title	Mechanistic understanding of gas transport in clay materials (GAS)		
Start month	1	End month	60

Objectives

Objectives

The main objectives of this WP are:

- To improve the mechanistic understanding of gas transport processes in natural and engineered clay materials, their couplings with the mechanical behaviour and their impact on the properties of these materials;
- To evaluate the gas transport regimes that can be active at the scale of a geological disposal system and their potential impact on barrier integrity and repository performance.

The programme of work will aim to provide results that are applicable to a wide range of National Programmes. This is possible because the results of previous efforts on the identification and characterisation of the possible gas transport processes suggest that the mechanisms at play in different clays are generally similar, while the conditions (gas pressure, stresses/deformations, saturation, ...) for the transition from one transport regime (diffusion, two-phase flow, pathway dilation and fracturing) to another strongly depend on the specific properties of a given clay material.

This WP will also aim to transfer knowledge gained from lab and in situ experiments to configurations that are commonly found in current repository designs, to address key questions from the end-users:

- How could gas migrate within the repository and which water soluble and volatile radionuclide transport could be associated with it?
- How and to what extent could the hydro-mechanical perturbations induced by gas effect barrier integrity and long-term repository performance?

This WP will build up heavily on the experience feedback and conclusions from the previous EC Project FORGE. The experimental investigation of gas transport in FORGE sometimes revealed complex mechanisms (e.g. such as the development of discrete, unstable pathways controlled by the mechanical behaviour of the porous media). However, it was also suggested that this complexity can be addressed as long as one can bound the effects of these mechanisms using simpler and robust descriptions for evaluation purposes. This WP will then aim at increasing the confidence in the overall understanding of gas behaviour in clay materials gained from the FORGE EC project and improving its integration in the conceptualisation process for the different components of a repository system. This should in turn support and justify the use of robust evaluation approaches and confirm the expert judgement at the end of FORGE that gas is not a show stopper for geological disposal but a question of managing uncertainties.

The WP is linked to EURAD Roadmap Theme 4 - Geoscience to understand rock properties, radionuclide transport and long-term geological evolution - phases 1-2.

Expected impacts

Regarding RWM implementation needs

- Provide input to implementers that may inspire design measures that further reduce the gas impact or the uncertainties associated with gas flow through geological disposal systems.
- Other impacts mentioned below also answer directly or indirectly RWM implementation needs.

Regarding safety

- Testing of various approaches for the treatment of gas in the safety case, identifying the inherent strengths and limitations of each approach and assessing its suitability in different contexts, as this may depend on the system that is being evaluated (host rock/design) or even the advancement of the (national) programme. Similarities of approaches between National Programmes will be identified and the rationale behind possible differences explained.
- Address the key questions that are common to all end-users, as per the second WP objective and confirm the insight from FORGE that gas is not a show-stopper for the Safety Case but a question of managing uncertainties.

Regarding increasing scientific and technical knowledge (beyond state-of-the-art) in the field of RWM

- Bridging the gap between experimentalists and modellers. Building on the lessons learned from FORGE, we do not propose a separate "modelling" (sub-)task. Modellers will be embedded with the experimentalists in subtasks of tasks 2 and 3 to encourage dialogue in the design of experiments and the development of shared conceptualisations of the observed behaviour.

- Building confidence in and extending the scientific bases on the fundamentals of gas transport in clay materials. Previous work suggests that the fundamental gas transport mechanisms that can develop in different clays are similar. Because a wide enough, but realistic, range of conditions will be explored for representative clay materials, this WP will provide data which will be of relevance for all disposal concepts that include clay barriers. Testing over a range

of conditions spanning low (diffusion) to high (advection) gas generation rates we will obtain a better understanding of processes which then has broader end-user appeal.

- Foster the transfer of knowledge between the scientific community (RE's) and the end-users (WMO's and TSO's), through the strong interactions between the three main tasks of this WP. Guidance by end-users will ensure that the experimental and model development work programme in tasks 2 and 3 remains focussed on materials and conditions that are of relevance. Scientists (RE's) will be asked to review the work performed in Task 4 to ensure that the evaluation of gas transport migration, its consequences and the treatment of residual uncertainties are consistent with the body of scientific knowledge.

Description of work and role of partners

WP6 - Mechanistic understanding of gas transport in clay materials (GAS) [Months: 1-60]

ONDRAF/NIRAS, ANDRA, BGE, CEA, CIEMAT, CNRS, COVRA, JUELICH, GRS, IRSN, KIT, LEI, NAGRA, PSI, RWM, SCK•CEN, SÚRAO, UHelsinki, UKRI

Description of work

Task 1 – S/T coordination, State-of-the-art and training material

Start: Month 1 – End: Month 60 - Task Leader: [ONDRAF/NIRAS]

Task Contributors: [IRSN] [NAGRA] [ONDRAF/NIRAS (ULiege)] [SCK•CEN] [UKRI-BGS]

Total PM: 10

Subtask 1.1 - S/T coordination

Start: Month 1 – End: Month 60 - Subtask Leader: [ONDRAF/NIRAS]

Total PM: 2

Given the objective of strong integration within this WP and the multiple interactions foreseen throughout the work programme defined in Tasks 2, 3 and 4, a scientific and technical coordinator [ONDRAF/NIRAS] will ensure that the R&D programme is going according to the plan, check coherency between actions and foster interactions between partners active in the different tasks. To facilitate a broad information exchange between tasks, the S/T coordinators and Task Leaders will organise 2 WP meetings (in workshop format) per year involving tasks 2, 3 and 4 together. Once a year, one of these meeting will be organised jointly with the WP HITEC, aligned with EURAD Annual meeting to minimise travel costs (i.e. Kick-off meeting month 1 + annual meeting months 13, 25, 37, 49, 60). The intermediate annual meeting, specific to the WP GAS, will be organised on months 8, 20, 32, 44, 56.

This scientific and technical WP Leader will then ensure interactions with other WPs among which HITEC, ACED, DONUT, UMAN and KM WPs, as well as the coordination of the production, cross-reviewing and edition of the GAS WP deliverables with the support of (sub)task leaders. These deliverables are:

- the initial (D6.1) and updated state of the art, SOTAs (D6.2) see subtask 1.2 below;
- three thematic technical reports, on gas transport and retention (D6.7), barrier integrity and conceptualisation (D6.8) and evaluation at the repository scale respectively (D6.9). The thematic reports will be drafted within the corresponding R&D tasks of the WP;
- a general introduction and conclusion will complement the three thematic reports so that these can be disseminated together at the end of the project as a coherent set of documents (D6.6).

The work performed in this WP and the results will be summarized in the three thematic reports that follow the same logic than WP organisation (respectively D6.2 related to Task 2, D6.3 related to Task 3 and D6.4 related to Task 4). Each thematic report will be coordinated by task and subtask leaders. Together with the peer-reviewed scientific papers that are expected be produced by (groups of) organisations involved in this WP, these thematic reports aim at providing reliable scientific/technical references about the knowledge produced in the GAS WP that can be of use to early stage and advanced programmes alike. The S/T WP Leader will also make sure that this collection of reports will be written so that it can be of use to the scientific community interested in gas transport through low-permeability geomaterials beyond the field of RWM.

At the end of the WP, a general workshop on “Mechanistic understanding of gas transport in clay-based materials” will be planned to facilitate the release of main findings of this WP within the whole scientific community and the end-user Lead organisation: [ONDRAF/NIRAS] month 56) (D6.5).

This subtask also includes the follow-up of interactions with other RD&D WPs and the KM WP.

List of WP meetings and Workshops:

Kick-off GAS WP Meeting (WPM1) month 1

GAS WP Meeting (WPM 2) month 7

GAS WP Meeting (WPM 3) jointly organised with the WP HITEC month 13

ACED - GAS - DONUT Joint Workshop month 13 - 18
 GAS WP Meeting (WPM 4) month 19
 GAS WP Meeting (WPM 5) jointly organised with the WP HITEC month 25
 GAS WP Meeting (WPM6) month 31
 ACED - GAS - DONUT Joint Workshop month 30 -37
 GAS WP Meeting (WPM 7) jointly organised with the WP HITEC month 37
 GAS WP Meeting (WPM 8) month 43
 GAS WP Meeting (WPM 9) month 49
 GAS WP Meeting (WPM 10) month 56
 Workshop on “Mechanistic understanding of gas transport in clay-based materials” (Month 56)

Subtask 1.2 - State-of-the-art reporting

Start: Month 1 – End: Month 60 - Subtask Leader: [ONDRAF/NIRAS]

Subtask contributors: [UKRI-BGS] [SCK•CEN] [NAGRA] [IRSN] [ONDRAF/NIRAS]

Total PM: 6

In the early stage of the WP, a state-of-the-art (SOTA) report on gas transport through clay materials (D6.1) will be produced including:

- a synthesis of the state of knowledge on gas transport through clay materials based mainly on current descriptions of diffusive and advective gas transports through clay materials as well as current descriptions of gas-induced impacts on barrier integrity (including self-sealing processes);
- An overview of the current conceptualisations of gas migration through geological disposal systems and related processes and an overview of the current modelling approaches, as used in the context of the safety case.

Not only current knowledge, but also key uncertainties and how these are currently treated will be presented. The reference material for drafting this overview document will come from National Programmes, previous EC projects (FORGE EC project in particular), other international projects (NEA, IAEA) and general scientific references (not limited to the world of RWM).

The aim of this initial SOTA is to give a general overview of the state-of-knowledge with respect to main WP R&D topics, with sufficient context so that it can be of use to a lay audience (with limited technical background), early stage programmes and R&D managers. The SOTA will also provide a baseline against which WP progress can be measured. This requires the pursuit of consensus from all partners (or identification of divergences) about the(ir) current understanding(s) of the key issues and may require some time for internal review (e.g., to make sure that key scientific issues and aspects of the treatment of gas in a Safety Case are unequivocally understood in the same way by all, or to record and explain differences of views, if any). This is why the proposed target date for delivery of the reviewed deliverable is month 18.

In the final stage of the WP, the state-of-the-art report (D6.2) will be updated integrating the key findings of the R&D tasks in this WP and relevant finding from other WP's. The main objective will be to put in evidence the significance of the findings of tasks 2 and 3 on the phenomenological descriptions of gas transport in clay materials and at repository scale and evaluate the consequences of these findings on the conceptualisation of gas migration through geological disposal systems (task 4).

Subtask 1.3 – Training materials

Start: Month 1 – End: Month 60 - Subtask Leader: [SCK•CEN] and [ONDRAF/NIRAS (ULiège)]

Subtask contributors: [SCK•CEN] and [ONDRAF/NIRAS (ULiège)]

Total PM: 2

Two training workshops (in the format of a doctoral schools) will be organised jointly with the WP on “Influence of temperature on clay-based material behaviour” (HITEC), as the target audiences are similar and the lecturers are likely to be involved in both WP's (D6.3 and D6.4). WP's will propose lectures and tutors on geomechanics and multi-physical coupling. Courses will integrate main WP's results on thermo-hydromechanical behaviour of clayey materials and on gas transport through clayey materials at this stage of the WP. The courses will highlight the consequences of thermal and gas-induced hydro-mechanical perturbations on barrier integrity and long-term performance.

More practically, the 1st school will be organised at the beginning of the WP (Lead organisation: [ONDRAF/NIRAS (ULiège)] month 6) in close link with Training/Mobility KM WP. The topic will be on multi-physical coupling in geomechanics (especially THM and Gas coupling issues). The objective will be to draw a state-of-knowledge on the fundamentals of these couplings at the beginning of the WP. The 2nd school will be organised at the end of the HITEC WP (during the 4th year). The objective will be to highlight the main results of EURAD-1 on THM and Gas issues with respect to the knowledge on multi-physical coupling in geomechanics and their applications.

Task 2 - Transport Mechanisms

Start: Month 1 – End: Month 60 - Task Leader: [SCK•CEN]

Task Contributors: [BGE] [CIEMAT (UPC)] [CNRS-SUBATECH (UGrenoble) (ULorraine) (UPoitiers)] [COVRA (TU Delft)] [IRSN] [KIT (BGR)] [ONDRAF/NIRAS (ULiege)] [PSI] [SÚRAO (CTU) (UJV)] [SCK•CEN] [UKRI-BGS]
Total PM : 350,4

Task Objectives:

Task 2 “Transport mechanisms” focusses on the main gas transport mechanisms which will take place in a disposal system in the post-closure phase. Different mechanisms are generally expected to be of importance in a geological repository:

- Gas produced within the system can dissolve in the pore water and can then be transported by diffusion. The diffusion of dissolved gas may be retarded by physio-sorption on the solid phase. Improving the mechanistic understanding of diffusive transport of dissolved gas and retention mechanisms will be the general objective of Subtask 2.1 “Gas diffusion and retardation processes at high level of water saturation”.
- If the gas production rate exceeds the rate at which gas can be dissolved and evacuated by diffusion, a free gas phase will develop. As gas pressure increases, advective transport will occur. Two primary modes for advective gas transport are proposed; (i) visco-capillary flow and (ii) the formation of discrete gas-filled pathways. Exploring which transport mechanisms prevail under which range of conditions and understanding how the coupling between pressure in the liquid and gas phase are the stresses in the solid phase control gas transport will be a general objective of Subtask 2.2 “Advection (displacement vs. dilation)”.

Specific objectives of Subtask 2.1 “Gas diffusion and retardation processes at high level of water saturation”: in order to compare the rates of gas generation and gas evacuation by dissolution and diffusion, knowledge of the diffusion parameters of dissolved gas through the used materials is essential. Up to now, diffusion parameters are available essentially in water saturated systems. As partial desaturation might occur at some point during the repository evolution, this WP will extend the available experimental data for gas diffusion to partially desaturated conditions. In line with the general objective to improve mechanistic understanding, interpretation of the experimental results will be supported by pore network modelling. The experimental and modelling work programme aims in particular to investigate how petrophysical parameters (e.g. mineralogy and density) and the stress state influence the diffusion parameters.

While diffusing through the pore water, dissolved gas might also interact with the barrier materials. Up to now, interactions (mainly gas sorption) have only been studied under dry conditions. In particular, hydrogen uptake due to sorption processes has only been studied under dry condition. One objective of this subtask is to determine if gas sorption could be a relevant retardation mechanism for diffusive transport under repository conditions, in clays that are partially or fully saturated with pore water. Again, the impacts of the pore network morphologies and the nature of the mineral assemblages on the gas sorption mechanisms will be investigated.

Key objectives of sub-task 2.1 are thus:

- 1) to determine gas diffusion parameters on different clayey materials at different degrees of water saturation and support experimental data interpretation by pore network modelling, and
- 2) to understand gas physisorption mechanisms in microporous systems.

The gas of interest in this task is chiefly H₂, but other apolar gases such as CH₄ (by-product of bacterial activity), He, Ar (naturally occurring noble gases) and Ne (H₂ proxy) will be also investigated in order to i) avoid artefacts related to bacterial activity triggered by H₂, ii) overcome safety problem especially in underground laboratories, and iii) probe the effect of polarizability and kinetic diameter on apolar gases mobility in porous networks.

Specific objectives of Subtask 2.2 “Advection (displacement vs. dilation)”: From previous work (including work done in the previous EC project FORGE), two primary modes for advective gas transport through natural mudrocks are proposed; (i) visco-capillary flow, where capillary forces must be overridden in order to allow displacement of the wetting phase, by migrating gas and (ii) the formation of discrete gas-filled pathways, by localised consolidation of the clay matrix. The potential for one specific mechanism to prevail is dependent on a range of factors, including the saturation state of the clay and the ratio of the clay to sand fraction. Natural heterogeneity within clay-hosted repositories may also play an important role in the migration of gas and the mitigation of peak gas pressure. For fully-saturated, pure clay bentonite materials, such as those used in engineered barriers, experimental evidence indicates that gas flow by pathway dilation is the preferred mode of transport. In such cases, significant hydromechanical coupling is observed, which cannot be satisfactorily explained by visco-capillary flow processes. This hydromechanical coupling between the immiscible phase, the interstitial fluid, and the total stress, remains unclear. Understanding these relationships, how they vary from one formation to another, and what impact, if any, they have on the integrity of the host rock, is now a priority research issue.

Through new experimental studies, this subtask aims to:

1) Provide reference data for various natural and engineered clay materials under a sufficiently broad range of conditions, which will make it possible to investigate in a more systematic way how petrophysical parameters, like mineralogy or density, and conditions such as the stress state influence free gas transport.

2) Improve understanding of the observed gas transport modes and identifying their main controls, through interpretation of the experimental results by models in which the representation of crack propagation and pathway dilatancy is implemented at a process level.

3) Conceptualisations of the transport mechanisms limited to the macro-scale (continuum representation + discrete conducting features) such as those developed, for instance, in the FORGE EC project will be compared to conceptualisations in which the micro-scale is also represented to better improve understanding of how micro-level heterogeneities and deformations affect macro properties.

The experimental and modelling programmes of the subtask 2.2 aim at characterising and understanding advective gas transport in fully saturated (or close to saturation) clayey materials. For bentonite, it will benefit from the results of the BEACON EC project that characterises the hydro-mechanical coupling of swelling clay materials during resaturation phase. For bentonite barriers, BEACON EC project, this WP and the HITEC WP are complementary as these together support the global description of hydro-mechanical processes from the installation of materials to their evolution over the long term (including the thermal phase in the case of heat-emitting waste) and the consequences of gas flow. The integration of knowledge will be facilitated by involvement in this subtask of the GAS WP of some BEACON and HITEC WP partners.

Subtask 2.1 – Diffusion and retardation

Start: Month 1 – End: Month 60 - Subtask Leader: [CNRS-SUBATECH (UGrenoble)]

Subtask contributors: [SCK•CEN] [PSI] [UKRI-BGS] [IRSN] [CNRS-SUBATECH (UGrenoble)]

Total PM: 128,9

Subtask 2.1 will focus on diffusion and gas adsorption experiments. Both will be supported by modelling activities.

- [SCK•CEN] and [PSI] will perform diffusion experiments on Boom Clay, Opalinus Clay and sand/bentonite mixtures and the experimental results will be supported by pore network modelling. Experiments will be carried out at different degrees of saturation, with different gases. This will allow determining how the effective diffusion coefficient is influenced by desaturation. By using lattice-Boltzmann modelling, the gas partitioning in pores of different sizes will be estimated. The proposed work plan is complementary to that of IRSN and collaboration will be considered.

- [UKRI-BGS] will perform and model experiments on clay simulants to investigate the impact of mineralogy on the diffusion coefficient. A series of tests will be performed providing reference values for different mineral combinations, yielding data of interest to multiple end-users.

- [IRSN] will use various techniques (gas absorption, micro, nano tomo RX, FIB) to characterize the pore network of different clay materials (Toarcian, Callovo-Oxfordian argillite, Opalinus Clay) and use this data to build synthetic pore network models that will allow to theoretically determine the effective diffusion coefficients as function of the water saturation. These values can be tested against those determined in the diffusion experiments by [SCK•CEN] [PSI] and [BGS].

- [CNRS-SUBATECH (UGrenoble)] will study hydrogen uptake in microporous systems (pure clay phases and various claystones). [CNRS-SUBATECH (UGrenoble)] will perform H₂ sorption isotherms over a wide range of pressure to study retention mechanisms and fundamental thermodynamic properties of the retention process and will also study the desorption processes to clearly evaluate hydrogen mobility and retardation mechanisms in clay-rich porous media. [CNRS-SUBATECH] will perform computational atomistic modelling to investigate the molecular mechanisms of gas sorption in clay-based materials with further extension to a mesoscale and multiscale modelling. [CNRS-SUBATECH (UGrenoble)] will work cooperatively to characterize the nanoporous structure properties and its effect on H₂ sorption (IR/Raman spectroscopy, X-Ray diffraction, QENS, etc.).

- In addition, [SCK•CEN] will perform an in-situ diffusion experiment in the Boom Clay. Results that will be available during the time span of this WP will be communicated to the organisations involved in this subtask. This is a contribution in kind.

Subtask 2.2 – Advection (displacement versus dilatant gas flow)

Start: Month 1 – End: Month 60 – Subtask Leader: [UKRI-BGS]

Subtask contributors: [CNRS (ULorraine) (UPoitiers)] [SÚRAO (CTU) (UJV)] [ONDRAF/NIRAS (ULiège)] [IRSN] [COVRA (TU Delft)] [CIEMAT (UPC)] [BGE] [JUELICH (UFZ)] [KIT (BGR)] [UKRI-BGS] [SCK•CEN]

Total PM: 221,5

The focus of this subtask is to determine if visco-capillary, dilatant flow or a combination of the two apply in clay-rich materials. The subtask is split into integrated components (laboratory/field and numeric) for which new experimental studies provide reference data to guide and validate numerical modelling.

Laboratory and field activities:

- [UKRI-BGS] will perform experiments to help identify the governing processes (displacement or dilation) for natural and engineered materials of interest to different European programmes. Additional tests will be performed on simulant materials to explore the dependency of transport mechanisms to petro-physical properties, which are of interest to Member-States that have not selected a particular clay-based host rock or EBS material. Pathway imaging techniques will also be used. Finally, observations will also be up-scaled to include in-situ measurements of gas migration at a repository-relevant scale using the Lasgit facility at the Äspö URL managed by SKB.
- [CNRS (UPoitiers)] will characterise gas propagation through Callovo-Oxfordian claystone using X-ray tomography at macro-scale and TEM on MMA-impregnated post-mortem samples for the micro-scale. Tests will cover range of gas injection pressures corresponding to the different stages of gas migration. 2D maps of the sample microstructure at several stages will allow exhibiting the changes of micro-structure of the claystone upon gas migration. The role of mineralogical heterogeneities (e.g., pyritic filaments and/or thin bedding laminations of non-clay minerals in clay rocks) will be also investigated.
- [CIEMAT] will focus on gas migration testing of EBS buffer material. The range of actual conditions (gas pressure, stress/deformation, saturation) at which each gas transport regime occurs will be determined for the Spanish EBS material, used as a representative reference material. This is expected to yield new knowledge about the mechanisms that control these transport regimes in engineered but also natural clay materials at low suctions (close to saturation, representative of long term conditions).
- [SÚRAO (CTU) (UJV)] will directly measure hydrogen migration at slow pressurization rates in the Czech Ca-Mg bentonite, complementing work by other Teams.

In addition, [SCK•CEN] will perform long-term, slow gas injection tests in the lab under well-controlled mechanical conditions to investigate the transition from the diffusive to the advective transport regimes. This is a contribution in kind. The proposed setup will be communicated to organisations active in Task 2 for review and the results will be made available to this WP.

Numerical modelling activities:

- [ONDRAF/NIRAS (ULiège)] will develop a Micro-Macro model (FE² method, Finite Element Method combining macro and micro-scale models) to take explicitly into account the presence of bedding planes and pore network morphologies at the micro-level. The objective is to predict at micro-level the deformations of these heterogeneities and to evaluate the impact on macro properties.
- [CNRS (ULorraine)] and [IRSN] will conduct numerical simulations of multiphase fluid transport through deformable nanoporous geomaterials. CNRS-Georessources will follow a digital rock physics approach based on FIB-SEM images of actual material, using a lattice-Boltzmann model. Numerical results will be used to upscale effective properties (deformation-dependent saturation curve, relative permeability). [IRSN] will extend its SPH code capable of simulating dilatancy flow by adding an appropriate damage model and improving the representation of water transfer via the gas phase (evaporation, vapour diffusion).
- [COVRA (TU Delft)] [CIEMAT (UPC)] [KIT (BGR)] [BGE] [JUELICH (UFZ)] will test conceptual models at the macro-scale against results from selected laboratory and field experiments. [COVRA (TU Delft)] and [CIEMAT (UPC)] will numerically investigate the effects of natural heterogeneities of material parameters and uncertainties on these parameters through the use of random and auto-correlated spatial distributions of certain material properties or model parameters. [KIT (BGR)] will collaborate with [BGE] & [JUELICH (UFZ)] and will test different continuum model approaches to describe the induced permeability change benchmarked against data from in situ gas injection experiments in saturated claystone (Mont Terri Rock Laboratory) and compacted bentonite Mx-80 (DECOVALEX) under high gas injection pressure.

Task 3 - Barrier Integrity

Start: Month 1 – End: Month 60 - Task Leader: [NAGRA]

Task Contributors: [Andra] [BGE] [CEA (EDF)] [CIEMAT (UPC)] [CNRS (ULorraine) (Upoitiers)] [COVRA (TU Delft)] [JUELICH (UFZ)] [GRS] [IRSN] [KIT (BGR)] [NAGRA (CIMNE) (EPFL) (ZHAW)] [ONDRAF/NIRAS (ULiège)] [SÚRAO (CTU)] [UKRI-BGS]

Total PM: 236,8

Task Objectives

Accumulation of gas in the back-filled structures of a deep geological repository associated with the build-up of excessive gas pressures may impair the long-term safety functions of the repository's multi-barrier system, namely the radionuclide retention and attenuation capacity of the engineered barrier system (EBS) and the geological barriers. Clay-rich rocks and clay-based EBS are particularly prone to failure due to their low mechanical strength. On the other hand, it is well known that clays exhibit the favourable feature to self-seal after sustaining mechanical failure. Task 3 is aimed at gaining a mechanistic understanding of the hydro-mechanical phenomena and processes, associated with:

- the gas-induced failure of clay barriers, i.e. within the engineered barrier system (EBS), within the Excavation Damage Zone (EDZ) and within the host rock (Subtask 3.1);
- the effectiveness of self-sealing processes along gas-induced pathways in the clay barriers of a geological repository (Subtask 3.2).

The evaluation of achievements is accomplished by model-supported data analyses, predictive modelling and the application of the newly developed modelling tool on in-situ experiments (Subtask 3.3).

As mentioned in Task 2, after the FORGE EC project, the hydromechanical coupling between the gas phase, the interstitial fluid, and the total stress, are still a priority research issue. For bentonite barriers the task will benefit from the BEACON EC project that characterises the hydro-mechanical coupling of swelling clay materials during the resaturation phase. This transfer of knowledge will be facilitated by involvement in this task of some BEACON partners.

Subtask 3.1 - Gas-induced impacts on barrier integrity

Start: Month 1 – End: Month 60 – Subtask Leader: [NAGRA]

Subtask contributors: [Andra] [CNRS (ULorraine) (Upoitiers)] [GRS] [IRSN] [NAGRA (CIMNE) (EPFL) (ZHAW)] [SÚRAO (CTU)] [UKRI-BGS]

Total PM: 84,4

Laboratory experiments will be designed and executed, aimed at investigating the evolution of damage in clay-rich geomaterials when subjected to excessive water / gas pressures. Different test set-ups and different test procedures will be required for the investigation of argillaceous rock and EBS material, respectively.

Host rock material (including Boom Clay, Callovo-Oxfordian argillite, Opalinus Clay, Lower Cretaceous Marls of Northern Germany)

Fracture initiation and fracture propagation processes in the intact host rock and fracture reactivation in the Excavation Damaged Zone (EDZ) as well as the reactivation of tectonic features depend on the rock fabric and on the prevailing in situ conditions (pore pressure and stress). Fracture opening and fracture sliding mechanisms will be investigated along typical stress paths, which are representative for real repository conditions.

- [NAGRA (CIMNE)] and [GRS] will perform hydro-mechanical laboratory experiments on rock samples, covering the above mentioned classes of host rocks. The test set-ups ensure the precise control of water/gas flow, pore pressure / total suction, stress state and strains during all test stages (isostatic/triaxial cells). The impact of texture and tectonic overprint on gas-induced damage evolution will be addressed by testing the rock samples parallel, perpendicular and at oblique angles to the principal orientations of micro-fabric, respectively.

- Further phenomenological experiments will be conducted by [UKRI-BGS] and [CNRS (UPoitiers) (ULorraine)]. [UKRI-BGS] will use a direct shear rig for water/gas injection experiments. Shear fractures will be created within the apparatus while tensile fractures will be created externally. Quantitative textural information of all fracture surfaces will be determined prior, and after, detailed gas testing. [CNRS (ULorraine)] will visualise gas transport processes in a permeameter cell which is transparent to X-rays. Thus, it is possible to follow the evolution of damage and self-sealing processes in the sample during gas injection and after shut-in using a high-resolution X-ray CT scanner. [CNRS (UPoitiers)] will provide additional capacities for microstructural analyses, including post-mortem TEM on MMA resin impregnated samples.

Buffer materials (including compacted granular bentonite, bentonite blocks, sand/bentonite mixtures)

[NAGRA (EPFL)] [IRSN] and [SÚRAO (CTU)] will conduct long-term water/gas injection tests in oedometric/isostatic cells to investigate pathway dilation and particle mobilization. The laboratory experiments shall reveal the impact of the as-compacted state (e.g., dry density, grain size distribution, initial water content) and the hydration process (e.g., imbibition process, water chemistry) on the gas breakthrough pressure of the hydrated material and on the fraction of mobilized bentonite.

Microstructural analyses of the investigated geomaterials (damaged or intact host rocks and EBS materials, respectively) before and after gas injection will be conducted with the support of [NAGRA (ZHAW)] to get insight in the prevailing failure mechanisms. This includes the evaluation of apertures, extensions and surface roughness of the induced fractures and statistical descriptions of the pore networks of the intact and of the damaged material.

Complementary activities by [NAGRA] and [Andra] in Task 3.1 comprise desk studies and the compilation of experimental data bases on gas induced rock failure from in-situ experiments in URLs (Bure, Mont Terri). Thus, a review of gas-related FEPs will be conducted as an initial action in the context of the State-of-the-art report (see Task 3.3) to address further detrimental effects associated with gas transport. The outcome of the FEP screening may lead to complementary experimental investigations in the later stages of the WP.

Subtask 3.2 – Pathway closure and sealing processes

Start: Month 1 – End: Month 60 - Subtask Leader: [Andra]

Subtask contributors: [Andra] [CNRS (ULorraine)] [GRS] [NAGRA (CIMNE) (ZHAW) (EPFL)] [SÚRAO (CTU)] [UKRI-BGS]

Total PM: 72

From a mechanistic point of view, the self-sealing capacity of clay-bearing materials is associated with various (thermo-)hydro-mechanical and –chemical processes and controlled by the prevailing state conditions. Mechanical closure of fractures (e.g., crack closure, fracture sliding), hydro-chemical interactions of the pore water with the clay-bearing solid phase of the geomaterial (e.g., swelling, dis-aggregation) and colloidal transport processes (e.g. sedimentation, clogging) have been identified as typical self-sealing mechanisms in clay-rich materials. In this context, it is important to consider also phenomena and processes that could prevent fracture closure, such as mineral transformations and hydromechanical reorganizations of the rock fabric caused by gas seepage through the clay barriers over long time periods of several 10⁴000 years.

- [NAGRA (CIMNE) (EPFL)] [GRS] [SÚRAO (CTU)] will investigate the self-sealing capacity of the tested geomaterials essentially with the same test configurations as used for the gas injection experiments. After termination of the gas injection experiments, the test specimen will be subjected to different pressure recovery conditions including re-saturation with different water compositions and different total stress scenarios. Subsequently, final water permeability testing will be conducted to qualify the loss of hydraulic barrier function of the test specimen. Different host rocks and different fracture modes will be addressed. Visualisation techniques such as micro-CT, SEM, and possibly others provided with the support of [NAGRA (ZHAW)] will allow revealing the microstructural changes of the investigated test samples at the end of the self-sealing stage.

- The phenomenological gas injection experiments by [UKRI-BGS] and [CNRS (UPoitiers) (ULorraine)] will also be extended beyond the shut-in phase to visualise at pore scale the complex HM-C interactions, which are associated with the self-sealing process.

- [Andra] and [NAGRA] will take responsibility for the desk studies (review of gas related FEPs, SOTA report) and the compilation of experimental data bases on large-scale self-sealing experiments in URLs (Bure: CDZ, GER; Mont Terri: FS-C).

The self-sealing studies of this subtask are closely connected to the ones planned in the subtask 2.1 of the HITEC WP (“Clay host rock” task – “Experiment near field with EDZ” subtask). The aim of these tasks in these two WPs will be to characterise (T)HM(-C)(+gas) processes associated to self-sealing mechanisms in clays. Hence, tests will be performed jointly during the duration of the WP under various thermal and chemical conditions to provide a complete characterisation of self-sealing processes in clays. To facilitate a broad information exchange between the two WPs on these aspects, joint workshops will be organised each year until the end of the HITEC WP (months 13, 25, 37).

Subtask 3.3 – Model-based interpretation and synthesis of results

Start: Month 1 – End: Month 60 - Sub-task Leader: [JUELICH (UFZ)]

Subtask contributors: [NAGRA (CIMNE) (EPFL)] [CIEMAT (UPC)] [CNRS (UPoitiers)] [CEA (EDF)] [ONDRAF/NIRAS (ULiège)] [COVRA (TU Delft)] [BGE] [KIT (BGR)] [Andra] [JUELICH (UFZ)]

Total PM: 80,3

Subtask 3.3 is dedicated to the interpretation of the experimental results and the synthesis of the scientific achievements (development of process models for pathway dilation and self-sealing). Furthermore, the scientific coordination of the subtasks and the exchange with Tasks 2 and 4 will be accomplished with the support of the S/T WP Leader.

[JUELICH (UFZ)] [Andra] and [NAGRA] will survey the state of knowledge by participating to the state-of-the-art report and the compilation of comprehensive experimental databases from previous research programmes (e.g.; NEA/ Clay Club Initiatives on “Gas” and on “Self-sealing”; EU FP7-FORGE). Drawing on the input from Tasks 3.1 & 3.2, UFZ will coordinate the elaboration of an experimental design report, which includes a detailed description of the experimental set-ups and test procedures and a revised version of the detailed work programme of Tasks 3.1, 3.2 and 3.3. The modelling teams [NAGRA (CIMNE) (EPFL)] [CIEMAT (UPC)] [COVRA (TU Delft)] [ONDRAF/NIRAS (ULiège)] [CNRS (UPoitiers)] [CEA (EDF)] and [BGE] [KIT (BGR)] and [JUELICH (UFZ)] will contribute to the experimental design of the laboratory experiments and the model-based interpretation of the acquired experimental results. Back analysis of the experiments will feed in the development of conceptual process models of gas-induced damage evolution and self-sealing processes for damaged or intact host rocks and EBS materials, respectively. Validation of these models will take place in a series of prediction-evaluation exercises, covering different loading paths in different geometric configurations (host rocks: isostatic / triaxial; EBS material: oedometric / isostatic). Eventually, the validated process models will be applied for the back-analysis of selected in-situ experiments in URLs.

In the final stage of the WP, a synthesis of the experimental achievements will be accomplished as part of the final task reporting. The execution of the 3 subtasks will be conducted in close cooperation with Tasks 2 and 4. This will ensure a consistent and balanced appraisal, which is in line with the overall objectives of the WP.

Task 4 - Repository performance aspects

Start: Month 1 – End: Month 60 - Task Leader: [Andra]

Task Contributors: [Andra] [CEA (EDF)] [COVRA (TU Delft)] [IRSN] [KIT (BGR)] [LEI] [NAGRA] [ONDRAF/NIRAS (ULiege)] [RWM] [SCK•CEN] [UHelsinki (Aalto University)]

PM : 70,5

Task objectives

This task aims at fulfilling the second high-level objective of the WP, which is to evaluate the gas transport regimes that can be active at the scale of a geological disposal system and their potential impact on repository performance. It is dedicated in particular to end-users questions concerning:

- the effects of the presence of gas and its transport on the transfer of soluble and volatile radionuclides;
- the consequences of gas-induced hydro-mechanical perturbations on barrier integrity and long-term performance.

From past evaluations it is known that gas generated by corrosion and/or radiolysis in large quantities may result in the development of a gas phase within the existing porosity of the engineered barrier system (EBS), within the Excavation Damaged Zone (EDZ) and, to some extent, within the host rock. Experimental evidence suggests that discrete, transient, gas-specific pathways may also form through (or between) EBS materials, the EDZ and the host rock in the form of sub-critical (pathway dilation) or supercritical (fracturing) cracks. The transient nature of such phenomena is to be emphasized. Desaturation can have a significant effect on soluble radionuclide migration: it may limit the extent of diffusion of soluble radionuclides but may also result in advective transport of radionuclides, if groundwater is displaced one way or another by gas as a consequence of pressurization or suction. High levels of desaturation may even affect the gas source term by decreasing the availability of water for gas production processes. Continuous gas pathways, possibly evolving and unstable, may form from the deposition zones to the repository access. These would affect the migration of volatile radionuclides. Finally, high gas pressures may possibly result in mechanical damage to the engineered and natural barriers, including the host rock, and could affect the global functioning of the repository. It is important to assess if this could occur in practice and if such damage would be transient only or would have a lasting effect and how this would affect (or not) the outcome of a safety case.

Task 4 will build and improve from the EC project FORGE, which ran from 2008-2013, in several ways, by:

- including in the analysis hydro-mechanical couplings;
- including in the analysis the transfer of soluble and volatile radionuclides;
- promoting the use of multiple assessment approaches, supported by different numerical modelling tools;
- being driven from an end-user perspective of gas induced effects.

This task will also benefit from recent advances in phenomenological understanding from the CAST (Carbon-14 source term and fate) and BEACON (bentonite mechanical evolution) EC projects allowing respectively (i) a better understanding of potential release mechanisms of carbon-14 (in the form of methane for instance) from radioactive waste materials under conditions relevant to geological disposal facilities and (ii) a better characterisation of hydro-mechanical coupling in swelling clayey materials (from the installation of materials to their evolution over the long term).

Task 4 will be mainly end-users oriented. Based on the input from tasks 2 and 3 of this WP and relevant input from other WPs in EURAD-1, the objective of subtask 4.1 will be to assemble phenomenological descriptions of gas transport and its likely consequences on barrier integrity and radionuclide transfer at repository relevant scale, in the form of storyboards. The resulting conceptualisations of gas transport and of its possible consequences for typical repository configurations in clayey host rocks will be passed on to subtask 4.2, which will be dedicated to the assessment of different approaches and tools (e.g. numerical modelling) that can be used for evaluating the effect of gas on repository performance.

To ensure seamless communication between the conceptualization group (subtask 4.1) and the evaluation/modelling group (subtask 4.2), the task 4 leader and the two subtask leaders will be jointly responsible for the coordination of actions and the synthesis of the results.

Subtask 4.1 – Conceptualization of gas migration at repository scale

Start: Month 1 – End: Month 60 - Subtask Leader: [RWM]

Subtask contributors: [Andra] [COVRA] [IRSN] [NAGRA] [ONDRAF/NIRAS] [RWM]

Total PM: 18,3

Sub-task 4.1 will be system oriented and will be carried out by end-users (i.e. WMO and TSO). REs will be involved through reviews of this work in Tasks 2 and 3 to ensure that good use is made of available scientific knowledge.

Current conceptualizations of gas migration through clay-rich host rock geological disposal systems and tools used for describing gas transport and its consequences at repository scale (e.g. numerical modelling) will be compiled and compared by the end-users partners involved [RWM] [Andra] [COVRA] [IRSN] [NAGRA] [ONDRAF/NIRAS] to highlight in particular:

- the gas transport processes and related processes considered as relevant at repository scale by each organization, shedding light on the similarities and differences between National Programmes;
- the key properties and conditions assumed to control these processes;
- the expected effects of gas on host rock, groundwater, radionuclide transfer and barrier integrity;
- the different modelling approaches that can be used to evaluate gas transport and related aspects (e.g. fully coupled at repository scale, lumping/homogenization, compartment modelling, ...), how these are related to the storyboards and the rationale for using one or another approach.

The storyboards/conceptualizations describing gas transport through typical repositories and its impact on system components will be phenomenologically-based. Special attention will be given to explain how the conceptualizations have been derived from the available scientific bases (references to experimental data, prioritization of processes for instance). First conceptualizations will be produced early on in the course of the WP (by Month 12) and will be reviewed by the participants to Tasks 2 and 3 to (i) check that repository-scale concepts are consistent with the scientific bases and, (ii) to inform the experimentalists / process-level modellers about the configurations and ranges of conditions that are relevant for repositories. An interaction will be organised at this stage (around Months 13 - 18) with the WP ACED, which also develops storyboards (of the chemical evolution of a disposal cell) to exchange information and ensure consistency.

This first conceptualization phase will be completed (by Month 12) by the definition of (i) a generic repository configuration and sets of properties and conditions on which sub-task 4.2 will test various evaluation approaches and (ii) a proposal for a set of indicators, covering the range of needs of various end-user in Europe for clay-based host rock repository, representative of the processes to be evaluated (transfer of RN, volatile and soluble, barrier integrity for instance). An interaction will also be organised at this stage with WP DONUT (between Months 13 – 18) to identify possible benchmark studies for DONUT and to exchange on numerical challenges and abstraction methodologies.

In a second phase, the focus will shift to the integration and understanding of the significance of the findings of Task 2 “Transport Mechanisms” and Task 3 “Barrier integrity” during the course of the WP. The phenomenological description improvements will be evaluated for transfer to the repository scale via updates to the storyboards. Uncertainties about which gas transport modes will effectively be active or about other gas-related aspects of the evolution of the system will be identified and evaluated in terms of possible scenarios to be investigated. Additional indicators may be proposed. These conceptualisation updates and alternative scenarios will be passed on to subtask 4.2 as input for the assessment of gas induced effects.

This integration task will imply strong interactions between the Task 4 and other tasks of the WP to ease the transfer of concepts from laboratory experiments and process-level models to the relevant configurations and scales. Interactions will also be organized again with other WP’s in order to take into account or provide input that can be relevant and/or appropriate (e.g. with the modelling WP DONUT and the chemical evolution assessment WPACED around Month 30 - 37, via a joint workshop focused on intermediate results of benchmark studies, numerical developments, and the application of abstraction methodologies). Along the course of this subtask, interactions will also be organised with the UMAN Strategic Study on understanding of uncertainty, risk and safety on the basis of the contribution of this subtask to the SOTAs (see below). These interactions will focus on the identification, characterization, potential significance and treatment of uncertainties in the abstraction process for gas transport (e.g. propagation of parameter uncertainties, scenario uncertainties...) and the evaluation of their consequences.

Subtask 4.2 – Model assisted assessment of gas induced effects

Start: Month 9– End: Month 60 - Subtask Leader: [IRSN]

Subtask contributors: [Andra] [CEA (EDF)] [COVRA (TU Delft)] [IRSN] [KIT (BGR)] [LEI] [ONDRAF/NIRAS (ULiège)] [SCK•CEN] [UHelsinki (Aalto University)]

Total PM: 52,2

Building on the storyboards, the definition of a generic repository and sets of properties and conditions, indicators and scenarios proposed in subtask 4.1, different approaches will be assessed to numerically describe disposal system behaviour in response to gas accumulation and pressure build-up. This assessment will compare:

- the use of coupled high-resolution models taking into account the full complexity at repository scale of gas related process understanding towards total system performance;
- the application of traceable, component-based model upscaling techniques, i.e. establishing detailed models of components, accounting for the complexity of the mechanistic understanding embodied in the process level models, then simplifying the representation of the components in the total system performance models.

To assess the relevancy of these different levels of complexity, several modelling teams [IRSN]

[UHelsinki (Aalto University)] [Andra] [BGR] [CEA (EDF)] [LEI] [SCK•CEN] [COVRA (TU Delft)] [ONDRAF/NIRAS (ULiège)] will apply various numerical approaches to a generic repository configuration with different sets of properties and conditions and with the scenarios defined in subtask 4.1. As the generic repository and the specificities

of models will directly depend on the conceptualization subtask 4.1, these will be examined in detail during a working meeting organized around month 9.

The main objective of subtask 4.2 is not to perform a formal performance assessment or a code benchmarking exercise, but to highlight the inherent strengths and limitations of each approach and assessing its suitability in different contexts depending on which system is being evaluated (host rock/design) or what is the quality of available data/what is the magnitude of uncertainties. The analysis of the results of numerical evaluations will focus on gas-oriented indicators, developed in cooperation with subtask 4.1, related to volatile and soluble radionuclides transfer and barrier integrity, which are of direct relevance to performance assessment.

Interactions will be organized with other WP's and especially the modelling WP DONUT to address the challenges of building and operating large (or multi-)scale coupled process models of a full disposal system and with the networking WP UMAN on understanding of uncertainty, risk and safety for aspects related to the treatment of uncertainties (e.g. propagation of parameter uncertainty) in the abstraction process (see also the description of interactions with UMAN in subtask 4.1).

Participation per Partner

Partner number and short name	WP6 effort
1 - ANDRA	15.00
4 - BGE	3.58
5 - CEA	0.00
EDF	9.50
6 - CIEMAT	26.00
UPC	19.00
8 - CNRS	15.30
ULorraine	50.70
UGrenoble	39.70
UPoitiers	35.20
9 - COVRA	2.75
TU Delft	17.50
15 - JUELICH	0.00
UFZ	12.00
16 - GRS	11.00
19 - IRSN	40.00
24 - KIT	0.00
BGR	13.00
25 - LEI	6.50
27 - NAGRA	9.00
ZHAW	12.00
CIMNE	34.00
EPFL	32.00
32 - ONDRAF/NIRAS	6.50
ULiège	45.80

Partner number and short name	WP6 effort
34 - PSI	24.00
37 - RWM	3.50
38 - SCK•CEN	31.40
42 - SÚRAO	4.50
CTU	36.00
ÚJV	12.50
48 - UHelsinki	0.00
Aalto	6.00
49 - UKRI	93.66
Total	667.59

List of deliverables

Deliverable Number ¹⁴	Deliverable Title	Lead beneficiary	Type ¹⁵	Dissemination level ¹⁶	Due Date (in months) ¹⁷
D6.1	GAS - Initial State-of-the-art (SOTA) report on gas transport through clay materials	32 - ONDRAF/NIRAS	Report	Public	18
D6.2	GAS - Updated State-of-the-art (SOTA) report on gas transport through clay materials	32 - ONDRAF/NIRAS	Report	Public	60
D6.3	GAS - Training materials of the 1st GAS/HITEC Joint training course (copy of the presentations of each doctoral school organised during the course of the project)	32 - ONDRAF/NIRAS	Report	Public	3
D6.4	GAS - Training materials of the 2nd GAS/HITEC Joint training course (copy of the presentations of each doctoral school organised during the course of the project)	32 - ONDRAF/NIRAS	Report	Public	48
D6.5	GAS - Book of proceedings of the final GAS workshop	32 - ONDRAF/NIRAS	Report	Public	60
D6.6	GAS - Technical report of the GAS WP	32 - ONDRAF/NIRAS	Report	Public	60
D6.7	GAS - Technical report Gas Transport	49 - UKRI	Report	Public	57

List of deliverables

Deliverable Number ¹⁴	Deliverable Title	Lead beneficiary	Type ¹⁵	Dissemination level ¹⁶	Due Date (in months) ¹⁷
	Mechanisms including diffusion, retention and advective processes in clay				
D6.8	GAS - Technical report on barrier integrity	27 - NAGRA	Report	Public	57
D6.9	GAS - Technical report on conceptualisation and evaluation at the repository scale	1 - ANDRA	Report	Public	57

Description of deliverables

- D6.1 – Initial State-of-the-art (SOTA) report on gas transport through clay materials
The SOTA will give a general overview of the state-of-knowledge with respect to main WP R&D topics, with sufficient context so that it would be of use to a lay audience (with limited technical background), early stage programmes and R&D managers. It will be based on state of knowledge before EURAD-1. The SOTA will also provide a baseline against which WP progress can be measured.
Delivery date: [Month 18] – Lead Beneficiary: [ONDRAF/NIRAS]
 - D6.2 – Updated State-of-the-art (SOTA) report on gas transport through clay materials
The SOTA report on gas transport through clay materials will be updated at the end of the WP in order to include EURAD-1 main findings.
Delivery date: [Month 60] – Lead Beneficiary: [ONDRAF/NIRAS]
 - D6.3 – Training materials of the 1st GAS/HITEC Joint training course course material (copy of the presentations of each doctoral school organised during the course of the project) Delivery date: [Month 6] – Lead beneficiary: [ONDRAF/NIRAS (ULiège)]
 - D6.4 – Training materials of the 2nd GAS/HITEC Joint training course course material (copy of the presentations of each doctoral school organised during the course of the project) Delivery date: [Month 48] – Lead beneficiary: [ONDRAF/NIRAS (ULiège)]
 - D6.5 – Book of proceedings of the workshop organised at the end of the WP. It will include a chapter on the advances in mechanistic understanding of gas transport from an end-user perspective.
Delivery date: [Month 60] – Lead beneficiary: [ONDRAF/NIRAS]
 - D6.6 – Technical report of the GAS WP This deliverable will be composed of a general introduction, three thematic technical reports of Dx2, D6.3 and D6.4. Together with the peer-reviewed scientific papers that are expected be produced by (groups of) organisations involved in this WP, this deliverable aims at providing reliable scientific/ technical references about the knowledge produced in the GAS WP. Delivery date: [Month 60] – Lead Beneficiary: [ONDRAF/NIRAS]
- D6.1 : GAS - Initial State-of-the-art (SOTA) report on gas transport through clay materials [18]
GAS - Initial State-of-the-art (SOTA) report on gas transport through clay materials
- D6.2 : GAS - Updated State-of-the-art (SOTA) report on gas transport through clay materials [60]
GAS - Updated State-of-the-art (SOTA) report on gas transport through clay materials
- D6.3 : GAS - Training materials of the 1st GAS/HITEC Joint training course (copy of the presentations of each doctoral school organised during the course of the project) [3]
GAS - Training materials of the 1st GAS/HITEC Joint training course (copy of the presentations of each doctoral school organised during the course of the project)
- D6.4 : GAS - Training materials of the 2nd GAS/HITEC Joint training course (copy of the presentations of each doctoral school organised during the course of the project) [48]
GAS - Training materials of the 2nd GAS/HITEC Joint training course (copy of the presentations of each doctoral school organised during the course of the project)

D6.5 : GAS - Book of proceedings of the final GAS workshop [60]
 GAS - Book of proceedings of the final GAS workshop

D6.6 : GAS - Technical report of the GAS WP [60]
 GAS - Technical report of the GAS WP

D6.7 : GAS - Technical report Gas Transport Mechanisms including diffusion, retention and advective processes in clay [57]
 GAS - Technical report Gas Transport Mechanisms including diffusion, retention and advective processes in clay

D6.8 : GAS - Technical report on barrier integrity [57]
 GAS - Technical report on barrier integrity

D6.9 : GAS - Technical report on conceptualisation and evaluation at the repository scale [57]
 GAS - Technical report on conceptualisation and evaluation at the repository scale

Schedule of relevant Milestones

Milestone number ¹⁸	Milestone title	Lead beneficiary	Due Date (in months)	Means of verification
MS1	EURAD Kick-off meeting (General Assembly n°1)	1 - ANDRA	1	EURAD Kick-off meeting (General Assembly n°1)
MS5	Kick-off GAS WP Meeting 1	32 - ONDRAF/NIRAS	1	Kick-off GAS WP Meeting 1
MS12	EURAD EJP Newsletters	1 - ANDRA	3	EURAD EJP Newsletters (Due date : M3 and then every quarter)
MS20	GAS Task 2.2 Experimental set-ups, geometries and boundary conditions	32 - ONDRAF/NIRAS	6	GAS Task 2.2 Experimental set-ups, geometries and boundary conditions
MS28	HITEC/GAS training n°1 on multi-physical coupling in geomechanics (especially THM and Gas coupling issues)	50 - VTT	6	HITEC/GAS training n°1 on multi-physical coupling in geomechanics (especially THM and Gas coupling issues)
MS30	EURAD General Assembly n°2	1 - ANDRA	7	EURAD General Assembly n°2
MS35	GAS WP Meeting 2	32 - ONDRAF/NIRAS	7	GAS WP Meeting 2
MS42	EURAD Annual Work Plan 2	1 - ANDRA	9	EURAD Annual Work Plan 2
MS44	GAS State-of-the-art chapter on diffusion and gas sorption in clayey materials as an input to D6.1	32 - ONDRAF/NIRAS	9	GAS State-of-the-art chapter on diffusion and gas sorption in clayey materials as an input to D6.1
MS45	GAS State-of-the-art chapter on advective gas transport in clayey materials as an input to D6.1	32 - ONDRAF/NIRAS	9	GAS State-of-the-art chapter on advective gas transport in clayey materials as an input to D6.1
MS46	GAS State-of-the-art chapter on gas-induced impacts on barrier integrity including	32 - ONDRAF/NIRAS	9	GAS State-of-the-art chapter on gas-induced impacts on barrier integrity including

Schedule of relevant Milestones

Milestone number¹⁸	Milestone title	Lead beneficiary	Due Date (in months)	Means of verification
	pathway closure and sealing processes as an input to D6.1			pathway closure and sealing processes as an input to D6.1
MS58	GAS Task 3 – interim experimental design report comprising a revised detailed work programme of subtasks 3.1, 3.2 and 3.3	32 - ONDRAF/NIRAS	12	GAS Task 3 – interim experimental design report comprising a revised detailed work programme of subtasks 3.1, 3.2 and 3.3
MS59	GAS SOTA chapter on gas-induced impacts on model-based interpretation including a survey of previous research programmes and a screening of gas-related FEP lists as an input to D6.1	32 - ONDRAF/NIRAS	12	GAS State-of-the-art chapter on gas-induced impacts on model-based interpretation including a survey of previous research programmes and a screening of gas-related FEP lists as an input to D6.1
MS60	GAS SOTA chapter drawing an overview of the conceptualizations of gas migration through geological disposal systems and related processes, at the scale of a repository and how these can be translated into models	32 - ONDRAF/NIRAS	12	GAS State-of-the-art chapter drawing an overview of the conceptualizations of gas migration through geological disposal systems and related processes, at the scale of a repository and how these can be translated into models as an input to D6.1
MS61	GAS Technical Note defining a generic repository configuration, sets of parameters, conditions and relevant indicators	32 - ONDRAF/NIRAS	12	GAS Technical Note defining a generic repository configuration, sets of parameters, conditions and relevant indicators on which sub-task 4.2 will test various evaluation approaches
MS81	EURAD General Assembly n°3 + EURAD Annual Meeting 1	1 - ANDRA	13	EURAD General Assembly n°3 + EURAD Annual Meeting 1
MS83	GAS WP Meeting 3 jointly organised with the WP HITEC	32 - ONDRAF/NIRAS	13	GAS WP Meeting 3 jointly organised with the WP HITEC
MS84	HITEC WP Meeting 3 jointly organised with the WP GAS	50 - VTT	13	HITEC WP Meeting 3 jointly organised with the WP GAS
MS85	EURAD Periodic Report 1	1 - ANDRA	14	EURAD Periodic Report 1
MS94	ACED - GAS - DONUT Joint Workshop - 1	32 - ONDRAF/NIRAS	16	ACED - GAS - DONUT Joint Workshop
MS99	GAS - Task 2.1 Experimental progress report	32 - ONDRAF/NIRAS	18	GAS Task 2.1 Experimental progress report
MS100	GAS Task 2.2 - Experimental progress report	32 - ONDRAF/NIRAS	18	GAS Task 2.2 Experimental progress report

Schedule of relevant Milestones

Milestone number¹⁸	Milestone title	Lead beneficiary	Due Date (in months)	Means of verification
MS103	EURAD General Assembly n°4	1 - ANDRA	19	EURAD General Assembly n°4
MS106	GAS WP Meeting 4	32 - ONDRAF/NIRAS	19	GAS WP Meeting 4
MS112	EURAD Annual Work Plan 3	1 - ANDRA	21	EURAD Annual Work Plan 3
MS122	GAS Task 2.1 Modelling progress report.	32 - ONDRAF/NIRAS	24	GAS Task 2.1 Modelling progress report
MS123	GAS Task 2.2 Modelling progress report	32 - ONDRAF/NIRAS	24	GAS Task 2.2 Modelling progress report
MS124	GAS Tasks 3.1 and 3.2 experimental progress report	32 - ONDRAF/NIRAS	24	GAS Tasks 3.1 and 3.2 experimental progress report
MS125	GAS Task 3 – Progress report describing Modelling / concepts, codes and validation workflows	32 - ONDRAF/NIRAS	24	GAS Task 3 – Progress report describing Modelling / concepts, codes and validation workflows
MS136	EURAD General Assembly n°5 + EURAD Annual Meeting 2	1 - ANDRA	25	EURAD General Assembly n°5 + EURAD Annual Meeting 2
MS138	GAS WP Meeting 5 jointly organised with the WP HITEC	32 - ONDRAF/NIRAS	25	GAS WP Meeting 5 jointly organised with the WP HITEC
MS139	HITEC WP Meeting 5 jointly organised with the WP GAS	50 - VTT	25	HITEC WP Meeting 5 jointly organised with the WP GAS
MS140	EURAD Periodic Report 2	1 - ANDRA	26	EURAD Periodic Report 2
MS153	EURAD General Assembly n°6	1 - ANDRA	31	EURAD General Assembly n°6
MS157	GAS WP Meeting 6	32 - ONDRAF/NIRAS	31	GAS WP Meeting 6
MS162	EURAD Annual Work Plan 4	1 - ANDRA	33	EURAD Annual Work Plan 4
MS165	ACED - GAS - DONUT Joint Workshop	32 - ONDRAF/NIRAS	33	ACED - GAS - DONUT Joint Workshop
MS172	GAS Task 2.1 Experimental progress report	32 - ONDRAF/NIRAS	36	GAS Task 2.1 Experimental progress report
MS173	GAS Task 2.2 Experimental progress report	32 - ONDRAF/NIRAS	36	GAS Task 2.2 Experimental progress report
MS174	GAS Task 4.2 progress report on modelling and evaluation approaches applied to the generic repository derived from the conceptualizations of gas migration through geological disposal systems and related processes, at the scale of a repository	32 - ONDRAF/NIRAS	36	GAS Task 4.2 progress report on modelling and evaluation approaches applied to the generic repository derived from the conceptualizations of gas migration through geological disposal systems and related processes, at the scale of a repository

Schedule of relevant Milestones

Milestone number¹⁸	Milestone title	Lead beneficiary	Due Date (in months)	Means of verification
MS185	EURAD General Assembly n°7 + EURAD Annual Meeting 3	1 - ANDRA	37	EURAD General Assembly n°7 + EURAD Annual Meeting 3
MS187	GAS WP Meeting 7 jointly organised with the WP HITEC	32 - ONDRAF/NIRAS	37	GAS WP Meeting 7 jointly organised with the WP HITEC
MS188	HITEC WP Meeting 7 jointly organised with the WP GAS	50 - VTT	37	HITEC WP Meeting 7 jointly organised with the WP GAS
MS189	EURAD Periodic Report 3	1 - ANDRA	38	EURAD Periodic Report 3
MS199	EURAD General Assembly n°8	1 - ANDRA	43	EURAD General Assembly n°8
MS202	GAS WP Meeting 8	32 - ONDRAF/NIRAS	43	GAS WP Meeting 8
MS206	EURAD Annual Work Plan 5	1 - ANDRA	45	EURAD Annual Work Plan 5
MS209	HITEC/GAS training n°2 on multi-physical coupling in geomechanics (especially THM and Gas coupling issues)	50 - VTT	46	HITEC/GAS training n°2 on multi-physical coupling in geomechanics (especially THM and Gas coupling issues)
MS216	GAS Task 2.1 Modelling progress report	32 - ONDRAF/NIRAS	48	GAS Task 2.1 Modelling progress report
MS217	GAS Task 2.2 Modelling progress report.	32 - ONDRAF/NIRAS	48	GAS Task 2.2 Modelling progress report
MS220	GAS Chapter on pathway closure and sealing processes of the WP thematic report on barrier integrity as input to D6.8 (in common with HITEC WP)	32 - ONDRAF/NIRAS	48	GAS Chapter on pathway closure and sealing processes of the WP thematic report on barrier integrity as input to D6.8 (in common with HITEC WP)
MS221	GAS WP Meeting 9	32 - ONDRAF/NIRAS	49	GAS WP Meeting 9
MS222	EURAD General Assembly n°9 + EURAD Annual Meeting 4	1 - ANDRA	49	EURAD General Assembly n°9 + EURAD Annual Meeting 4
MS224	EURAD Periodic Report 4	1 - ANDRA	50	EURAD Periodic Report 4
MS225	GAS Update of the State-of-the-art chapter on diffusion and gas sorption in clayey materials as an input to D6.2	32 - ONDRAF/NIRAS	52	GAS Update of the State-of-the-art chapter on diffusion and gas sorption in clayey materials as an input to D6.2
MS226	GAS Update of the State-of-the-art chapter on advective gas transport in clayey materials as an input to D6.2	32 - ONDRAF/NIRAS	52	GAS Update of the State-of-the-art chapter on advective gas transport in clayey materials as an input to D6.2
MS227	GAS Chapter on diffusion and retention processes of the	32 - ONDRAF/NIRAS	54	GAS Chapter on diffusion and retention processes of the

Schedule of relevant Milestones

Milestone number¹⁸	Milestone title	Lead beneficiary	Due Date (in months)	Means of verification
	WP thematic report on gas transport mechanisms as input to D6.7			WP thematic report on gas transport mechanisms as input to D6.7
MS228	GAS Chapter on advective gas transport of the WP thematic report on gas transport mechanisms as input to D6.7	32 - ONDRAF/NIRAS	54	GAS Chapter on advective gas transport of the WP thematic report on gas transport mechanisms as input to D6.7
MS229	GAS Chapter on gas induced impact of the WP thematic report on barrier integrity as input to D6.8	32 - ONDRAF/NIRAS	54	GAS Chapter on gas induced impact of the WP thematic report on barrier integrity as input to D6.8
MS230	GAS Chapter on model-based interpretation and synthesis of results of the WP thematic report on barrier integrity as input to D6.8	32 - ONDRAF/NIRAS	54	GAS Chapter on model-based interpretation and synthesis of results of the WP thematic report on barrier integrity as input to D6.8
MS231	GAS Update of the State-of-the-art chapter on model-based interpretation including a survey of previous research programmes and a screening of gas-related FEP lists as an input to D6.2	32 - ONDRAF/NIRAS	54	GAS Update of the State-of-the-art chapter on model-based interpretation including a survey of previous research programmes and a screening of gas-related FEP lists as an input to D6.2
MS232	GAS Chapter of the WP thematic report on conceptualisation and evaluation at repository scale	32 - ONDRAF/NIRAS	54	GAS Chapter of the WP thematic report on conceptualisation and evaluation at repository scale presenting the gas storyboards and the testing of various approaches for the evaluation of gas impact at repository scale in a performance assessment context (as an input to D6.9)
MS233	GAS Update of the State-of-the-art chapter drawing an overview on the conceptualizations of gas migration through geological disposal systems and related processes, at the scale of a repository	32 - ONDRAF/NIRAS	54	GAS Update of the State-of-the-art chapter drawing an overview on the conceptualizations of gas migration through geological disposal systems and related processes, at the scale of a repository and how these can be translated into models as an input to D6.2
MS234	EURAD General Assembly n°10	1 - ANDRA	55	EURAD General Assembly n°10
MS236	GAS WP Meeting 10	32 - ONDRAF/NIRAS	56	GAS WP Meeting 10

Schedule of relevant Milestones

Milestone number¹⁸	Milestone title	Lead beneficiary	Due Date (in months)	Means of verification
MS237	GAS Workshop on “Mechanistic understanding of gas transport in clay-based materials”	32 - ONDRAF/NIRAS	56	GAS Workshop on “Mechanistic understanding of gas transport in clay-based materials”
MS238	GAS Chapter of the WP thematic report 4 on conceptualisation and evaluation at repository scale comparing modelling and evaluation approaches (as an input to D6.9)	32 - ONDRAF/NIRAS	57	GAS Chapter of the WP thematic report 4 on conceptualisation and evaluation at repository scale comparing modelling and evaluation approaches (as an input to D6.9)
MS240	EURAD General Assembly n°11 + EURAD Annual Meeting 5	1 - ANDRA	60	EURAD General Assembly n°11 + EURAD Annual Meeting 5
MS241	EURAD Periodic Report 5	1 - ANDRA	60	EURAD Periodic Report 5 (Due date: 60+2)

Work package number ⁹	WP7	Lead beneficiary ¹⁰	50 - VTT
Work package title	Influence of temperature on clay-based material behaviour (HITEC)		
Start month	1	End month	48

Objectives

Objectives

1. The overall objective is to evaluate whether an increase of temperature is feasible and safe by applying existing and within the work package produced novel knowledge about the behaviour of clay materials at elevated temperatures:
 - a. to improve understanding of the THM behaviour of clay rock and engineered clay material (buffer) under high temperature and provide suitable THM models both for clay host rock and buffer,
 - b. to better assess effect of overpressures build up induced by the heat produced from the radioactive waste on the THM behaviour and properties of the clay host rock, and
 - c. to identify processes at high temperature and the impact of high temperature on the THM properties of the buffer material.
2. Host clays formations: aim is to deploy knowledge to mechanics of clay in order to better evaluate and model possible damage evolution during the temperature transient phase, and better assess the consequences of a possible damage.
3. Buffer bentonite: aim is to deploy knowledge to hydro-mechanical behaviour at high temperature. The temperature impact on important processes will be measured either while the clay is at the high temperature or after a high temperature exposure. Processes that may have a temperature dependence are swelling pressure, hydraulic conductivity, erosion properties, transport of solutes etc.
4. The fourth objective is to document all the above to be utilised in Safety Cases studies
 - a. The safety functions include properties such as mechanical properties, swelling pressure, hydraulic conductivity, while the integrity of the clay may be evaluated as changes in mineralogy, chemical content or physical integrity of the compacted blocks.

The safety functions and the overall integrity of the bentonite and/or clay host rock will be evaluated after a high temperature exposure. The programme of work will aim to provide results that are applicable to a wide range of buffer material and clay host rock, which can be useful for different National Programmes.

Expected impacts

Regarding RWM implementation needs

For the disposal of HLW (vitrified waste and spent fuel in particular) it is important to assess the consequences of the heat produced by the radioactive decay during operation and in the post-closure phase. The heat pulse may affect the long-term performance (requirements set based on safety functions) of either the natural barriers and/or the engineered barriers. At this stage most of safety case considers a maximum temperature of 100°C in the buffer and in the host rock as an upper threshold. Being able to better accommodate higher temperatures while ensuring similar safety standards can have significant advantages with respect to disposing of higher enrichment/burn-up fuels, interim storage requirements, (re)packaging of the waste, reducing footprint of the disposal (optimizing tunnel spacing and canister spacing in the emplacement tunnels).

The WP is linked to the Roadmap Theme 4 (geoscience to understand rock properties, radionuclide transport and long-term geological evolution) phases 1-2.

Regarding safety case concerns

The second impact composes of knowledge about utilising higher temperatures, setting up limits of temperature and which kind of overall impacts higher temperatures causes to materials and systems.

Proving that temperatures higher than presently accepted are acceptable is very relevant even for current concepts. It increases safety margin and gives greater credibility to the design (e.g. if it is proven to work for 130°C then for 100°C it is definitely safe).

Regarding increasing scientific and technical Knowledge (beyond state-of-the-art) in the field of RWM

There is now only limited knowledge about the clay material behaviour at higher than 100°C. However, the existing knowledge shows that mineralogical alteration will on acceptable level up to 150°C. Therefore, the WP aims to increase scientific and technical knowledge mainly in mechanical behaviour of the clay materials.

Regarding radioactive waste management routes

The WP offers much support in thermal dimensioning of spent fuel repository, and has an effect to intermediate storage of spent fuel, because the storing time may be shortened. The programme of work will aim to provide results that are applicable to a wide range of clay host rock and buffer material, which can be useful for different National Programme.

WP7 - Influence of temperature on clay-based material behaviour (HITEC) [Months: 1-48]

VTT, ANDRA, BGE, CEA, CIEMAT, ChRDI, CNRS, ENRESA, KIT, LEI, NAGRA, ONDRAF/NIRAS, POSIVA, RWM, SKB, SÚRAO, UHelsinki, UKRI

Task 1 – S/T coordination, State-of-the-art and training material

Start: Month 1 – End: Month 48 - Task Leader: [VTT]

Task Contributors: [Andra] [BGE] [CIEMAT] [ENRESA] [NAGRA] [ONDRAF/NIRAS (EURIDICE)] [ULiege]] [Posiva] [SÚRAO (CTU)] [RWM] [SKB] [VTT]

Total PM : 25,4

Subtask 1.1 – S/T coordination

Start: Month 1 – End: Month 48 Subtask Leader: [VTT]

Total PM: 2

The scientific and technical coordination of HITEC WP will be performed by the WP Leader [VTT]. The WP Leader will be supported by the Task leaders and co-leaders: [CNRS (ULorraine)] [SÚRAO (CTU)] [Andra] [SKB] [NAGRA] which together with [VTT] constitute the WP Board of HITEC. The WP Leader will make sure that EURAD rules are followed by all partners, that the scientific milestones and deliverables are reached timely, and that the results are disseminated efficiently inside and outside the project. The WP Leader will ensure the interface between the WP Board, between the participants of HITEC WP, and with the Programme Management Office and the other EURAD WPs.

This subtask consists of ensuring information transfer between different (sub)tasks. This is accomplished by 2 WP meetings per year (in workshop format) involving Task 2,3 and 4. Once a year, one of these meeting will be organised jointly with WP6-GAS aligned with the EURAD Annual conference to minimise travel costs. The intermediate annual meeting, specific to WP7-HITEC will be organised at month 6, 18, 42, 54.

Subtask 1.2 – State-of-the-art

Start: Month 1 – End: Month 48 - Subtask Leader: [CIEMAT]

Subtask contributors: [Andra] [BGE] [CIEMAT] [ENRESA] [ONDRAF-NIRAS (EURIDICE)] [NAGRA] [POSIVA] [RWM] [SKB] [SÚRAO]

Total PM : 16,4

The two main objectives are the state-of-the-art and existing data about clay materials at high temperature. Previous and ongoing national and Community-supported research programmes have led to the detailed understanding of the various key thermo-hydro-mechanical and chemical (THM-C) processes taking place in the buffer material up to 100°C (FEBEX, PROTOTYPE, BACCHUS, RESEAL, ECOCLAY, PEBS, DOPAS, BELBaR, Beacon, ...) and in host claystone (SELFRACT, TIMODAZ, NF-PRO,...). Those data on THM on clay materials (buffer and clay host rock) at different temperature will be the starting point of the state of the art which will be produced in the early stage of the project, including:

- o a synthesis of the state of knowledge on the THM behaviour of different buffer materials at different temperatures. A focus has to be made on data obtained over 100°C;

- o a synthesis of the state of knowledge on the THM behaviour of host claystone (Boom clay, Opalinus Clay, Callovo Oxfordian claystone). The effect of temperature in near field on the EDZ (extension, permeability properties, self-sealing processes ...) and in far field on the thermal pressurization.

Task 1.2 will resume the state-of-the-art in terms of experimental procedure, processes, parameters and models available at low or high temperature for the different buffer material and host rock (D7.1). A focus will be made in identifying existing or ongoing large-scale in situ experiments which can be proposed in Tasks 2 and 3 as benchmark exercises.

In the final stage of the project, the state-of-the-art will be updated integrating the findings of all R&D tasks in this WP and relevant finding from other WP's (D7.2). The main objective will be to put in the evidence and the significance of the findings of Tasks 2 and 3 on the THM behaviour in clay materials at high temperature and at repository scale and evaluate the consequences of these findings on safety and optimization of geological disposal systems (Task 4).

Subtask 1.3 - Training materials

Start: Month 1 – End: Month 48 - Subtask Leader: [ONDRAF/NIRAS (ULiege)]

Subtask contributors : [SÚRAO (CTU)] [VTT] [ONDRAF/NIRAS (ULiege)]

Total PM : 7

Two training workshops (in the format of a doctoral schools) will be organised jointly with the WP on “Mechanistic understanding of gas transport (GAS)” as the target audiences are similar and the lecturers are likely to be involved in both WP's. WP's will propose lectures and tutors on geomechanics and multi-physical coupling. Courses will integrate main WP's results on thermo-hydrmechanical behaviour of clayey materials and on gas transport through clayey

materials at this stage of the project. The courses will highlight the consequences of thermal and gas-induced hydro-mechanical perturbations on barrier integrity and long-term performance.

More practically, the 1st school will be organised at the beginning of the project (Lead organisation: ULiège, month 6). The topic will be on multi-physical coupling in geomechanics (especially THM and Gas coupling issues). The objective will be to draw a state-of-knowledge at the beginning of the project. The 2nd school will be organised at the end of the HITEC project (during the 4th year). The topic will be to include the main results of EURAD-1 on THM and Gas issues to the knowledge on multi-physical coupling in geomechanics. The objective will be to highlight the contribution of EURAD-1 on the state-of-knowledge at the end of the project. (Combined deliverables with WP6-GAS D6.3 and D6.4)

Task 2 - Clay host rock <120°C

Start: Month 1 – End: Month 48 - Task Leader: [CNRS (ULorraine)]

Subtask contractors: [Andra] [BGE] [CEA (EDF)] [CIEMAT (UPC)] [CNRS-3SR (ULorraine)] [LEI] [NAGRA] [ONDRAF-NIRAS (EURIDICE) (ULiège)] [RWM] [UKRI-BGS]

Total PM: 255,6

Task objectives:

The heat generated by waste must not affect the favourable properties of the host rock, especially its transport properties, for containment. The overpressure generated by the difference between thermal expansion coefficient of pore water and the solid rock skeleton may have deleterious consequences. In far field, this could induce rock damage and reactivate fractures/faults. In the near field (i.e., in the vicinity of the cell) characterised by a fractured zone, this could induce fracture opening or propagation in this fractured zone, altering the permeability.

Thus, the main objective is to increase knowledge of the THM behaviour of clay host rock to help to optimise the repository design. More specifically, from experiments (for both near and far fields), modelling and benchmarking, the following questions will be addressed:

Do we sufficiently understand the processes leading to the observed overpressures and changes in the stress state? How can experiments be best designed to characterise the most sensitive parameters?

How good are the current THM models in representing the stress changes at repository-relevant conditions?

What are the THM criteria that can act as credible site-specific design criteria? The basic assumption is that no irreversible or long-term damage to the rock should occur. How can one best demonstrate that these design criteria can be met?

In the very unlikely case of damaging (fracturing) the rock, what will be the consequences and can we expect self-sealing in clay rich rock to occur as soon as the energy is released?

The characterisation of in-situ THM behaviour of the clay host rock is significant for the design of the underground nuclear waste disposal facility and to provide long-term safety. When temperature increases in a low-permeability medium, the pore water is compressed as a consequence of the difference between its thermal expansion coefficient and that of the solid skeleton of the rock, which leads to an overpressure.

In the near field (Subtask 2.1), the excavation of galleries or micro tunnels creates a fractured zone around them. The evolution of the effective stress field in the vicinity of the galleries due to the temperature rise can induce fracture opening or propagation of the excavation-induced fractured zone.

In far field (Subtask 2.2), the pore pressure induced by the temperature increase leads to a decrease of the effective vertical stress, which can reach the tensile strength of the rock and cause damage. Fracture or fault reactivation are also possible.

An improved knowledge of the THM behaviour will help to optimise repository design (spacing in between HLW cells, load on casing/canister).

Subtask 2.1 – Experiments near field with EDZ

Start: Month 1 – End: Month 48 – Subtask Leader: [CNRS-3SR (ULorraine)]

Subtask contributors: [CNRS-3SR (ULorraine)] [UKRI-BGS] [RWM]

Total PM: 54,4

Subtask 2.1 will be focussed on the near field in order to assess a possible extension of the excavation-induced fracture network. Subtask 2.1 is based on lab experiments to provide answers to the following two questions

a) Can an extension of the fracture zone occur?

b) What is the permeability evolution of the fracture zone?

Experimental methodologies will take advantage of lessons learned from a previous European project TIMODAZ and the improvement of technologies (for example X-ray and neutron tomography) in order to go further in the analysis of processes than was done during the TIMODAZ and SELFRAC projects.

1. The possible extension of the fracture zone

- o Effect of temperature on THM behaviour: Elastic properties and shear resistance of the material and volumetric/pore water pressure response during heating and cooling under drained/undrained conditions (isotropic and triaxial conditions) and under different stress paths.

- o Propagation of fractures under a thermal field to characterise the effect of the temperature increase on the behaviour of the excavation-induced fracture zone.

2. The permeability evolution of the fracture zone.

- o From a mechanistic point of view, the self-sealing capacity of fractured claystone is associated with various thermo-hydro-mechanical and –chemical processes and controlled by the prevailing state conditions. Mechanical closure of fractures (e.g. crack closure, fracture sliding) and hydro-chemical interactions of the pore water with the clay-bearing solid phase of the geomaterial (e.g. swelling, disaggregation) have been identified as typical self-sealing mechanisms in clay-rich materials. The impact of temperature on the self-sealing processes has to be investigated experimentally. X-ray and neutron tomography scanning will be performed on fractured samples at different test stages and temperatures to analyse the closure of fractures under heat and water percolation.

- o Time dependent deformation is a particular self-sealing mechanism of clay-based geomaterials. The significance of this “creep” mechanism is known to be affected by temperature as a potential self-sealing mechanism. Effect of creep related to permeability could be studied.

- o To assess permeability change due to damage and possible effects of self-sealing.

Subtask 2.1 will focus on lab experiments on different clay host rocks (Boom Clay, Opalinus Clay, Callovo-Oxfordian clay):

- o [CNRS-3SR (ULorraine)] will perform mechanical tests on COX and Opalinus claystones in a transparent triaxial cell under X-ray nano-tomography to study the propagation of fractures at elevated temperatures (40 °C, 60°C, 80 °C, 100 °C) and to characterize fracture shape and size at different stages of a triaxial loading.

- o Self-sealing will be studied by [CNRS-3SR (ULorraine)] [UKRI-BGS] [RWM] on 3 clay materials. Experiments will be conducted under triaxial loading on fractured samples (with two bedding orientations) mimicking the damage expected in the near field under X-ray tomography [CNRS-3SR (ULorraine)] and under different constant temperatures (40 °C, 60°C, 100 °C) completed by neutron tomography monitoring to assess water flux. [CNRS-3SR (ULorraine)] [UKRI-BGS] [RWM] will investigate the self-sealing and hydromechanical properties of a number of clay-based materials under different thermal loads in a shear box. The effect of heating on the material properties (e.g. strength and permeability) and the self-sealing capacity of the clay will be studied simultaneously. The benefit of conducting both stages is that the approach is holistic and will give a complete understanding of the self-sealing properties of the tested clay materials.

Related Deliverable: D7.3

Subtask 2.2 – Experiments on far field - effect of over pressure due to thermal load

Start: Month 1 – End: Month 48 - Subtask Leader: [UKRI-BGS]

Subtask contributors: [RWM] [CNRS (ULorraine)] [CEA] [UKRI-BGS]

Total PM: 54,7

Subtask 2.2 will focus on the thermal pressurisation and the risk of damage when the effective stress increases up to the overburden weight.

The temperature rise in a low permeability porous medium, such as Callovo-Oxfordian and Opalinus claystones, generates a pore pressure increase essentially due to the difference between the thermal expansion coefficients of water ($\sim 10^{-4} \text{K}^{-1}$) and the argillaceous rock skeleton ($\sim 1.28 \cdot 10^{-5} \text{K}^{-1}$ for Cox). Thermal pressurisation is the key mechanism for the potential damage induced by the heat emitted from the waste. There is a competition between excess pore pressure due to thermal pressurisation and drainage due to pore pressure gradient increase. With the periodic distribution of an important number of similar parallel tunnels/micro tunnels and their lengths, it can be expected that the induced pore pressure between tunnels/micro tunnels could not be dissipated in the horizontal direction. Due to the symmetry conditions, horizontal displacement, thermal flow and fluid flow are set to zero on the lateral boundaries of the model. The periodic distribution of parallel cells prevents lateral expansion of the rock and thus provokes compression of the thermal stresses in the horizontal direction. The decrease of the total stress sets off the effect of the pore pressure build-up on the horizontal components of the effective stress tensor. However, the vertical effective stress increases and can reach the tensile strength of the rock (i.e potential appearance of sub-horizontal cracks).

The main objectives of the subtask are:

- o to better assess the behaviour of claystone under such stress paths (thermal pressurisation effect,...).

- o to determine the damage appearance and the effect of a macro cracking over the pore pressure field.

In order to achieve these objectives, the subtask 2.2 is dedicated to experimental work in order to increase knowledge through:

lab tests on samples to better determine the behaviour of claystone under such stress paths during heating (high temperature, increase of lateral stress and decrease of vertical stress).

pressurisation tests under isotropic stress.

triaxial tests with temperature in drained and undrained conditions (up to the tensile effective strength).

Table 3 shows for Subtask 2.1 and Subtask 2.2 the different lab tests that will be performed by the different teams to characterise the THM behaviour of the three clay materials. Due to the existing data in the state of the art (subtask 1.2), the budget and the need of the different participants of the subtask 2, the lab test programme will differ for the different clay materials but will remain sufficient in order to make comparison of the different THM behaviours and to determine the key parameters.

Subtask 2.2 will focus on lab experiments on different clay host rocks (Boom Clay, Opalinus Clay, Callovo-Oxfordian claystone):

- [CNRS (ULorraine)] proposes to experimentally investigate the short- and long-term thermo-mechanical behaviour of 2 claystones (Opalinus Clay, Callovo-Oxfordian claystone) at elevated temperatures (40, 60, 80 and 100 °C):

- Short-term triaxial tests to characterise mechanical properties (failure criterion, elastic coefficients) at macroscopic (decimetric) scale. Experiments will reproduce stress paths during heating (i.e., high temperature, overpressure, and increase in lateral stress and decrease in vertical stress). Ultrasonic velocities and acoustic emissions will be measured to assess the evolution of elastic properties and then damage (micro-cracking). Thermal profiles will be performed before and after TM tests with the optical scanning method to determine the evolution of thermal properties with damage.

- Long-term triaxial tests under 2 confining pressures (2 and 12 MPa) to characterise creep properties at macroscopic (decimetric) scale. Acoustic emissions will be measured during creep tests in order to assess the evolution of damage (micro-cracking).

- [CEA] will perform several biaxial tests at elevated temperatures under drained or undrained conditions. These tests will allow measurement of the response and potential damage of the rock to different kinds of thermo-mechanical loading paths, especially along an extension path. Two different clay host rocks (Opalinus Clay, Callovo-Oxfordian claystone) will be tested. They will also perform creep test (on Opalinus and Boom Clays) complementary to those performed by CNRS-GéoRessource. The aim is to determine : a) the failure criterion for the host rock along an extension path for different maximum temperatures (100°C, 120°C); b) the creep coefficient of the fully saturated rock under deviatoric stress for different temperature increments (40, 60, 80 and 100°C).

- [UKRI-BGS] [RWM] will perform tests on intact samples of all host rocks under representative thermal gradients to assess the evolution of pore pressure (overpressure) and permeability (which will strongly influence the size of the overpressure) during the heating phase. [UKRI-BGS] [RWM] will combine isotropic, constant volume and triaxial testing to define the influence of thermal load on the evolution of mechanical properties, as well as changes in material permeability. These fundamental tests will therefore provide information on the coupled nature of the THM properties of each of the materials tested providing insight to multiple end-users.

Related Deliverables: D7.4 and D7.5

Subtask 2.3 – THM modelling of effect of temperature in near and far field – Benchmark exercise

Start: Month 1 – End: Month 48 - Subtask Leader: [Andra]

Subtask contributors: [Andra] [BGE] [CNRS-3SR] [CEA (EDF)] [LEI] [NAGRA] [ONDRAF-NIRAS (EURIDICE) (Uliege)] [CIEMAT (UPC)]

Total PM: 146,5

Subtask 2.3 will focus on the development of THM models which are able to consider processes studied in subtasks 2.1 and 2.2. Many models still exist but could be improved in the task, taking into account the results of the previous subtasks. THM models could be used in near and far field and, in that way, the model development activities have been gathered and not split from the experiment activity (Task 2.1 and 2.2). Results obtained in Tasks 2.1 and 2.2 will be used to calibrate the model in order to perform benchmark exercises on existing in-situ experimental data. The benchmark exercise is the most important part of the subtask for demonstrating the availability and efficiency of such models to perform THM calculations.

The modelling exercise will be performed on in-situ experiments (from 1.2) which address the two main subjects studied in subtask 2.1 (near field EDZ) and subtask 2.2 (far field) like experiments Praclay (Boom clay, Hades URL), FE (Opalinus Clay, Mont Terri URL) and HA cell (Callovo-Oxfordian claystone, Meuse Haute-Marne URL). Specific experiments like CRQ performed at Meuse Haute-Marne URL on fracturing under thermal loading with a stress path depicted in between HLVL cells could be used as a benchmark exercise (from subtask 2.2) to check if the models are able to predict/depict the damaging (fracturing) of the rock under elevated temperatures in the far field and the consequences for rock mass properties.

The number of benchmark exercises has to be limited to three depending on the outcomes from task 1.2 and task 2.1 and 2.2. Teams involved in subtask 2.3 will participate at least to 2-3 benchmark exercises on two different clay stones.

A final comparison on the THM behaviour of different clay stones will be done in order to establish similarities and differences in terms of processes which have to be taken into account in the modelling approaches.

Subtask 2.3 will focus on development of THM model, calibration and benchmark exercises on in-situ experiments (not funded in the WP) on different clay host rocks (Boom Clay, Opalinus Clay, Callovo-Oxfordian claystone):

- [Andra] [ONDRAF-NIRAS (EURIDICE)] and [NAGRA] will provide experimental data from the large-scale and long-term in-situ HA cells and CRQ experiments (Meuse Haute Marne URL), FE experiment (Mont Terri URL) and PRACLAY heater test (URL HADES). Data and selected experimental lab test results on the THM behaviour will be available for use as benchmark exercises. Andra, EURIDICE and [NAGRA] will give the modelling teams access to the database and coordinate the effort for each specific benchmark. Andra will also participate in the benchmark exercise on CRQ experiment using a probabilistic damage model to study the effect of the rock heterogeneity on its possible cracking due to the effective stress change. In the same way, [ONDRAF-NIRAS (EURIDICE)] will participate in the benchmark exercise on PRACLAY heater test using anisotropic thermo-elasto-plastic approaches to evaluate the effects of EDZ and of its evolution on the near and far field Boom Clay THM behaviour.

- Thermo-visco-elasto-plastic model will be developed and used for the benchmark by:

[BGE]: a basic elasto-plastic model for claystone taking into account dependency of permeability on irreversible strains is existing and will be developed taking into account strength and stiffness anisotropy and time-dependent deformation. Improvement will be performed taking into account the second Gradient Model for Damage

[CEA (EDF)]: the constitutive model LKR (thermo-viscoelastic model) has been developed in Code_Aster in a poromechanical formalism (THM). The anisotropy in the visco-plasticity law (first model currently developed with a PHD student) is in progress and can be used in the current WP. Improvement of permeability evolution with strain will be developed and HPC modelling for 3D computation will be done

[LEI] will develop their constitutive model and participate in the benchmark exercise

[ONDRAF/NIRAS (ULIEGE)] has been partner of TIMODAZ. Their FE code (Lagamine) has been validated on a number of THM benchmarks. Constitutive modelling has been improved, mainly on the volumetric compression and deviatoric stress paths. The major effect of anisotropy has been taken into account (thermal plume, fluid flow, extent of EDZ). A Rankine yield surface will be tested to model extension fractures. Strain localisation will be taken into account thanks to our second grade models, which regularise the problem and control the fracture zone thickness. The fracture's interdistance will be obtained in relation with the material permeability, which will evolve strongly in fractured zones. The fracture closure due to the self-sealing process at high temperature will be modelled in interface finite elements, whose constitutive models will be improved to take into account the time dimension in the sealing process, which is related to the small-scale water availability. This activity will benefit from development in EURAD Gas WP.

[CIEMAT (UPC)]: A recently developed stress-strain law for clay rocks will be made available. It includes non-linearity and plasticity before peak strength, softening after peak, anisotropy of stiffness and strength, creep (visco-elastic and visco-plastic) and permeability variation due to damage and self-sealing. The law will be further developed by introducing thermo-plasticity. Another key development will be the simulation fracture generation due to overpressure and/or temperature and their propagation. Again, a recently developed non-local formulation has proved capable of predicting the development and propagation of discontinuities under isothermal conditions. The formulation will be generalised to include specific thermal effects taking into account the variation of permeability in the discontinuity.

[CNRS-3SR] will develop and use constitutive modelling of the THM behaviour by a double scale FEM2 approach. At the microscale, the microstructure of the material is defined by inclusions (quartz, carbonate, etc...) imbedded in a clay matrix, separated by cohesive interfaces. Fluid can percolate in the pore network that is formed by these interfaces and fluid pressure acts statically on the (impermeable) grains. The homogenised response to kinematic loading of this REV is used to provide the macroscopic material point behaviour. The new contribution here is the thermal coupling extension of this double scale hydro-mechanical model. Thermal effects concern the heterogeneity of the thermal strain of the microstructure (inclusions, clay matrix, pore fluid) that can induce relative damage at the interfaces and pore fluid channel modification inducing permeability change. It will result in a macro-behaviour that will include a thermal dependence on the hydro-mechanical response. Related Deliverable: D7.6

Task 3 - Clay buffers >100°C

Start: Month 1 – End: Month 48 - Task Leader: [SÚRAO (CTU)]

Task contributors: [Andra (BRGM)] [CHRD (KIPT) (SIIGNASU)] [CIEMAT (UAM) (UPC)] [KIT (BGR)] [POSIVA] [SÚRAO (CTU) (CU) (UJV)] [RWM] [SKB] [UHelsinki (GTK) (JYU)] [UKRI-BGS] [VTT]

Total PM: 392,2

Task objectives: The overall objective is to evaluate whether an increase of temperature is feasible and safe by applying (i) existing and (ii) the within the task newly produced knowledge about the behaviour of clay buffer materials at elevated temperatures.

The increase of temperature may result in strong evaporation near the heater and vapour movement towards the external part of the buffer. As a consequence, part of the barrier, or all of it, depending on the particular disposal concept,

will remain unsaturated and under high temperatures during periods of time that can be very long. Moreover the high temperature gradient (and pore pressure) even crossing boiling point of water will lead to several adverse effects as Sauna effects (Birgersson, 2017).

The European Project PEBS identified the following uncertainties for this case (Johnson et al. 2014):

- The impact of the duration of the elevated temperature period on the property change is not clear, but changes can occur even after short heating/cooling cycles.
- Although the existing data do not point to very significant impacts, a comprehensive view on the impact of temperatures up to 150°C on THM properties is not yet in place. The data supporting the modelling between 100°C and 150°C is sparser compared to the support at temperatures lower than 100°C.
- In relation to the above, some impact of vapour on bentonite properties under repository relevant conditions (120-150°C) can be expected and should be clarified taking into account repository relevant vapour regimes. This impact might be due to minor surface cementation effects although this needs further confirmation.
- The modelling performed at the URL highlighted the sensitivity of the modelled temperatures and relative humidity to the evolution of the thermal conductivity, especially when the bentonite is at very low saturation, and to the parameters determining the relative permeability curve.

Taking these uncertainties into account the objectives of Task 3 have been defined:

- Assessment of the impact of having clay buffer subjected to high temperatures over long time periods on the clay buffer properties. (Subtask 3.1)
- Determination of bentonite hydro-mechanical properties for temperatures higher than 100°C, which will provide parameters for the modelling work. (Subtask 3.2)
- Identification of key processes at high temperature, particularly those affecting the saturation rate, because this will condition the time the buffer is in dry conditions and under high temperature. (Subtask 3.3)
- Calibration and development of suitable THM models for clay buffer at higher temperatures. (Subtask 3.3)

The experimental work will mostly focus on bentonites that are well characterised for temperatures below 100°C and proposed in several disposal concepts: MX-80, FEBEX and BCV. The target will be to extend the knowledge above 100°C into the range up to 130-150°C.

Subtask 3.1– Characterisation of material treated by high temperature

Start: Month 1 – End: Month 48 - Subtask Leader: [SKB]

Subtask contributors: [CIEMAT (UAM)] [KIT (BGR)] [ChRDI (KIPT) (SIIGNASU)] [SKB] [SÚRAO (CTU) (CU) (UJV)] [UHelsinki] [VTT]

Total PM: 136

Objectives:

- Investigate material changes after high temperature treatment on the safety functions (important properties) and on its integrity (e.g. mineralogy, chemistry, mechanical parameters...)
- Determination of parameters necessary for mathematical modelling e.g. to fill up blank spots in material database for temperatures above 100°C

Material subjected to the high temperature will be studied and changes of properties (mechanical, hydro physical, transport, geotechnical, chemical and mineralogical) will be determined. Both laboratory treated material and samples from in-situ experiments are included (note: in-situ experiments itself are not part of the WP).

The material studied in Subtask 3.1 will come from three main sources:

- In-situ experiment(s)
- Small scale laboratory experiments (Subtask 3.3)
- Laboratory treatment

1) Materials subjected to high temperature under repository-like conditions (in-situ experiments).

At the moment of preparing this WP only the ABM-5 in situ test is planned to be dismantled in the course of the WP. Hence, samples coming from this experiment (provided by SKB), in which different bentonites are being used, will be analyzed by different labs:

[CIEMAT] will analyse changes in the FEBEX bentonite solid and liquid composition. Squeezing tests will be performed to extract the liquid phase

[KIT (BGR)] will analyse the mineralogical changes in relation to the thermal gradient.

[SKB] will analyse the chemistry and mineralogy of blocks of the MX80, DepCAN (Milos), Asha505 (Kutch) and Calcigel bentonites

New high temperature experiments are planned by various National Programmes. Depending on the timing samples from those experiments can be included in Subtask 3.1.

Note: in-situ experiments itself are not part of the WP

2) Within Subtask 3.3 small scale experiments simulating repository like conditions are planned. These experiments will provide input into Subtask 3.1.:

[CIEMAT (UAM)] will focus on the post mortem analyses of the laboratory-scale thermo-hydraulic cells performed by CIEMAT mainly concerning mineralogical changes that could explain the macroscopic changes observed.

[SÚRAO (CTU) (CU) (ÚJV)] will focus on the post mortem analyses of the small scale laboratory experiments performed by CTU. CTU will focus on geotechnical properties. ÚJV will focus on geochemical analysis.

3) Materials subjected to high temperature in the laboratory and then tested to determine different properties. The bentonite will be first subjected to high temperature (either in batch or compacted conditions) and then their properties will be tested at room temperature and compared with those expected for the untreated materials:

[ChRDI (SIIGNASU)] will analyze mineralogical alterations in local bentonite treated with saline solutions or synthetic groundwater in autoclave at 170-190°C.

SÚRAO:

- o [SÚRAO (CTU)] will treat BCV bentonite by high temperature and investigate changes in geotechnical properties especially permeability, swelling pressure and Atterberg limits.

- o [SÚRAO (CU)] will investigate swelling under constant load tests, oedometric load-unload tests and water retention tests on heat treated BCV bentonite.

- o [SÚRAO (ÚJV)] will perform geochemical analyses on BCV treated by CTU (CEC, specific surface (EGME and BET), mineralogy (XRD) with respect to change of expandable structures of clay minerals (combination of methods TG, FTIR) and re-hydration.

[UHelsinki] will treat the bentonite in batch tests at temperatures up to 200°C and then determine rheological and mechanical properties, morphological features, thermal stability and nanoparticle formation.

[ChRDI (KIPT)] will treat a local bentonite at 150°C treatment for periods of time longer than 3 months and investigate material changes after each of periods of high temperature treatment, in particular, mechanical parameters, swelling pressure and permeability. Analytical investigations will be carried out to detect any temperature-induced changes in material structure, and chemical/transport changes in bentonite after various periods of 150 °C heat treatment will be studied too.

[VTT] will treat MX-80 bentonite as dry powder and as wet compacted samples at temperatures up to 200°C (also cyclic heating-cooling periods) and perform experiments on the heat treated samples (in room temperature): a) triaxial shear and isotropic compression tests (to study the mechanical behaviour), b) XRD analysis (to study the interlayer distance and clay mineralogy) and c) post mortem chemical analysis (bentonite chemistry).

Other tasks' participants will review the testing plans [POSIVA] assist in the preparation of the experimental programme and participate in the interpretation of results [SÚRAO].

Related Deliverables: D7.7

Subtask 3.2– Determination of parameters at temperatures >100°C

Start: Month 1 – End: Month 48 - Subtask Leader: [BGS]

Subtask contributors: [Andra (BRGM)] [UKRI-BGS] [ChRDI (KIPT)] [CIEMAT] [RWM] [SÚRAO (CTU) (CU)] [UHelsinki (GTK) (JYU)] [VTT]

Total PM: 154,2

Objectives:

- Investigate processes and material properties at high temperature
- Determination of parameters necessary for mathematical modelling (input into Subtask 3.3)

The aim of this task is to check how the hydro-mechanical properties of the bentonite change with temperature, i.e. when they are measured at temperatures other than room temperatures. This effect has been investigated in previous researches, but for many properties the results available are scarce and refer to temperatures below 100°C. Hence, an effort will be made to modify the testing technique to allow for testing at temperature >100°C.

[Andra (BRGM)] will measure swelling pressure during the hydration of a bentonite (Kunipia-G or MX-80) at temperatures between 100 and 150°C with solutions of different compositions (cations and ionic strength) using an oedometer cell suitable for X-ray tomography acquisition to visualize in situ the evolution of the microstructure evolution. Swelling experiments will be simulated accounting for both mechanical compaction, temperature changes, water flow and chemical effects. A comparison of modelling approaches will be made with the Charles University hypoplastic model for swelling clays.

[UKRI-BGS] will measure the evolution in permeability and swelling pressure of pre-compacted samples of MX80 bentonite at temperatures ranging between 100 and 200°C to ensure the integrity of the buffer remains intact. Dry density will also be varied to assess impact on permeability and swelling pressure. Changes in microstructure will be assessed post-mortem with optical microscopy, SEM and X-Ray CT imaging.

[ChRDI (KIPT)] will investigate the material properties (swelling pressure and hydraulic conductivity) of a local bentonite at high temperature (120°C and 150°C).

[CIEMAT] will determine the water retention capacity of bentonites with different exchangeable cations (FEBEX, MX-80) at temperatures of up to 150°C, with particular accuracy in the low suction range (using sensors in bentonite compacted to different dry densities with different water contents).

SÚRAO:

- [SÚRAO (CTU)] will study permeability and swelling pressure of BCV bentonite at temperature up to 150°C
 - [SÚRAO (CU)] will study BCV material at 100 °C and 150 °C in specialized cell. 2 swelling pressure tests with suction control, 2 swelling under constant load tests with suction control, 1 oedometric load-unload test will be performed.
- [UHelsinki (GTK) (JYU)] will study swelling of bentonite (MX80 or equivalent) samples using non-intrusive X-ray tomographic techniques at elevated temperatures up to 150 °C.

[VTT] will perform a) triaxial shear and isotropic compression tests for compacted MX-80 samples at temperatures above 100°C (to study the mechanical behavior of bentonite), b) XRD analysis for samples undergone the high temperature triaxial tests (to study the changes in interlayer distances and mineralogy), and c) chemical monitoring of compacted bentonite samples at high temperatures up to 200°C by using in situ ion selective electrodes. Differential scanning calorimetry (DSC) will be used to select suitable temperatures for the other experiments.

[SÚRAO] will assist in the preparation of the experimental programme and participate in the interpretation of results of its LTP.

[RWM] will evaluate the results of the experimental work they will fund being undertaken by the BGS (see below), and prepare a synthesis report on how RWM will use the findings of the BGS experiments in our geological disposal programme. RWM will share the findings of our report, and participate in discussions through participation at selected Task 3 meetings. RWM will fund the 50% of BGS's experimental costs (the 50% not covered by EU) for Task 3.2. The scope of these test is summarized above under 'BGS'.

Milestones:

- Mathematical models – description of models and plan for improvements (Description of conceptual models and tools, plan for the models improvement, UPC, M12).
- Modelling benchmarks – description (Description of calibration case, verification cases and benchmarks selected for T3.3 in cooperation with DONUT, UPC, M24).

Related Deliverables: D7.8

Subtask 3.3– Small scale experiments, model development and verification

Start: Month 1 – End: Month 48 - Subtask Leader: [CIEMAT (UPC)]

Subtask contributors: [CIEMAT (UPC)] [POSIVA] [SÚRAO (CTU) (CU)] [VTT]

Total PM: 102

Objectives:

Understanding of processes at larger scale

Development and validation of mathematical models (at concept/element level)

Benchmark of available and developed codes to assess their suitability for high temperatures

Laboratory tests in cells, in which the conditions of the repository will be simulated (hydration under thermal gradient), will provide online information for the validation of THM models and their post mortem analyses (performed in subtask 3.1) will complement this information and provide insights into the processes occurred. The advantage of this kind of tests is that the boundary conditions are well controlled and can be easily varied to respond to the uncertainties identified. Additionally, the modelling work will aim at verifying the validity of the available models when applied to higher temperature and incorporate in them if necessary the processes identified in this subtask and the other ones.

[CIEMAT] will perform

- o a set of thermo-hydraulic tests in cells (3 or 4), in which hydration under different thermal gradients (two heater temperatures) will be accomplished. Depending on conversation with other partners and conclusions from the SoA, two different bentonite-based buffer materials could be tested (in principle FEBEX and/or MX-80 bentonites).
- o A THM test in a 50-cm long cell has been going on at [CIEMAT]'s facilities since 2012. In this test pellets of MX-80 bentonite are used and the heater is set at a temperature of 140°C, while it is hydrated with Pearson water. It simulates the conditions of the HE-E in situ test going on at the Mont Terri URL. This cell would be dismantled in the course of the WP (in the first or second year)

Because of the high temperatures, parts of the bentonite columns will remain unsaturated for long time periods and the effect of this on the bentonite properties will be analysed. Part of the post mortem analyses (mineralogy and geochemistry) will be performed by UAM in subtask 3.1.

- o [CIEMAT (UPC)] will perform modelling addressing two aspects: Process modelling and benchmarks/experiments simulation. For process modelling, the main objective is to develop a conceptual framework and a mathematical model (at element level) for clay buffer materials able to incorporate the effects of high temperature on their predicted thermo-hydro-mechanical behavior. For modelling benchmarks and experiments, the main objective is the demonstration that the numerical formulation and computer code are able to reproduce and to predict the benchmarks selected from T3.3 that involve clay buffer material at temperatures higher than 100°C.

SÚRAO:

o [SÚRAO (CTU)] has two objectives in T3.3:

The first objective is to investigate bentonite barrier at high temperature at system level. A set of small-scale experiments is planned. The small scale experiments are designed to simulate a section bentonite barrier with temperature gradient and (forced if necessary) saturation. A pressure vessel will be used in order to allow simulating the conditions in a deep repository.

The second objective is to further develop (high temperature effects) and calibrate a CU's hypoplastic model in the CTU's SIFEL FEM package. A dataset obtained in T3.1, 3.2 and 3.3 will be used for model development, calibration and benchmarking.

o [SÚRAO (CU)] will further develop and validate a hypoplastic model for bentonite at high temperature. [SÚRAO (CU)] will particularly focus on simulations of CTU's experiments.

[VTT] & [POSIVA] aims in T3.3 are 1) to contribute to experiments design in T3.1 and T3.2 from modelling perspective to ensure the ability to utilize the experimental results in THM modelling, 2) to interpret and compile obtained experimental data for modelling purposes and 3) to perform benchmark exercises with available models using the new experimental data.

[SÚRAO] will assist in the preparation of the experimental programme and participate in the interpretation of results of its LTP.

Related Deliverables: D7.9 and D7.10

Task 4 - Impacts and deployment of results

Start: Month 24 – End: Month 48 - Task Leader: [VTT]

Task Contributors: [Andra] [BGE] [ENRESA] [NAGRA] [ONDRAF/NIRAS (EURIDICE)] [POSIVA] [SÚRAO] [RWM] [SKB] [VTT]

Total PM: 20,2

Task objectives:

- The objective for T4.1 is to formulate the existing and new knowledge into a form possible to be utilised in different Safety Cases to enable the update of those studies up to higher temperatures – I=
- Final reporting T4.2

While, in the Task 1.2, assessment criteria will be created, the success of the Work package will be compared to these criteria T4.2

Subtask 4.1– Guidance for safety case development and repository optimization

Start: Month 24– End: Month 48 - Subtask Leader: [NAGRA]

Subtask contributors: [Andra] [BGE] [ENRESA] [ONDRAF/NIRAS (EURIDICE)] [NAGRA] [POSIVA] [RWM] [SKB] [SÚRAO]

Total PM : 13,2

This task will be based on the progress beyond the state of the art that was realized in Task 2 and Task 3 to develop guidance for the WMOs (D7.11). Individual WMOs, with safety cases already in place and optimization question being raised, will assess the impact for each of their specific safety cases and optimization targets (safety and cost). The guidance will aid all other programmes facing questions related to thermal dimensioning of the repository.

In the case of bentonite being used as an engineered barrier, it will be assessed by each WMO planning to use bentonite in their reference concept or as part of their catalogue of options [SKB] [POSIVA] [NAGRA] [RWM] [SÚRAO] [ENRESA] [BGE] how the progress beyond the state-of-the-art in Task 3 allows to reduce the uncertainties and increase the margin by which the safety functions can be fulfilled. In terms of repository optimization it will be assessed how the canister loading can be optimized and what the consequences will be when higher temperatures are permitted and to what extent the performance of the bentonite is still intact.

In the case of the geological barrier consisting of a clay hostrock, it will be assessed by each WMO that considers clay host rocks either as a reference or as an option [NAGRA] [Andra] [[ONDRAF/NIRAS (EURIDICE)] [BGE] [RWM] [ENRESA] how the progress beyond the state-of-the-art in Task 2 contributes to confirming the threshold criteria that have been put forward to ensure the integrity of the geological barrier in the respective safety cases. In terms of repository optimization, it will be assessed how higher thermal loads, changes in canister pitch and/or tunnel spacing affect the likely performance of the geological barriers. This includes an assessment of the consequences of locally surpassing the thresholds.

This analysis will provide clear insight in the role of thermal dimensioning of a repository and its flexibility during repository design and safety assessment. The anticipated increase in process understanding at higher temperatures in both the bentonite barrier and the clay hostrock is expected to contribute to defining and/or confirming performance criteria and thresholds in these higher temperature ranges. Before the start of EURAD, both the parameter values and the process understanding were insufficiently characterized to support this.

Subtask 4.2– Final workshop, final report and evaluation of progress achieved within HITEC WP

Start: Month 37– End: Month 48 - Task Leader: [VTT]

Total PM: 7

At the end of the WP, a general workshop (MS204) on Influence of temperature on clay-based material behaviour will be planned to facilitate the release of main findings of this WP within the whole scientific community and the end-user (lead organisation: VTT, month 46)

Furthermore, this subtask aims to coordinate the writing of the final HITEC technical report (D7.12). The HITEC final technical report utilises the State-of-the-art (D7.2) and the Guidance for safety case development and repository optimization (D.7.11) together with technical reports from T2 and T3, and from task 5 – Interaction with Civil Society. The final report aimed to be published in open access journals.

Deliverables (brief description and month of delivery)

- D7.1 - Initial State-of-the-art on THM behaviour of i) buffer clay materials and of ii) host clay materials – [CIEMAT] Month 6

- D7.2 - Updated State-of-the-art on THM behaviour of i) buffer clay materials and of ii) host clay materials [CIEMAT] Month 48

- Contribution to D6.3 – HITEC/GAS Training materials: course material (copy of the presentations of each doctoral school organised during the course of the project Delivery date: [Month 6] – Lead beneficiary: [ONDRAF/NIRAS (ULiège)]

- Contribution to D6.4 – HITEC/GAS Training materials: course material (copy of the presentations of each doctoral school organised during the course of the project) Delivery date: [Month 48] – Lead beneficiary: [ONDRAF/NIRAS (ULiège)]

- D7.3 – Final technical report on thermal effects on near field properties (subtask 2.1) – This deliverable shall contain i) Dataset of self-sealing capacities under elevated temperature, ii) Dataset of fracture propagation under elevated temperature; iii) Dataset of mechanical properties of fractured media under elevated temperature and iv) Comparison of the results for different host claystones. Month 46 Lead: [CNRS (ULorraine)].

- D7.4 – Specific GAS/HITEC technical report on self-sealing processes - Similar self-sealing experiments will be performed by HITEC WP subtask 2.1 (influence of temperature) and GAS WP subtask 3.2 (influence of gas pressure). Report will include test results, self- sealing process understanding, similarities and differences between different claystones and effectiveness under temperature and gas. Month 46 Lead: [Andra].

- D7.5 - Final technical report on effect of temperature on far field properties (subtask 2.2) – will include i) Dataset of short-term thermo-mechanical properties; ii) Dataset of long-term thermo-mechanical properties; iii) Impact of heating on overpressure and permeability and iv) Comparison of the result on different host claystones. Month 46 Lead: [CNRS (ULorraine)].

D7.6 - Final modelling report on effect of temperature on near field properties (subtask 2.3) – will include Model description, Benchmark description, Comparison of the model and a Synthesis. Direct input to task 4 (input from all participants) Month 46 Lead: [ANDRA]

- D7.7: HITEC technical report on Material characterisation – Task 3.1 final results - [SKB] Month 46

- D7.8: HITEC technical report on test at high temperature – Task 3.2 final results – material investigation – [UKRI-BGS] Month46

- D7.9: Experimental works (small and mid-scale laboratory experiments) – final report (Results of the experimental works of T3.3, [CIEMAT] Month46

- D7.10: Modelling - final report (Results of all modelling task carried in T3.3 in cooperation with DONUT, UPC, Month46

- D7.11 Guidance for safety case development and repository optimization [NAGRA] Month 46

- D7.12: Final report on Influence of temperature on clay-based material behaviour [VTT] Month 48

Participation per Partner

Partner number and short name	WP7 effort
1 - ANDRA	13.70
BRGM	16.70
4 - BGE	13.70
5 - CEA	15.00

Partner number and short name	WP7 effort
EDF	10.50
6 - CIEMAT	37.00
UPC	48.50
UAM	6.00
7 - ChRDI	0.00
KIPT	48.00
SIIGNASU	21.00
8 - CNRS	50.00
ULorraine	33.00
14 - ENRESA	2.10
24 - KIT	0.00
BGR	9.00
25 - LEI	10.00
27 - NAGRA	3.40
32 - ONDRAF/NIRAS	0.00
ULiège	40.50
EURIDICE	4.90
33 - POSIVA	2.50
37 - RWM	10.90
39 - SKB	9.00
42 - SÚRAO	11.00
CTU	54.00
ÚJV	10.00
CU	45.00
48 - UHelsinki	28.00
JYU	28.00
GTK	6.00
49 - UKRI	77.30
50 - VTT	28.50
Total	693.20

List of deliverables

Deliverable Number ¹⁴	Deliverable Title	Lead beneficiary	Type ¹⁵	Dissemination level ¹⁶	Due Date (in months) ¹⁷
D7.1	HITEC - Initial State-of-the-art on THM	6 - CIEMAT	Report	Public	6

List of deliverables

Deliverable Number¹⁴	Deliverable Title	Lead beneficiary	Type¹⁵	Dissemination level¹⁶	Due Date (in months)¹⁷
	behaviour of i) buffer clay materials and of ii) host clay materials				
D7.2	HITEC -Updated State-of-the-art on THM behaviour of i) buffer clay materials and of ii) host clay materials	6 - CIEMAT	Report	Public	48
D7.3	HITEC -Final technical report on thermal effects on near field properties	8 - CNRS	Report	Public	46
D7.4	HITEC -Specific GAS/ HITEC technical report on self-sealing processes	1 - ANDRA	Report	Public	46
D7.5	HITEC -Final technical report on effect of temperature on far field properties	8 - CNRS	Report	Public	46
D7.6	HITEC - Final modelling report on effect of temperature on near field properties	1 - ANDRA	Report	Public	46
D7.7	HITEC - technical report on Material characterisation – Task 3.1 final results	39 - SKB	Report	Public	46
D7.8	HITEC - HITEC technical report on test at high temperature – Task 3.2 final results	49 - UKRI	Report	Public	46
D7.9	HITEC - Experimental works (small and mid-scale laboratory experiments) – final report (Results of the experimental works of T3.3)	6 - CIEMAT	Report	Public	46
D7.10	HITEC - Modelling – final report (Results of all modelling task carried in T3.3 in cooperation with DONUT	6 - CIEMAT	Report	Public	46
D7.11	HITEC - Guidance for safety case development and repository optimization	27 - NAGRA	Report	Public	46

List of deliverables

Deliverable Number¹⁴	Deliverable Title	Lead beneficiary	Type¹⁵	Dissemination level¹⁶	Due Date (in months)¹⁷
D7.12	HITEC - Final report on Influence of temperature on clay-based material behaviour	50 - VTT	Report	Public	48

Description of deliverables

D7.1 - Initial State-of-the-art on THM behaviour of i) buffer clay materials and of ii) host clay materials – [CIEMAT] Month 6

D7.2 - Updated State-of-the-art on THM behaviour of i) buffer clay materials and of ii) host clay materials [CIEMAT] Month 48

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Contribution to D6.4 – HITEC/GAS Training materials: course material (copy of the presentations of each doctoral school organised during the course of the project) Delivery date: [Month 48] – Lead beneficiary: [ONDRAF/NIRAS (ULiège)]

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D7.4 – Specific GAS/HITEC technical report on self-sealing processes - Similar self-sealing experiments will be performed by HITEC WP subtask 2.1 (influence of temperature) and GAS WP subtask 3.2 (influence of gas pressure). Report will include test results, self-sealing process understanding, similarities and differences between different claystones and effectiveness under temperature and gas. Month 46 Lead: [Andra].

D7.5 - Final technical report on effect of temperature on far field properties (subtask 2.2) – will include i) Dataset of short-term thermo-mechanical properties; ii) Dataset of long-term thermo-mechanical properties; iii) Impact of heating on overpressure and permeability and iv) Comparison of the result on different host claystones. Month 46 Lead: [CNRS (ULorraine)].

D7.6 - Final modelling report on effect of temperature on near field properties (subtask 2.3) – will include Model description, Benchmark description, Comparison of the model and a Synthesis. Direct input to task 4 (input from all participants) Month 46 Lead: [ANDRA].

D7.7: HITEC technical report on Material characterisation – Task 3.1 final results - [SKB] Month 46

D7.8: HITEC technical report on test at high temperature – Task 3.2 final results – material investigation – [UKRI-BGS] Month 46

D7.9: Experimental works (small and mid-scale laboratory experiments) – final report (Results of the experimental works of T3.3, [CIEMAT] Month 46

D7.10: Modelling - final report (Results of all modelling task carried in T3.3 in cooperation with DONUT, UPC, Month 46

D7.11 Guidance for safety case development and repository optimization [NAGRA] Month 46

D7.12: Final report on Influence of temperature on clay-based material behaviour [VTT] Month 48

D7.1 : HITEC - Initial State-of-the-art on THM behaviour of i) buffer clay materials and of ii) host clay materials [6]
HITEC - Initial State-of-the-art on THM behaviour of i) buffer clay materials and of ii) host clay materials

D7.2 : HITEC -Updated State-of-the-art on THM behaviour of i) buffer clay materials and of ii) host clay materials [48]

HITEC -Updated State-of-the-art on THM behaviour of i) buffer clay materials and of ii) host clay materials

D7.3 : HITEC -Final technical report on thermal effects on near field properties [46]

HITEC -Final technical report on thermal effects on near field properties

D7.4 : HITEC -Specific GAS/HITEC technical report on self-sealing processes [46]

HITEC -Specific GAS/HITEC technical report on self-sealing processes

D7.5 : HITEC -Final technical report on effect of temperature on far field properties [46]
HITEC -Final technical report on effect of temperature on far field properties

D7.6 : HITEC - Final modelling report on effect of temperature on near field properties [46]
HITEC - Final modelling report on effect of temperature on near field properties

D7.7 : HITEC - technical report on Material characterisation – Task 3.1 final results [46]
HITEC - technical report on Material characterisation – Task 3.1 final results

D7.8 : HITEC - HITEC technical report on test at high temperature – Task 3.2 final results [46]
HITEC - HITEC technical report on test at high temperature – Task 3.2 final results

D7.9 : HITEC - Experimental works (small and mid-scale laboratory experiments) – final report (Results of the experimental works of T3.3) [46]
HITEC - Experimental works (small and mid-scale laboratory experiments) – final report (Results of the experimental works of T3.3)

D7.10 : HITEC - Modelling – final report (Results of all modelling task carried in T3.3 in cooperation with DONUT [46]
HITEC - Modelling – final report (Results of all modelling task carried in T3.3 in cooperation with DONUT

D7.11 : HITEC - Guidance for safety case development and repository optimization [46]
HITEC - Guidance for safety case development and repository optimization

D7.12 : HITEC - Final report on Influence of temperature on clay-based material behaviour [48]
HITEC - Final report on Influence of temperature on clay-based material behaviour

Schedule of relevant Milestones

Milestone number ¹⁸	Milestone title	Lead beneficiary	Due Date (in months)	Means of verification
MS1	EURAD Kick-off meeting (General Assembly n°1)	1 - ANDRA	1	EURAD Kick-off meeting (General Assembly n°1)
MS6	Kick-off HITEC WP Meeting 1	50 - VTT	1	Kick-off HITEC WP Meeting 1
MS12	EURAD EJP Newsletters	1 - ANDRA	3	EURAD EJP Newsletters (Due date : M3 and then every quarter)
MS28	HITEC/GAS training n°1 on multi-physical coupling in geomechanics (especially THM and Gas coupling issues)	50 - VTT	6	HITEC/GAS training n°1 on multi-physical coupling in geomechanics (especially THM and Gas coupling issues)
MS30	EURAD General Assembly n°2	1 - ANDRA	7	EURAD General Assembly n°2
MS36	HITEC WP Meeting 2	50 - VTT	7	HITEC WP Meeting 2
MS42	EURAD Annual Work Plan 2	1 - ANDRA	9	EURAD Annual Work Plan 2
MS47	HITEC experimental progress report	50 - VTT	9	HITEC experimental progress report
MS48	HITEC Task 2.1 and Task 2.2 Experimental test plan (Combined with MS62)	50 - VTT	9	HITEC Task 2.1 and Task 2.2 Experimental test plan (Combined with MS62)

Schedule of relevant Milestones

Milestone number¹⁸	Milestone title	Lead beneficiary	Due Date (in months)	Means of verification
MS49	HITEC Selection of benchmark exercises for task 2.3	50 - VTT	9	HITEC Selection of benchmark exercises for task 2.3
MS62	HITEC Task 2.1 and Task 2.2 Experimental test plan (Combined with MS48)	50 - VTT	12	HITEC Task 2.1 and Task 2.2 Experimental test plan (Combined with MS48)
MS63	HITEC Task 3.3 - Mathematical models – description of models and plan for improvements (Description of conceptual models and tools, plan for the models improvement)	50 - VTT	12	HITEC Task 3.3 - Mathematical models – description of models and plan for improvements (Description of conceptual models and tools, plan for the models improvement)
MS81	EURAD General Assembly n°3 + EURAD Annual Meeting 1	1 - ANDRA	13	EURAD General Assembly n°3 + EURAD Annual Meeting 1
MS83	GAS WP Meeting 3 jointly organised with the WP HITEC	32 - ONDRAF/NIRAS	13	GAS WP Meeting 3 jointly organised with the WP HITEC
MS84	HITEC WP Meeting 3 jointly organised with the WP GAS	50 - VTT	13	HITEC WP Meeting 3 jointly organised with the WP GAS
MS85	EURAD Periodic Report 1	1 - ANDRA	14	EURAD Periodic Report 1
MS103	EURAD General Assembly n°4	1 - ANDRA	19	EURAD General Assembly n°4
MS107	HITEC WP Meeting 4	50 - VTT	19	HITEC WP Meeting 4
MS112	EURAD Annual Work Plan 3	1 - ANDRA	21	EURAD Annual Work Plan 3
MS130	HITEC Task 3.3 -Modelling benchmarks – description (Description of calibration case, verification cases and benchmarks selected for T3.3 in cooperation with DONUT	50 - VTT	24	HITEC Task 3.3 -Modelling benchmarks – description (Description of calibration case, verification cases and benchmarks selected for T3.3 in cooperation with DONUT
MS136	EURAD General Assembly n°5 + EURAD Annual Meeting 2	1 - ANDRA	25	EURAD General Assembly n°5 + EURAD Annual Meeting 2
MS138	GAS WP Meeting 5 jointly organised with the WP HITEC	32 - ONDRAF/NIRAS	25	GAS WP Meeting 5 jointly organised with the WP HITEC
MS139	HITEC WP Meeting 5 jointly organised with the WP GAS	50 - VTT	25	HITEC WP Meeting 5 jointly organised with the WP GAS
MS140	EURAD Periodic Report 2	1 - ANDRA	26	EURAD Periodic Report 2
MS153	EURAD General Assembly n°6	1 - ANDRA	31	EURAD General Assembly n°6

Schedule of relevant Milestones

Milestone number¹⁸	Milestone title	Lead beneficiary	Due Date (in months)	Means of verification
MS158	HITEC WP Meeting 6	50 - VTT	31	HITEC WP Meeting 6
MS162	EURAD Annual Work Plan 4	1 - ANDRA	33	EURAD Annual Work Plan 4
MS185	EURAD General Assembly n°7 + EURAD Annual Meeting 3	1 - ANDRA	37	EURAD General Assembly n°7 + EURAD Annual Meeting 3
MS187	GAS WP Meeting 7 jointly organised with the WP HITEC	32 - ONDRAF/NIRAS	37	GAS WP Meeting 7 jointly organised with the WP HITEC
MS188	HITEC WP Meeting 7 jointly organised with the WP GAS	50 - VTT	37	HITEC WP Meeting 7 jointly organised with the WP GAS
MS189	EURAD Periodic Report 3	1 - ANDRA	38	EURAD Periodic Report 3
MS199	EURAD General Assembly n°8	1 - ANDRA	43	EURAD General Assembly n°8
MS203	HITEC WP Meeting 8	50 - VTT	43	HITEC WP Meeting 8
MS206	EURAD Annual Work Plan 5	1 - ANDRA	45	EURAD Annual Work Plan 5
MS207	HITEC Final Workshop on Influence of temperature on clay-based material behaviour	50 - VTT	46	HITEC Final Workshop on Influence of temperature on clay-based material behaviour
MS209	HITEC/GAS training n°2 on multi-physical coupling in geomechanics (especially THM and Gas coupling issues)	50 - VTT	46	HITEC/GAS training n°2 on multi-physical coupling in geomechanics (especially THM and Gas coupling issues)
MS220	GAS Chapter on pathway closure and sealing processes of the WP thematic report on barrier integrity as input to D6.8 (in common with HITEC WP)	32 - ONDRAF/NIRAS	48	GAS Chapter on pathway closure and sealing processes of the WP thematic report on barrier integrity as input to D6.8 (in common with HITEC WP)
MS222	EURAD General Assembly n°9 + EURAD Annual Meeting 4	1 - ANDRA	49	EURAD General Assembly n°9 + EURAD Annual Meeting 4
MS224	EURAD Periodic Report 4	1 - ANDRA	50	EURAD Periodic Report 4
MS234	EURAD General Assembly n°10	1 - ANDRA	55	EURAD General Assembly n°10
MS240	EURAD General Assembly n°11 + EURAD Annual Meeting 5	1 - ANDRA	60	EURAD General Assembly n°11 + EURAD Annual Meeting 5
MS241	EURAD Periodic Report 5	1 - ANDRA	60	EURAD Periodic Report 5 (Due date: 60+2)

Work package number ⁹	WP8	Lead beneficiary ¹⁰	39 - SKB
Work package title	Spent Fuel Characterization and Evolution Until Disposal (SFC)		
Start month	1	End month	48

Objectives

Objectives

- To produce experimentally verified procedures to reliably determine the nuclide content (here called source terms) of spent nuclear fuel (SNF), including realistic uncertainties.
- To establish beyond state-of-the-art characterization techniques for spent nuclear fuel during its evolution from reactor unloading until disposal (here called pre-disposal activities).
- To establish beyond state-of-the-art uncertainty quantification of the characteristics of the spent fuel during its evolution during pre-disposal activities.
- To understand the performance of the spent fuel during prolonged storage prior to its transport, during the transport and emplacement in a deep geological repository, in order to build the capability for ensuring the safety of all safety relevant operations.
- To understand the behaviour of fuel, cladding, pellet-cladding interaction and ageing effect under normal and postulated accident scenarios until disposal, in order to identify relevant or typical bounding cases at time of re-conditioning and pre-disposal activities (treatment, conditioning and transport).
- To provide contributions to operational safety concepts for fuel handling at SNF packaging facilities.
- To contribute to education, training and building of competence in the subject.

Please note that in the text of this work package, we use the words “source term” to denote only the nuclide content of spent fuel. We do not extend its meaning to release processes and corresponding mechanisms.

Interactions with existing European projects

The properties and behaviour of the spent nuclear fuel during its disposal after it is placed in the repository is out. SNF dissolution after emplacement in a deep geological repository is not part of this work package, since it is extensively covered in other projects (e.g. First Nuclides, DISCO).

Safety cases (as already done elsewhere) are out because they are often too nationally focused. General cases that can be of use for all of Europe can be included.

The work package will focus on BWR- and PWR-assemblies in the first wave of the programme, due to budget constraints. Other types, e.g. RBMK or VVER, will be deferred to be studied in a second wave for tasks where the budget was not enough. In this way, studies of those fuel types can then benefit from the methods and procedures developed in this first wave.

Three specific measurement techniques targeted to conditioned nuclear waste are studied in the CHANCE project; Calorimetry, Muon Tomography (MT) and Cavity Ring-Down Spectroscopy (CRDS). In this work package, calorimetry on nuclear fuel assemblies is studied which is complementary to the studies of conditioned waste studied in CHANCE. MT and CRDS are not studied in this WP.

Complementary to the CAST project, which dealt with the fate of a single radionuclide C-14 in metals, ion-exchange resins, Zircaloy, in task 2 we intend to determine inventories of a variety of radionuclides (fission products, activation products, even actinides).

The WP is complementary to the planned work in on back-end issues for Phase IV of the Studsvik Cladding Integrity Project (SCIP). Both projects have creep investigations but with different emphasis (e.g. local effects). Special or failed fuel rods are not focused here. Hydride reorientation in this WP is discussed mainly in comparison with the development of un-irradiated mock-up material. Fracture mechanics investigations are on classical hydride embrittlement (not delayed hydride failure as in SCIP-IV).

Expected impacts

Regarding RWM implementation needs

o The decay heat and reactivity of nuclear fuel assemblies determine the number of assemblies that can be loaded in a canister. Hence, these characteristics have an impact on the volume of underground galleries in a geological disposal. Therefore, a reduced uncertainty of the decay heat implies very large economical savings when constructing the repository.

Regarding safety

o Reduced uncertainties on safety related parameters.

o To contribute and further develop guidance on the operational safety of both interim storage and fuel packaging facilities.

o This WP will improve the current knowledge on the safety of spent nuclear fuel (SNF), by analysing the likely scenarios expected in a short-term framework for present operational facilities. Safety assessment on existing pre-disposal technologies will enable to predict the consequences of design changes, for example in case of a planned extension of operating time.

Regarding increasing scientific and technical Knowledge (beyond the state-of-the-art) in RWM

o Both fuel and cladding experience in time several degrading mechanisms (oxidation, corrosion, irradiation, etc.) that will inevitably affect their chemistries (oxidation state, chemical composition, microstructure, etc.) and hence alter their thermo-mechanical properties. The WP will provide new and meaningful insight on these mechanisms that are still not explained.

o The present WP is a significant contribution to the scientific and technical knowledge in the field of RWM as the conducted pioneering researchers will overcome several identified gaps and propose beyond-the-state-of-the-art scientific results.

o This WP will increase knowledge specific to the European case. Indeed, numerous experimental data gained from SNF tests mainly in the U.S. are known from literature. Such data are specifically correlated to the selected materials and do not cover European conditions, esp. higher burn-up of spent fuel, MOX fuel, temperature profiles and histories from vacuum drying procedures and subsequent storage conditions throughout Europe.

o In addition, the combination of both numerical calculations and experimental methods will also provide a complete and thorough understanding of the mechanisms driving the behaviour of the SNF rods during its extended storage in both normal and accidental conditions.

Regarding radioactive waste management routes

o Results from this WP will have a valuable impact from performance assessment and regulatory requirements point of view. These issues are closely connected in several EU countries to the licensing process for alternative storage schemes before the final disposal. The inclusion of WMOs in the project ensures that the research conducted in the proposed project will be relevant and useful for the ultimate goal of safe radioactive waste management. In addition, it provides a direct communication channel between researchers and implementing organizations.

o The results obtained in the project will contribute to the implementation of the EU Waste Directive and of the EC communication as the nuclear illustrative programme PINC.

The project will provide a better understanding of long-term uncertainties which would in turn address and reply to the fears and doubts of the EU citizens regarding the idea to develop a nuclear storage. The results obtained will provide a rigorous scientific approach to develop the technical bases for continued safe and secure storage of spent nuclear fuel, in terms of transport, retrieval and predisposal options

Description of work and role of partners

WP8 - Spent Fuel Characterization and Evolution Until Disposal (SFC) [Months: 1-48]

SKB, CEA, CIEMAT, ChRDI, CNRS, FTMC, ENRESA, JUELICH, JSI, JRC, KIT, LEI, MTA EK, NAGRA, PSI, SCK•CEN, SSTC NRS, SÚRAO, TUS, VTT

Description of work (where appropriate, broken down into tasks), lead partner and role of participants

Task 1 is focused on coordination of the work package. The S/T tasks are focused on building knowledge that is compiled and used in task 4. Task 5 is focused on the interaction with civil society in the S/T activities. The graphic below illustrates how the work package is constructed. Two groups of interested external parties, an “advisory group” and a “spent fuel owners’ group”, are constructed to provide a platform for exchange of experience and information. To these groups, representatives from other entities have been invited. A list of organisation that have initially shown an interest to participate are shown below. This list may be expanded during the programme.

List of organisation that have initially shown an interest to participate in an “advisory group” and a “spent fuel owners’ group”:

Organisation Country

Chalmers University of Technology SE

Czech Radioactive Waste Repository Authority (SÚRAO) CZ

Electric Power Research Institute (EPRI) USA

Endesa SP

Gesellschaft für Anlagen- und Reaktorsicherheit (GRS) DE

Italian National Agency for New Technologies, Energy and Sustainable Economic Development (ENEA) IT

Kharkov Institute of Physics and Technology UA

Lawrence Livermore National Laboratory USA

National Nuclear Laboratory UK

Oak Ridge National Laboratory USA
 OECD NEA Data Bank OECD
 Pacific Northwest National Laboratory USA
 Radioactive Waste Management (RWM) UK
 Studsvik (SCIP project) SE
 Swedish Academic Initiative on Nuclear Technology Research (SAINT) SE
 TS Enercon HU
 University of Bristol UK
 Tokyo Institute of Technology JP

Task 1 – S/T coordination, State-of-the-art and training material Start: Month 1 – End: Month 48 - Task Leader: [SKB]
 Task contributors: [CIEMAT] [JRC] [KIT-BAM] [NAGRA] [SKB]

Total PM: 12.3

Task objectives:

- To provide efficient management and administration of the work package, to identify potential problems at an early stage and provide timely and effective solutions.
- Developing/updating State-of-the-art, performing WP-specific gap analysis.
- Developing training materials as an input to KM.
- Collecting data from tasks 2-4.
- Collecting experience from the project to guide efforts in a possible future 2nd wave of the programme.

Subtask 1.1 – S/T coordination

Start: Month 1 – End: Month 48 –S/T Coordinator: [SKB]

Total PM: 4.3

The scientific and technical coordination of SFC will be performed by the WP Leader [SKB]. The WP Leader will be supported by the Task leaders and co-task leaders: [JRC] [KIT (BAM)] [CIEMAT] [PSI] [JUELICH (HZDR)] and [NAGRA] which together with [SKB] constitute the WP Board of SFC.

WP operational management and performance monitoring: The subtask will monitor compliance of the work package with the time schedule and ensure that all resources committed to this work package are mobilized. Monthly, ~one hour, remote status reporting meetings will be organised between the WP leader and task leaders with the purpose of monitoring progress with, and possible deviations from, the project plan. Performance and progress of the tasks are to be reported to the PMO.

WP information and communication management: The work package leader and task leaders are responsible for the internal information dissemination, not at least to ensure that project results are communicated for effective exploitation and dissemination of results.

Subtask 1.2 – State-of-the-art and Gap analysis

Start: Month 1 – End: Month 48 – Sub-task Leader: [NAGRA] Subtask contributors: [KIT (BAM)] [CIEMAT] [JRC] [NAGRA]

Total PM: 4

1. Current state-of-the-art: The current state-of-the-art of nuclear fuel characterisation and evolution of its properties will be summarized in a state-of-the-art report (Deliverable 8.1). Already known gaps in knowledge should be included. Both experimental techniques and computational capabilities will be covered. The report will be living document that shall be distributed at least to other work packages and will be updated throughout the project. Deliverables of tasks 2-4 will be used to collect material for the report. The state-of-the-art report can contain commercial fuel types not currently included in tasks 2-4 such as, e.g., RBMK and VVER fuels.

2. Updated state-of-the-art: At the end of the project, the report describing state-of-the-art will be complemented with text on how state-of-the-art has been improved by contributions from the project (Deliverable 8.2). It shall include gaps of knowledge identified, but not covered, by the project as a means to guide future efforts in a possible 2nd wave of EURAD-1. All tasks in the work package will report updated state-of-the-art and gaps of knowledge throughout the project.

Subtask 1.3 – Training materials

Start: Month 24 – End: Month 48 – Sub-task Leader: [CIEMAT] Subtask contributors: [KIT (BAM)] [CIEMAT] [JRC] [NAGRA]

Total PM: 4

Training material, in the form of e.g. lecture materials, containing state-of-the-art of nuclear fuel modelling, characterisation and evolution of nuclear fuel until disposal, is to be developed during the project in close link with KM Training/Mobility WP. Tasks 2-4 provide this training material as part of their respective reporting. In this subtask,

training materials are collected from participating organizations by the task leaders, and summarized in short annual reports describing the form of the materials (Deliverable 8.3).

Task 2 - Fuel properties characterisation and related uncertainty analysis Start: Month 1 – End: Month 48 - Task Leader: [JRC]

Task Contributors: [CIEMAT] [FTMC] [SÚRAO (CTU)] [ENRESA] [JRC] [JSI] [KIT (PEL)] [LEI] [NAGRA] [SSTC NRS] [PSI] [SCK•CEN] [TUS] [SKB] [VTT]

Total PM: 159.8

Task objectives

The main objective is to produce experimentally verified procedures to determine reliable source terms of spent nuclear fuel (SNF), including realistic uncertainties. The focus is on source terms which are of primary importance for a safe, secure, ecological and economical handling, transport, intermediate storage and final disposal of SNF. The main source terms of interest are gamma-ray and neutron emission rate spectra, decay heat and the inventory of specific nuclides, i.e. activation products (e.g. ^{14}C and ^{36}Cl), long lived fission products (FP), fissile nuclides (^{235}U , ^{239}Pu) and minor actinides (^{241}Am , $^{242,244}\text{Cm}$). The inventory of fissile nuclides is needed for reactivity calculations to prevent criticality and for nuclear safeguards requirements. The inventory of activation products and long-lived FP are important to study the impact to the biosphere. Some of the FP (e.g. ^{148}Nd) are used for burnup determination.

The source term estimates are based on a combination of theoretical calculations and results of NDA measurements. The calculations involve neutron transport and nuclide creation and depletion codes. The results of such calculations strongly depend on nuclear data (including cross sections, FP yields, neutron emission probabilities and spectra, decay data,...), fuel fabrication data (design, composition), and reactor operation and irradiation conditions (burnup, neutron spectrum). The design, composition, production, operation and irradiation conditions will be referred to as "fuel history".

Procedures to estimate the source terms taking into account the different levels/qualities of fuel history documentation will be defined. In addition, recommendations will be given to improve the source term estimation. These recommendations include nuclear data requests for the nuclear data community, which will be an input for the NRFP-2018 call, and required details regarding fuel irradiation history to achieve targeted uncertainties. In a first phase the focus will be on medium burn-up SNF from BWR and PWR reactors. However, general purpose procedures will be proposed which are also valid for SNF of high burn-up UO_2 and MOX fuel. The focus on BWR and PWR is due to the availability of experimental data that can be used to verify and validate codes and the available budget.

The objectives will be realised by:

- comparing performance of different deterministic and stochastic transport and depletion codes
- performing theoretical calculations, including sensitivity analysis and full uncertainty propagation, using state-of-the-art methods and tools
- radiochemical analysis of BWR SNF samples with an average burn-up of 50 GWd/tHM with well documented fuel irradiation histories
- developing innovative methods to determine the nuclide inventory of SNF samples (UO_2/MOX) by NDA
- developing and improving NDA methods/systems to characterise SNF (UO_2/MOX) samples and assemblies
- characterisation by NDA of a SNF pellet with a well-known fuel history
- studying the importance of impurities in fuel and structural materials for characterisation of SNF and structural material irradiation
- determining the importance of fuel assembly structural materials to the overall SNF source term
- establishing correlation schemes between experimental observables and fuel parameters to improve information about SNF assemblies
- applying dedicated statistical analysis schemes to estimate average source terms including realistic confidence limits of a batch of SNF assemblies

The activities in Task 2 profit from the SKB-50 project, which is executed within the JRC(EURATOM)/DOE agreement, the First Nuclides project of FP7 and the REGAL Programme, which is organised by the SCK•CEN and supported by the JRC. The REGAL project provides access to results of radiochemical analysis. The SKB-50 project will provide results of the characterisation of BWR and PWR SNF assemblies by neutron (active and passive), gamma-ray and heat NDA measurements. It offers the possibility to have access to such data avoiding large investments to design and build dedicated NDA equipment and to pay for access to SNF material with a well-known fuel history. As compensation, we will improve the analysis procedures of the SKB-50 NDA measurements. Additionally, the objectives of the Task 2 activities are complementing the efforts organised by SKB and the OECD/NEA, with 20 organizations, to assess possible code biases and uncertainties in a so-called "blind test" for the determination of quantities of interest for issues related to SNF long-term storage or disposal. In general, this task will contribute with the generation of complementary and new data (i.e. neutron emission, decay heat, SNF reference sample) to what exists at present. Evidently this is of interest for the entire back-end chain (interim storage, cask transport, disposal) and demonstrates the relevance of Task 2 to current development in the back-end fuel cycle.

Subtask 2.1 – Theoretical study of SNF source terms Start: Month 1 – End: Month 48 - Subtask Leader: [PSI]

Subtask contributors: [CIEMAT] [JSI] [NAGRA] [PSI] [SCK•CEN] [VTT]

Total PM: 39,1

SNF source terms can be determined theoretically by dedicated neutron transport and nuclide creation and depletion code systems. Confidence limits of calculated SNF source terms strongly depend on the quality of both the nuclear data and the documentation of the fuel history. It was shown that uncertainties on estimated SNF decay heat and neutron emission rates based on realistic cycle irradiation and nuclear data files can be higher than 10%, depending on the assembly burnup and cooling time. The impact of the model (single assembly or full core) and of the irradiation history is not negligible on calculated uncertainties, depending on the quantity of interest. This indicates the impact of the assumptions which are at the start of the SNF source term simulations. It shows the importance of user effects and calls for guidelines and recommendations to reduce user bias and define realistic confidence intervals.

To rationalise future recommendations, dedicated sensitivity analyses will be performed to define the nuclear data and fuel irradiation history parameters that have a dominant impact on the estimations. Realistic uncertainty margins based on the present status of the nuclear data libraries will be determined. In addition, nuclear data requirements to improve the source term estimations will be defined.

The performance of different code systems will be compared. To identify bias effects and obtain best estimates of the source terms together with their uncertainties, the same fuel assemblies will be used by all participants. This will indicate how well we believe SNF quantities can be calculated and with which confidence limits. To be efficient and in-line with the available budget, a small number (between 3 and 5) of PWR and BWR assemblies will be selected. They can refer to the SKB-50 project, with a large variety of assemblies, or the REGAL programme, as well as SFCOMPO, and can be complemented in subtask 2.2 by measured quantities. These assemblies will be defined at the start of the project. The performance of different stochastic and deterministic code systems will be compared based on the selected assemblies, presenting their advantages and drawback for SNF calculations and indicating the possible sources of biases. The considered systems are SCALE, SERPENT, MCNP (in combination with ACAB, ALEPH2, FISPACT and ORIGEN), and finally CASMO/SIMULATE/SNF. Source term uncertainty calculations will be based on the specific methods developed by each participant (e.g. Monte Carlo, conventional uncertainty propagation, Bayesian analysis).

This subtask involves the following activities:

- Compare and benchmark state-of-the-art codes for SNF depletion calculations based on the selected assemblies.
- Perform sensitivity studies and propagate nuclear data uncertainties to define confidence limits based on the present status of nuclear data libraries and identify nuclear data requiring improvement.
- Identify fuel irradiation history parameters that influence the source terms and propagate uncertainties of these parameters to the observables.
- A workshop will be organised to present the results of the different calculations: summarise the present status of transport and depletion codes and provide a list of nuclear data to be improved (month 24)

Subtask 2.2 – Develop, improve and demonstrate NDA methods/systems for SNF characterisation Start: Month 1 – End: Month 48 - Subtask Leader: [SCK•CEN]

Subtask contributors: [CIEMAT] [JRC] [ENRESA] [SCK•CEN] [SKB]

Total PM: 54.9

The main objective is to assess and improve current NDA methods and develop innovative ones for the characterisation of SNF. The metrological parameters of the measurement and analysis processes will be identified to reduce bias effects and to evaluate uncertainties of the experimental observables. It will result in improved NDA systems providing data to verify and validate codes estimating the SNF source terms. Two types of measurement systems will be investigated: systems to characterise small SNF samples (including pellets) and systems to characterise entire SNF assemblies.

One of the most ambitious objectives is to demonstrate the characterisation of SNF samples by NRTA (Neutron Resonance Transmission Analysis). This NDA method determines the inventory of U, Pu and Am isotopes and main FP avoiding a complex chemical analysis. A successful completion of this activity will open new roots to characterise SNF samples with a substantial reduction in time, cost and man-power independent of the fuel type, hence, also applicable to MOX. In addition, a NDA detection system will be developed to measure directly the neutron output of a SNF pellet outside a hot cell in a conventional controlled area. The results obtained with NRTA together with decay heat and neutron emission measurements will complement existing radiochemical assays at pellet-level and electron probe micro-analyser (EPMA) measurements for elemental inventory.

NRTA will be applied to contribute to the most complete characterisation, world-wide, of a SNF pellet. Also the neutron emission rate and gamma-ray emission spectrum of the pellet will be determined by NDA. The pellet is part of a fuel pin from the REGAL programme for which both design and fabrication data, and the fuel irradiation history are extensively documented. Since the SNF pellet will not be destroyed for chemical analysis and fully characterised by NDA it can be considered as a first world-wide reference fuel pellet. Neighbouring pellets of the reference pellet are characterised by radiochemical analysis as part of the REGAL programme.

Calorimetric, gamma-ray spectroscopic and active (DDA, Differential Die-Away) and passive (DDSI, Differential Die-Away Self-Interrogation) neutron measurements are carried out within the SKB-50 project to characterise a set of PWR and BWR assemblies at CLAB. The data reduction and analysis procedures of the calorimetric decay heat measurements at CLAB will be improved to achieve a target uncertainty of less than 2%. DDA and in particular DDSI have the potential to be included in the routine verification process of each SNF assembly. We will contribute to improve the analysis procedures for routine operation. These NDA methods including the analysis procedures and final results will be fully documented.

Innovative radiation resistant detectors, i.e. a CLYC detector and one based on diamond technology, will be developed and tested in high intense neutron and gamma-ray fields. These detectors can be used as stand-alone devices or can be integrated in larger detection systems such as DDA or DDSI

In addition to the characterisation of SNF by NDA, the nuclide inventory of a series of samples originating from BWR fuel that was irradiated to an average burn-up of above 40 GWd/tHM, determined by radio-chemical analysis will be provided. The samples being investigated cover a range of initial enrichments and coolant void histories. The results will be used for code validation.

This subtask involves the following activities:

- Develop and demonstrate beyond state-of-the-art NDA systems to characterise SNF pellets (determine the neutron emission rate and nuclide inventory)
- Improve the data analysis and uncertainty evaluation procedures of the NDA systems used at CLAB as part of the SKB-50 project: target uncertainty of less than 2% on the measured heat output
- Nuclide inventory by radiochemical analysis of a set of BWR SNF samples and results of the characterisation of a SNF pellet as part of the REGAL project (part of Deliverable 8.5)
- Develop and test innovative neutron and gamma-ray detectors for SNF characterisation
- A report will be produced (Deliverable 8.4) describing the principles and performance of NDA systems and innovative detection techniques used for the characterisation of SNF samples and assemblies
- Workshop presenting the results of the activities (month 36)

Subtask 2.3 – Determine the inventory of activation and fission products in cladding material Start: Month 1 – End: Month 48 - Subtask Leader: [KIT]

Subtask contributors: [CIEMAT] [SÚRAO (CTU)] [KIT] [LEI] [NAGRA] [VTT]

Total PM: 17,7

The main objective is to analyse inventories of activation products and fission products of irradiated Zircaloy. The inventory of these products comprise the fraction that is formed during irradiation within Zircaloy and the fraction that is precipitated on the inner surface of the cladding. For the experimental studies, two kinds of samples will be used:

- clad fuel pellets of UO₂ (50 GWd/tHM) and mixed oxide fuel (38 GWd/tHM) irradiated in a pressurised water reactor (PWR).

- a plenum cladding obtained from a UO₂ fuel rod segment irradiated in a PWR.

Subsamples of these highly active claddings will be analysed by means of different (radio-)chemical analytical methods, such as classical nuclear spectroscopic methods (gamma-spectrometry, alpha-spectrometry, LSC) and ICP- mass spectrometry. Special efforts will be made to determine radionuclides critical for long-term safety of SNF, such as ¹⁴C and ³⁶Cl. These radionuclides will be separated using various extraction techniques and the extraction yield will be determined. Experimentally determined radionuclide inventories will be compared to calculated ones.

This subtask involves the following activities:

- preparation of sub-samples of irradiated materials in the KIT-INE shielded box-line
- digestion of sub-samples
- separation of ¹⁴C and ³⁶Cl using various extraction techniques and determination of the extraction yield; (radio-)chemical analyses of activation and fission products and actinides in dissolved samples (part of Deliverable 8.5)
- calculation of radionuclide inventories based on chemical compositions of the materials before irradiation (including trace contaminations) and irradiation histories based on a comparison of calculated and measured data, improved procedures for inventory determination will be assessed.

Subtask 2.4 – Define and verify procedures to determine the source terms of SNF assemblies with realistic confidence limits

Start: Month 13 – End: Month 48 - Subtask Leader: [KIT (PEL)]

Subtask contributors: [CIEMAT] [FTMC] [JRC] [ENRESA] [JSI] [SSTC NRS] [KIT (PEL)] [SCK•CEN] [TUS] [SKB]

Total PM: 48.1

The main objective is to define, verify and recommend state-of-the-art procedures to determine the source terms of SNF assemblies with realistic uncertainties. This is accomplished by focussing on at most two or three codes selected by the evaluation from 2.1 and applying them to a big SNF data set. One code will represent current industry standards (“best

practice industry”) and another code (“sophisticated”) will represent the state-of-the-art developed in 2.1. The big data approach will minimize uncertainties from sources random in character: reactor irradiation histories, manufacturing parameters, experimental procedures and focus on the remaining, systematic biases in nuclear data, modelling and measurement methods.

The results of the calorimetric, gamma-ray spectroscopic, DDA and DDSI carried out within the SKB-50 project to characterise a set of PWR and BWR assemblies at CLAB will be made available to this WP. These data together with data produced in subtask 2.2 will be used in 2.4. Possibly also the results of the blind test measurements of SKB and selected data from SFCOMPO will be taken into consideration. Evidently, results of other projects that would offer full access to experimental data on characterisation of SNF assemblies and their history will also be considered.

Based on the analysis with the “best practice industry” code and the “sophisticated” code the reliability of current methods will be analysed and recommendations made for future developments and improvements.

Since experimental capacities are limited for the characterisation of SNF assemblies in an industrial environment, correlation schemes between observables of NDA experiments (gamma-ray spectroscopic, DDA and DDSI) and fuel history parameters will be extracted from the above analysis. This will reduce bias effects related to incomplete knowledge about fuel history parameters of a SNF assembly.

One of the codes considered in subtask 2.1 will be chosen based on its ability to propagate, as completely and as consistently as possible, the impact of nuclear data uncertainties, irradiation and burnup boundary conditions. Complementary to this the “best practice industry” code represents off-the-shelf, current industrial practices. To be efficient with the available budget and to maximise the payoff for all participants the focus will be on working on a common dataset and by selecting codes available to most participants.

Based on the comparison of results between these two categories of codes, procedures to estimate the SNF source terms in a production or industrial environment will be defined and recommended. They include realistic uncertainty margins based on recommended nuclear data libraries and depending on the quality of the input of the fuel irradiation history. These procedures will be largely focused on LWR SNF assemblies and the present status of the nuclear data files.

This subtask involves the following activities:

- Selection of two codes based on recommendations from 2.1 and distribution of workload among groups in order to make predictions for all of SKB-50’s results and the data produced in subtask 2.2 for all selected codes. If budget and time schedule allows data from SFCOMPO will be added.
- Document results and performance of “sophisticated” and “best-practice industry” code for the considered data sets. Quantify biases and stochastic components. Analyse for trends in results with regards to fuel parameters or irradiation histories. (Deliverable 8.6)
- Create correlation schemes between conventional fuel history parameters, e.g. burnup, initial enrichment, cooling time, and source term strengths (part of Deliverable 8.7)
- Define a procedure to estimate the SNF source terms including realistic uncertainty margins based on theoretical calculations with “best-practice industry” code and NDA measurements which can be routinely performed (Deliverable 8.6)
- workshop to present the final results of Task 2 (month 48)

Task 3 - Behaviour of nuclear fuel and cladding after discharge Start: Month 1 – End: Month 48 - Task Leader: [KIT (BAM)]

Task contributors: [CIEMAT (UPM)] [CNRS-ICSM/CEMHTI (UMontpellier)] [JUELICH (HZDR)] [JRC] [KIT (BAM)] [MTA EK] [NAGRA] [PSI] [TUS] [VTT]

Total PM: 406,5

Task objectives

The aim of the work is to understand and describe numerically the behaviour of spent nuclear fuel (SNF), irradiated cladding, fuel/cladding chemical interaction (FCCI) and ageing effect under conditions of extended interim storage, transportation and emplacement in a final disposal system. These objectives will be achieved by involving experimental works and modelling studies.

The focus of the experimental studies is on the effect of hydrogen load, hydride distribution and fuel / clad interaction on the cladding integrity. Physicochemical and mechanical properties of claddings and of fuel pellets are influenced by various factors which will be examined in this task. Intrusion of air into a cladged SNF rod may cause oxidation and a significant swelling of the pellets, which may in turn stress the cladding and thereby contribute to crack initiation or propagation. Concerning the cladding degradation, one key issue influencing the nuclear fuel rod integrity is radial hydride precipitation which reduces ductility during dry storage and raises the risk of accidents during handling. The experimental programme is planned to examine the integrity of the cladding in order to improve the predictive models on the dependence of the stress state and mechanical properties with the hydrogen chemical potential and temperature. The experimental studies will be applied over various non-irradiated and irradiated fuel types (UO₂, doped UO₂, high burn-up spent UO₂ fuel, spent MOX fuel) and clads. Provision of new experimental data on fuel behaviour (coupled

with cladding) will improve the knowledge on consequences of extended storage on cladding stability, embrittlement, fissuring, creep, effect of corrosion resistance on SNF-cladding behaviour as well as oxidation of fuel and mechanical impact during storage and handling until disposal.

The modelling studies rely on general purpose software for finite element calculation and software for special applications. On one hand the experiments provide data for validation of the numerical simulations. On the other hand these numerical simulations are used to generate results beyond the available experimental data. By simulation of well-arranged experiments the understanding of the underlying processes and mechanisms is improved. Individual effects can be combined to complex scenarios which is the scientific background for the assessment of complex accident scenarios during storage e.g. a drop or an impact of SNF rods within casks. The change of initial or boundary conditions in the models enables predictions which can be hardly achieved by experimental work, e.g. extrapolation of results from hot cell experiments at room temperature to elevated temperatures.

Subtask 3.1 – Thermo-mechanical-chemical properties of the SNF rods and cladding Start: Month 1 – End: Month 48 - Subtask Leader: [CIEMAT (UPM)]

Subtask contributors : [KIT (BAM)] [CIEMAT (UPM)] [JRC] [MTA-EK] [NAGRA] [PSI] [TUS] [VTT]

Total PM: 181,4

The subtask 3.1 focuses on the integrity of spent nuclear fuel rods affected by thermo-mechanical conditions as well as fuel/cladding chemical interaction. Objectives of the experimental studies are to quantify the effects of hydrogen load, hydride distribution and re-orientation as well as mechanical loading. Comparing studies of irradiated high-burnup material with non-irradiated but treated mock-up material allow the evaluation of validity and significance of laboratory tests outside of hot cells. Physicochemical and fracture mechanical properties of clads are influenced by various processes which will be examined by numerical simulations being complementary to the experimental studies of this sub-task (Deliverable 8.8).

The experimental conditions consider thermo-mechanical loads which would be expected during storage and transportation of used fuel. Generated experimental data and developed calculation methods including derived material models and parameters as well as failure criteria are an essential base for trustworthy simulations of accidental scenarios in task 4.

Subtask 3.2 – Behaviour of SNF pellets under interim storage conditions Start: Month 1 – End: Month 48 - Subtask Leader: [CIEMAT]

Subtask contributors : [CIEMAT] [CNRS-CEMHTI/ICSM (UMontpellier)] [JUELICH (HZDR)] Total PM: 147,5

The subtask 3.2 focuses on the behaviour of irradiated fuels and simulated spent nuclear fuel pellets both under (ab-)normal dry interim storage conditions and under conditions of water contact, i.e. container or cladding failure scenarios, respectively. The main goal is to provide new insights on the ageing and degradation mechanisms of the SNF (e.g. He build-up, oxidation of the SNF, influence of the various fission products, etc.). The potential evolution of the SNF in case of mal operations conditions (e.g. moisture, aqueous dissolution of the UO₂ matrix, corrosion of the SNF, etc.) will be also considered. The whole of these phenomena will be investigated combining both numerical methods and experimental techniques. Cutting-edge synchrotron methods at the Rossendorf beamline (i.e. high resolution diffraction, x-ray absorption spectroscopy and x-ray emission spectroscopies) will be performed to understand these degrading mechanisms at the atomic level (Deliverable 8.9).

Subtask 3.3 – Pellet-cladding interaction under conditions of extended storage, transport and handling of SNF rods. Start: Month 6 – End: Month 48 - Subtask Leader: [CIEMAT]

Subtask contributors : [CIEMAT] [KIT] [MTA-EK] [PSI] Total PM: 77,6

The objective of this subtask 3.3 is to study the pellet-cladding interaction, in particular chemical effects of activation and fission products on the cladding integrity, and activity release considerations under dry storage and subsequent transportation conditions.

Analyses of pellet/cladding interactions will be performed using non-irradiated UO₂ fuel, high burn-up UO₂ fuel and MOX fuel irradiated in commercial PWR. Morphological and chemical/spectroscopic analyses of the fuel/cladding interfaces and claddings will be performed by means of XPS, RAMAN, SEM, XAS to elucidate FCCI mechanisms and provide radionuclide inventories and chemical speciation. High energy resolution XAS and XES analyses of the radionuclide speciation at the interface of the various fuel types and claddings will be carried out, going beyond conventional fluorescence XAS studies (Deliverable 8.10).

Task 4 - Accident scenario and consequence analysis Start: Month 1 – End: Month 48 - Task Leader: [CIEMAT]

Task contributors: [CEA] [ChRDI] [CIEMAT (IDOM)] [NAGRA] [TUS]

Total PM: 74,1

The main goal of this work package is to study SNF behaviour under accident conditions which may lead to a potential loss of confinement during storage, transport and pre-disposal activities. As a result, the task will be fed by the

empirical formulations in conjunction with mathematical numerical models produced in task 2 and task 3 and building up synergetic activities, to the development of concepts for the mitigation of the consequences. One key issue which may influence the performance of nuclear fuel rods during dry storage is hydrogen embrittlement, especially radial hydride precipitation. Radial hydrides may affect the cladding ductility, which can be critical in relevant operations, i.e. transport, handling, etc. In addition, in those countries where centralised interim storage is considered, other potential accident scenarios can be considered.

In the postulated case of loss of integrity of the cladding barrier, the penetration of oxygen into the spent fuel matrix should also be considered, which can lead to a relatively fast corrosion process with consequent degradation of the fuel. The task 4 will amalgamate the experimental findings like mechanical response of the SNF to external loading and fuel release quantification as consequence of cladding failure tackled in previous work but reshaped to the accidental scenarios conditions.

A further goal would be to perform criticality safety analysis for credible transport accident scenarios after long-term storage, including significant fuel rod failure and in-cask fuel distribution, and to determine the accumulated doses in materials relevant for moderation and/or shielding, e.g. polyethylene (PE) rods or plates.

The main tasks aim to contribute to ensuring the safe packaging of the fuel in the disposal canisters. This can be achieved through the following steps:

- Identification and description of potential accident scenarios (Deliverable 8.11);
- Study of potential accident scenarios during transport and long-term dry interim storage of spent nuclear fuel as well as fuel handling operations, such as fuel unloading from T/S casks (Deliverable 8.11);
- In-depth experimental study on spent rodlet (UOX or MOX) that underwent oxidation treatment, emulating accidental conditions (part of Deliverable 8.12);
- Development of a fuel assembly FEM (based on Task 3 findings like load-displacement curves derived with 3-point bending tests performed on commercial spent fuel rods) with the aim of evaluating mechanical response and possible failure locations under relevant operational/accident loading scenarios (Deliverable 8.12);
- To perform a consequence analysis of postulated accidents also by means of experimental investigations on fuel rod (also here based on Task 3 findings like impact/crash tests) and numerical simulations (Deliverable 8.12);
- To carry out an assessment of criticality safety for accident scenarios (fuel release estimation from Task 3 activities like impact/crash tests) (Deliverable 8.11);
- Consideration of environmental factors during storage and analysis of the degradation dynamics of the state of containers (Deliverable 8.13).

Subtask 4.1 – Accident scenario for fuel under dry interim storage conditions Start: Month 6 – End: Month 48 - Subtask Leader: [NAGRA]

Subtask contributors : [CEA] [CIEMAT] [NAGRA] [TUS] Total PM: 29,9

The subtask aims to provide a synthetic analysis of identified potential but credible accident scenarios related to the transport and long-term dry interim storage of SNF. Furthermore, given the availability of results from Tasks 2 and 3, to be translated into realistic operational conditions (such as in a dry storage facility), a finite element analysis will be conducted to estimate fuel response to normal and accident conditions during fuel handling (Deliverable 8.11).

The development of a methodology trying to link degradation mechanisms to fuel performance and possible accident scenarios would be beneficial to support future specific National Programmes in relation of a safe management of SNF during interim storage and related operations.

In the case of accident conditions during transport, two main specific objectives are planned (Deliverable 8.12):

1. Establishment of a comprehensive methodology for assessing the postulated scenarios, based on analytical tools with 3D capabilities (e.g. FEM with ANSYS);
2. Development of an engineering methodology capable of assessing the scenarios with considerably less computational cost and without losing accuracy (on the basis of previous scenarios analysis).

Regarding accident conditions in interim storage, two specific tasks are to be tackled (part of Deliverable 8.12):

1. Development of a vault model adapted to a lumped parameter code (e.g. MELCOR).
2. Based on this, establishment of a methodology for the determination of the potential source term (activities from Task 2 on characterisation of SNF to be used as supporting material).

An in-depth experimental study is also planned on spent UOX or MOX rodlet to determine which modification in the fuel may lead under accidental scenarios to cracks in the Zy4 cladding (Task 3 findings as starting point).

A possible activity in the T/S cask issue would be to address the case of loss of internal pressure in the cask, in particular the galvanic corrosion of metallic outer lid seals on multiple storage cask lids, between the aluminium seal and the stainless-steel cask body (Deliverable 8.12).

Subtask 4.2 – Consequence analysis of accident scenarios Start: Month 13 – End: Month 48 - Subtask Leader: [ChRDI]

Subtask contributors : [ChRDI] [CIEMAT (IDOM)] [NAGRA] [TUS] Total PM: 44,2

Experimental investigations and analytical studies from Tasks 2, 3 and 4.1 are considered to assess accident scenarios with loss of cladding integrity. The experimental derivation of fuel mass release from fuel impact and/or rupture tests (i.e. activities foreseen in Task 3.1) is intended to serve as a basis for defining worst-case accident scenarios with the aim of avoiding the over-conservative assumptions commonly used nowadays. This would be valuable for the assessment of accident scenarios during storage, transport or handling of the SNF, such as the possible re-criticality of the fuel. The safety margins of the fuel and related uncertainties (nuclear data, geometric uncertainties, design uncertainties...) will be carefully assessed.

The experience gained from investigating the real consequences of beyond design basis accident at Chernobyl NPP would also support the assessment of simulation models for radiation release and environmental impact.

Furthermore, experimental characterisation techniques developed in Task 2 (like Neutron Resonance Transmission Analysis) can be integrated here for the burn-up verification limit as requirement for criticality safety (acceptance criteria) (Deliverable 8.12).

Different transport accident scenarios including partial fuel rod failure of varying extent, are to be considered and criticality safety analysis for different loading schemes for transport/storage casks (loaded with LWR fuel) will be addressed. Shielding property degradation and the related impact on dose-rate are to be considered. Calculation tools: SCALE package, MCNP, GRS home-built DORTABLE (shielding only). The re-criticality of the irradiated fuel will be evaluated in the case of accident conditions. Detailed MCNP calculations will be performed to evaluate the possible re-criticality level of specific accident geometric re-configurations (Deliverable 8.12).

Other valuable studies foreseen are: analysis of the dynamics of the state of emergency radioactive waste packages that were stored after the Chernobyl catastrophe. Consideration of environmental factors during storage (results from monitoring data on the state of the containers for 32 years) with respect to the performance of engineering barriers; e.g. analysis of the degradation dynamics of the state of containers with liquid radioactive waste and solid radioactive waste stored at the specialised sites of Ukrainian NPPs. Modelling of degradation of containers for storage of spent nuclear fuel Transportation of emergency radioactive materials and emergency nuclear fuel to places of their temporary storage, forecasting of possible radiation accidents during transportation (part of Deliverable 8.12; deliverable 8.13).

Participation per Partner

Partner number and short name	WP8 effort
5 - CEA	10.90
6 - CIEMAT	160.27
IDOM	14.21
UPM	48.00
7 - ChRDI	4.50
8 - CNRS	71.10
UMontpellier	8.00
10 - FTMC	3.83
14 - ENRESA	1.39
15 - JUELICH	0.00
HZDR	36.00
22 - JSI	10.80
23 - JRC	63.48
24 - KIT	19.34
PEL	2.10
BAM	30.00
25 - LEI	7.00

Partner number and short name	WP8 effort
26 - MTA EK	22.00
27 - NAGRA	8.84
34 - PSI	30.10
38 - SCK•CEN	15.54
39 - SKB	54.72
40 - SSTC NRS	3.12
42 - SÚRAO	0.00
CTU	0.44
46 - TUS	16.97
50 - VTT	10.00
Total	652.65

List of deliverables

Deliverable Number ¹⁴	Deliverable Title	Lead beneficiary	Type ¹⁵	Dissemination level ¹⁶	Due Date (in months) ¹⁷
D8.1	SFC - State-of-the-art report	27 - NAGRA	Report	Public	6
D8.2	SFC - Updated State-of-the-art report	27 - NAGRA	Report	Public	48
D8.3	SFC - Summary of training materials produced during the SFC WP	6 - CIEMAT	Report	Public	48
D8.4	SFC - principles and performance of NDA systems and innovative detection techniques used for the characterisation of SNF samples and assemblies	23 - JRC	Report	Public	36
D8.5	SFC - results of the characterisation of SNF samples by NDA and radiochemical analysis: results from subtasks 2.2 and 2.3	38 - SCK•CEN	Report	Public	48
D8.6	SFC - performance of “sophisticated” and “best-practice industry” codes based on SKB-50 data and data produced in subtask 2.2 and 2.3	34 - PSI	Report	Public	48

List of deliverables

Deliverable Number¹⁴	Deliverable Title	Lead beneficiary	Type¹⁵	Dissemination level¹⁶	Due Date (in months)¹⁷
D8.7	SFC - recommended procedures to determine the SNF source terms	39 - SKB	Report	Public	48
D8.8	SFC - Thermo-mechanical-chemical properties of unirradiated and irradiated samples of spent nuclear fuel rod segments and cladding	24 - KIT	Report	Public	48
D8.9	SFC - Influence of oxygen and fission products on microstructure of UO ₂ fuel and He within the UO ₂ matrix	15 - JUELICH	Report	Public	48
D8.10	SFC - Chemical and structural / crystallographic properties of simulated fuel pellets and irradiated fuel pellets at the cladding/fuel interface	24 - KIT	Report	Public	48
D8.11	SFC - Identification and analysis of potential accident scenarios for fuel assembly damage and fuel material release during fuel handling in an interim storage and/or packaging facility	27 - NAGRA	Report	Public	36
D8.12	SFC - Assessment of fuel performances for a postulated accident scenario under storage conditions: re-criticality, integrity under mechanical loads and container degradation studies	6 - CIEMAT	Report	Public	48
D8.13	SFC - Analysis of the dynamics of the state-of-emergency radioactive waste packages from the Chernobyl catastrophe	7 - ChRDI	Report	Public	36

Description of deliverables

Task 1

- D8.1 State-of-the-art report - this report will summarize the state-of-the-art of nuclear fuel characterisation and evolution of its properties at the beginning of the WP

Lead [NAGRA] Month 6.

- D8.2 Updated State-of-the-art report - the report will describe how state-of-the-art has been improved by contributions from the WP. It shall include gaps of knowledge identified, but not covered, by the WP as a means to guide future collaborative research efforts

Lead [NAGRA] Month 48

- D8.3 Summary of training materials produced during the SFC WP - This report will compile training material, in the form of e.g. lecture materials, containing state-of-the-art of nuclear fuel modelling, characterisation and evolution of nuclear fuel until disposal, that will be developed during the WP in close link with KM Training/Mobility WP.

Lead: [CIEMAT] Month 48

Task 2

- D8.4 principles and performance of NDA systems and innovative detection techniques used for the characterisation of SNF samples and assemblies Lead: [JRC] Month 36

- D8.5 results of the characterisation of SNF samples by NDA and radiochemical analysis: results from subtasks 2.2 and 2.3 Lead: [SCK•CEN] Month 48

- D8.6 performance of “sophisticated” and “best-practice industry” codes based on SKB-50 data and data produced in subtask 2.2 and 2.3 Lead: [PSI] Month 48,

- D8.7 recommended procedures to determine the SNF source terms including realistic source terms using "best-practice industry codes combined with results of NDA of the SNF assembly under industrial conditions during the loading process Lead: [SKB] Month 48

Task 3

- D8.8 Thermo-mechanical-chemical properties of unirradiated and irradiated samples of spent nuclear fuel rod segments and cladding Lead: [KIT (BAM)] Month 48

- D8.9 Influence of oxygen and fission products on microstructure of UO₂ fuel and He within the UO₂ matrix Lead: [JUELICH (HZDR)] Month 48

- D8.10 Chemical and structural / crystallographic properties of simulated fuel pellets and irradiated fuel pellets at the cladding/fuel interface Lead: [KIT] Month 48

Task 4

- D8.11 Identification and analysis of potential accident scenarios for fuel assembly damage and fuel material release during fuel handling in an interim storage and/or packaging facility.

Lead: [NAGRA] Month 36

- D8.12 Assessment of fuel performances for a postulated accident scenario under storage conditions: re-criticality, integrity under mechanical loads and container degradation studies. Lead: [CIEMAT] Month 48

- D8.13 Analysis of the dynamics of the state-of-emergency radioactive waste packages from the Chernobyl catastrophe Lead: [ChRDI] Month 3

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D8.1 : SFC - State-of-the-art report [6]

SFC - State-of-the-art report

D8.2 : SFC - Updated State-of-the-art report [48]

SFC - Updated State-of-the-art report

D8.3 : SFC - Summary of training materials produced during the SFC WP [48]

SFC - Summary of training materials produced during the SFC WP

D8.4 : SFC - principles and performance of NDA systems and innovative detection techniques used for the characterisation of SNF samples and assemblies [36]

SFC - principles and performance of NDA systems and innovative detection techniques used for the characterisation of SNF samples and assemblies

D8.5 : SFC - results of the characterisation of SNF samples by NDA and radiochemical analysis: results from subtasks 2.2 and 2.3 [48]

SFC - results of the characterisation of SNF samples by NDA and radiochemical analysis: results from subtasks 2.2 and 2.3

D8.6 : SFC - performance of “sophisticated” and “best-practice industry” codes based on SKB-50 data and data produced in subtask 2.2 and 2.3 [48]

SFC - performance of “sophisticated” and “best-practice industry” codes based on SKB-50 data and data produced in subtask 2.2 and 2.3

D8.7 : SFC - recommended procedures to determine the SNF source terms [48]

SFC - recommended procedures to determine the SNF source terms

D8.8 : SFC - Thermo-mechanical-chemical properties of unirradiated and irradiated samples of spent nuclear fuel rod segments and cladding [48]

SFC - Thermo-mechanical-chemical properties of unirradiated and irradiated samples of spent nuclear fuel rod segments and cladding

D8.9 : SFC - Influence of oxygen and fission products on microstructure of UO₂ fuel and He within the UO₂ matrix [48]

SFC - Influence of oxygen and fission products on microstructure of UO₂ fuel and He within the UO₂ matrix

D8.10 : SFC - Chemical and structural / crystallographic properties of simulated fuel pellets and irradiated fuel pellets at the cladding/fuel interface [48]

SFC - Chemical and structural / crystallographic properties of simulated fuel pellets and irradiated fuel pellets at the cladding/fuel interface

D8.11 : SFC - Identification and analysis of potential accident scenarios for fuel assembly damage and fuel material release during fuel handling in an interim storage and/or packaging facility [36]

SFC - Identification and analysis of potential accident scenarios for fuel assembly damage and fuel material release during fuel handling in an interim storage and/or packaging facility

D8.12 : SFC - Assessment of fuel performances for a postulated accident scenario under storage conditions: re-criticality, integrity under mechanical loads and container degradation studies [48]

SFC - Assessment of fuel performances for a postulated accident scenario under storage conditions: re-criticality, integrity under mechanical loads and container degradation studies

D8.13 : SFC - Analysis of the dynamics of the state-of-emergency radioactive waste packages from the Chernobyl catastrophe [36]

SFC - Analysis of the dynamics of the state-of-emergency radioactive waste packages from the Chernobyl catastrophe

Schedule of relevant Milestones

Milestone number ¹⁸	Milestone title	Lead beneficiary	Due Date (in months)	Means of verification
MS1	EURAD Kick-off meeting (General Assembly n°1)	1 - ANDRA	1	EURAD Kick-off meeting (General Assembly n°1)
MS12	EURAD EJP Newsletters	1 - ANDRA	3	EURAD EJP Newsletters (Due date : M3 and then every quarter)
MS29	SOTA from RD&D SFC WP as input to UMAN T3.5	39 - SKB	6	SOTA from RD&D SFC WP as input to UMAN T3.5
MS30	EURAD General Assembly n°2	1 - ANDRA	7	EURAD General Assembly n°2
MS42	EURAD Annual Work Plan 2	1 - ANDRA	9	EURAD Annual Work Plan 2
MS64	SFC Task 2.3 Characteristics of irradiated material to be characterised	24 - KIT	12	SFC Task 2.3 Characteristics of irradiated material to be characterised
MS81	EURAD General Assembly n°3 + EURAD Annual Meeting 1	1 - ANDRA	13	EURAD General Assembly n°3 + EURAD Annual Meeting 1

Schedule of relevant Milestones

Milestone number¹⁸	Milestone title	Lead beneficiary	Due Date (in months)	Means of verification
MS85	EURAD Periodic Report 1	1 - ANDRA	14	EURAD Periodic Report 1
MS103	EURAD General Assembly n°4	1 - ANDRA	19	EURAD General Assembly n°4
MS112	EURAD Annual Work Plan 3	1 - ANDRA	21	EURAD Annual Work Plan 3
MS126	SFC Task 2.1 Workshop – 24	39 - SKB	24	SFC Task 2.1 Workshop – 24
MS136	EURAD General Assembly n°5 + EURAD Annual Meeting 2	1 - ANDRA	25	EURAD General Assembly n°5 + EURAD Annual Meeting 2
MS140	EURAD Periodic Report 2	1 - ANDRA	26	EURAD Periodic Report 2
MS153	EURAD General Assembly n°6	1 - ANDRA	31	EURAD General Assembly n°6
MS162	EURAD Annual Work Plan 4	1 - ANDRA	33	EURAD Annual Work Plan 4
MS175	SFC Task 2.2 Workshop – 36	39 - SKB	36	SFC Task 2.2 Workshop – 36
MS185	EURAD General Assembly n°7 + EURAD Annual Meeting 3	1 - ANDRA	37	EURAD General Assembly n°7 + EURAD Annual Meeting 3
MS189	EURAD Periodic Report 3	1 - ANDRA	38	EURAD Periodic Report 3
MS199	EURAD General Assembly n°8	1 - ANDRA	43	EURAD General Assembly n°8
MS206	EURAD Annual Work Plan 5	1 - ANDRA	45	EURAD Annual Work Plan 5
MS218	SFC Task 2.4 Workshop – 48	39 - SKB	48	SFC Task 2.4 Workshop – 48
MS222	EURAD General Assembly n°9 + EURAD Annual Meeting 4	1 - ANDRA	49	EURAD General Assembly n°9 + EURAD Annual Meeting 4
MS224	EURAD Periodic Report 4	1 - ANDRA	50	EURAD Periodic Report 4
MS234	EURAD General Assembly n°10	1 - ANDRA	55	EURAD General Assembly n°10
MS240	EURAD General Assembly n°11 + EURAD Annual Meeting 5	1 - ANDRA	60	EURAD General Assembly n°11 + EURAD Annual Meeting 5
MS241	EURAD Periodic Report 5	1 - ANDRA	60	EURAD Periodic Report 5 (Due date: 60+2)

Work package number ⁹	WP9	Lead beneficiary ¹⁰	19 - IRSN
Work package title	Waste management routes in Europe from cradle to grave (ROUTES)		
Start month	1	End month	60

Objectives

Objectives

- Provide an opportunity to share experience and knowledge on waste management routes between interested organisations (from different countries, with programmes at different stages of development, with different amounts and types of radioactive waste to manage).
- Identify safety-relevant issues and their R&D needs associated with the waste management routes (cradle to grave), including the management routes of legacy and historical waste, considering interdependencies between the routes.
- Describe and compare the different approaches to characterisation, treatment and conditioning and to long-term waste management routes, and identify opportunities for collaboration between MS (Member-States).

The WP will consider experience of completed and on-going EU projects, such as THERAMIN, CHANCE on the topics of interest and other initiatives carried out at international level such as IAEA, NEA.

Expected impacts

Regarding RWM implementation needs

In the work package a gap analysis is conducted with respect to RD&D activities and strategic needs required for implementation of the different spent fuel and radioactive waste management and disposal routes in Europe. This gap analysis is based on experience and operational feedback from the participants and makes use of past and present EU projects on the topics of interest and other initiatives carried out at international level including those of the IAEA and OECD/NEA.

Regarding safety

Safety-relevant issues and R&D needs associated with the waste management routes (cradle to grave) will be identified, considering waste characterization, the development of waste acceptance criteria (WAC) prior to the availability of disposal facilities, options for disposal of small waste inventories, and options to share technology and facilities.

Regarding increasing scientific and technical Knowledge (beyond the state-of-the-art) in the field of RWM

No new research will be conducted in the work package. Rather, it will consolidate and integrate existing knowledge to identify good practices and challenges, and to provide guidance for research activities in the second wave of activities or in subsequent EURAD implementation phases..

Regarding radioactive waste management routes

In addition to providing an overview of good practices for different steps in radioactive waste management and guidance for research activities, the work package will provide an opportunity to consider sharing of technology and facilities. As such, it will support countries with early-stage programme / small inventory programmes (SIMS small inventory member state) in the development of their national RWM programmes, for compliance with the Council Directive 2011/71 EURATOM. The results will provide a strong input to KM WPs, in particular to support knowledge transfer in the RWM over generation.

Description of work and role of partners

WP9 - Waste management routes in Europe from cradle to grave (ROUTES) [Months: 1-60]

IRSN, ANDRA, ARAO, BEL V, CEA, CIEMAT, COVRA, FTMC, Dekom, EEAE, JUELICH, GRS, IAE, INCT, IST, IST ID, JSI, LEI, NCSR, NES, NJF, NRG, ONDRAF/NIRAS, RATEN, SCK•CEN, SKB, SSTC NRS, STUBA, SÚRAO, SURO, TS Enercon, TUS, UCyprus, VTT, VUJE

Description of work

Task 1 – S/T coordination, State-of-the-art and training material

Start: Month 1 – End: Month 60 - Task Leader: [IRSN]

Task Contributors: [Andra] [JUELICH] [IRSN] [NCRSD (DMT)] [ONDRAF/NIRAS] [SURO] [COVRA] MKG

Total PM: 6,3 + 3

IRSN] ensures the overall coordination WP ROUTES with EURAD.

- ensures consistency and coherence of the work conducted in the ROUTES WP and in the ROUTES Extension
- avoids any redundancy in the work plan

Subtask 1.1 – S/T coordination

Start: Month 1 – End: Month 60- Subtask Leader: [IRSN]

Total PM: 2 + 1

Coordination of the WP is performed both at the WP and the task level. Subtask 1.1 describes the coordination work performed by the WP leader at the WP level. The coordination work performed by other task leaders is included in the description of the other tasks. The technical coordination of ROUTES will be performed by the WP Leader [IRSN]. The WP Leader will be supported by the Task leaders [Andra] [JUELICH] [ONDRAF/NIRAS] [NCRSD (DMT)] [COVRA] which together with [IRSN] constitute the WP Board of ROUTES. The WP Leader will make sure that the rules of EURAD are followed by all partners, that the scientific milestones and deliverables are reached timely, and that the results are disseminated efficiently inside and outside the project.

Subtask 1.1 consists of the following actions:

- Organisation of the annual ROUTES WP meetings (WPM) and the WP Board meetings (2 per year);
- Participation in WP board meetings to ensure that the project is progressing according to the agreed specifications, milestones and planning ;
- Reporting to the PMO of the work progress and of possible modifications of the WP work plan;
- Coordinate the exchanges with NEA and IAEA and with relevant projects such as CHANCE, THERAMIN, , etc.

Some meeting points will be proposed with the SHARE CSA on decommissioning in order to exchange on needs/ solutions and build a common Roadmap in the field of management of waste coming from decommissioning. Some R&D topics coming out of SHARE roadmap could be addressed in common in the future. EURAD addresses all kinds of waste, not only from decommissioning and it could be of interest to discuss about common solution including waste from operations, legacy waste and waste from dismantling

A kick off meeting (month 2) will be organised in order to, in particular, develop a collective questionnaire for collecting information from the organisations involved in this WP on Member-States practices in waste management as an input the task 2, 3, 4 and 6. This will be done in collaboration with their task leaders.

List of ROUTES annual WP meetings (WPM):

- ROUTES Kick-off meeting (ROUTES WPM1) (month : 1)
- ROUTES WPM2 (Month: 13)
- ROUTES WPM3 (Month: 25)
- ROUTES WPM4 (Month: 37)
- ROUTES WPM5 (Month: 49)
- ROUTES WPM6 (Month: 60)

ROUTES Extension:

The additional coordination work for Task 8 is included in ROUTES Task 1. [NCRSD (DMT)], already Task leader of ROUTES Task 5 and member of the WP Board, will be the Task leader of task 8 (and SURO already co-Task leader of ROUTES Task 5, will be the co-Task leader) which ensures the continuity of the work with Task 5. The WP coordinator together with the WP board will ensure that the work conducted in Task 8 is consistent and coherent with the work conducted in the whole WP in order to avoid any redundancy in the work plan.

Subtask 1.2 – Interactions with KM WP

Start: Month 1 – End: Month 60- Subtask Leader: [IRSN]

Total PM: 2 + 1,5

Fundamental R&D will not be undertaken as part of strategic studies. Nonetheless, the work carried out in WP9- ROUTES Tasks 2 to 6 could lead to the development/improvement of strategies, approaches/tools, and collaboration between participants will raise the general level of knowledge across Europe. The knowledge consolidated or generated through knowledge/know-how sharing and discussions of common challenging issues will constitute a valuable input to EURAD KM activities (i.e. guidance, state-of-knowledge).

This subtask will consist in the following actions:

- Interacting with KM WPs regarding the input of the WP to the state-of-knowledge, guidance and training/mobility in terms of content and format (IRSN - 0,25 pm)
- Development of training material (input to KM WP3) (IRSN - 1,75 pm) D9.1

ROUTES Extension:

- Knowledge transfer is a key activity in the Task 8 ROUTES Extension. The work expects a deep collaborative work by SIMS and LIMS (MAP and LAP). Firstly it aims at knowledge transfer from LIMS to SIMS as well as at determination of training and skills improvement needed. SIMS will be supported by expertise of LIMS.
- Interactions with on-going EURAD WP and EC funded projects will be crucial for task 8 work in order to ensure an effective knowledge transfer between SIMS and LIMS or among SIMS at different stages of development. To this end

specific guidance documents could be developed. Specific work in close interaction with KM WPs and initiatives at international level, need to be strengthened.

- Interaction with PREDIS has already started. A common work on WAC has been initiated. This will be continued for Task 8. Moreover a work on how technologies developed under PREDIS (conditioning, monitoring) could be tailored to fit SIMS needs is considered of deep interest. To this end, additional activities at the Coordination level are needed. More specifically, the following specific actions in interaction with KM WPs have been discussed and agreed with KM WPs leaders.

- Input to WP11 – KM State of Knowledge: The results of the RD&D gaps survey and the findings from Task 8 WS1 (M48) and WS2 (M53) will/could contribute to the improvement/establishing the State of Knowledge in topics specific for RWM in SIMS. Future ROUTES Extension Task 8 outputs can be used as an additional source of information about SIMS RD&D and knowledge transfer needs for their integration into WP11 documents. Task 8 team can take part in WP11 deliverables reviews or comment them from SIMS prospective.

- Input to WP12 - KM Guidance: Some requests for specific guidances development in relation to the disposal options for SIMS can be identified within Routes Extension, then deliverables issued from Subtasks 8.1 and 8.2 work will/can be used as one of inputs to the WP12 documents. Other joint activity is seen in WP12 deliverables comments/reviews by end-users from SIMS engaged in Task 8.

Input to WP13- KM Training/mobility: The survey on training needs already performed by WP KM Training and Mobility will be completed by new requests arisen during the work on ROUTES Extension (Task 8). A potential support of training courses modules and course syllabuses development on topics which could strength those MSs RWM programmes implementation is foreseen. The EURAD Mobility program will be supported by Task 8 participants to enable mutual scientific knowledge exchange and practical skills improvement.

Subtask 1.3 – Integration

Start: Month 13 – End: Month 60- Subtask Leader: [IRSN]

Subtask contributors: [IRSN] [Andra] [JUELICH] [ONDRAF/NIRAS] [NCRSD (DMT)] [COVRA]

Total PM: 2,3 + 0,5

This subtask will consist in integrating the recommendations for future RD&D, strategic study and KM activities arising in other tasks – related deliverables: D9.2 and D9.3, extended by Task 8 results. Integration of results of ROUTES Extension into ROUTES final documentation (Month: 56-60).

Task 2 - Identify challenging wastes to be collaboratively tackled within EURAD

Mapping and shared understanding at EU level of practical issues on waste management routes

Start: Month 1 – End: Month 48 - Task Leader: [Andra] and [SSTC NRS]

Task contributors: [Andra] [BEL V] [CEA (ORANO)] [CIEMAT] [EEAE] [FTMC] [JUELICH] [GRS] [IAE]

[INCT] [IRSN] [IST-ID] [IST-LPSR] [JSI] [LEI] [NCSR (DMT)] [NES] [NRG] [ONDRAF/NIRAS] [RATEN] [SÚRAO] [SCK.CEN] [SKB] [SSTC NRS] [STUBA] [SURO] [TS Enercon] [TUS] [UCY] [VTT (GSL)]

Total PM: 16,7

Task objectives:

- Identify challenging wastes and related difficult issues to be collaboratively tackled within the Joint Programme, such as: Sludge; Organic waste; Ion exchange resin; Bituminized waste; Graphite waste; Uranium/radium/thorium bearing waste; Decommissioning waste (soil, rubble etc.); Particular spent fuel such as metal uranium and aluminium cladding; Disused radioactive sealed sources (from category 1 to 5, including neutron sources and radium sources); Waste containing reactive metals such as aluminium, magnesium, zirconium, sodium; Waste containing chemotoxic material such as beryllium, mercury, asbestos, lead; Legacy waste.

- Map and share understanding at EU level of the practical issues on waste management routes, taking into account specific issues relating to challenging wastes and small inventory programmes.

Subtask 2.1 – Collection and analysis of existing work on categorisation and classification of radioactive waste with regard to disposal options, identification of waste for which there is not yet a complete management plan in each Member State, identification of waste management routes for pre-disposal steps

Start: Month 1 – End: Month 24- Subtask Leader: [Andra] [SSTC NRS]

Subtask contributors: [BEL V] [CIEMAT] [FTMC] [JUELICH] [GRS] [VTT (GSL)] [RATEN] [IRSN] [IST-LPSR] [IAE] [JSI] [LEI] [NRG] [SCK.CEN] [ONDRAF/NIRAS] [CEA (ORANO)] [SKB] [SÚRAO] [SURO] [TS Enercon] [TUS] [UCY] [Andra] [SSTC NRS] [NCRSD (DMT)] [EEAE] [INCT] [NES] [STUBA]

Total PM: 11,2

This subtask will start with an up-to-date overview on radioactive waste categorisation/classification based on contributions from participants (collection and synthesis of answers to questionnaire, see Task 1). Outcomes of NEA and IAEA initiatives on waste classification will be used in parallel. Comprehensive contributions on waste without complete management plans in participating states will also be collected.

Experience and knowledge on pre-disposal steps will be shared, describing and comparing the different approaches, defining R&D needs and identifying opportunities of collaboration. The particular problems to be solved for challenging wastes will be described, relating to their pre-disposal steps and in view of their disposal. Specific challenges arising from having just a limited volume of waste will also be addressed. The work takes into account information gained in other EU projects such as CHANCE and THERAMIN.

Sharing experience and knowledge will make it possible to establish an accurate and consistent list of challenging wastes in terms of their categorisation as well as their management route.

An exchange meeting will be organized during Subtask 2.1 (month 7).

The results and outputs of Task 2.1 will be compiled in a final report D9.4.

Subtask 2.2 - Understanding at EU level of the practical issues on RWM routes for challenging waste

Start: Month 13 – End: Month 48- Subtask Leader: [Andra] [SSTC NRS]

Subtask contributors: [BEL V] [CIEMAT] [FTMC] [NCRSD (DMT)] [EEAE] [VTT (GSL)] [INCT] [JUELICH] [GRS] [RATEN] [IRSN] [IST-LPSR] [JSI] [LEI] [NRG] [NES] [SCK.CEN] [ONDRAF/NIRAS] [CEA (ORANO)] [SKB] [SÚRAO] [SURO] [TS Enercon] [TUS] [UCY] [IST-ID] [STUBA]

Total PM: 5,5

Based on the outcomes of subtask 2.1, as well as outcomes from the other tasks of the ROUTES WP, this subtask 2.2 consists in mapping and sharing knowledge on waste inventories, classification and pre-disposal steps with regard to disposal routes. It aims at providing an overview of issues related to management and disposal of challenging wastes. This overview makes it possible to identify R&D needs, to be considered as part of future activities of EURAD.

The results and outputs of Task 2.2 will be compiled in a final reports D9.5 and D9.6. Draft and final syntheses are prepared and shared with participants.

Task 3 - Description and comparison of radwaste characterisation approaches

Start: Month 7 – End: Month 33 - Task Leader: [JUELICH] [CIEMAT]

Task contributors: [CEA (ORANO)] [CIEMAT] [EEAE] [JUELICH] [IRSN] [IST-ID] [JSI (EIMV)] [NCSRSD (DMT)] [SCK.CEN] [SSTC NRS] [STUBA] [TUS] [UCY] [VUJE]

Total PM: 25,9

Task objectives

- Identification of characterisation techniques for radioactive waste (waste selected in Task 2);
- Comparison of the characterisation methods applied for the same radioactive waste in different countries;
- Analysis of the existing approaches and identification of the knowledge gaps;
- Recommendations for the future R&D to eliminate knowledge gaps;
- Recommendations for characterisation approaches for countries with non-developed waste management concept.

Subtask 3.1-Radioanalytical characterisation of radioactive waste and waste with complex/toxic properties

Start: Month 7 – End: Month 24- Subtask Leader: [JUELICH] [CIEMAT]

Subtask contributors: [IRSN] [JUELICH] [CIEMAT] [CEA (ORANO)] [JSI (EIMV)] [SCK•CEN] [EEAE] [ONDRAF/NIRAS] [NCSRSD (DMT)] [UCY] [TUS] [SSTC NRS] [SKB] [Dekom] [INCT] [IST-ID] [STUBA] [VUJE]

Total PM: 17,4

Collection, analysis and comparison of the existing knowledge about techniques and practices for radioanalytical characterisation of radioactive waste, identified in Task 2. The motivations and criteria for characterisation of radioactive wastes (e.g. treatment, reprocessing or WAC for existing repositories) will be identified (input from Task 4), like certain radionuclides and their inventories, requirements of waste acceptance regarding radionuclides limits, radionuclide release rates and speciation. Based on that the contributors will provide experience on characterisation of radioactive waste in different countries. Along with that the issues in characterization of radioactive wastes with complex chemical properties (e.g. organic wastes or SIERS) and toxic radioactive wastes (e.g. beryllium, mercury, asbestos) will be addressed. Due to their special behaviour, routine waste characterisation approaches might not be directly applicable and will require some methodological refinements. Knowledge and experience on characterisation of these wastes will be collected and systematically analysed in order to identify the main issues and knowledge gaps in order to give recommendations for further R&D to eliminate them. The subtask will also consider the means of providing an efficient transfer of knowledge and experience to countries without mature waste disposal concept, e.g. to SIMS.

The outcomes of this subtask will be a report summarising good practices for radioanalytical characterisation of selected radioactive, toxic wastes and wastes with complex chemical properties, highlighting the main motivation for characterization, issues and difficulties in handling these materials, including knowledge gaps and recommendation for future R&D for closing them.

Three workshops will be organized during Subtask 3.1 (months 7, 16 and 20). The last meeting will be in common with the first meeting of subtask 3.2 (see below).

This subtask will take into account information gained in CORI WP, SFC WP and GAS WP.

The results and outputs of Task 3.1 will be compiled in D9.7

Subtask 3.2 – Characterization and segregation of legacy waste

Start: Month 19 – End: Month 33- Subtask Leader: [JUELICH] [CIEMAT]

Subtask contributors: [IRSN] [JUELICH] [CEA (Orano)] [CIEMAT] [JSI (EIMV)] [SCK•CEN] [NCRSD (DMT)] [SSTC NRS] [SKB] [UCY] [EEAE] [INCT] [ONDRAF/NIRAS] [TUS] [Dekom] [SURO] [IST-ID] [VUJE]

Total PM: 8,5

Characterization and segregation of legacy waste as well as of small amounts of waste will be investigated. The contributors will provide for systematic collection and analysis of existing knowledge about historical and legacy wastes, like amount and key radionuclides, in order to identify management issues. Contributors will also share their experience in handling or provide knowledge for building up an approach for characterization. Depending on the status of the radioactive wastes (e.g. conditioned, interim storage or undefined), further steps in R&D must be identified in order to be included into designing an integrated approach for management of historical and legacy wastes. This will include retrieval, sampling, characterization as well as treatment, conditioning and disposal.

The outcome of this subtask will be a comprehensive report on sampling and characterization methods for historical and legacy wastes, required for determining the acceptability of these of radioactive wastes for disposal (D9.8).

Two workshops will be organized during Subtask 3.2 (months 20 and 32). The first meeting will be in common with the last meeting of subtask 3.1.

Task 4 – Identification of WAC used in EU Member-States for different disposal alternatives in order to inform development of WAC in countries without WAC/facilities

Start: Month 1 – End: Month 40 - Task Leader: [ONDRAF/NIRAS] [VTT (GSL)]

Task contributors: [Andra] [CEA (ORANO)] [CIEMAT] [EEAE] [FTMC] [JUELICH] [GRS] [IAE] [INCT] [IRSN] [IST-LPSR] [JSI (EIMV)] [LEI] [NCSR] [ONDRAF/NIRAS] [RATEN] [SÚRAO] [SKB] [SSTC NRS] [STUBA] [SURO] [TUS] [VTT (GSL)]

Total PM: 37,1

Task objectives

- Overview of the current application in Member-States of WAC at different stages in the waste lifecycle.
- Offer a structured approach to support decision-taking of “no regret” waste management measures.
- Identification of R&D needs and opportunities for collaboration between Member-States

Subtask 4.1 –Current use of waste acceptance criteria (start Month: 1 – end Month: 15)

Start: Month 1 – End: Month 15- Subtask Leader: [RATEN] [VTT (GSL)]

Subtask contributors: [RATEN] [ONDRAF/NIRAS] [VTT (GSL)] [TUS] [Andra] [IRSN] [CEA (ORANO)] [JUELICH] [LEI] [IAE] [INCT] [JSI (EIMV)] [CIEMAT] [SKB] [SSTC NRS] [SÚRAO] [FTMC] [GRS] ; [STUBA]

Total PM: 7,1

This subtask will provide an up-to-date overview per country on the use of waste acceptance criteria (WAC) in Member-States, hereby focusing on the use of WAC as a tool for waste cycle management.

The inputs of subtask 4.1 consists of:

- A review of available existing information (e.g. from NEA and IAEA);
- Descriptions of the current use of WAC per country. The descriptions will be based on a questionnaire. Organisations of the same country shall consult with their WMO (if participating) to provide a single input from their country.

Each description will comprise:

- Identification of currently used WAC (considering also preliminary/draft WAC);
- Methodology for setting up WAC and link with waste classification;
- How compliance with WAC is verified;
- How non-conformances are dealt with;
- other (e.g. qualifications, in order to ensure compliance with WAC, of operators’ methods for waste characterisation or methods for waste conditioning).

The inputs will be integrated into an overview per country, in the form of a summary table or other. This work will not require an analysis, nor will it involve a meeting/workshop. At the discretion of the participants in Subtask 4.1, this overview could involve a summary of identified commonalities like in THERAMIN. The output of subtask 4.1 is an internal memorandum, presenting the above mentioned overview per country.

Subtask 4.2 – Sharing experience on waste management with/without WAC available

Start: Month 6 – End: Month 29- Subtask Leader: [ONDRAF/NIRAS] [VTT (GSL)]

Subtask contributors: [ONDRAF/NIRAS] [VTT (GSL)] [TUS] [RATEN] [Andra] [IRSN] [CEA (ORANO)] [LEI] [INCT] [JSI (EIMV)] [CIEMAT] [SSTC NRS] [SÚRAO] [FTMC] [IST-LPSR] [NCSR] [EEAE] [GRS] [SURO]

Total PM: 14,4

This subtask will provide a GAP-analysis of different approaches of waste management while maintaining compatibility with the option(s) for disposal. This will offer a structured approach to support decision-taking of “no regret” waste management measures.

The input of subtask 4.2 consists of :

- Case descriptions, per country, of waste conditioning without a final disposal solution being available. Only challenging wastes (identified in Task 2) should be considered. Each description will comprise a summary of lessons learned. The descriptions will be based on a questionnaire. Organisations of the same country shall consult with their WMO (if participating) to provide a single input from their country;
- Case descriptions derived from a review of existing information available from e.g. NEA and IAEA;
- The 1st memorandum (i.e. output of subtask 4.1).

Based on this input, a comparative (GAP) analysis will be performed between the situation where final WAC for disposal are available (“ideal situation”) and the situation where only preliminary, draft or even no WAC for disposal are available. The GAP-analysis will make a distinction between routes leading to surface disposal and other routes. The analysis will identify differences and perceived shortcomings.

This comparative analysis will involve a workshop (in month 25). At the discretion of Task 1, this workshop could be organised together with a workshop of another task (e.g. Task 2).

The output of subtask 4.2 is a second internal memorandum, summarising the workshop outcomes.

Subtask 4.3 – R&D needs and opportunities of collaboration

Start: Month 29 – End: Month 40- Subtask Leader: [ONDRAF/NIRAS] [VTT (GSL)]

Subtask contributors: [INCT] [ONDRAF/NIRAS] [VTT (GSL)] [TUS] [Andra] [IRSN] [CEA (ORANO)] [LEI] , [JSI (EIMV)] [CIEMAT] [SSTC NRS] [SÚRAO] [FTMC] [RATEN] [NCSR] [EEAE] [GRS] [SURO] [STUBA]

Total PM: 15,6

This subtask will identify and prioritise common R&D needs related to the management of challenging wastes and identify opportunities of collaboration between Member-States. This subtask will also integrate the overall results of Task 4 and document these in a deliverable report.

The inputs of subtask 4.3 consists of:

- Identification, per country, of R&D needs with respect to the management of challenging wastes (belonging to the list identified in Task 2), particularly in relation to the conditioning of waste while maintaining compatibility, with the option(s) for disposal. Organisations of the same country shall consult with their WMO (if participating) to provide a single input from their country.
- The 2nd memorandum (i.e. output of subtask 4.2).

Based on this input, a workshop will be held (Month 33) to:

- Assimilate and prioritise the R&D needs
- Identify opportunities for collaboration between organisations of different Member-States

The outcome of the workshop will be summarised in a third internal memorandum.

Consequently, the outputs of subtasks 4.1, 4.2 and 4.3 will be combined into one deliverable report D9.9.

Task 5 - RWM solutions for small amounts of wastes

Start: Month 6 – End: Month 36 - Task Leader: [NCSR] (DMT)] and [SURO]

Task contributors: [EEAE] [GRS] [INCT] [IST-ID] [IST-LPSR] [JSI] [NCSR] (DMT)] [NES] [SURO]

Total PM: 25,3

Task objectives

Disposal strategies established by SIMS are often less advanced. These countries have small amounts of waste from research reactors and from medicine, industry and research but not from nuclear power plants. Commensurate solutions are mostly not available for these countries, regarding safety, time and costs. Often, these countries have not the expertise for planning, licensing, erection, operation and closure of a disposal facility. Downscaling of disposal concepts for disposal of small amount is failing and special concepts for SIMS are needed.

• Collection, analysis and comparison of the actual existing knowledge about disposal options for small amounts of waste. This will be complementary to the relevant IAEA project taking into account the results of a planned IAEA consultancy meeting about disposal options for small radioactive inventories in Sept. 2018 and a Technical Meeting planned for mid-2019. The work of IAEA is based only on the contributions of their Member-States. Therefore, participants of this task will actively take part as IAEA Member-States in this IAEA project.

- Description of the necessary predisposal routes for the disposal options
- Evaluation of the possible small-scale disposal solutions and description of their positive and negative aspects, knowledge and experience will be reviewed in order to identify knowledge gaps
- Dissemination of the results to other SIMS and description of the spin off for countries with large amounts of radioactive waste

- Identification of R&D gaps

Subtask 5.1 – Collecting and analysing actual existing knowledge about disposal options for SIMS

Start: Month 6 – End: Month 24- Subtask Leader: [NCRSD (DMT)] and [SURO]

Subtask contributors: [NCRSD (DMT)] [SURO] [NES] [JSI] [INCT] [GRS] [EEAE] [IST-LPSR] [IST-ID]

Total PM: 15

This subtask needs some of the results of subtask 2.1 and 2.2, as well as information from the questionnaire with regard to information from SIMS. The waste data can be completed by data for non-problematic waste for SIMS, if not already available, to get a reliable basis for the required size of a disposal facility. Information from EC Candidate Countries with small inventory of radioactive waste will be included if available.

Several options are in principle suitable. These options might be (listed here with increasing depth from the surface):

- a long-term interim storage on surface for decay to reduce the amount of waste [NES]
- a disposal near surface e.g. in silo-type facilities, shallow borehole (some tens meters), bunkers and caverns underground [JSI] supported by [SURO]
- a disposal in old mines, tunnels, deep shafts or boreholes adjusted to amount and activity (some 100 meter) [NCRSD (DMT)] supported by [SURO]
- a very deep borehole disposal (some km) [GRS]

In some countries like Denmark and Norway first conceptual designs up to already operating facilities are existing. These options have to be collected together with studies for other options being still under discussion. This will also include a consideration of combinations of the disposal options mentioned above. This work will be performed complementary to the relevant IAEA project.

For this purpose, two workshops will be organised (months: 7 and 16).

The results and outputs of Task 5.1 will be compiled in a final report D9.10

Subtask 5.2 – Describe the necessary predisposal routes for the disposal options of subtask 5.1

Start: Month 18 – End: Month 36- Subtask Leader: [NES] and [NCRSD (DMT)]

Subtask contributors: [NES] [NCRSD (DMT)] [SURO] [IST-LPSR] [EEAE] [GRS] [JSI]

Total PM: 10,3

Using the information on waste volumes and characteristics from task 2, questionnaire and if necessary the information generated in subtask 5.1, an evaluation will be made available predisposal routes coming from subtask 2.2, which are suitable even without WAC. For this purpose, a workshop will be organised (month: 30). The report of the workshop is the deliverable of this subtask.

The scope of this subtask is not within the scope of the planned activities of IAEA for small inventories.

The results and outputs of Task 5.2 will be compiled in a final report D9.11

Task 6 – Shared solutions in European countries (start Month: 1 – end Month: 42)

Start: Month 1 – End: Month 42 - Task Leader: [COVRA]

Task contributors: [ARAO] [CEA (ORANO)] [CIEMAT] [COVRA] [DEKOM] [EEAE] [FTMC] [JUELICH] [IRSN] [IST-ID] [IST-LPSR] [JSI (EIMV)] [NCRSD (DMT)] [NES] [NJF] [SKB] [SSTC NRS] [SURO] [VTT (GSL)]

Total PM: 29,6

Task objectives

- Describe and assess knowledge on and approaches to sharing technology and facilities between Member-States.
- Provide an overview of the interest in and experience with sharing technology/facilities in the different steps of waste management.
- Identify gaps and define needs for R&D, strategic priorities and opportunities for collaboration between Member-States, as applied to challenging wastes as defined in task 1 and early stage RWM programmes and Small Inventory Programmes.

Subtask 6.1: State of the art on shared development and use of technologies and facilities

Start: Month 1 – End: Month 12- Subtask Leader: [COVRA] and [Dekom]

Subtask contributors: [COVRA] [DEKOM] [ARAO] [JUELICH] [SSTC NRS] [CIEMAT] [SKB] [EEAE] [NCRSD (DMT)] [NES] [SURO] [IRSN] [JSI (EIMV)] [FTMC] [IST-LPSR] [VTT (GSL)] [CEA (ORANO)]

Total PM: 5,5

Summarise EC and IAEA studies on shared development and use of technologies and facilities for characterisation, treatment, storage and disposal. Summarise any existing or planned sharing of facilities between Member-States.

Activities:

1) Review EC projects (including SAPIERR, SAPIERR II, Chance, Theramin) and IAEA studies on the topic, based in part on contributions of organisations involved in (previous or ongoing) projects on the development of shared solutions for radioactive waste.

2) Review the National Programmes submitted to the EC that describe existing and planned waste management routes in Member-States, to indicate interest in shared development and use of technologies and facilities. Obtain information from participating organisations on such sharing.

The output of subtask 6.1 is D9.12, which will document and integrate the internal report. It will provide a state-of-the-art of the European experience in developing shared solutions for radioactive waste management. A workshop will be organized for this subtask (month 7).

Subtask 6.2: Case studies on shared development and use of technologies and facilities.

Start: Month 13 – End: Month 30- Subtask Leader: [COVRA] and [CEA (ORANO)]

Subtask contributors: [CEA (ORANO)] [JSI (EIMV)] [VTT (GSL)] [DEKOM] [ARAO] [JUELICH] [SSTC NRS] [CIEMAT] [SKB] [EEAE] [NCRSD (DMT)] [NES] [SURO] [IRSN] [FTMC] [IST-LPSR] [COVRA] [STUBA]

Total PM: 10

Document experience of Member-States in sharing technologies and facilities.

Activities:

1) Participants are asked to prepare a general description with:

a) their experience with sharing (one or more cases), for example:

i) treatment, conditioning, storage and disposal of waste from/in other Member-States,

ii) mobile technologies for waste characterisation, treatment and conditioning.

b) the lessons learned.

i) Participants from the same country are requested to coordinate with each other, in order to provide one contribution per country.

2) A workshop (in month 19), in which participants will:

a) review the interest in sharing,

b) examine the experience,

c) analyse the requirements for this to take place, and

d) assess the feasibility.

The output of subtask 6.2 is D9.13, which reports on the results of the workshop.

Subtask 6.3: Assess the feasibility of developing further European shared solutions for waste management from cradle to grave

Start: Month 25– End: Month 42- Subtask Leader: [COVRA] and [CEA (ORANO)]

Subtask contributors: [COVRA] [CEA (ORANO)] [VTT (GSL)] [DEKOM] [ARAO] [JUELICH] [SSTC NRS] [CIEMAT] [SKB] [EEAE] [NCRSD (DMT)] [NES] [SURO] [IRSN] [JSI (EIMV)] [FTMC] [IST-LPSR] [IST-ID] [STUBA]

Total PM: 14,1

A gap analysis will be performed whereby the interests and needs of Member-States to share technologies and facilities from cradle to grave is compared with present and past experience in Europe. A comparison and assessment will be made of possible approaches to and structures for sharing of characterisation, conditioning, storage and disposal technologies and facilities. A specific focus will be given to the challenging waste defined in task 1 and LAPs. The identified gaps will be examined in a workshop to define needs for R&D, strategic priorities and opportunities for collaboration.

Activities:

1) A gap analysis is conducted using the outputs the Subtask 6.1 and 6.2 and tasks 2-4(5):

a) Outputs of Task 2 will enable assessment of the level of interest in developing shared solutions for waste for which there is not yet a complete management plan and to identify the R&D needs for further development

b) Outputs of Task 3 will enable identification of R&D needs and opportunities for the development of shared characterisation approaches, techniques or shared (common or centralised) laboratories for specific type of waste or radionuclides

c) Outputs of Task 4 will enable identification of R&D opportunities and needs of shared approaches or facilities for waste management routes or waste streams and/or countries for which there are no applicable WAC

2) A workshop will be held to:

a) Discuss the gap analysis

b) Assimilate the R&D needs and strategic priorities

c) Prioritise the R&D needs according to potential for challenging waste and LAPs

d) Identify opportunities of collaboration between (organisations from) the Member-States.

The workshop (in month 36) will involve the same participants as in the workshop of subtask 6.2.

The output of subtask 6.3 is D9.14.

Task 7 – Interactions with Civil society

Start: Month 1 – End: Month 60 - Task Leader: [IRSN (NTW)]

Task contributors: [IRSN (NTW)] [JSI (EIMV)]

Total PM: 6,6

In the framework of EURAD, the broader objectives and approach of the interactions with Civil Society are described under Section 3.1.e.

Task objectives

- To facilitate the translation of scientific/technical results of the WP to allow effective interaction with CS group
- To create the conditions for the CS Group to express their expectations or views in link with the topic addressed in the ROUTES WP.
- To improve the mutual understanding on the RD&D needed to develop safe acceptable solutions in the processing and disposal of radioactive waste.

Task 7 will be carried out by CS experts interacting with the CS Group according to the methodology described under Section 3.1.e. of EURAD description.

The work within task 7 will be carried out in three subtasks.

The CS experts will work in an organised process together with representatives from WMOs, TSOs and REs in the tasks 2-6 of the WP as described in the subtasks below.

Subtask 7.1– Scoping of ROUTES tasks 2-6, initial input from the CS experts and development of Interaction with Civil Society (ICS) action plan

Start: Month 1– End: Month 12 - Task Leaders: [JSI (EIMV), [IRSN (NTW)]

Subtask contributors: [JSI (EIMV), [IRSN (NTW)]

Total PM: 1,6

The inception phase of the WP will be an opportunity for CS experts to better apprehend and scope the subjects and activities performed in ROUTES tasks 2-6. During the first year subtask 7.1 will perform a scoping of the objectives and actions in ROUTES tasks 2-6 in order to identify issues that are deemed of more specific interest in the perspective of developing interactions between civil society and EURAD partners along the course of the WP. This will be done in dialogue and collaboration between the CS Experts and scientific/technical experts from WMOs, TSOs and REs in the WP.

Part of the work of the CS experts will be to analyse the ROUTES WP in a larger context - how is it related to on-going RWM activities and connected with disposal projects and the challenges they are facing. The CS experts will attend the kick-off meetings of EURAD and the WP in Month 1 and representatives of task 7 will attend a selection of task 2-6 meetings during Month 1-11.

The scoping exercise carried out during the first year will give the CS experts the possibility to identify specific interests and actions that will allow greater input and participation in the WP. Although it is too early to know exactly what topics the CS experts in consultation with the CS group will identify as especially interesting, possible topics include the comprehension of RD&D activities and strategic needs required for implementation of the different spent fuel and radioactive waste management and disposal routes in Europe, radioactive waste management options for unusual or small amounts of wastes, and an analysis of the advantages and disadvantages of shared radioactive waste management option in Europe.

The result will be described in an ICS action plan. Therefore, the focus of the work of task 7 will be primarily oriented each year (year 2, 3 and 4) to a specific topic as selected in the development of the action plan.

As part of the subtask there will be a dedicated meeting in Month 8 involving CS experts and a panel of WMOs, TSOs and REs representatives from tasks 2-6 is foreseen in order to discuss the draft ICS action plan (at least by videoconference). In addition, Task 7.1 will organise a dedicated ROUTES session within the ICS workshop (Year 1) organised at EURAD level by the PMO WP task 8.

There will be a Deliverable 9.15 “Scoping of ROUTES, initial ICS input and ICS action plan” in Month 11.

The results of the task will be presented at the first WP annual meeting (Month 12) within a specific session (CS experts + WP Board) including attendance from members of the CS group (Month 12).

Subtask 7.2– Implementing ICS action plan

Start: Month 13– End: Month 48 - Task Leaders: [JSI (EIMV), [IRSN (NTW)]

Subtask contributors: [JSI (EIMV)] [IRSN (NTW)]

Total PM: 3,4

Subtask 7.2 will implement the ICS action plan (D9.15). Interactions involving both the CS group and a panel of WMOs, TSOs and REs will be steered by the CS experts on the yearly specific topics (year 2, 3 and 4) identified in the ICS action plan.

The subtask will contribute to enhance mutual understanding and dialogue skills among the different categories of participants. The CS experts will continuously follow, discuss tasks 2-6 in the work package and the results (with a

focus on each of the yearly specific topics). This will be done in dialogue and collaboration between the CS Experts and scientific/technical experts from WMOs, TSOs and REs in the WP.

CS experts will, with reservation about available resources, attend the meetings of other tasks, and comment the most relevant deliverables from tasks 2-6 of the WP (preferably in the draft versions).

In order to better support interactions with the CS group, Task 7.2 will organise a dedicated ROUTES session within the ICS workshops (year 2, 3 and 4) organised at programme level by the PMO WP task 8.

At each annual WP meeting (Month 24, Month 36, Month 48) the CS experts will present the progress of their work including comments, suggestions, questions and other observations.

These activities will bring the opportunity to present the work achieved and discuss the results.

Yearly feedback to ROUTES 2-6 tasks will be organised by subtask 7, providing them with an input on the first and second specific topics identified in the ICS action plan (D9.16, D9.17, D9.18).

Subtask 7.3– Synthesis work and dissemination

Start: Month 49– End: Month 60 - Task Leaders: [JSI (EIMV), [IRSN (NTW)]

Subtask contributor: [JSI (EIMV)] [IRSN (NTW)]

Total PM: 1,6

Towards the end of the WP, the CS experts will summarise the conducted work in task 7 and documentation will be done of the interaction framework developed in the work package. This will be done in dialogue and collaboration between the CS Experts and scientific/technical experts from WMOs, TSOs and REs in the WP.

Task 7.3 will organise a dedicated ROUTES session within the ICS workshops (year 5) organised at programme level by the PMO WP task 8

D9.19 will be a synthesis report of the work and results of task 7 including the documentation of the interaction framework developed and used, including recommendations for future CS interaction.

The results and deliverable D9.19 will be presented at the final WP annual meeting.

Task 7.3 will contribute to a popularised description of the results of the WP in collaboration with the other tasks in the WP and the KM WP (D9.20).

Subtask 7.4 – Interactions with Civil Society (ICS) within the ROUTES Extension

Start Month 25 – End Month 60 – Subtask leader : [IRSN (NTW)]

Total PM: 1

In the framework of EURAD, the broader objectives and approach of the interactions with Civil Society (ICS) are described under Section 3.1.e. in the EURAD GA Annex 1 - Description of the action (part A).

Subtask objectives

- To facilitate the translation of scientific/technical results of the ROUTES WP, and in this case especially to allow effective interaction with civil society (CS)
- To create the conditions for the CS Experts and the CS Larger Group to express their expectations or views in link with the topics addressed in the ROUTES Extension Task 8.
- To improve the mutual understanding on the RD&D needed to develop safe acceptable solutions in the processing and disposal of radioactive waste.

Subtask implementation

Subtask 7.4 will be carried out by CS experts interacting with the CS Larger Group according to the methodology described under Section 3.1.e. of EURAD description.

The CS experts will work in an organised process together with representatives from WMOs, TSOs and REs in the same way that has been established in subtasks 7.1 and 7.2 in the ROUTES WP.

The inception phase of the WP will be an opportunity for CS experts to better apprehend and scope the subjects and activities performed in ROUTES Extension Task 8. During the first year of ROUTES Extension (month 25 – 36), subtask 7.4 will perform a scoping of the objectives and actions in ROUTES Extension subtasks 8.1 and 8.2 in order to identify issues that are deemed of more specific interest in the perspective of developing interactions between civil society and EURAD partners along the course of the ROUTES Extension Task 8. This will be done in dialogue and collaboration between the CS Experts and scientific/technical experts from WMOs, TSOs and REs in the ROUTES Extension Task 8. Part of the work of the CS experts will be to analyse the ROUTES Extension Task 8 in a larger context - how is it related to on-going RWM activities and connected with disposal projects and the challenges they are facing.

The scoping exercise carried out during the first year will give the CS experts the possibility to identify specific interests and actions that will allow greater input and participation in the ROUTES Extension Task 8. The result of the scoping with an action plan for work for years 2 and 3 will be reported as a new section of the already foreseen Deliverable D9.17 “Implementation of the ROUTES ICS action plan second phase – CS discussion and input focused on the second topic identified in the ICS action plan (task 7.2)” (due date M35) from the work of subtask 7.2.

During years two and three of the ROUTES Extension Task 8 (month 37 – 60), Subtask 7.4 will work together with subtasks 8.1 and 8.2 on issues in the action plan identified during the first year.

The subtask 7.4 will contribute to enhance mutual understanding and dialogue skills among the different categories of participants. The work will be done in dialogue and collaboration between the CS Experts and scientific/technical experts from WMOs, TSOs and REs in the ROUTES Extension Task 8.

Task 7.4 will contribute to the ICS larger group workshops organised at programme level by the PMO WP task 8.

The result of the work will be presented in a new section of the already foreseen deliverable D9.18 “Implementation of the ROUTES ICS action plan second phase – CS discussion and input focused on the second topic identified in the ICS action plan (task 7.2)” (due date month 47) from the work of subtask 7.2.

There will also be contributions to the deliverables of subtask 7.3 in ROUTES, i.e., in deliverable D9.19 “Final synthesis ROUTES report of the work and results of task 7 including the documentation of the interaction framework developed, including recommendations for future CS interaction” and deliverable D9.20 “Contribution to ROUTES factsheet presenting the results and outcomes of ROUTES and in a larger context” (both due date month 60).

Task 8 - ROUTES Extension on the evaluation of the possible waste management solutions for Member States without WAC and with small inventories (SIMS)

Start month 25 – End month 60

Total PM: 21.1

ROUTES Extension Task 8’s objectives are as follows:

- . Qualitative analysis and assessment of the predisposal routes of challenging waste for SIMS
- . Qualitative analysis and assessment of existing disposal options for SIMS
- . Analysis of the applicability of the disposal options for SIMS (e.g. inventory, costs, retrievability)
- . Preparation of two case studies showing typical waste pathways (predisposal routes and disposal option)
- . Interaction with KM WPs

Subtask 8.1 - Qualitative analysis of the predisposal routes

Start Month: 25 – End month: 44 – Subtask leader [NCSRD]

Subtask contributors: [ANDRA], [CIEMAT], [COVRA], [DEKOM], [EEAE], [GRS], [INCT], [IST], [IST-ID], [JSI (EIMV)], [LEI], [NCSRD (DMT)], [NES], [NJF], [ONDRAF/NIRAS], [RATEN], [SSTC NRS], [STUBA], [SURO], [UCY], [VTT (GSL)]

Total PM: 10.9

Subtask Objectives

Based on the results for SIMS of the work carried out in WP ROUTES – Task 2-6 regarding challenging wastes inventory, characterization topics, WAC, shared solutions etc., this subtask will qualitatively analyse predisposal routes in relation to waste type and activity (classification VLLW, LLW, ILW, HLW and challenging waste types in either class), compare how similar waste streams are managed in LIMS and determine opportunities for sharing in case national solutions are not adapted to small amounts of waste and cannot be implemented.

Part 8.1.1 - Extended analysis and assessment of existing predisposal routes for SIMS

Start: Month 25 – End: Month 36

Description of work:

Utilisation and assessment by the participants from SIMS of the available results of the initial ROUTES WP: tasks 2 (Challenging wastes), 3 (Waste Characterization), 4 (WAC), 6 (shared solutions) and taking into account specificities and needs of SIMS.

Best practices for predisposal routes for small amounts of waste will be selected. This can help SIMS to exclude not commensurate predisposal routes of radioactive waste as well as difficult to implement technology and/or determine opportunities for sharing.

This task will utilise the results of the initial WP ROUTES during the work phase until month 36. As a reminder, the WP ROUTES subtasks 2.1 “Collection and analysis of existing work on categorisation and classification of radioactive waste with regard to disposal options, identification of waste for which there is not yet a complete management plan in each Member State, identification of waste management routes for pre-disposal steps”, 3.1 “Radioanalytical characterization of radioactive waste and waste with complex/toxic properties”, 3.2 “Characterization and segregation of legacy waste”, 4.1 “Current use of waste acceptance criteria”, 4.2 “Sharing experience on waste management with/without WAC available”, 6.1 “State of the art on shared development and use of technologies and facilities” and 6.2 “Case studies on shared development and use of technologies and facilities” will be considered.

Two Task meetings/workshop will be held in M25 (MS246) and M33 (MS272).

Results will be integrated in an Internal memorandum (MS281) which will be further integrated in D9.21

Part 8.1.2 - Expansion of existing predisposal routes for SIMS with regard to disposal options

Start: Month 36 – End: Month 44

Description of work:

- Revise and expand the existing description of the predisposal routes considering the results of Part 8.1.1. Qualitative assessment of the predisposal routes based on the findings of WP ROUTES Subtask 5.2 of WP ROUTES which describe the necessary predisposal routes for the disposal options for SIMS and under consideration of the available results of the tasks 2, 3, 4 and 6 of WP ROUTES. The assessment will be done regarding the necessary resources for implementation (i.e. infrastructures, specialized personnel, guidance development).
- Identification of implications of predisposal routes on the disposals options.

Deliverable D9.21

The results and outputs of the Part 8.1 are compiled in a draft report (MS289) of Deliverable 9.21: “Evaluation of existing predisposal routes for SIMS with regard to disposal options”.

Subtask 8.2 - Qualitative analysis of the disposal options

Start month : 25 – End month : 55 – Subtask leader: [NCSR D (DMT)]

Subtask contributors: [ANDRA], [COVRA], [DEKOM], [EEAE], [GRS], [INCT], [IST], [IST-ID], [JSI (EIMV)], [LEI], [NCSR D (DMT)], [NES], [NJF], [ONDRAF/NIRAS], [RATEN], [STUBA], [SURO], [UCY], [VTT (GSL)]

Total PM: 10.2

Subtask Objectives

Based on the results of WP ROUTES Task 5.1 and ROUTES Extension Subtask 8.1 this subtask will analyze possible disposal options in relation to the implementation of different predisposal routes. This also includes an analysis regarding the influence of the disposal option (borehole, used mine, silo) on the cost of the facility itself as well as in relation to the cost for conditioning of challenging waste.

The accessible recommendation and guidance available will be considered (as IAEA, NEA) and related national reports, as well.

Part 8.2.1 - Extended analysis and assessment of existing disposal options for SIMS in relation to pre-disposal options

Start: Month 25 – End: Month 52

Description of work:

Qualitative assessment of all relevant disposal options considering the results of task 5.1 (ROUTES)

The information and knowledge gathered from Subtask 5.1 and 8.1 on how similar waste streams are managed in different countries (including lessons learnt) will be used. Furthermore, an exercise will be carried out to identify the relevant technologies for disposal options against identified problematic waste stream so to make a first selection of possible technologies to effectively identify and eliminate any disposal options that are immediately apparent as unworkable for SIMS.

Evaluation of the impacts of the waste and the predisposal routes on the disposal options. Consideration of the combination of different disposal options. The evaluation will be performed by using the same structured approach to identify suitable solutions for an aligned RWM strategy. Therefore, the boundary conditions and effects of the waste (physical, chemical and radiological condition), predisposal routes (treatment and packaging) and disposal options (disposal facility) as well as impact on environment and if applicable social aspects are contrasted to each other. Best practice strategies and exclusion criteria for specific combinations of waste, treatment and disposal are derived from the results.

Analysis of the applicability of the disposal options for SIMS (e.g. inventory, costs, retrievability)

Besides the technical considerations of the waste, the treatment and the disposal options, the aspects costs, retrievability, environmental are important issues that will be explored in this analysis. Furthermore Member States’ specific issues are included (e. g. the absence of used mines as possible disposal facility).

SIMS and LIMS can use the results as a guidance to find their most suitable solution(s) - like taking the right tool from a tool box - and developed an aligned RWM strategy for their waste.

Identification of R&D gaps of the waste routes, e. g. disposal of challenging wastes which do not fit into the interplay of considered disposal options and predisposal routes.

A kick off meeting will be held in M25 (MS246) and a two subtask meetings/workshops will be held in M30 (MS289) and in M38 (MS284).

The outputs of this analysis will be integrated into an Internal Memorandum (MS306) for the summary report (D9.22).

Part 8.2.2 - Case studies and summary report

Start: Month 45 – End: Month 55

For a better understanding of the application of the tool box with the different predisposal routes and the disposal options, two case studies will be conducted. Two waste families are selected whose management (predisposal route and disposal option) are different and whose requirements already cover a large part of other waste families (i.e. different order of

magnitude of mass specific activity of long lived radionuclides which mean respectively GBq/g or MBq/g as well as waste containing Ra-226). Therefore, the following two waste families were selected for the case studies based on the discussions during the workshop of task 5 and task 3 of ROUTES from 9 to 11 Dec 2020:

Activated control rods from research reactors and

Lightning rods containing radioactive sources with e.g. Am-241 and Ra-226.

Before starting to work on the case studies in month 46, the planned case studies are checked against the results of subtask 4.2 (available from month 29), of subtask 5.2 (available from month 36) of task 6 (available from month 42) and new information from IAEA about predisposal management and WAC. If the results of these tasks indicate that there are case studies that are more relevant for SIMS, the selection of case studies can be changed. The necessary discussion and final selection of case studies will take place at the task meeting in month 45 (MS294).

These two waste families are selected because they cover a large number of other waste families regarding different mass specific activities of long lived and in case of Ra-226 lightning rods, waste families which should be monitored during storage for airborne radioactivity production.

Both represent challenging wastes. The main requirements for and properties of these two waste families are listed in the following table:

Nuclide inventory :

Activated control rods : Long lived activation products in neutron absorber and cladding material through neutron capture during use. Contaminated surface with fission products and alpha-emitters/nuclear fuel.

Lightning rods: Sources with Am-241 and Ra-226 with different activities

Waste volume

Activated control rods : Only a few control rods per research reactor.

Lightning rods: Large number of lightning rods per state (usually some hundreds or some thousands).

Dismantling and treatment

Activated control rods : Dismantling, treatment and packaging under water or in a hot cell due to very high dose rates.

Possible separation of higher and lower activated parts. Lightning rods: On-site dismantling without additional shielding due to lower dose rates. Separation of the sources from the other material.

Interim storage

Activated control rods : High activated parts only in shielded packages. Lower activated parts can maybe be stored in containers depending on activity and dose rate.

Lightning rods: Drums or containers. Depending on the amount of material and packaging, additional shielding is necessary. Airborne radioactivity precaution in case of Ra-226 lightning rods (Rn-222 production).

Disposal

Activated control rods : Deep Geological Disposal

Lightning rods: Long term stable disposal due to long half-lives. Compared to the activated control rods, shallow depth disposal possible.

The case studies will be prepared in cooperation with the CS experts and the relevant members of the CS Larger Group from Task 7: "Interaction with Civil Society (ICS)". In Task 7, Subtask 7.4: "Interactions with Civil Society (ICS)" within the ROUTES Extension will be established to accompany the ROUTES Extension, so that the concerns of ICS are also taken into account.

The IAEA works with different teams on similar topics as in ROUTES and ROUTES Extension. Therefore, close cooperation is not only useful but also necessary. In the course of ROUTES Task 5 so far, the IAEA has already been involved. IAEA representatives attended the workshop (ROUTES TASK 3 and Task 5) held in December 2020, where the findings in the field of disposal options were exchanged and further cooperation was discussed. As this cooperation has been recognized as helpful from both sides, it will be continued for the upcoming work in ROUTES Extension and expanded to the IAEA work on the topic of predisposal routes and WAC. With the involvement of IAEA representatives in the relevant workshops and meetings of ROUTES Extension, information from the IAEA can also be included in the final selection of case studies. The IAEA has already emphasised that the results of ROUTES and ROUTES Extension are a valuable addition to its work.

Summary Report

- Integration of Task 8 work results
- Task 8 Summary report development

Deliverable D9.22: Summary report on analysis, assessment and evaluation of disposal options for SIMS (taking into account both potential disposal options and predisposal routes), including Annex: Case studies on typical waste pathways

Part 8.2.3 - Dissemination activities and development of guidance in interaction with KM WP

Start Month: 25 – End month: 55

Two Workshops (MS298 and MS309) will be organised (SIMS and LIMS interaction):

- First Workshop with limited participants (Routes Extension and interested LIMS), with the option to give feedback for the final preparation of D 9.1E

Key topics to be discussed in the WS

- o The comparison of the different types and amounts of waste between SIMS and LIMS from initial ROUTES WP will be utilized (D9.10 subtask 5.1).

- o Identification of boundary conditions regarding the LIMS's waste and requirements for the disposal (e.g. long term safety, radiation protection).

- o Identification of applicable results and findings.

- o Presenting advanced possible solutions for disposal of small amounts of waste not in line with WAC of the existing/ planned disposal facilities of LIMS (e.g. after closure of disposal facilities) or for decay storage.

The results and outputs of the workshops are documented with Minutes of the WSs, with the presentations in Annex.

- Second Workshop (MS310) to transport the results to all interested participants of EURAD. It aims to disseminate results of Task 8. Also interested guests from outside of EURAD will be invited, as the IAEA, NEA. The draft of deliverable D9.22 shall be discussed during the second workshop. Therefore, the draft of D9.22 needs to be available short before the second workshop (MS310).

Interaction with KM WPs

The interaction with KM WPs will be performed at coordination level (see description of additional work in Task 1)

In the framework of Task 8 some specific guidance taking into account the methodology and the lessons learnt in the whole task and more specifically in the Case Studies Part 8.2.2 will be integrated in a Guidance Document developed together with KM WPs.

Participation per Partner

Partner number and short name	WP9 effort
1 - ANDRA	6.40
2 - ARAO	1.20
3 - BEL V	0.30
5 - CEA	0.00
Orano	6.30
6 - CIEMAT	7.00
9 - COVRA	4.40
10 - FTMC	3.10
12 - Dekom	2.40
13 - EEAE	3.50
15 - JUELICH	6.00
16 - GRS	3.10
17 - IAE	1.10
18 - INCT	6.00
19 - IRSN	9.59

Partner number and short name	WP9 effort
NTW	5.90
20 - IST	4.80
21 - IST ID	4.80
22 - JSI	2.20
EIMV	8.40
25 - LEI	2.30
28 - NCSR	7.40
DMT	11.30
29 - NES	5.97
30 - NJF	1.90
31 - NRG	0.30
32 - ONDRAF/NIRAS	5.90
36 - RATEN	4.00
38 - SCK•CEN	1.30
39 - SKB	1.70
40 - SSTC NRS	10.50
41 - STUBA	3.60
42 - SÚRAO	1.90
43 - SURO	10.70
45 - TS Enercon	0.30
46 - TUS	4.90
47 - UCyprus	1.30
50 - VTT	0.00
GSL	8.60
51 - VUJE	2.00
Total	172.36

List of deliverables

Deliverable Number ¹⁴	Deliverable Title	Lead beneficiary	Type ¹⁵	Dissemination level ¹⁶	Due Date (in months) ¹⁷
D9.1	ROUTES - Training materials	19 - IRSN	Report	Public	60
D9.2	ROUTES - Recommendations for future RD&D, strategic study and KM activities	19 - IRSN	Report	Public	18

List of deliverables

Deliverable Number¹⁴	Deliverable Title	Lead beneficiary	Type¹⁵	Dissemination level¹⁶	Due Date (in months)¹⁷
	for the 2nd wave of EURAD-1				
D9.3	ROUTES - Recommendations for future RD&D, strategic study and KM activities for future European collaboration	19 - IRSN	Report	Public	58
D9.4	ROUTES - Overview of existing work on categorization/ classification of RWs in participating states	1 - ANDRA	Report	Public	10
D9.5	ROUTES - Overview of issues related to challenging wastes	1 - ANDRA	Report	Public	24
D9.6	ROUTES - Common understanding of the practical issues on waste management routes	1 - ANDRA	Report	Public	48
D9.7	ROUTES - Review of radioanalytical characterisation of selected radioactive wastes and wastes with complex chemical and toxic properties	15 - JUELICH	Report	Public	24
D9.8	ROUTES - Review of characterization of legacy and historical wastes	15 - JUELICH	Report	Public	33
D9.9	ROUTES - Report suggestions for the management of challenging wastes while maintaining compatibility with the option(s) for disposal	50 - VTT	Report	Public	40
D9.10	ROUTES - Report about the knowledge for existing and potential disposal options for SIMS	28 - NCSR	Report	Public	24
D9.11	ROUTES - Report presenting the results of the workshop dealing with possible	29 - NES	Report	Public	36

List of deliverables

Deliverable Number¹⁴	Deliverable Title	Lead beneficiary	Type¹⁵	Dissemination level¹⁶	Due Date (in months)¹⁷
	conditioning routes for SIMS				
D9.12	ROUTES - Studies and plans for developing shared solutions for radioactive waste management in Europe	9 - COVRA	Report	Public	12
D9.13	ROUTES - Case studies of shared development and use of technologies and facilities	5 - CEA	Report	Public	24
D9.14	ROUTES - Report on the feasibility of developing further European shared solutions for waste management from cradle to grave	9 - COVRA	Report	Public	42
D9.15	Scoping of ROUTES, initial CS input and ICS action plan (task 7.1)	22 - JSI	Report	Public	11
D9.16	Implementation of the ROUTES ICS action plan first phase - CS discussion and input focused on the first topic identified in the ICS action plan (task 7.2)	19 - IRSN	Report	Public	23
D9.17	Implementation of the ROUTES ICS action plan second phase - CS discussion and input focused on the second topic identified in the ICS action plan (task 7.2)	19 - IRSN	Report	Public	35
D9.18	Implementation of the ROUTES ICS action plan third phase - CS discussion and input focused on the third topic identified in the ICS action plan (task 7.2)	19 - IRSN	Report	Public	47
D9.19	Final synthesis ROUTES report of the work and results of task 7 including the documentation of the interaction framework developed, including	22 - JSI	Report	Public	60

List of deliverables

Deliverable Number ¹⁴	Deliverable Title	Lead beneficiary	Type ¹⁵	Dissemination level ¹⁶	Due Date (in months) ¹⁷
	recommendations for future CS interaction				
D9.20	Contribution to ROUTES factsheet presenting the results and outcomes of ROUTES and in a larger context	19 - IRSN	Report	Public	60
D9.21	ROUTES - Report on Evaluation of existing predisposal routes for SIMS with regard to disposal options. The final report is an updated version of the milestone MS289	28 - NCSR	Report	Public	44
D9.22	ROUTES - Summary report on analysis, assessment and evaluation of disposal options for SIMS (taking into account both potential disposal options and predisposal routes) including Annex: C case studies on typical waste pathways. The final report is an upda	28 - NCSR	Report	Public	55

Description of deliverables

Deliverables (brief description and month of delivery)

- D9.1 - ROUTES Training materials (Lead organisation: IRSN. Due month: 60)
- D9.2 - Recommendations for future RD&D, strategic study and KM activities for the 2nd wave of EURAD-1: This deliverable identifies the needs for future RD&D, strategic study and KM activities for the 2nd wave of EURAD-1 that arise from the WP activities carried out during the first 18 months. Lead organisation: IRSN. Due month: 18.
- D9.3 - Recommendations for future RD&D, strategic study and KM activities for future European collaboration: This deliverable identifies the needs for future RD&D, strategic study and KM activities for a possible EURAD-2 that arise from the WP activities. Lead organisation: IRSN. Due month: 58.
- D9.4 - Overview of existing work on categorization/classification of RWs in participating states (Andra, SSTC NRS; draft version: Month 6; final version: Month 10)
- D9.5 - Overview of issues related to challenging wastes (Andra, SSTC NRS; Month: 24) This deliverable provides a comprehensive list of challenging wastes taking into account the situation in participating Member-States. It describes the particular problems to be solved for these wastes taking into account pre-disposal and disposal steps. A preliminary draft of the deliverable will be available at month 13 in order to provide information to other tasks
- D9.6 - Common understanding of the practical issues on waste management routes (Andra, SSTC NRS; Month: 48) This final deliverable identifies practical issues and R&D needs on the basis of current knowledge on waste inventories, classification, pre-disposal steps and disposal.
- D9.7 - Review of radioanalytical characterisation of selected radioactive wastes and wastes with complex chemical and toxic properties. This deliverable corresponds to the completion of subtask 3.1. and provides for a comprehensive radioanalytical description of properties of radioactive wastes taking into account particular situations in Member-

States. It describes particular problems to be solved for these wastes in the context of conditioning and disposal approaches. D3.1 will be coordinated by [JUELICH] due date 24 months.

- D9.8 - Review of characterization of legacy and historical wastes. This deliverable consolidates information on characterization approaches for historical and legacy wastes, and data on waste inventory, and provide good practice on handling and conditioning for disposal. D3.2 will also indicate existing issues and knowledge gaps in characterization of legacy and historical wastes, providing suggestions for solving these issues and closure of knowledge gaps, where appropriate. Lead organisation: [JUELICH] due date: Month 33
- D9.9 - Report suggestions for the management of challenging wastes while maintaining compatibility with the option(s) for disposal. This report will i) give an overview of the current application in Member-States of WAC at different stages in the waste lifecycle ; ii) identify differences and perceived shortcomings of different approaches of waste management while maintaining compatibility with the option(s) for disposal; iii) Support decision-taking of “no regret” waste management measures; iv) identify and prioritise common R&D needs related to the management of challenging wastes and v) Identify opportunities of collaboration between Member-States - Lead organisation: [VTT (GSL)] - Due month: 40
- D9.10 - Report about the knowledge for existing and potential disposal options for SIMS. This report will be based on a collection of IAEA standards, guidelines and TecDocs related to small amounts of radioactive waste, which will soon be published. It will also take into account the results of an IAEA Consultancy Meeting about disposal options for countries with small inventories planned for 2018 and a Technical Meeting for the same issue planned for Mid of 2019. This report will also list further needs of R&D in this issue. Lead organisation [NCSR] due month: 24
- D9.11 - Report presenting the results of the workshop dealing with possible conditioning routes for SIMS. Especially, Austria (NES) can demonstrate their best practice as an example for other SIMS. All participants can evaluate these different conditioning processes for their needs and contribute their own experiences and needs. Results will be given in a report. Lead organisation: NES - due month: 36
- D9.12 - Studies and plans for developing shared solutions for radioactive waste management in Europe - This deliverable summarises the knowledge on and approaches to sharing technology and facilities between Member-States. It also provides an overview of the plans of Member-States for shared solutions in different steps of the waste lifecycle. lead organisations: [COVRA] due month: 12
- D9.13 - Case studies of shared development and use of technologies and facilities. This deliverable i) provides practical examples of shared solutions in the different steps of the waste management lifecycle, ii) analyses the requirements for this to take place and iii) makes general observations and draw conclusions about feasibility (from reviewing Member-States’ inputs) and gives an overview the different approaches (summarising the most pertinent information). lead organisation: [CEA (ORANO)] due month: 24
- D9.14 - Report on the feasibility of developing further European shared solutions for waste management from cradle to grave. This deliverable will integrate DX.X and DX.X and will also include a chapter on R&D needs, opportunities. It will i) document the performed gap analysis for the development of shared European facilities for characterisation, treatment, conditioning, storage and disposal of radioactive wastes; ii) identify and prioritise strategic priorities and R&D needs related to the management of challenging wastes; iii) Identify opportunities for collaboration between Member-States with respect to this R&D and iv) Give a common vision and the work to be done for sharing knowledge and developing facilities between Member-States. lead organisation: [COVRA] due month: 42
- D9.15 - Scoping of ROUTES, initial CS input and ICS action plan (task 7.1) - Lead organisations: [JSI (EIMV)] - Due month: 11
- D9.16 - Implementation of the ROUTES ICS action plan first phase - CS discussion and input focused on the first topic identified in the ICS action plan (task 7.2) - Lead organisations: [IRSN (NTW)] - Due month: 23
- D9.17 - Implementation of the ROUTES ICS action plan second phase - CS discussion and input focused on the second topic identified in the ICS action plan (task 7.2) - Lead organisations: [IRSN (NTW)] - Due month: 35
- D9.18 - Implementation of the ROUTES ICS action plan third phase - CS discussion and input focused on the third topic identified in the ICS action plan (task 7.2) - Lead organisations: [IRSN (NTW)] - Due month: 47
- D9.19 - Final synthesis ROUTES report of the work and results of task 7 including the documentation of the interaction framework developed, including recommendations for future CS interaction - Lead organisations: [JSI (EIMV)] - Due month: 59
- D9.20 - Contribution to ROUTES factsheet presenting the results and outcomes of ROUTES and in a larger context - how is it related to on-going RWM activities and connected with disposal projects and the challenges they are facing their impact on implementation, safety, governance, route – this deliverable is intended for the general public and will be prepared based on the material/documentation provided to the CS Group - Lead organisation: [IRSN (NTW)] - Due month: 60
- D9.21 - ROUTES - Report on Evaluation of existing predisposal routes for SIMS with regard to disposal options. The final report is an updated version of the milestone MS289 - Lead organisation: [NCSR] - Due month: 44

• D9.22 - ROUTES -Summary report on analysis, assessment and evaluation of disposal options for SIMS (taking into account both potential disposal options and predisposal routes) including Annex: C case studies on typical waste pathways. The final report is an updated version of the milestone MS310 - Lead organisation: [NCSRD (DMT)] - Due month: 55

D9.1 : ROUTES - Training materials [60]

ROUTES - Training materials

D9.2 : ROUTES - Recommendations for future RD&D, strategic study and KM activities for the 2nd wave of EURAD-1 [18]

ROUTES - Recommendations for future RD&D, strategic study and KM activities for the 2nd wave of EURAD-1

D9.3 : ROUTES - Recommendations for future RD&D, strategic study and KM activities for future European collaboration [58]

ROUTES - Recommendations for future RD&D, strategic study and KM activities for future European collaboration

D9.4 : ROUTES - Overview of existing work on categorization/classification of RWs in participating states [10]

ROUTES - Overview of existing work on categorization/classification of RWs in participating states

D9.5 : ROUTES - Overview of issues related to challenging wastes [24]

ROUTES - Overview of issues related to challenging wastes

D9.6 : ROUTES - Common understanding of the practical issues on waste management routes [48]

ROUTES - Common understanding of the practical issues on waste management routes

D9.7 : ROUTES - Review of radioanalytical characterisation of selected radioactive wastes and wastes with complex chemical and toxic properties [24]

ROUTES - Review of radioanalytical characterisation of selected radioactive wastes and wastes with complex chemical and toxic properties

D9.8 : ROUTES - Review of characterization of legacy and historical wastes [33]

ROUTES - Review of characterization of legacy and historical wastes

D9.9 : ROUTES - Report suggestions for the management of challenging wastes while maintaining compatibility with the option(s) for disposal [40]

ROUTES - Report suggestions for the management of challenging wastes while maintaining compatibility with the option(s) for disposal

D9.10 : ROUTES - Report about the knowledge for existing and potential disposal options for SIMS [24]

ROUTES - Report about the knowledge for existing and potential disposal options for SIMS

D9.11 : ROUTES - Report presenting the results of the workshop dealing with possible conditioning routes for SIMS [36]

ROUTES - Report presenting the results of the workshop dealing with possible conditioning routes for SIMS

D9.12 : ROUTES - Studies and plans for developing shared solutions for radioactive waste management in Europe [12]

ROUTES - Studies and plans for developing shared solutions for radioactive waste management in Europe

D9.13 : ROUTES - Case studies of shared development and use of technologies and facilities [24]

ROUTES - Case studies of shared development and use of technologies and facilities

D9.14 : ROUTES - Report on the feasibility of developing further European shared solutions for waste management from cradle to grave [42]

ROUTES - Report on the feasibility of developing further European shared solutions for waste management from cradle to grave

D9.15 : Scoping of ROUTES, initial CS input and ICS action plan (task 7.1) [11]

Scoping of ROUTES, initial CS input and ICS action plan (task 7.1)

D9.16 : Implementation of the ROUTES ICS action plan first phase - CS discussion and input focused on the first topic identified in the ICS action plan (task 7.2) [23]

Implementation of the ROUTES ICS action plan first phase - CS discussion and input focused on the first topic identified in the ICS action plan (task 7.2)

D9.17 : Implementation of the ROUTES ICS action plan second phase - CS discussion and input focused on the second topic identified in the ICS action plan (task 7.2) [35]

Implementation of the ROUTES ICS action plan second phase - CS discussion and input focused on the second topic identified in the ICS action plan (task 7.2)

D9.18 : Implementation of the ROUTES ICS action plan third phase - CS discussion and input focused on the third topic identified in the ICS action plan (task 7.2) [47]

Implementation of the ROUTES ICS action plan third phase - CS discussion and input focused on the third topic identified in the ICS action plan (task 7.2)

D9.19 : Final synthesis ROUTES report of the work and results of task 7 including the documentation of the interaction framework developed, including recommendations for future CS interaction [60]

Final synthesis ROUTES report of the work and results of task 7 including the documentation of the interaction framework developed, including recommendations for future CS interaction

D9.20 : Contribution to ROUTES factsheet presenting the results and outcomes of ROUTES and in a larger context [60]

Contribution to ROUTES factsheet presenting the results and outcomes of ROUTES and in a larger context

D9.21 : ROUTES - Report on Evaluation of existing predisposal routes for SIMS with regard to disposal options. The final report is an updated version of the milestone MS289 [44]

ROUTES - Report on Evaluation of existing predisposal routes for SIMS with regard to disposal options. The final report is an updated version of the milestone MS289

D9.22 : ROUTES - Summary report on analysis, assessment and evaluation of disposal options for SIMS (taking into account both potential disposal options and predisposal routes) including Annex: C case studies on typical waste pathways. The final report is an update [55]

ROUTES - Summary report on analysis, assessment and evaluation of disposal options for SIMS (taking into account both potential disposal options and predisposal routes) including Annex: C case studies on typical waste pathways. The final report is an updated version of the milestone MS310

Schedule of relevant Milestones

Milestone number ¹⁸	Milestone title	Lead beneficiary	Due Date (in months)	Means of verification
MS1	EURAD Kick-off meeting (General Assembly n°1)	1 - ANDRA	1	EURAD Kick-off meeting (General Assembly n°1)
MS9	ROUTES Kick-off meeting (ROUTES WPM1)	19 - IRSN	2	ROUTES Kick-off meeting (ROUTES WPM1)
MS12	EURAD EJP Newsletters	1 - ANDRA	3	EURAD EJP Newsletters (Due date : M3 and then every quarter)
MS13	ROUTES Questionnaire	19 - IRSN	3	ROUTES Questionnaire
MS30	EURAD General Assembly n°2	1 - ANDRA	7	EURAD General Assembly n°2
MS37	ROUTES Workshop 1 on Radioanalytical characterisation of radioactive waste and waste with complex/toxic properties (T3.1)	19 - IRSN	7	ROUTES Workshop 1 on Radioanalytical characterisation of radioactive waste and waste with complex/toxic properties (T3.1)

Schedule of relevant Milestones

Milestone number¹⁸	Milestone title	Lead beneficiary	Due Date (in months)	Means of verification
MS38	ROUTES Workshop 1 on disposal options for SIMS (T5.1)	19 - IRSN	7	ROUTES Workshop 1 on disposal options for SIMS (T5.1)
MS39	ROUTES workshop on European experience in developing shared solutions for RWM	19 - IRSN	7	ROUTES workshop on European experience in developing shared solutions for RWM
MS42	EURAD Annual Work Plan 2	1 - ANDRA	9	EURAD Annual Work Plan 2
MS65	ROUTES WPM2	19 - IRSN	12	ROUTES WPM2
MS66	ROUTES Workshop on Case studies on shared development and use of technologies and facilities	19 - IRSN	12	ROUTES Workshop on Case studies on shared development and use of technologies and facilities
MS71	Methodology for ICS activities assessment	19 - IRSN	12	Methodology for ICS activities assessment
MS81	EURAD General Assembly n°3 + EURAD Annual Meeting 1	1 - ANDRA	13	EURAD General Assembly n°3 + EURAD Annual Meeting 1
MS82	ICS Workshop 1	19 - IRSN	13	ICS Workshop 1
MS85	EURAD Periodic Report 1	1 - ANDRA	14	EURAD Periodic Report 1
MS88	ROUTES up-to-date overview per country on the use of waste acceptance criteria (WAC) in Member-States, hereby focusing on the use of WAC as a tool for waste cycle management	19 - IRSN	15	ROUTES up-to-date overview per country on the use of waste acceptance criteria (WAC) in Member-States, hereby focusing on the use of WAC as a tool for waste cycle management
MS90	ROUTES Workshop 2 on Radioanalytical characterisation of radioactive waste and waste with complex/toxic properties (T3.1)	19 - IRSN	16	ROUTES Workshop 2 on Radioanalytical characterisation of radioactive waste and waste with complex/toxic properties (T3.1)
MS91	ROUTES Workshop 2 on disposal options for SIMS (T5.1)	19 - IRSN	16	ROUTES Workshop 2 on disposal options for SIMS (T5.1)
MS103	EURAD General Assembly n°4	1 - ANDRA	19	EURAD General Assembly n°4
MS110	ROUTES Workshop 3 on Radioanalytical characterisation of radioactive waste and waste with complex/toxic properties (T3.1) +Workshop 1 on Characterization and	19 - IRSN	20	ROUTES Workshop 3 on Radioanalytical characterisation of radioactive waste and waste with complex/toxic properties (T3.1) +Workshop 1 on Characterization and

Schedule of relevant Milestones

Milestone number¹⁸	Milestone title	Lead beneficiary	Due Date (in months)	Means of verification
	segregation of legacy waste (T3.2)			segregation of legacy waste (T3.2)
MS112	EURAD Annual Work Plan 3	1 - ANDRA	21	EURAD Annual Work Plan 3
MS127	ROUTES WPM3	19 - IRSN	24	ROUTES WPM3
MS132	ROUTES Workshop on waste management with/without WAC available (T4.2)	19 - IRSN	25	ROUTES Workshop on waste management with/without WAC available (T4.2)
MS136	EURAD General Assembly n°5 + EURAD Annual Meeting 2	1 - ANDRA	25	EURAD General Assembly n°5 + EURAD Annual Meeting 2
MS137	ICS Workshop 2	19 - IRSN	25	ICS Workshop 2
MS140	EURAD Periodic Report 2	1 - ANDRA	26	EURAD Periodic Report 2
MS144	ROUTES summary of Task 4.2 workshop outcomes on Sharing experience on waste management with/without WAC available	19 - IRSN	28	ROUTES summary of Task 4.2 workshop outcomes on Sharing experience on waste management with/without WAC available
MS151	ROUTES Workshop predisposal routes for the disposal options for SIMS (T5.2)	19 - IRSN	30	ROUTES Workshop predisposal routes for the disposal options for SIMS (T5.2)
MS152	Last input from ROUTES to UMAN	19 - IRSN	30	Last input from ROUTES to UMAN
MS153	EURAD General Assembly n°6	1 - ANDRA	31	EURAD General Assembly n°6
MS161	ROUTES Workshop 2 on Characterization and segregation of legacy waste (T3.1)	19 - IRSN	32	ROUTES Workshop 2 on Characterization and segregation of legacy waste (T3.1)
MS162	EURAD Annual Work Plan 4	1 - ANDRA	33	EURAD Annual Work Plan 4
MS163	ROUTES Workshop on identification of R&D needs and opportunities of collaboration related to the management of challenging wastes (T4.3)	19 - IRSN	33	ROUTES Workshop on identification of R&D needs and opportunities of collaboration related to the management of challenging wastes (T4.3)
MS176	ROUTES WPM4	19 - IRSN	36	ROUTES WPM4
MS177	ROUTES Workshop on the feasibility of developing further European shared solutions for waste management from cradle to grave (T6.3)	19 - IRSN	36	ROUTES Workshop on the feasibility of developing further European shared solutions for waste management from cradle to grave (T6.3)

Schedule of relevant Milestones

Milestone number¹⁸	Milestone title	Lead beneficiary	Due Date (in months)	Means of verification
MS185	EURAD General Assembly n°7 + EURAD Annual Meeting 3	1 - ANDRA	37	EURAD General Assembly n°7 + EURAD Annual Meeting 3
MS186	ICS Workshop 3	19 - IRSN	37	ICS Workshop 3
MS189	EURAD Periodic Report 3	1 - ANDRA	38	EURAD Periodic Report 3
MS192	ROUTES Note on identification, per country, of R&D needs with respect to the management of challenging wastes	19 - IRSN	40	ROUTES Note on identification, per country, of R&D needs with respect to the management of challenging wastes
MS199	EURAD General Assembly n°8	1 - ANDRA	43	EURAD General Assembly n°8
MS206	EURAD Annual Work Plan 5	1 - ANDRA	45	EURAD Annual Work Plan 5
MS219	ROUTES WPM5	19 - IRSN	48	ROUTES WPM5
MS222	EURAD General Assembly n°9 + EURAD Annual Meeting 4	1 - ANDRA	49	EURAD General Assembly n°9 + EURAD Annual Meeting 4
MS223	ICS Workshop 4	19 - IRSN	49	ICS Workshop 4
MS224	EURAD Periodic Report 4	1 - ANDRA	50	EURAD Periodic Report 4
MS234	EURAD General Assembly n°10	1 - ANDRA	55	EURAD General Assembly n°10
MS235	ICS Workshop 5	19 - IRSN	55	ICS Workshop 5
MS239	ROUTES WPM6	19 - IRSN	60	ROUTES WPM6
MS240	EURAD General Assembly n°11 + EURAD Annual Meeting 5	1 - ANDRA	60	EURAD General Assembly n°11 + EURAD Annual Meeting 5
MS241	EURAD Periodic Report 5	1 - ANDRA	60	EURAD Periodic Report 5 (Due date: 60+2)
MS246	ROUTES - Kick off meeting / Task 8 meeting	28 - NCSR	25	ROUTES - Kick off meeting / Task 8 meeting
MS260	ROUTES - Part 8.2.1 meeting 1	28 - NCSR	30	ROUTES - Part 8.2.1 meeting 1
MS272	ROUTES - Part 8.1.2 meeting 1	29 - NES	33	ROUTES - Part 8.1.2 meeting 1
MS281	ROUTES - Internal memorandum with results of Part 8.1.1 for final report D 9.1E	28 - NCSR	37	ROUTES - Internal memorandum with results of Part 8.1.1 for final report D 9.1E
MS284	ROUTES - Part 8.2.1 meeting 2	43 - SURO	38	ROUTES - Part 8.2.1 meeting 2

Schedule of relevant Milestones

Milestone number¹⁸	Milestone title	Lead beneficiary	Due Date (in months)	Means of verification
MS289	ROUTES - Draft report on Evaluation of existing predisposal routes for SIMS with regard to disposal options	28 - NCSR	42	ROUTES - Draft report on Evaluation of existing predisposal routes for SIMS with regard to disposal options
MS294	ROUTES - Part 8.2.2 meeting 3	28 - NCSR	45	ROUTES - Part 8.2.2 meeting 3
MS298	ROUTES 1st workshop: SIMS and LIMS interaction (Part 8.2.3)	29 - NES	48	ROUTES 1st workshop: SIMS and LIMS interaction (Part 8.2.3)
MS306	ROUTES - Internal memorandum with results of Part 8.2.1 for final report D 9.22	43 - SURO	52	ROUTES - Internal memorandum with results of Part 8.2.1 for final report D 9.22
MS309	ROUTES - 2nd workshop: SIMS and LIMS interaction (Part 8.2.3)	21 - IST ID	53	ROUTES - 2nd workshop: SIMS and LIMS interaction (Part 8.2.3)
MS310	ROUTES - Draft summary report on analysis, assessment and evaluation of disposal options for SIMS (taking into account both potential disposal options and predisposal routes) including Annex: 2 case studies on typical waste pathways	28 - NCSR	53	ROUTES - Draft summary report on analysis, assessment and evaluation of disposal options for SIMS (taking into account both potential disposal options and predisposal routes) including Annex: 2 case studies on typical waste pathways

Work package number ⁹	WP10	Lead beneficiary ¹⁰	3 - BEL V
Work package title	Uncertainty Management multi-Actor Network (UMAN)		
Start month	1	End month	60

Objectives

Objectives

The main objectives of the WP are as follows:

- Develop a common understanding among the different categories of actors (WMOs, TSOs, REs & Civil Society) on uncertainty management and how it relates to risk & safety. In cases where a common understanding is beyond reach, the objective is to achieve mutual understanding on why views on uncertainties and their management are different for different actors.
- Share knowledge/know-how and discuss common methodological/strategical challenging issues on uncertainty management.
- Identify the contribution of past & on-going R&D projects to the overall management of uncertainties.
- Identify remaining and emerging issues and needs associated with uncertainty management.

Expected impacts

The WP is expected to contribute to the EURAD Vision statement by:

- fostering mutual understanding and trust between actors;
- enhancing the understanding of the risks and uncertainties;
- ensuring societal visibility and transparency of RD&D.

The WP could be used as well to target future EURAD scope onto uncertainties that are most significant in terms of their impact on safety cases and facility implementation.

Regarding RWM implementation needs

The WP will contribute to the fulfillment of implementation needs by:

- compiling, reviewing, comparing and refining uncertainty management strategies, approaches and tools that could be used in a radioactive waste disposal programme (Task 2);
- addressing the identification & characterization of potentially safety-relevant uncertainties that need to be taken into consideration when implementing a disposal programme (Task 3);
- identifying possible options for the management of specific safety-relevant uncertainties at different programme phases (Task 4);
- providing an opportunity for technical experts to interact with various types of actors including civil society (Tasks 2 to 5);
- contributing to building mutual trust and understanding between various stakeholders.

Regarding safety

The WP will address safety case concerns by:

- compiling, reviewing, comparing and refining uncertainty management strategies, approaches and tools that could be used to demonstrate safety (Task 2);
- addressing the identification & characterization of potentially safety-relevant uncertainties that need to be taken into consideration in a safety case (Task 3);
- identifying possible options for the management of specific safety-relevant uncertainties in a safety case at different programme phases (Task 4);
- fostering a mutual understanding by the different actors of key concepts and paradigms underlying uncertainty management and the safety case at different steps of a geological disposal programme (Task 5);
- identifying methods for discussing and exchanging on uncertainties and uncertainty management during the development and review of the safety case (Task 5).

Regarding the outreach of EURAD-1

Collaborations and synergies with other international initiatives and organizations (such as IAEA, NEA, NUGENIA) are planned. In particular, interactions with NEA (IGSC) on uncertainty management strategies, approaches and tools (Task 2) and on interactions between different categories of actors, including Civil Society (Task 5) are foreseen. As regards pre-disposal issues, interactions with waste generators members of NUGENIA will be sought after (through questionnaire, invitation to workshops...).

WP10 - Uncertainty Management multi-Actor Network (UMAN) [Months: 1-60]

BEL V, ANDRA, BGE, CIEMAT, CNRS, COVRA, FTMC, ENRESA, JUELICH, GRS, IRSN, JSI, KIT, LEI, NAGRA, NRG, ONDRAF/NIRAS, POSIVA, PSI, RATEN, RWM, SCK•CEN, SSTC NRS, STUBA, SÚRAO, SURO, TS Enercon, TUS, VTT

Description of work

Task 1 – S/T coordination, interactions with KM WP & integration

Start: Month 1 – End: Month 60 - Task Leader: [Bel V]

Task Contributors: [BEL V] [BGE] [GRS] [IRSN (MUTADIS)] [RATEN]

Total PM: 11,7 + 3

Existing Task 1 is extended in order to:

- organize an additional WP meeting & WP board meetings
- coordinate and report the activities;
- review milestone documents and deliverables;
- interact with KM & R&D WPs;
- integrate the recommendations for future RD&D, strategic study and KM activities identified by participants and contributors to other tasks.

Subtask 1.1 – S/T coordination

Start: Month 1 – End: Month 60 – Subtask Leader: [Bel V]

Subtask contributors: [Bel V] [BGE] [GRS] [IRSN (MUTADIS)] [RATEN]

Total PM: 7 +2,6

Coordination of the WP is performed both at WP and task level. Subtask 1.1 describes the coordination work performed by the WP leader at the WP level. The coordination work performed by other task leaders is included in this subtask. This subtask consists also of the following actions:

- o Organization of WP meetings (3meetings organised together with 3seminars of Task 5) and of the meetings of the WP Board (2 per year) composed of the WP leader and of the task leaders [Bel V]
- o Participation in WP board meetings to ensure that the project is progressing according to the agreed specifications, milestones and planning [Bel V].
- o Reporting to the PMO of the work progress and of possible modifications of the WP work plan. [Bel V].

This extension of the subtask consists also of the following actions:

- Organization of an additional WP meeting and 2 additional meetings of the WP Board composed of the WP leader and of the leaders of Tasks 1, 3, 4 & 5 to ensure that the project is progressing according to the agreed specifications, milestones and planning. These meetings will take place during year 5 [Bel V].
- Reporting to the PMO of the work progress and possible modifications of the WP work plan [Bel V]
- Verification of milestone documents and deliverables [Bel V]
- Organization of interactions with other R&D WPs [Bel V]

Additional coordination work of Task 3, 4 & 5 leaders [BGE] [IRSN (MUTADIS)] [RATEN]

Milestones

- MS304: UMAN WP meeting 4 (Month 49)

Subtask 1.2 – Interactions with KM WP

Start: Month 1 – End: Month 60 – Subtask Leader: [Bel V]

Total PM: 2 +0,1

Owing to the nature of this WP, it is not foreseen to increase scientific knowledge. Nonetheless, the work carried out in Tasks 2 to 5 could lead to the development or improvement of strategies, approaches and tools. The knowledge consolidated or generated through knowledge/know-how sharing and discussions of common challenging issues could constitute a valuable input to KM activities (i.e. guidance, state-of-knowledge).

This subtask will consist in the following actions:

- o Interacting with KM WPs regarding the input of the WP to the state-of-knowledge, development of guidance and training activities in terms of content and format [Bel V]
- o Development of training material (input to KM WP3) [Bel V]) (Related deliverable: D10.1)

Subtask 1.3 – Integration

Start: Month 1 – End: Month 60 – Sub-Task Leader: [Bel V]

Subtask contributors: [Bel V] [BGE] [GRS] [IRSN (MUTADIS)] [RATEN]

Total PM: 2,7 +0,3

This subtask will consist in integrating the recommendations for future RD&D, strategic study and KM activities identified by WP participants in other tasks.

These recommendations could constitute a useful input to future updates of the SRA. An internal milestone is foreseen to ensure that input from other tasks is provided in due time. Milestones are foreseen to ensure that input from other tasks is provided in due time.

Milestone

MS208: Recommendations of UMAN for future RD&D, strategic study and KM activities for future EURAD implementation phase (Month 46)

Task 2 - Strategies, approaches and tools

Start: Month 1 – End: Month 48 - Task Leader: [GRS]

Task Contributors: [Andra] [Bel V] [CIEMAT] [CNRS (IMT Atlantique)] [COVRA] [JUELICH (HZDR)] [GRS] [IRSN (MUTADIS)] [JSI (EIMV)] [KIT (TU Clausthal)] [LEI] [NAGRA] [NRG] [ONDRAF/NIRAS] [SÚRAO] [RWM] [SCK.CEN] [SSTC NRS] [STUBA] [TUS] [VTT (GSL)]

Total PM: 25,8

The overall objective of this task is to compile, review, compare and refine strategies, approaches and tools for the management of uncertainties in the safety analysis and the safety case that are being used, planned to be used or being developed in different countries.

Subtask 2.1– Generic strategies for managing uncertainties

Start: Month 1 – End: Month 36 – Subtask Leader: [VTT (GSL)]

Subtask contributors: [Andra] [Bel V] [IRSN (MUTADIS)] [LEI] [NAGRA] [NRG] [SÚRAO] [RWM] [VTT (GSL)]

Total PM: 7,5

Since the strategies applied depend on the applicable regulations as well as on the various quantitative or qualitative criteria that might be used for assessing safety, this work topic includes a comparing overview of the regulatory background and applied safety strategies in participating countries and their consequences. Possible strategies and approaches for managing uncertainties will be systematically compiled and assessed with regard to their pros and cons. This includes the approaches used in the safety assessment (e.g. for simplification purposes when going from a detailed performance analysis of the disposal system to its safety analysis, uncertainty propagation methods,...) as well as RD&D, site characterisation, site selection, design, construction and management measures aimed at avoiding, mitigating or reducing uncertainties. The interplay between these approaches and measures will also be investigated considering the stepwise nature of disposal programmes and the decisions associated with each programme phase. The identification of possible areas of development and the improvement of advanced strategies is also within the scope of this work topic. (Related deliverable: D10.2)

Interactions with other tasks:

- Task 3: Interactions with Subtask 3.1 where the different types of uncertainties are identified and their evolution discussed are foreseen.
- Task 4: the needs/views of the different kinds of actors for/on options for managing uncertainties associated to specific topics will be investigated in Task 4. Task 2 can provide Task 4 with generic options and strategies. Task 4 will give an input to Task 2 for identifying and elaborating appropriate strategies.
- Task 5: experts involved in Task 2 will liaise with their own community to collect available information and provide the material for interacting with a broader audience including civil society. These broader interactions and the methods to organise them will be developed and implemented within Task 5. Interactions with Task 5 are managed through a participation of Task 5 representatives (MUTADIS & Andra) in key meetings of Task 2 to ensure that the needs of Task 5 are properly understood.

Subtask 2.2– Uncertainty identification, classification and quantification

Start: Month 1 – End: Month 36 – Sub-Task Leader: [JUELICH (HZDR)]

Subtask contributors: [RWM] [SÚRAO] [NAGRA] [JSI (EIMV)] [JUELICH (HZDR)] [ONDRAF/NIRAS] [CIEMAT] [GRS] [SCK.CEN] [TUS] [STUBA] [SSTC NRS]

Total PM: 12,3

Approaches to identify uncertainties that might be of relevance will be compiled, assessed and improved where relevant and possible. This includes systematic expert elicitation. Possible schemes of classification of uncertainties will be described and refined if necessary. The classification process should be linked to the identification process as well as to the strategies and approaches considered in Subtask 2.1. Numerical uncertainties are generally quantified in the form of probability density functions. The selection of an appropriate function type (e.g. uniform or normal distribution)

and its correct parametrisation, according to the available knowledge, will be addressed. Previous international work that specifically addressed these topics will be taken into account and possible areas of development will be identified. (Related deliverable: D10.3)

INTERACTIONS WITH OTHER TASKS

Task 3: the needs/views of the different kinds of actors for/on the identification, classification and quantification of uncertainties associated with specific topics will be investigated in Task 3. Task 2 will provide Task 3 with approaches for these uncertainty management steps. Task 3 will give an input to Task 2 for identifying and elaborating appropriate approaches. Interactions with Subtask 3.1 where the different types of uncertainties are identified and their evolution discussed are also foreseen.

Subtask 2.3– Methodological approaches to uncertainty and sensitivity analysis

Start: Month 13 – End: Month 48 – Sub-Task Leader: [KIT (TU Clausthal)]

Subtask contributors: [NAGRA] [RWM] [IRSN] [SCK•CEN] [CNRS (IMT Atlantique)] [GRS] [JUELICH (HZDR)] [Andra] [COVRA] [KIT (TU Clausthal)]

Total PM: 6,1

A variety of mathematical methods for uncertainty and sensitivity analysis are available. The goal of this work topic is to investigate how typical numerical PA models can best be analysed in view of uncertainty and sensitivity with classical and modern methods and, where sensible, to coordinate, initiate or recommend the development of appropriate computational tools. The work topic comprises:

- o identification of methods for uncertainty and sensitivity analysis already applied in repository PA
- o analysis of the general understanding of these methods and their outcome
- o identification of specific strengths and weaknesses of these methods
- o suggestions for application of newly developed methods
- o suggestions for refinement of methods

The work might also include exemplarily application of different methods to existing sets of probabilistic PA calculations.

(Related deliverable: D10.4)

Task 3 - Characterization and significance of uncertainties for different categories of actors

Start: Month 1 – End: Month 57 - Task Leader: [RATEN]

Task contributors: [Andra] [Bel V] [CIEMAT] [CNRS (IMT Atlantique)] [COVRA] [ENRESA] [FTMC] [IRSN (MUTADIS)] [JSI (EIMV)] [KIT] [ONDRAF/NIRAS] [POSIVA (Envirocase)] [PSI] [RATEN] [SÚRAO] [SCK.CEN] [SSTC NRS] [TS ENERCON] [VTT]

Total PM: 37,4 + 8,6

Task objectives

The overall objective of Task 3 is to synthesize existing knowledge and views of different kinds of actors on the identification, classification, characterisation and significance of uncertainties associated with specific topics, and to formulate recommendations for the future R&D, KM and strategic study activities.

UMAN Extension:

A Subtask 3.6 is added to the UMAN WP. The goal of this new subtask would be to address the following key questions:

- What uncertainties associated with near-field systems are potentially safety-significant?
- Why are they potentially significant for safety?

How can they be characterized?

APPROACH

For each Subtask, the work will be carried out by an expert group of 4 organisations (as far as possible representing the different kinds of actors). Subtask 3.1 will develop a framework for the activities carried out in the WP by defining the different types of uncertainties and temporal aspects to be considered by other tasks and subtasks. Subtasks 3.2 to 3.5 will compile, review and synthesize the existing information on the identification and characterization (including the methods) of relevant uncertainties and identify their potential implications for safety (based on national reports, IAEA TECDOCs, NEA Reports and related European research projects). This information will be also collected using questionnaires to liaise with the whole community. Where relevant, interactions with RD&D WPs will be developed and the state-of-the-art produced in these WPs will be used as input. These working groups will produce material that will be used as input for the discussions with a broader audience including civil society during the seminars organized in Task 5. The working groups will also identify needs for further RD&D, KM and strategic study activities.

The focus will be put in the 1st wave of EURAD-1 on uncertainties related to the waste inventory, spent fuel, human aspects, site and geosphere. These topics are of particular interest for National Programmes at an early stage and

will allow addressing in particular the following high-priority subdomains of the Programme Document: inventory uncertainty, radionuclide release from wastefroms other than spent fuel, impacts of extended storage on waste packages, and site descriptive models. The selection of these topics allows as well addressing key pre-disposal issues like waste characterization and ageing associated with extended storage. It is foreseen to address during the 2nd wave of EURAD-1 uncertainties related to near-field evolution and to radionuclide migration so as to address uncertainties investigated by the RD&D WPs on cement-organic-radionuclide interactions, radionuclide mobility, gas, temperature and chemical evolution. These studies, if accepted, would start during the 3rd year of EURAD-1.

INTERACTIONS WITH OTHER TASKS

- Task 2: see Task 2 description.
- Task 4: in Task 4 the views of the different kinds of actors will be exchanged on how to treat, reduce, mitigate or avoid uncertainties. These exchanges will focus on uncertainties addressed in Task 3.
- Task 5: experts involved in Task 3 will liaise with their own community to collect available information and develop the material for interacting with a broader audience including civil society. These broader interactions and the methods to organise them will be developed and implemented within Task 5. Interactions with Task 5 are managed through a participation of Task 5 representatives (MUTADIS & IRSN) in key meetings to ensure that the needs of Task 5 are properly understood by Task 3 participants.

Subtask 3.1 – Types of uncertainties relevant to the safety analysis and the safety case

Start: Month 1 – End: Month 36 - Task Leader: [CNRS (IMT Atlantique)]

Subtask contributors: [ONDRAF-NIRAS] [JSI] [RATEN] [POSIVA (Envirocase)] [CNRS (IMT Atlantique)]

Total PM: 8,5

This subtask will address the following generic key questions:

- According to the views of the different actors, what types of uncertainties need to be addressed in a safety analysis and in a safety case?
- How could these uncertainties evolve throughout the different phases of a disposal programme and what are views of the different actors on these possible evolutions?

This subtask will provide a high-level integrated picture of the various types of uncertainties that are potentially relevant for safety (Related deliverable: D10.5). This picture will serve as framework for the activities carried out in the WP by defining the different types of uncertainties and temporal aspects to be considered by other tasks and subtasks. The activities will consist in the review of related literature, liaising with the community through a questionnaire and discuss the results in a seminar organized by Task 5 to exchange views on the various types of uncertainties and their evolution and establish a common approach or a common understanding of the different approaches.

Subtask 3.2 – Uncertainties on waste inventory and on the impact of predisposal steps

Start: Month 9 – End: Month 36 – Sub-task Leader: [SCK•CEN] Subtask contributors: [TS Enercon] [ENRESA] [FTMC] [SCK•CEN] Total PM: 7,2

Knowledge of the radionuclide and chemical inventory (including metals and organic compounds) of wastes requiring disposal in a deep geological repository is important for the transport, operations and post-closure safety cases. Data quality of waste inventories is often variable, with uncertainty often dominated by waste heterogeneity. Relevant uncertainties related to the inventory of radioactive wastes other than SF (e.g. vitrified waste, metallic waste, high-organic waste, graphite, cementitious waste forms,...), the evolution of these uncertainties and their potential significance for safety will be addressed. The possible impact of predisposal steps (e.g. ageing occurring during extended storage) will also be investigated. The aim is to focus the work in the 1st wave of EURAD-1 on a limited number of waste types that will be identified following interactions with Task3 of the WP on waste management routes dedicated to waste characterization. This task starts at Month 9 and ends at Month 30. All these activities will focus on safety-relevant radionuclides, their physico-chemical forms and release kinetics as well as on species altering their migration in the near-field. The Expert Group will first identify and characterize associated uncertainties based on available information from National Programmes and international initiatives (IAEA, NEA/OECD, NUGENIA,...), and relevant past and ongoing European RD&D projects in close collaboration with the Strategic Study WP on Waste Management Routes and, for the aspects related to waste containing organic matter, with the RD&D WP on Cement-Organic-Radionuclide-Interactions. The Expert Group review will be completed (via a questionnaire) with information from other EURAD-1 participants and possibly from waste generators members of NUGENIA.

This will lead to the elaboration of a draft of deliverable D10.6 to be used in Task 4 where possible options for the management of these uncertainties will be identified and in Task 5 for discussion with a broader stakeholder group. The views of different actors collected during the workshop dedicated to the management of these uncertainties organized in Task 4 and the seminars organized in Task 5, will then be used to update and finalize deliverable D10.6.

Subtask 3.3 – Site and geosphere related uncertainties

Start: Month 1 – End: Month 36 – Sub-Task Leader: [RATEN] Subtask contributors: [PSI] [IRSN] [SÚRAO] [RATEN]

Total PM: 7,5

As stated in the Programme Document, there is a need to develop the state-of-the-art on the management of uncertainties associated with site characteristics. Such uncertainties need also to be taken into account when developing site descriptive models. This subtask will focus on the identification, characterization, evolution and significance of the following uncertainties related to both near-surface and geological disposal sites in the context of different host rocks (crystalline, clay and salt rocks):

- uncertainties to be taken into consideration when conceptualizing natural barriers and aquifers;
- uncertainties associated with geodynamics and tectonic perturbations of the site in the long-term (including seismic events and faulting) ;
- uncertainties associated with future climate changes, such as potential future glaciations and other possible processes (e.g. flooding and desertification, subglacial erosion and permafrost formation).

The Expert Group will first identify and characterize uncertainties based on available information from National Programmes and international initiatives (IAEA, NEA/OECD,...), and relevant past and ongoing European RD&D projects. The aspects related to radionuclide transport in the geosphere will be approached in close collaboration with the RD&D WP on Fundamental understanding of radionuclide mobility. The Expert Group review will be completed (via a questionnaire) with information from other EURAD-1 participants. This will lead to the elaboration of a draft of deliverable D10.7 to be used in Task 4 where possible options for the management of these uncertainties will be identified and in Task 5 for discussion with a broader stakeholder group. The views of different actors collected during the workshop dedicated to the management of these uncertainties organized in Task 4 and the seminars organized in Task 5, will then be used to update and finalize deliverable D10.7.

Subtask 3.4 – Uncertainties related to human aspects

Start: Month 1 – End: Month 36 – Sub-task Leader: [Andra] Subtask contributors: [Andra] [VTT] [COVRA] [JSI (EIMV)] Total PM: 7

This subtask will address the identification, characterization, evolution and significance of uncertainties associated with social, economic and other human aspects identified as potentially relevant to safety and the decision-making process, including the custodianship and transgenerational aspects associated with long-term operation of SF storage facilities. The relationships between these uncertainties, strategic choices (e.g. reversibility and retrievability) and programmatic decisions will be investigated. The Expert Group will first identify and characterize uncertainties based on available information from National Programmes and international initiatives (IAEA, NEA/OECD,...) and relevant past European RD&D projects. The Expert Group review will be completed (via a questionnaire) with information from other EURAD-1 participants. This will lead to the elaboration of a draft of deliverable D10.8 to be used in Task 4 where possible options for the management of these uncertainties will be identified and in Task 5 for discussion with a broader stakeholder group. The views of different actors collected during the workshop dedicated to the management of these uncertainties organized in Task 4 and the seminars organized in Task 5, will then be used to update and finalize deliverable D10.8.

Subtask 3.5 – Spent fuel related uncertainties

Start: Month 1 – End: Month 48 - Task Leader: [CIEMAT]

Subtask contributors: [Bel V] [CIEMAT] [KIT] [SSTC NRS] Total PM: 7

Knowledge of the radionuclides of spent fuel (SF) and of their chemical form is important for the safety case. Relevant uncertainties related to the source term of SF, centered on their radiological inventory and heat generation, their evolution and potential significance for safety will be addressed. These activities will focus on safety-relevant radionuclides, their physico-chemical forms and release processes. Uncertainties associated with ageing (due to extended storage and/or operational phase of the disposal facility) will also be investigated. In particular, the long-term behaviour and integrity of fuel cladding (oxidation, hydration, swelling) and the ageing of the cask and of its sealing system will be considered. The potential significance of uncertainties for the safety of transport, storage and disposal (both operational and post-closure safety) will be as well considered in this subtask. The Expert Group will first identify and characterize uncertainties based on available information from National Programmes and international initiatives (IAEA, NEA/OECD,...), and relevant past and ongoing European RD&D projects in close collaboration with the RD&D WP on SF. The Expert Group review will be completed (via a questionnaire) with information from other EURAD-1 participants and possibly from NUGENIA members involved in SF characterization, transport and/or storage.

This will lead to the elaboration of a draft of deliverable D10.9 to be used in Task 4 where possible options for the management of these uncertainties will be identified and in Task 5 for discussion with a broader stakeholder group. The views of different actors collected during the workshop dedicated to the management of these uncertainties organized in Task 4 and the seminars organized in Task 5, will then be used to update and finalize deliverable D10.9.

Subtask 3.6 – Near-field related uncertainties (UMAN Extension)

Start: Month 25 – End: Month 57 – Sub-Task Leader: [PSI]

Subtask contributors:

Expert group: [PSI] [IRSN] [SÚRAO] [SCK-CEN]

Workshop organizer: [RATEN]

Workshop participants: [ANDRA] [BEL V] [BGE] [GRS] [KIT] [LEI] [NAGRA] [ONDRAF/NIRAS] [SSTC NRS] [STUBA] [SURO] [TUS] [VTT]

Total PM: 8,6 PM

This subtask will focus on the identification, characterization, evolution and significance of the following uncertainties related to the near-field of HLW/SF disposal facilities in the context of two different host rocks (crystalline and clay):

- uncertainties related to the processes governing or altering radionuclide migration and the performance of disposal system components in the near field;
- uncertainties to be taken into consideration when conceptualizing waste packages, technical barriers and adjacent EDZ of natural barriers;
- uncertainties associated with thermal, hydraulic, mechanical, chemical, biological and radiation conditions and processes (THMCBR) dominating at different time scales (except those already taken into account in subtask 3.2 on the waste inventory and subtask 3.3 on geosphere and sites related uncertainties) as well as with gas migration in near-field systems.

The Expert Group will first address the key questions identified here above based on available information from national programmes and international initiatives (IAEA, NEA/OECD,...), and relevant past and ongoing European RD&D projects (ACED, GAS and HITEC as well as ConCorD and MAGIC if accepted). The aspects related to radionuclide transport in the near-field will be approached in close collaboration with the RD&D WP on Fundamental understanding of radionuclide mobility (FUTURE). The Expert Group review will be completed (via a questionnaire and a workshop) with information from other EURAD-1 participants and members of the End User Group. This will lead to the elaboration of a draft deliverable to be used in Task 4 where possible options for the management of these uncertainties will be identified and in Task 5 for discussion with a broader stakeholder group and the organisation of the 5th UMAN Seminar. The views of different actors collected during the workshop dedicated to the management of these uncertainties organized in Task 4 and the outcome of the 5th seminar organized by Task 5 will then be used to update and finalize the deliverable.

Milestones

- MS261 UMAN Preliminary list of uncertainties from UMAN Subtask 3.6 as input to Subtask 4.2 and questionnaire (Month 30)
- MS252 MS262: SOTA from RD&D (CONCORD & MAGIC WP) as input to UMAN Subtask 3.6 (Month 27&30)
- MS282: UMAN Draft D10.18 as input to workshop and Tasks 4 and 5 (Month 37)
- MS285: Workshop on the significance and characterization of near-field uncertainties (Month 39)

Deliverable

D10.18: UMAN - Views of the different actors on the identification, characterization and potential significance of uncertainties on the near-field. This deliverable will describe the views of different categories of actors on uncertainties associated with the near-field that need to be addressed in a safety case for different disposal concepts as well as on their characterization, evolution and potential significance for safety, and will include recommendations for future RD&D, KM and strategic study activities.

Lead organisation: PSI. Due Month: 57

Task 4 - Uncertainty management options and preferences of different actors across the various programme phases

Start: Month 1 – End: Month 57 - Task Leader: [BGE]

Task contributors: [Andra] [Bel V] [BGE] [CNRS (IMT Atlantique)] [ENRESA] [IRSN (MUTADIS)] [KIT] [LEI] [NAGRA] [NRG] [ONDRAF/NIRAS] [STUBA] [SURO] [TUS]

Total PM: 24,3 +8,3

Task objectives

The overall objectives of Task 4 are to identify, for different phases of a disposal programme and the associated decision-making, a bundle of possible options for:

- o treating uncertainties associated with specific topics in the safety assessment (e.g. uncertainty propagation methods, scenario development, stylisation approaches,...),
- o avoiding, reducing or mitigating these uncertainties,
- o making a safety case robust vis-à-vis these uncertainties.

The views and preferences of the different kinds of actors on these possible options will be identified considering their roles in the decision-making process. Task 4 will offer a platform for networking on relevant issues regarding uncertainty

management as a part of risk and safety management throughout the implementation of a disposal programme. Special focus will be put on potential impacts of preferences of different categories of actors and derived management options.

UMAN Extension:

Existing Subtasks 4.2 and 4.3 would be extended to address the following question: What are the possible options and preferences of the different actors for the management of uncertainties associated with the near-field?

INTERACTIONS WITH OTHER TASKS

- o Task 2: see Task 2 description.
- o Task 3: see Task 3 description.
- o Task 5: Task 4 will provide an input to Task 5 concerning possible uncertainty management options considering preferences of various actors. Task 4 will also provide a list of actors directly involved in or related to radioactive waste management processes and information about their roles, interests and preferences. Interactions with Task 5 are managed through:
 - o a participation of Task 5 representatives (MUTADIS & Topic 3 leader) in key meetings to ensure that the needs of Task 5 are properly understood by Task 4 participants,
 - o the review by Task 4 participants of deliverable D10.15 so as to ensure the consistency of all deliverables

Subtask 4.1 – Identification and characterization of the different actors across the entire radioactive waste management process

Start: Month 1 – End: Month 12 – Sub-task Leader: [BGE] Subtask contributors: [BGE] [SURO]

Total PM: 2,5

The objective of this subtask is to identify and characterize the different actors across all phases of a disposal programme in order to improve understanding of their interests and preferences regarding the management of different types of uncertainties. The outcome of this work (Deliverable D10.10) will serve as input to Sub-Tasks 4.2 and 4.3 and Task 5 (Topic 3). To achieve this goal a questionnaire will be established. The questionnaire's structure will be based on the generic phases identified in the EURAD Roadmap. This will allow identifying the actors involved and their roles in the process while remaining independent from national regulations or specificities. All organisations participating in the strategic studies (i.e. in this WP as well as in the WP on Waste Management Routes) will be invited to fill out the questionnaire and give information about actors and their characterization. The answers to the questionnaire will be the basis for the analysis, description and grouping the different actors. Although the subtask will address all phases of a programme, the focus will be put in the first wave on uncertainties related to waste inventory, spent fuel, human aspects and the site/geosphere relevant to disposal.

Subtask 4.2 – Compilation and review of available information on possible uncertainty management options

Start: Month 6 (Month 30 UMAN Extension) – End: Month 57 - Task Leader: [NAGRA]

Subtask contributors: [Andra] [Bel V] [BGE] [SURO] [KIT] [LEI] [NAGRA] [NRG] [TUS]

Total PM: 12,3 +5,5

The objective of this subtask is to develop a comprehensive overview about different approaches and uncertainty management options to assess and where relevant to reduce risks and optimise safety (Related deliverable: D10.11). Existing documentation (e.g. regulations, guidelines, handbooks, national reports, lists of options, cross-mappings, sets of interrelated or interacting elements) on the management of uncertainties including examples of pitfalls will be compiled, reviewed and synthesized. The schemes for classification of uncertainties resulting from Subtask 3.1 will serve as a tool to identify management options depending on the type of uncertainty and temporal aspects.

The focus will be put on the following topics also addressed in Task 3:

- o Site- and geosphere-related uncertainties (in particular in the course of host rock and site selection processes),
- o Uncertainties related to human aspects,
- o Uncertainties related to the waste inventory (including uncertainties associated with their pre-disposal management having implications for the safety of the disposal facility),
- o Uncertainties related to spent fuel (including those associated with their possible long-term storage and characterization).

UMAN Extension:

The objectives of this subtask are as follows:

- to develop an overview about different approaches and uncertainty management options to assess and where relevant to reduce risks and optimise safety;
- to prepare the material needed by Subtask 4.3 and Task 5 to interact with different types of actors including civil society on their views regarding the management of uncertainties associated with the near-field;

Whereas Task 3 is more systematic in identifying potentially safety-significant uncertainties (bottom-up approach), Subtasks 4.2 and 4.3 will focus on the most safety-significant uncertainties identified by Subtask 3.6 and on a limited number of illustrative cases for which there is a high level of common interest (top-down approach). Available information from national programmes (safety cases, regulatory guides,...), international initiatives (IAEA, NEA/OECD,...) and relevant past and ongoing European RD&D projects related to the management of uncertainties associated with the near-field (including examples of pitfalls where available) will be compiled, reviewed and synthesized. The outcomes of Subtasks 2.1 & 3.1 will serve as input to identify management options depending on the type of uncertainty and temporal aspects.

Milestone

MS291: UMAN compiled and reviewed information about possible management options for near-field related uncertainties (Month 43)

Subtask 4.3 – Preferences of the different actors on uncertainty management options

Start: Month 13 – End: Month 57 – Sub-task Leader: [NRG]

Subtask contributors: [Andra] [Bel V] [BGE] [CNRS (IMT Atlantique)] [SURO] [ENRESA] [LEI] [IRSN (MUTADIS)] [NAGRA] [ONDRAF-NIRAS] [STUBA] [NRG]

Total PM: 9,6 +2,8

The objectives of this subtask are as follows:

- o Preparing the material needed by Task 5 to interact with a broader audience on the views of different actors considering the whole process of radioactive waste management (input to Task 5),
- o Synthesizing the preferences of the different actors for uncertainties associated with specific topics based on the outcomes of Subtasks 4.1, 4.2 and 5.1,
- o Identifying needs for future RD&D, KM or strategic study activities.

Based on the results of Subtasks 4.1 and 4.2, the management options for the different types of uncertainties considered in the task and the preferences of different actors as well as the rationale behind them are discussed, analysed and described (Related deliverable: D10.12). Four workshops bringing together organisations contributing to Subtask 4.3, one of the expert groups of Subtasks 3.2 to 3.5 (depending on the addressed topic) as well as other interested EURAD partners, are planned:

- WS1 (Milestone MS108): Management options and preferences of different actors regarding site and geosphere related uncertainties (Month: 19)
- WS2 (Milestone MS134): Management options and preferences of different actors regarding human aspects related uncertainties (Month: 25)
- WS3 (Milestone MS146): Management options and preferences of different actors regarding SF-related uncertainties (Month: 28)
- WS4 (Milestone MS164): Management options and preferences of different actors regarding waste inventory related uncertainties (Month: 33)

The outcome of this work will be documented and serve as input for Task 5 organising the seminars where the discussions will be broadened to a larger audience including civil society.

UMAN Extension:

The objectives of this subtask are as follows:

- Identifying and synthesizing the preferences of the different actors based on the outcomes of a workshop and of Subtasks 4.2 and 5.2;
- Identifying needs for future RD&D, KM or strategic study activities.

Based on the results of Subtask 4.2, the management options for the uncertainties considered in the task and the preferences of different actors as well as the rationale behind them are discussed, analysed and described. A workshop bringing together organisations contributing to Subtasks 4.2 and 4.3, the expert group of Subtask 3.6 as well as other interested EURAD partners and members of the End User Group is planned to discuss the outcome of the literature study performed by subtask 4.2 and exchange on possible options and preferences. The outcome of this work will be documented in a deliverable presenting the outcome of Subtasks 4.2 and 4.3 and providing an input for the seminar organized by Task 5.

Milestone

MS295: WS5 - Management options and preferences of different actors regarding near-field related uncertainties (Month 45)

Deliverable

D10.19 UMAN - Identification, analysis and description of preferences of different actors on options for managing uncertainties related to the near field (Month: 57)

Task 5 - Interactions between all categories of actors, including Civil Society

Start: Month 1 – End: Month 60 - Task Leader: [IRSN (MUTADIS)]

Task contributors: [Andra] [Bel V] [GRS] [IRSN (MUTADIS) (NTW)] [JSI (EIMV)] [KIT (TU Clausthal)] [POSIVA (Envirocase)] [RWM] [SSTC NRS] [TUS]

Total PM: 34,8 + 3,7

Task objectives

The overall objectives of this task are:

- To develop a common understanding or understanding of the different viewpoints among the different categories of actors on:

- o uncertainty management and how it relates to risk & safety,

- o whether and why a safety case is robust vis-à-vis uncertainties.

- To share knowledge/know-how and discuss common methodological/strategical challenging issues on uncertainty management among a broader group of actors.

Although not a goal in itself, the communication of uncertainty is embedded in the task through the preparation of seminars by “methodological groups” and Topic 4.

UMAN Extension:

Existing Task 5 would be extended to test with a broader stakeholder group including civil society the methods for a pluralistic assessment of uncertainties and their management identified during the 4th UMAN Seminar using near-field uncertainties as case studies. Hence the proposed work would complement the seminar process foreseen in the current WP activities and in particular Topic 4 of the current WP aimed at exploring methods that can be used for discussing and organising pluralistic assessments of uncertainties with civil society stakeholders throughout a disposal programme. This topic includes the communication of these issues and addresses both the development and the review of the safety case. The work performed in this task will be based on the outcome of subtasks 3.6, 4.2 and 4.3 as well as of the previous UMAN seminars.

APPROACH

This task will organise a pluralistic analysis of key outcomes of other tasks of the WP with a pluralistic stakeholder group including Civil Society organisations (CSOs), TSOs, WMOs and Research Entities. This pluralistic analysis will take the form of a series of seminars gathering pluralistic stakeholder groups, supported and facilitated by a methodological group. Interactions with civil society will be organised at two levels. Besides the participation of CS experts in specific subtasks of Tasks 2 to 4 (Subtask 5.2), seminars organised by Subtask 5.1 will include a wider range of civil society actors: national civil society organisations, local organisations in communities directly engaged in geological disposal projects (e.g. representatives of local partnerships or local commissions). Participants will not include members of the general public. Organisations contributing to other WP tasks will be invited to the seminars as stakeholders (without person-month budget). Additional participants that are not members of the WP (CSOs, other EURAD-1 participants, other relevant stakeholders from outside EURAD-1,...) will be identified by the methodological group preparing and organising the seminar. Each potential participant in a seminar will be contacted by the methodological group. Their involvement in the seminars will be formalised by a memorandum of understanding. This memorandum of understanding will provide a clear framework for CSO engagement, where the expectations of CSOs and WP Task 5 members are made explicit and where the roles of the different participants in the seminars (WP members, CSOs and CS experts engaged in subtask 5.2, CSOs not directly involved in the WP,...) are identified. The seminars will include presentations of outcomes of the other WP tasks prepared by members of the methodological group (see Subtask 5.1), facilitated discussions with the participants in working groups.

Subtask 5.1 - Preparation, support and reporting of pluralistic analyses

Start: Month 1 – End: Month 60 - Subtask Leader: [IRSN (MUTADIS)]

Subtask contributors: [IRSN (MUTADIS)] [Andra] [KIT (TU Clausthal)] [RWM] [JSI (EIMV)] [TUS] [POSIVA (Envirocase)] [SSTC NRS] [Bel V] [GRS]

Total PM: 27,4 + 1,7

A methodological group will support the pluralistic analyses by:

- Setting up the stakeholder groups (identification of potential members of the stakeholder group, preparation of a memorandum of understanding, contact and liaison with the different stakeholders, etc.);
- Reviewing materials of Tasks 2 to 4 and preparing materials related to Topics 1 to 4 to be discussed during the seminars, under a form enabling discussion between expert and non-expert members of the stakeholder groups;
- Proposing methods for structured discussions between stakeholders on Topics 1 to 4;
- Animating/facilitating the multi-stakeholder seminars;
- Analysing the outputs of seminars and preparing deliverables;
- Organising interactions with Civil Society and other stakeholders.

The 4 following topics will be addressed in Task 5:

- Topic 1: Meaning for different actors of uncertainty management and of its relationships with risk, safety and the safety case. This topic will investigate the views of each type of actors regarding what uncertainty management involves as well as how it relates to risk, safety and the safety case considering the decisions associated with each phase of a disposal programme. It will use as input existing literature, the outcomes of Subtasks 2.1 (generic strategies for managing uncertainties), Task 3, where the significance of different types of uncertainties will be identified, and Subtask 4.1 (identification and characterization of actors), as well as the outcome of the 1st seminar and additional elements stemming from subsequent seminars. (Related deliverable: D10.13)
- Topic 2: Uncertainty pictures at different steps of a geological disposal programme. This topic will investigate the evolution of the different types of uncertainties and of their significance for the different types of actors throughout a disposal programme based on the outcomes of Task 3, of the 1st and 2nd seminars as well as on additional outcomes from the 3rd seminar. (Related deliverable: D10.14)
 - Topic 3: Uncertainty management options for addressing uncertainties throughout a geological disposal programme. This topic will discuss the different options for the management of specific types of uncertainties and their implications. It will also investigate the preferences of the different types of actors on possible options. It will use as input the outcomes of Subtasks 2.1 and 4.3 and broaden the discussions initiated in Subtask 4.3 to a larger audience during the 3rd and 4th seminars. (Related deliverable: D10.15)
- Topic 4: Methods for a pluralistic assessment of uncertainties and their management along the disposal programme. This topic will explore methods that can be used for discussing and organising pluralistic assessments of uncertainties with civil society stakeholders throughout a disposal programme. This topic includes the communication of these issues and addresses both the development and the review of the safety case. It will be based on the outcome of Subtasks 2.1 and 4.1, on existing processes of exchanges between stakeholders in the EU, on the outcomes of the other topics as well as of the 4th seminar. (Related deliverable: D10.16)

4 seminars will be organised, covering the 4 topics (several topics can be addressed during 1 seminar):

- The 1st seminar (month 13) will set the scene by addressing the meaning for different actors of uncertainty management and of its relationships with risk, safety and the safety case (Topic 1). It will include discussions about the paradigms underlying the safety case. It will also address the outcome of the work performed in Subtask 3.1 concerning the different types of uncertainties to be addressed in a safety case.
- The 2nd seminar (month 25) will address uncertainty pictures at different steps of a geological disposal programme (Topic 2). Additionally, the seminar could also address available outcomes of Task 4.
- The 3rd seminar (month 37) will address options for managing uncertainties throughout a geological disposal programme (Topic 3). Additionally, the seminar could also address other outcomes of Task 2.
- During the 4th seminar (month 43) further exchanges on options for managing uncertainties (Topic 3) are foreseen, as well as exchanges on methods for a pluralistic assessment of uncertainties and their management along a disposal programme (Topic 4), on the basis of propositions of the methodological group.

Interactions with other tasks: Work, meetings and workshops in other tasks allow developing the « raw material » for the discussions with a broader audience during the multi-stakeholder seminars organised by Task 5 (see also other task descriptions).

UMAN Extension:

Subtask 5.1 will organize a 5th seminar aimed at testing the methodology developed during the 4th seminar using the material prepared by subtasks 3.6, 4.2 and 5.2 (see also other task descriptions).

Milestones

MS293: Composition of the pluralistic stakeholder group for UMAN Seminar 4 (Month 44)

MS308: Materials to be discussed in UMAN Seminar 5 (Month 52)

MS312: UMAN Seminar 5 (Month 54)

Deliverable

D10.20: UMAN - Application of the methods for a pluralistic assessment of uncertainties and their management to near-field uncertainties. This deliverable will document the outcome of the 5th seminar and the stakes related to the outcomes of UMAN activities related to near-field uncertainties from a civil society point of view (outcomes of Subtask 5.2). Lead organisation: IRSN (MUTADIS). Due month: 60.

Subtask 5.2 - Input of civil society experts

Start: Month 1 – End: Month 60 - Subtask Leader: [IRSN (MUTADIS)]

Subtask contributors: [IRSN (MUTADIS) (NTW)] [RWM]

Total PM: 7,4 + 2

A team of 4 civil society (CS) experts will be involved in different activities of the WP. However, for organizational convenience purposes, their contribution to the WP is described in a dedicated subtask. This allows having a clear framework for CSO engagement in WP activities that is methodologically coherent, regular in time, and coordinated

with the other CSO activities in EURAD. The role of CS experts is to sketch out and map the key stakes related to the work performed in the different subtasks from a civil society point of view in order to facilitate liaison with the broader CS group involved in EURAD and, in particular, in the WP through the seminars organised by Subtask 5.1 (Related deliverable: D10.17). These CS experts will:

- Follow the work performed in Tasks 2 to 4 and participate in key working meetings of these tasks;
- Contribute to the preparation of Task 5 seminars by preparing and performing specific presentations mapping the progress of the different tasks and the associated stakes for civil society. This progressive mapping of WP UMAN outcomes will finally be synthesised in Deliverable D10.17 (see below).
- Contribute to skill building of the broader CS group by preparing and animating a specific session dedicated to the WP UMAN in the CS annual workshop (which are different from Task 5 multi-stakeholder seminars).

Interactions with other tasks

- Tasks 2 to 4: Follow-up of the work performed in these tasks and mapping of the stakes related to the outcomes of these tasks from a civil society point of view
- EURAD as a whole: WP UMAN session during the CS annual workshop.

Existing Subtask 5.2 would be extended to include exchanges with civil society through:

- a review of subtask 3.6 and task 4 milestone documents & deliverables;
- the participation of civil society experts in the workshops.

Civil society (CS) experts would be in charge of preparing and organizing these interactions. For organizational convenience purposes, their contribution to the WP is described in a dedicated subtask. This allows having a clear framework for CSO engagement in WP activities that is methodologically coherent, regular in time, and coordinated with the other CSO activities in EURAD. The role of CS experts is to sketch out and map the key stakes related to the work performed in subtasks 3.6, 4.2 and 4.3 from a civil society point of view in order to facilitate liaison with the broader CS group involved in EURAD. These CS experts will:

- Follow the work performed in other subtasks and participate in key working meetings of these tasks;
- Contribute to the preparation of the 5th UMAN seminar by preparing and performing specific presentations on the stakes for civil society. These views will be finally documented in a new deliverable (see Subtask 5.1).
- Contribute to skill building of the broader CS group by preparing and animating a specific session dedicated to the WP UMAN in the CS annual workshop.

Milestone

MS307: Mapping of the stakes related to the outcome of subtasks 3.6, 4.2 & 4.3 (Month 52)

Participation per Partner

Partner number and short name	WP10 effort
1 - ANDRA	9.33
3 - BEL V	12.90
4 - BGE	6.50
6 - CIEMAT	3.50
8 - CNRS	0.00
IMT Atlantique	3.50
9 - COVRA	1.50
10 - FTMC	2.00
14 - ENRESA	2.50
15 - JUELICH	0.00
HZDR	3.30
16 - GRS	6.40
19 - IRSN	7.10
MUTADIS	12.80

Partner number and short name	WP10 effort
NTW	4.90
22 - JSI	1.50
EIMV	5.30
24 - KIT	2.70
Uni Clausthal	5.50
25 - LEI	3.70
27 - NAGRA	4.20
31 - NRG	3.80
32 - ONDRAF/NIRAS	2.50
33 - POSIVA	0.00
Envirocase	3.00
34 - PSI	5.33
36 - RATEN	8.40
37 - RWM	3.00
38 - SCK•CEN	5.40
40 - SSTC NRS	5.00
41 - STUBA	1.70
42 - SÚRAO	5.10
43 - SURO	3.60
45 - TS Enercon	1.20
46 - TUS	5.00
50 - VTT	2.93
GSL	2.50
Total	157.59

List of deliverables

Deliverable Number ¹⁴	Deliverable Title	Lead beneficiary	Type ¹⁵	Dissemination level ¹⁶	Due Date (in months) ¹⁷
D10.1	UMAN - Training materials	3 - BEL V	Report	Public	48
D10.2	UMAN - Strategies for managing uncertainties	50 - VTT	Report	Public	36
D10.3	UMAN - Uncertainty identification, classification and quantification	15 - JUELICH	Report	Public	36

List of deliverables

Deliverable Number¹⁴	Deliverable Title	Lead beneficiary	Type¹⁵	Dissemination level¹⁶	Due Date (in months)¹⁷
D10.4	UMAN - Methodological approaches to uncertainty and sensitivity analysis	24 - KIT	Report	Public	48
D10.5	UMAN - Uncertainties relevant to the safety case	8 - CNRS	Report	Public	36
D10.6	UMAN - Views of the different actors on the identification, characterization and potential significance of uncertainties on waste inventory and on the impact of predisposal steps	38 - SCK•CEN	Report	Public	36
D10.7	UMAN - Views of the different actors on the identification, characterization and potential significance of uncertainties on site and geosphere	36 - RATEN	Report	Public	36
D10.8	UMAN - Views of the different actors on the identification, characterization and potential significance of uncertainties on human aspects	1 - ANDRA	Report	Public	36
D10.9	UMAN - Views of the different actors on the identification, characterization and potential significance of uncertainties associated with spent fuel	6 - CIEMAT	Report	Public	48
D10.10	UMAN - Analysis and description of groups of different actors	4 - BGE	Report	Public	12
D10.11	UMAN - Study on management options for different types of uncertainties and programme phases	27 - NAGRA	Report	Public	42
D10.12	UMAN - Identification, analysis and description of preferences of different actors on	31 - NRG	Report	Public	48

List of deliverables

Deliverable Number¹⁴	Deliverable Title	Lead beneficiary	Type¹⁵	Dissemination level¹⁶	Due Date (in months)¹⁷
	uncertainty management options				
D10.13	UMAN - Understanding of uncertainty management by the various stakeholders	24 - KIT	Report	Public	40
D10.14	UMAN - Pluralistic analysis of uncertainty pictures	19 - IRSN	Report	Public	40
D10.15	UMAN - Pluralistic analysis of uncertainty management options and preferences of stakeholders vis-à-vis uncertainty management	1 - ANDRA	Report	Public	48
D10.16	UMAN - Methods for a pluralistic assessment of uncertainties and their management along the disposal programme	19 - IRSN	Report	Public	48
D10.17	UMAN - Synthetic mapping of the stakes related to WP UMAN outcomes from a civil society point of view	19 - IRSN	Report	Public	48
D10.18	UMAN - Views of the different actors on the identification, characterization and potential significance of uncertainties on the near-field.	34 - PSI	Report	Public	57
D10.19	UMAN - Identification, analysis and description of preferences of different actors on options for managing uncertainties related to the near field	16 - GRS	Report	Public	57
D10.20	UMAN - Application of the methods for a pluralistic assessment of uncertainties and their management to near-field uncertainties.	19 - IRSN	Report	Public	60

Description of deliverables

- D10.1: Training materials - Lead: [Bel V] Due month: 48
- D10.2: Strategies for managing uncertainties: Regulatory background, overview of applied strategies, interactions between strategies, consideration of the stepwise nature of the decision-making process, identification of areas of possible further development. Lead: [VTT (GSL)]. Due month: 36.
- D10.3: Uncertainty identification, classification and quantification: Approaches to identifying uncertainties, expert elicitation, classification of uncertainties, objective quantification of uncertainties, and identification of areas of possible further development. Lead: [JUELICH (HZDR)]. Due month: 36.
- D10.4: Methodological approaches to uncertainty and sensitivity analysis: Overview of mathematical methods for uncertainty and sensitivity analysis, comparison of their specifics, identification of areas for further development. Lead: [KIT (TU Clausthal)] Due month: 48.
- D10.5: Uncertainties relevant to the safety case: This deliverable will describe the various types of uncertainties that need to be addressed in a safety analysis and in a safety case as well as how these uncertainties may evolve throughout the different phases of a disposal programme. Lead: [CNRS] Due Month: 36.
- D10.6: Views of the different actors on the identification, characterization and potential significance of uncertainties on waste inventory and on the impact of predisposal steps: This deliverable will describe the views of different categories of actors on the uncertainties associated with the waste inventory which need to be addressed in a safety case as well as on their characterization, evolution and potential significance including the impact of predisposal phases and their significance for the disposal safety. Recommendations for future R&D, KM or strategic study activities will be provided. Lead: [SCK•CEN]. Due Month: 36.
- D10.7: Views of the different actors on the identification, characterization and potential significance of uncertainties on site and geosphere: This deliverable will describe the views of different categories of actors on uncertainties associated with the site and geosphere that need to be addressed in a safety case for different disposal concepts as well as on their characterization, evolution and potential significance for safety, and will include recommendations for future RD&D, KM and strategic study activities. Lead [RATEN] Due Month: 36.
- D10.8: Views of the different actors on the identification, characterization and potential significance of uncertainties on human aspects: This deliverable will describe the views of different categories of actors on uncertainties on human aspects that need to be addressed in a safety case as well as on their characterization, evolution and potential significance for safety. The deliverable will also include recommendations for characterization of non-technical uncertainties as well as for future RD&D, KM and strategic study activities. Lead [Andra] Due Month: 36.
- D10.9: Views of the different actors on the identification, characterization and potential significance of uncertainties associated with spent fuel. This deliverable will describe the views of different categories of actors on uncertainties on SF storage, transport and disposal that need to be addressed in a safety case as well as on their characterization, evolution and potential significance for safety. The deliverable will also include recommendations for the future RD&D, KM and strategic study activities. Lead [CIEMAT] Due Month: 48.
- D10.10: Analysis and description of groups of different actors: This deliverable will identify the different categories of actors involved in each phase of a disposal programme as well as their roles and interests. Lead [BGE] Due month: 12.
- D10.11: Study on management options for different types of uncertainties and programme phases. This deliverable will identify possible management options for different types of uncertainties and programme phases based on existing information. Draft versions of this deliverable will provide a basis for the discussions and exchanges held in Subtask 4.3. Lead [NAGRA] Due month: 42.
- D10.12: Identification, analysis and description of preferences of different actors on uncertainty management options: This deliverable will identify and describe preferences on uncertainty management options by groups of different actors as well as the rationale behind these preferences. Draft versions of this deliverable will provide a basis for the discussions and exchanges held in the seminars organised by Task 5. Lead [NRG] Due month: 48.
- D10.13: Understanding of uncertainty management by the various stakeholders. This deliverable will document the work related to Topic 1. Lead organisation: TU Clausthal. Due month: 40.
- D10.14: Pluralistic analysis of uncertainty pictures. This deliverable will document the work related to Topic 2. Lead [IRSN] Due month: 40.
- D10.15: Pluralistic analysis of uncertainty management options and preferences of stakeholders vis-à-vis uncertainty management. This deliverable will document the work related to Topic 3. Lead [Andra] Due month: 48.
- D10.16: Methods for a pluralistic assessment of uncertainties and their management along the disposal programme. This deliverable will document the work related to Topic 4. Lead [MUTADIS] Due month: 48.
- D10.17: Synthetic mapping of the stakes related to WP UMAN outcomes from a civil society point of view. This deliverable will synthesise the stakes related to the work and outcome of the different tasks of the WP from a civil society point of view. Lead [MUTADIS] Due month: 48.
- D10.18 UMAN - Views of the different actors on the identification, characterization and potential significance of uncertainties on the near-field Lead: [PSI] Due month: 57

- D10.19 UMAN - Identification, analysis and description of preferences of different actors on options for managing uncertainties related to the near field Lead [GRS] Due month: 57
- D10.20 UMAN - Application of the methods for a pluralistic assessment of uncertainties and their management to near-field uncertainties. Lead [IRSN] Due month: 60

D10.1 : UMAN - Training materials [48]

UMAN - Training materials

D10.2 : UMAN - Strategies for managing uncertainties [36]

UMAN - Strategies for managing uncertainties

D10.3 : UMAN - Uncertainty identification, classification and quantification [36]

UMAN - Uncertainty identification, classification and quantification

D10.4 : UMAN - Methodological approaches to uncertainty and sensitivity analysis [48]

UMAN - Methodological approaches to uncertainty and sensitivity analysis

D10.5 : UMAN - Uncertainties relevant to the safety case [36]

UMAN - Uncertainties relevant to the safety case

D10.6 : UMAN - Views of the different actors on the identification, characterization and potential significance of uncertainties on waste inventory and on the impact of predisposal steps [36]

UMAN - Views of the different actors on the identification, characterization and potential significance of uncertainties on waste inventory and on the impact of predisposal steps

D10.7 : UMAN - Views of the different actors on the identification, characterization and potential significance of uncertainties on site and geosphere [36]

UMAN - Views of the different actors on the identification, characterization and potential significance of uncertainties on site and geosphere

D10.8 : UMAN - Views of the different actors on the identification, characterization and potential significance of uncertainties on human aspects [36]

UMAN - Views of the different actors on the identification, characterization and potential significance of uncertainties on human aspects

D10.9 : UMAN - Views of the different actors on the identification, characterization and potential significance of uncertainties associated with spent fuel [48]

UMAN - Views of the different actors on the identification, characterization and potential significance of uncertainties associated with spent fuel

D10.10 : UMAN - Analysis and description of groups of different actors [12]

UMAN - Analysis and description of groups of different actors

D10.11 : UMAN - Study on management options for different types of uncertainties and programme phases [42]

UMAN - Study on management options for different types of uncertainties and programme phases

D10.12 : UMAN - Identification, analysis and description of preferences of different actors on uncertainty management options [48]

UMAN - Identification, analysis and description of preferences of different actors on uncertainty management options

D10.13 : UMAN - Understanding of uncertainty management by the various stakeholders [40]

UMAN - Understanding of uncertainty management by the various stakeholders

D10.14 : UMAN - Pluralistic analysis of uncertainty pictures [40]

UMAN - Pluralistic analysis of uncertainty pictures

D10.15 : UMAN - Pluralistic analysis of uncertainty management options and preferences of stakeholders vis-à-vis uncertainty management [48]

UMAN - Pluralistic analysis of uncertainty management options and preferences of stakeholders vis-à-vis uncertainty management

D10.16 : UMAN - Methods for a pluralistic assessment of uncertainties and their management along the disposal programme [48]

UMAN - Methods for a pluralistic assessment of uncertainties and their management along the disposal programme

D10.17 : UMAN - Synthetic mapping of the stakes related to WP UMAN outcomes from a civil society point of view [48]

UMAN - Synthetic mapping of the stakes related to WP UMAN outcomes from a civil society point of view

D10.18 : UMAN - Views of the different actors on the identification, characterization and potential significance of uncertainties on the near-field. [57]

UMAN - Views of the different actors on the identification, characterization and potential significance of uncertainties on the near-field.

D10.19 : UMAN - Identification, analysis and description of preferences of different actors on options for managing uncertainties related to the near field [57]

UMAN - Identification, analysis and description of preferences of different actors on options for managing uncertainties related to the near field

D10.20 : UMAN - Application of the methods for a pluralistic assessment of uncertainties and their management to near-field uncertainties. [60]

UMAN - Application of the methods for a pluralistic assessment of uncertainties and their management to near-field uncertainties.

Schedule of relevant Milestones

Milestone number ¹⁸	Milestone title	Lead beneficiary	Due Date (in months)	Means of verification
MS1	EURAD Kick-off meeting (General Assembly n°1)	1 - ANDRA	1	EURAD Kick-off meeting (General Assembly n°1)
MS12	EURAD EJP Newsletters	1 - ANDRA	3	EURAD EJP Newsletters (Due date : M3 and then every quarter)
MS21	UMAN Draft D10.5 as input to Task 2, Task 4, Task 5 and other subtasks of Task 3	3 - BEL V	6	UMAN Draft D10.5 as input to Task 2, Task 4, Task 5 and other subtasks of Task 3
MS22	UMAN Preliminary list of uncertainties from UMAN subtask 3.3 as input to Subtask 4.2	3 - BEL V	6	UMAN Preliminary list of uncertainties from UMAN subtask 3.3 as input to Subtask 4.2
MS23	UMAN Preliminary list of uncertainties from subtask 3.4 as input to Subtask 4.2	3 - BEL V	6	UMAN Preliminary list of uncertainties from subtask 3.4 as input to Subtask 4.2
MS24	UMAN Identification of the different actors across the various programme phases including a first characterization of their roles and interests (Draft D10.10)	3 - BEL V	6	UMAN Identification of the different actors across the various programme phases including a first characterization of their roles and interests (Draft D10.10)
MS25	UMAN Composition of the pluralistic stakeholder group for Seminar 1	3 - BEL V	6	UMAN Composition of the pluralistic stakeholder group for Seminar 1
MS26	SOTA from RD&D CORI WP as input to UMAN T3.2	24 - KIT	6	SOTA from RD&D CORI WP as input to UMAN T3.2

Schedule of relevant Milestones

Milestone number ¹⁸	Milestone title	Lead beneficiary	Due Date (in months)	Means of verification
MS27	SOTA from RD&D FUTuRE WP as input to UMAN T3.3	15 - JUELICH	6	SOTA from RD&D FUTuRE WP as input to UMAN T3.3
MS29	SOTA from RD&D SFC WP as input to UMAN T3.5	39 - SKB	6	SOTA from RD&D SFC WP as input to UMAN T3.5
MS30	EURAD General Assembly n°2	1 - ANDRA	7	EURAD General Assembly n°2
MS40	UMAN Draft deliverable D10.2 as input to Tasks 4 and 5	3 - BEL V	7	UMAN Draft deliverable D10.2 as input to Tasks 4 and 5
MS42	EURAD Annual Work Plan 2	1 - ANDRA	9	EURAD Annual Work Plan 2
MS54	UMAN Preliminary list of uncertainties from subtask 3.5 as input to Subtask 4.2	3 - BEL V	10	UMAN Preliminary list of uncertainties from subtask 3.5 as input to Subtask 4.2
MS67	UMAN Recommendations for future RD&D, strategic study and KM activities for the 2nd wave of EURAD-1	3 - BEL V	12	UMAN Recommendations for future RD&D, strategic study and KM activities for the 2nd wave of EURAD-1
MS68	Materials to be discussed in UMAN Seminar 1	3 - BEL V	12	Materials to be discussed in UMAN Seminar 1
MS69	UMAN Mapping of the stakes related to the outcomes of Task 2 and Subtask 3.1 from a civil society point of view for the 1st Task 5 seminar	3 - BEL V	12	UMAN Mapping of the stakes related to the outcomes of Task 2 and Subtask 3.1 from a civil society point of view for the 1st Task 5 seminar
MS71	Methodology for ICS activities assessment	19 - IRSN	12	Methodology for ICS activities assessment
MS74	UMAN WP meeting 1	3 - BEL V	13	UMAN WP meeting 1
MS75	UMAN Draft D10.3 as input to Task 3	3 - BEL V	13	UMAN Draft D10.3 as input to Task 3
MS76	UMAN Draft D10.7 as input to Task 4 and 5	3 - BEL V	13	UMAN Draft D10.7 as input to Task 4 and 5
MS77	UMAN Seminar 1	3 - BEL V	13	UMAN Seminar 1
MS81	EURAD General Assembly n°3 + EURAD Annual Meeting 1	1 - ANDRA	13	EURAD General Assembly n°3 + EURAD Annual Meeting 1
MS82	ICS Workshop 1	19 - IRSN	13	ICS Workshop 1
MS85	EURAD Periodic Report 1	1 - ANDRA	14	EURAD Periodic Report 1
MS89	UMAN Compiled and reviewed information about possible management options for site and geosphere related uncertainties as input to Subtask 4.3	3 - BEL V	15	UMAN Compiled and reviewed information about possible management options for site and geosphere related uncertainties as input to Subtask 4.3

Schedule of relevant Milestones

Milestone number¹⁸	Milestone title	Lead beneficiary	Due Date (in months)	Means of verification
MS92	UMAN Preliminary list of uncertainties from subtask 3.2 as input to Subtask 4.2	3 - BEL V	16	UMAN Preliminary list of uncertainties from subtask 3.2 as input to Subtask 4.2
MS101	UMAN Draft D10.8 as input to Task 4 and 5	3 - BEL V	18	UMAN Draft D10.8 as input to Task 4 and 5
MS102	Composition of the pluralistic stakeholder group for UMAN Seminar 2	3 - BEL V	18	Composition of the pluralistic stakeholder group for UMAN Seminar 2
MS103	EURAD General Assembly n ^o 4	1 - ANDRA	19	EURAD General Assembly n ^o 4
MS108	UMAN Workshop 1 on management options and preferences of different actors regarding site and geosphere related uncertainties	3 - BEL V	19	UMAN Workshop 1 on management options and preferences of different actors regarding site and geosphere related uncertainties
MS111	UMAN Draft D10.9 as input to Task 4 and 5	3 - BEL V	20	UMAN Draft D10.9 as input to Task 4 and 5
MS112	EURAD Annual Work Plan 3	1 - ANDRA	21	EURAD Annual Work Plan 3
MS113	UMAN Compiled and reviewed information about possible management options for uncertainties related to the human aspects as input to Subtask 4.3	3 - BEL V	21	UMAN Compiled and reviewed information about possible management options for uncertainties related to the human aspects as input to Subtask 4.3
MS118	UMAN Compiled and reviewed information about possible management options for uncertainties related to spent fuel as input to Subtask 4.3	3 - BEL V	23	UMAN Compiled and reviewed information about possible management options for uncertainties related to spent fuel as input to Subtask 4.3
MS128	Materials to be discussed in UMAN Seminar 2	3 - BEL V	24	Materials to be discussed in UMAN Seminar 2
MS129	Mapping of the stakes related to the outcomes of UMAN Tasks 2, 3 and 4 from a civil society point of view for the 2nd Task 5 seminar	3 - BEL V	24	Mapping of the stakes related to the outcomes of UMAN Tasks 2, 3 and 4 from a civil society point of view for the 2nd Task 5 seminar
MS133	UMAN WP meeting 2	3 - BEL V	25	UMAN WP meeting 2
MS134	UMAN Workshop 2 on management options and preferences of different actors regarding human aspects related uncertainties	3 - BEL V	25	UMAN Workshop 2 on management options and preferences of different actors regarding human aspects related uncertainties
MS135	UMAN Seminar 2	3 - BEL V	25	UMAN Seminar 2

Schedule of relevant Milestones

Milestone number¹⁸	Milestone title	Lead beneficiary	Due Date (in months)	Means of verification
MS136	EURAD General Assembly n°5 + EURAD Annual Meeting 2	1 - ANDRA	25	EURAD General Assembly n°5 + EURAD Annual Meeting 2
MS137	ICS Workshop 2	19 - IRSN	25	ICS Workshop 2
MS140	EURAD Periodic Report 2	1 - ANDRA	26	EURAD Periodic Report 2
MS143	UMAN Draft 10.6 as input to Task 4 and 5	3 - BEL V	26	UMAN Draft 10.6 as input to Task 4 and 5
MS145	UMAN Compiled and reviewed information about possible management options for uncertainties related to waste inventory as input to Subtask 4.3	3 - BEL V	28	UMAN Compiled and reviewed information about possible management options for uncertainties related to waste inventory as input to Subtask 4.3
MS146	UMAN Workshop 3 on management options and preferences of different actors regarding SF-related uncertainties	3 - BEL V	28	Change of "... regarding waste inventory..." into "SF-related uncertainties" New title: UMAN Workshop 3 on management options and preferences of different actors regarding SF-related uncertainties
MS147	Composition of the pluralistic stakeholder group for UMAN Seminar	3 - BEL V	29	Composition of the pluralistic stakeholder group for UMAN Seminar
MS152	Last input from ROUTES to UMAN	19 - IRSN	30	Last input from ROUTES to UMAN
MS153	EURAD General Assembly n°6	1 - ANDRA	31	EURAD General Assembly n°6
MS159	UMAN Input to Task 5 on management options and preferences of different actors regarding site and geosphere and human aspects related uncertainties	3 - BEL V	31	UMAN Input to Task 5 on management options and preferences of different actors regarding site and geosphere and human aspects related uncertainties
MS162	EURAD Annual Work Plan 4	1 - ANDRA	33	EURAD Annual Work Plan 4
MS164	UMAN Workshop 4 on management options and preferences of different actors regarding SF-related uncertainties	3 - BEL V	33	Change of "... regarding SF-related uncertainties" into "waste inventory related uncertainties" New title: UMAN Workshop 4 on management options and preferences of different actors regarding waste inventory related uncertainties

Schedule of relevant Milestones

Milestone number¹⁸	Milestone title	Lead beneficiary	Due Date (in months)	Means of verification
MS166	Composition of the pluralistic stakeholder group for UMAN Seminar 4	3 - BEL V	35	Composition of the pluralistic stakeholder group for UMAN Seminar 4
MS178	Materials to be discussed in UMAN Seminar 3	3 - BEL V	36	Materials to be discussed in UMAN Seminar 3
MS179	Mapping of the stakes related to the outcomes of UMAN Tasks 2, 3 and 4 from a civil society point of view for the 3rd Task 5 seminar	3 - BEL V	36	Mapping of the stakes related to the outcomes of UMAN Tasks 2, 3 and 4 from a civil society point of view for the 3rd Task 5 seminar
MS182	UMAN WP meeting 3	3 - BEL V	37	UMAN WP meeting 3
MS183	UMAN Input to Task 5 on management options and preferences of different actors regarding waste inventory and SF related uncertainties	3 - BEL V	37	UMAN Input to Task 5 on management options and preferences of different actors regarding waste inventory and SF related uncertainties
MS184	UMAN Seminar 3	3 - BEL V	37	UMAN Seminar 3
MS185	EURAD General Assembly n°7 + EURAD Annual Meeting 3	1 - ANDRA	37	EURAD General Assembly n°7 + EURAD Annual Meeting 3
MS186	ICS Workshop 3	19 - IRSN	37	ICS Workshop 3
MS189	EURAD Periodic Report 3	1 - ANDRA	38	EURAD Periodic Report 3
MS197	Materials to be discussed in UMAN Seminar 4	3 - BEL V	42	Materials to be discussed in UMAN Seminar 4
MS198	Mapping of the stakes related to the outcomes of UMAN Tasks 2, 3 and 4 from a civil society point of view for the 4th Task 5 seminar	3 - BEL V	42	Mapping of the stakes related to the outcomes of UMAN Tasks 2, 3 and 4 from a civil society point of view for the 4th Task 5 seminar
MS199	EURAD General Assembly n°8	1 - ANDRA	43	EURAD General Assembly n°8
MS204	UMAN Seminar 4	3 - BEL V	43	UMAN Seminar 4
MS206	EURAD Annual Work Plan 5	1 - ANDRA	45	EURAD Annual Work Plan 5
MS208	Recommendations of UMAN for future RD&D, strategic study and KM activities for future EURAD implementation phase	3 - BEL V	46	Recommendations of UMAN for future RD&D, strategic study and KM activities for future EURAD implementation phase
MS222	EURAD General Assembly n°9 + EURAD Annual Meeting 4	1 - ANDRA	49	EURAD General Assembly n°9 + EURAD Annual Meeting 4
MS223	ICS Workshop 4	19 - IRSN	49	ICS Workshop 4
MS224	EURAD Periodic Report 4	1 - ANDRA	50	EURAD Periodic Report 4

Schedule of relevant Milestones

Milestone number¹⁸	Milestone title	Lead beneficiary	Due Date (in months)	Means of verification
MS234	EURAD General Assembly n°10	1 - ANDRA	55	EURAD General Assembly n°10
MS235	ICS Workshop 5	19 - IRSN	55	ICS Workshop 5
MS240	EURAD General Assembly n°11 + EURAD Annual Meeting 5	1 - ANDRA	60	EURAD General Assembly n°11 + EURAD Annual Meeting 5
MS241	EURAD Periodic Report 5	1 - ANDRA	60	EURAD Periodic Report 5 (Due date: 60+2)
MS252	UMAN - SOTA from the CONCORD WP as input to UMAN Subtask 3.6	16 - GRS	27	UMAN - SOTA from the CONCORD WP as input to UMAN Subtask 3.6
MS261	UMAN - Preliminary list of uncertainties from UMAN Subtask 3.6 as input to Subtask 4.2 and questionnaire	3 - BEL V	30	UMAN - Preliminary list of uncertainties from UMAN Subtask 3.6 as input to Subtask 4.2 and questionnaire
MS262	UMAN - SOTA from the MAGIC WP as input to UMAN Subtask 3.6	8 - CNRS	30	UMAN - SOTA from the MAGIC WP as input to UMAN Subtask 3.6
MS282	UMAN Draft D10.18 as input to workshop and Tasks 4 and 5	3 - BEL V	37	UMAN Draft D10.18 as input to workshop and Tasks 4 and 5
MS285	UMAN - Workshop on the significance and characterization of near-field uncertainties	3 - BEL V	39	UMAN - Workshop on the significance and characterization of near-field uncertainties
MS291	UMAN - Compiled and reviewed information about possible management options for near-field related uncertainties	3 - BEL V	43	UMAN - Compiled and reviewed information about possible management options for near-field related uncertainties
MS293	UMAN - Composition of the pluralistic stakeholder group for UMAN Seminar 5	3 - BEL V	44	UMAN - Composition of the pluralistic stakeholder group for UMAN Seminar 5
MS295	UMAN - WS5 - Management options and preferences of different actors regarding near-field related uncertainties	3 - BEL V	45	UMAN - WS5 - Management options and preferences of different actors regarding near-field related uncertainties
MS304	UMAN - WP meeting 4	3 - BEL V	49	UMAN - WP meeting 4
MS307	UMAN - Mapping of the stakes related to the outcome of subtasks 3.6, 4.2 & 4.3 as input to UMAN Seminar 5	3 - BEL V	52	UMAN - Mapping of the stakes related to the outcome of subtasks 3.6, 4.2 & 4.3 as input to UMAN Seminar 5

Schedule of relevant Milestones

Milestone number¹⁸	Milestone title	Lead beneficiary	Due Date (in months)	Means of verification
MS308	UMAN - Materials to be discussed in UMAN Seminar 5	3 - BEL V	52	UMAN - Materials to be discussed in UMAN Seminar 5
MS312	UMAN - 5th UMAN Seminar	3 - BEL V	54	UMAN - 5th UMAN Seminar

Work package number ⁹	WP11	Lead beneficiary ¹⁰	4 - BGE
Work package title	State-of-Knowledge		
Start month	1	End month	60

Objectives

Objectives

The main goal of the KM SoK WP is to establish the State-of-Knowledge (SoK), i.e. preserving, capitalising of and providing open-access to knowledge generated in the field of radioactive waste management (RWM) research that can be extracted by present and future generations of experts and by any interested end-users in Europe and beyond (including for example WMO, TSOs, REs, Programme Owners,).

In EURAD, we define ‘State-of-Knowledge’ as the science and technology underpinning RWM in a given topic. Its management will be enhanced by providing access to a structured review and summary of relevant published scientific literature by producing corresponding documents. ‘State-of-Knowledge’ includes access to:

- State-of-the-art on scientific/technical knowledge that has been generated internationally over the past (EURATOM projects FP6, FP7, H2020), as well as the current status of understanding with respect to RD&D needs and potential impacts regarding implementation and safety; and
- Relevant complementary scientific/technical sources developed/generated in the framework of, IGD-TP, SITEX, IAEA, NEA, national programmes, etc. and that are publicly available. This includes training materials and initiatives, international guidance, etc.

Approach

The proposed stepwise approach of this WP consists of

- i) establishing procedures to document the State-of-Knowledge in a given topic, and how it can be regularly revised in order to integrate new knowledge.
- ii) testing and improving the procedures on a few demonstration cases. By developing such demonstration cases the general approach of the KM Programme will establish a clear specification (i.e. requirements, procedures and functionalities) for the SoK.
- iii) performing a review on experiences made for similar approaches by other organisations and in other areas. Subsequently the added-value of establishing a specific platform dedicated to provide access to SoK developed in EURAD will be evaluated. In addition, the EURAD community will be asked for feedback, prior to full development and initiation of a prioritised programme of SoK population.

The mission is to coordinate all work and mobilise and manage the necessary resources to allow the WP work to keep focussed on the 1st stage of the approach for the first two years and to prepare a proposal for decision by the GA on how to move forward at the end of the 2nd year. This approach will assure that there will be regular exchanges between WP11 with the colleges through the Bureau (respecting their needs), between and with WP12, WP13, to (including their needs) and with EURAD community at large to mobilise available internal resources and to limit needs for external experts.

Description of work and role of partners

WP11 - State-of-Knowledge [Months: 1-60]

BGE, ANDRA, BEL V, CIEMAT, JUELICH, JRC, SSTC NRS

Task 1- Transfer from existing knowledge programmes towards the development of the KM programme

Start: Month 1– End: Month 60 - Task Leader: [JUELICH (HZDR, 10 pm)]

Task Contributors: [BGE, 5 pm] [SSTC NRS, 4 pm] [ANDRA, 0,7 pm] [CIEMAT, 0,7 pm],[JRC, 0,1 pm] as well as EURAD experts [Bel V, 4 pm] and external experts.

Screening and review (Deliverable 11.1) of existing/available knowledge management approaches and/or tools that have been developed for similar purposes with respect to their functionalities and suitability for EURAD KM. This includes lessons learned and best practice. The work is managed by the WP team with input from the EURAD Bureau, from Experts identified as part of WP1 Task 4 EURAD.

Results from the screening exercise of KM programmes among large organisations (performed during the first 2 years) will be used as starting point to identify and adapt suitable tools to the EURAD programme. Activities will be:

- Discussion of the results with well-established partners, e.g. IAEA, in respect to feasibility and costs.
- Definition of the envisaged functionality of the EURAD KM platform prototype, including feedback functionalities and selection of suitable IT platforms / coding environments (MS 242, Month 36) (link to Task 4).

- Initiate a beta testing phase in order to further develop the prototype platform as a key function of the EURAD KM programme.

Deliverable D11.9 (Month 36) will describe and explain reasons and arguments for the choice and development of the KM platform including an estimation of needed resources. These activities shall include first thoughts about specifications for a long-term hosting of the KM platform, beyond EURAD-1. For the years 4 and 5 it is planned to define the requirements and path the way for a sustainable hosting solution.

Task 2 – Setting up and implementation of SoK documents

Start: Month 1 – End: Month 60 - Task Leader: [BGE, 29,80 pm]

Task Contributors: [JUELICH (HZDR), 11 pm] [SSTC NRS, 5 pm] [ANDRA, 0,5 pm] [CIEMAT, 0,25 pm]

Year 1

At the onset of the WP, a few topics suitable as demonstration cases are selected. The topics are deduced from the Roadmap. Criteria for final selection of the best suitable demonstration cases include already existing training materials from other projects or international guidance, relevance for end-users, access to information/knowledge, active RD&D projects and availability of experts. For implementation of the demonstration cases, a first proposal is made for accessibility of, mapping, selection, structuring and processing of existing knowledge. This is an iterative process, including feed-back from the Bureau, PMO, etc. In a next step, an estimation is made for efforts and resources required for establishing further developed demonstration cases (individual cases), reflecting different levels of detail and width. This information is addressed to the Bureau, and is used for decisions on population options for the demonstration cases. (Deliverable 11.2)

Year 2

At latest at the start of the second, year, the Competence Matrix becomes available (D1.5). It is used for refining the access to expertise and competence for further population of the Demonstration cases. There is an ongoing refinement process including optimisation of criteria, procedures, by screening already existing training materials from other projects or international guidance, as well as a dissemination process. In addition, Quality Assurance and intellectual property issues are addressed and updated. Feedback by the EURAD colleges is collected and integrated through the Bureau. In case of intersection with ongoing R&D and SS WP's, the corresponding SOTA are also used. Assessment of the costs for populating the demonstration cases influence the final decision on the SoK structure and content, as well as the planning for broad SoK implementation in the following years (Deliverable 11.3)

Additionally, the coordination of the Domain Insight production will be performed by WP11 from February 2021 (year 2).

This activity is linked to the activities for SoK production, to the implementation of Theme overviews and in will be conducted close collaboration with the PMO, the Roadmap Development Team and input from all EURAD WPs (RD&D, StS and KM). Implementation status, results, lessons learned and improvements will be regularly reported towards PMO, Bureau and towards the GA (MS 245, month 32). It is envisaged to submit a deliverable with the results, lessons-learned and recommendations for future KM programme by the end of year 5. All these activities will last until the end of EURAD-1

Task 3 – Identification and engagement of experts for knowledge transfer

Start: Month 3 – End: Month 60 - Task Leader: [BGE, 10 pm] & [JUELICH (HZDR), 10 pm]

Task Contributors: [SSTC NRS, 5 pm]

This task establishes procedures for engagement of knowledge providers (covering both individual experts, institutions, and international organisations) and will be elaborated in cooperation with them (e.g. IAEA) Deliverable 1.14. Such knowledge providers are needed to give orientation on generic waste disposal issues, as well as direct scientific-technical involvement on specific topics.

Once developed, the competence matrix provides the key source for identification of knowledge providers. As necessary, additional competence carriers for specific needs in identifying, extracting and translating information and knowledge may be identified.

When writing the SoK and populating it, there is an interplay between KM WP11 and EURAD identified experts. The WP 11 partners will contribute by organizing the work, i.e. managing the process. The key sources of expertise, however, will be recruited by addressing the colleges and where relevant, on-going RD&D WPs.

The same applies to Domain Insight documents. The coordination of the Domain Insight production will be performed by WP11 from February 2021 (year 2). Results, lessons learned and improvements to processes will be reported to the GA (MS 243, Month 32). All these activities will last until the end of EURAD-1.

Task 4 - SoK Quality Management – evaluation and optimisation of methods and procedures

Start: Month 4 – End: Month 60 - Task Leader: [SSTC NRS, 17 pm]

Task Contributors: [JUELICH (HZDR), 5 pm] [BGE, 3 pm] [ANDRA, 2,2 pm] [CIEMAT, 0,2] [JRC, 0,1]

The objective of this task is to develop QA procedures for the generation of SoK, assessing the appropriateness of the SoK generation process. For that purpose, with the support by the colleges, a QA plan is established, and revised and updated in several. The QA plan includes criteria, specifications, procedures for its implementation and control mechanisms. QA criteria reflect needs for end-users, including scientific excellence, inclusiveness, confidence levels and confidentiality levels. The GA approves the QA plan at the end of the second ProjectYear.

The QA plan will ensure that the SoK is balanced and inclusive, provides the basis for next generation of experts to enter the field, contains the scientific-technical state-of-the-art (SOTA) and is fit for purpose in the overall KM Programme. Furthermore, the QA plan will ensure that the SoK does not contain policy statements or other statements potentially compromising the interests of the WMOs, TSOs or REs (Deliverables 11.5 and 11.6)

Questions of QA will also be addressed regarding the Domain Insight documents and the links to the EURAD KM programme. Developed mechanisms and results will be reported in D 11.10 (MS 244, Month 36).

In year 4 it is envisaged to formulate recommendations and draft the integration of full feedback functionality into the KM system. All of these activities will last until the end of EURAD-1.

Task 5 – Contribution to Roadmap Mapping

Start date: Month 13 End Date: Month 24

Task Leader: [BGE, 3 pm]

The objective of this task is to prepare a results summary of the previous elaborated written specifications and documentation as well as the resulting technical implementation of SoK structure and content, QA Procedures, and Guidelines (Deliverable 11.7)

At the end of the second ProjectYear the decision is taken on how to proceed in the General Assembly. This could be done by a technical implementation tool which could be a single platform or a combination of different ones, making use of both existing ones (that possibly need adaptations) and new ones that need to be developed.

Participation per Partner

Partner number and short name	WP11 effort
1 - ANDRA	3.40
3 - BEL V	4.00
4 - BGE	50.80
6 - CIEMAT	1.15
15 - JUELICH	0.00
HZDR	36.00
23 - JRC	0.20
40 - SSTC NRS	31.00
Total	126.55

List of deliverables

Deliverable Number ¹⁴	Deliverable Title	Lead beneficiary	Type ¹⁵	Dissemination level ¹⁶	Due Date (in months) ¹⁷
D11.1	Screening and review of existing/available knowledge management approaches and/or tools	15 - JUELICH	Report	Public	13

List of deliverables

Deliverable Number¹⁴	Deliverable Title	Lead beneficiary	Type¹⁵	Dissemination level¹⁶	Due Date (in months)¹⁷
D11.2	List of selected demonstration cases, criteria for final selection, proposal and estimation of effort and resources	4 - BGE	Report	Public	9
D11.3	Outcomes of the demonstration cases	4 - BGE	Report	Public	22
D11.4	Procedures to Involve Knowledge providers	4 - BGE	Report	Public	13
D11.5	QA procedures for the generation of SoK demonstration cases	40 - SSTC NRS	Report	Public	4
D11.6	revised QA procedures	40 - SSTC NRS	Report	Public	19
D11.7	Contribute to establishment of the initial SoK Roadmap Mapping and Gap Analysis led by WP1 (PMO)	4 - BGE	Report	Public	24
D11.8	KM SoK - Authors Guidance & Template	4 - BGE	Report	Public	24
D11.9	KM SoK - Specification of the EURAD KM platform	15 - JUELICH	Report	Public	36
D11.10	KM SoK - Feedback mechanism for Domain Insights, SoK documents and KM Systems – Methods and results	40 - SSTC NRS	Report	Public	36

Description of deliverables

- Deliverable 11.1 – Screening and review of existing/available knowledge management approaches and/or tools (Month: 13) : [JUELICH (HZDR)]
- Deliverable 11.2 – List of selected demonstration cases, criteria for final selection, proposal and estimation of effort and resources (Month 9) Lead: [BGE]
- Deliverable 11.3 – Outcomes of the demonstration cases (Month 22) Lead: [BGE]
- Deliverable 11.4 – Procedures to Involve Knowledge providers (Month 13) Lead: [BGE]
- Deliverable 11.5 – QA procedures for the generation of SoK demonstration cases (Month 4) Lead: [SSTC NRS]
- Deliverable 11.6 – revised QA procedures (Month 19) Lead: [SSTC NRS]
- Deliverable 11.7 – Contribute to establishment of the initial SoK Roadmap Mapping and Gap Analysis led by WP1 (PMO) (Month 24) Lead: [BGE]
- Deliverable 11.8 - Authors Guidance & Template (Version 1) (Month 24) Lead: [BGE]
- Deliverable 11.9 - Specification of the EURAD KM platform (Month 36) Lead: [JUELICH]
- Deliverable 11.10 - Feedback mechanism for Domain Insights, SoK documents and KM Systems –Methods and results (Month 36) Lead: [SSTC]

D11.1 : Screening and review of existing/available knowledge management approaches and/or tools [13]

Screening and review of existing/available knowledge management approaches and/or tools
D11.2 : List of selected demonstration cases, criteria for final selection, proposal and estimation of effort and resources [9] List of selected demonstration cases, criteria for final selection, proposal and estimation of effort and resources
D11.3 : Outcomes of the demonstration cases [22] Outcomes of the demonstration cases
D11.4 : Procedures to Involve Knowledge providers [13] Procedures to Involve Knowledge providers
D11.5 : QA procedures for the generation of SoK demonstration cases [4] QA procedures for the generation of SoK demonstration cases
D11.6 : revised QA procedures [19] revised QA procedures
D11.7 : Contribute to establishment of the initial SoK Roadmap Mapping and Gap Analysis led by WP1 (PMO) [24] Change of the title "Results summary of WP11 during Year 1 and 2 and proposal for the for broad SoK implementation in the following years" into "Contribute to establishment of the initial SoK Roadmap Mapping and Gap Analysis led by WP1 (PMO)"
D11.8 : KM SoK - Authors Guidance & Template [24] Authors Guidance & Template
D11.9 : KM SoK - Specification of the EURAD KM platform [36] Specification of the EURAD KM platform
D11.10 : KM SoK - Feedback mechanism for Domain Insights, SoK documents and KM Systems –Methods and results [36] Feedback mechanism for Domain Insights, SoK documents and KM Systems –Methods and results

Schedule of relevant Milestones

Milestone number ¹⁸	Milestone title	Lead beneficiary	Due Date (in months)	Means of verification
MS1	EURAD Kick-off meeting (General Assembly n°1)	1 - ANDRA	1	EURAD Kick-off meeting (General Assembly n°1)
MS7	KM SoK - launch of screening exercise (task 1)	15 - JUELICH	1	KM SoK - launch of screening exercise (task 1)
MS12	EURAD EJP Newsletters	1 - ANDRA	3	EURAD EJP Newsletters (Due date : M3 and then every quarter)
MS14	KM SoK - List of Demonstration cases	4 - BGE	7	KM SoK - List of Demonstration cases
MS15	KM SoK - list of criteria for selecting demonstration cases	4 - BGE	4	KM SoK - list of criteria for selecting demonstration cases
MS30	EURAD General Assembly n°2	1 - ANDRA	7	EURAD General Assembly n°2
MS42	EURAD Annual Work Plan 2	1 - ANDRA	9	EURAD Annual Work Plan 2
MS78	KM SoK - Initial draft QA plan	40 - SSTC NRS	4	KM SoK - Initial draft QA plan

Schedule of relevant Milestones

Milestone number¹⁸	Milestone title	Lead beneficiary	Due Date (in months)	Means of verification
MS79	KM SoK - proposal to the General Assembly for future work	4 - BGE	24	KM SoK - proposal to the General Assembly for future work
MS81	EURAD General Assembly n°3 + EURAD Annual Meeting 1	1 - ANDRA	13	EURAD General Assembly n°3 + EURAD Annual Meeting 1
MS85	EURAD Periodic Report 1	1 - ANDRA	14	EURAD Periodic Report 1
MS87	KM SoK - updated QA procedure documents	40 - SSTC NRS	19	KM SoK - updated QA procedure documents
MS93	KM SoK - start of broad SoK implementation	4 - BGE	25	KM SoK - start of broad SoK implementation
MS103	EURAD General Assembly n°4	1 - ANDRA	19	EURAD General Assembly n°4
MS112	EURAD Annual Work Plan 3	1 - ANDRA	21	EURAD Annual Work Plan 3
MS136	EURAD General Assembly n°5 + EURAD Annual Meeting 2	1 - ANDRA	25	EURAD General Assembly n°5 + EURAD Annual Meeting 2
MS140	EURAD Periodic Report 2	1 - ANDRA	26	EURAD Periodic Report 2
MS153	EURAD General Assembly n°6	1 - ANDRA	31	EURAD General Assembly n°6
MS162	EURAD Annual Work Plan 4	1 - ANDRA	33	EURAD Annual Work Plan 4
MS185	EURAD General Assembly n°7 + EURAD Annual Meeting 3	1 - ANDRA	37	EURAD General Assembly n°7 + EURAD Annual Meeting 3
MS189	EURAD Periodic Report 3	1 - ANDRA	38	EURAD Periodic Report 3
MS199	EURAD General Assembly n°8	1 - ANDRA	43	EURAD General Assembly n°8
MS206	EURAD Annual Work Plan 5	1 - ANDRA	45	EURAD Annual Work Plan 5
MS222	EURAD General Assembly n°9 + EURAD Annual Meeting 4	1 - ANDRA	49	EURAD General Assembly n°9 + EURAD Annual Meeting 4
MS224	EURAD Periodic Report 4	1 - ANDRA	50	EURAD Periodic Report 4
MS234	EURAD General Assembly n°10	1 - ANDRA	55	EURAD General Assembly n°10
MS240	EURAD General Assembly n°11 + EURAD Annual Meeting 5	1 - ANDRA	60	EURAD General Assembly n°11 + EURAD Annual Meeting 5
MS241	EURAD Periodic Report 5	1 - ANDRA	60	EURAD Periodic Report 5 (Due date: 60+2)

Schedule of relevant Milestones

Milestone number¹⁸	Milestone title	Lead beneficiary	Due Date (in months)	Means of verification
MS242	KM SoK - Specification of the EURAD KM/SoK prototype	15 - JUELICH	36	KM SoK - Specification of the EURAD KM/SoK prototype
MS243	KM SoK - Update of the SoK experts involvement	4 - BGE	32	KM SoK - Update of the SoK experts involvement
MS244	KM SoK - Feedback mechanism for Domain Insights, SoK documents and KM Systems –Methods and results	40 - SSTC NRS	36	KM SoK - Feedback mechanism for Domain Insights, SoK documents and KM Systems –Methods and results
MS245	KM SoK - Implementation status, results, lessons learned and improvements on DI and SoK document production	4 - BGE	32	KM SoK - Implementation status, results, lessons learned and improvements on DI and SoK document production

Work package number ⁹	WP12	Lead beneficiary ¹⁰	42 - SÚRAO
Work package title	Guidance		
Start month	1	End month	60

Objectives

Objectives

The key objective of the KM Guidance WP is to develop a comprehensive suite of instructional Guidance Documents that can be used by Member-States with RWM programmes that are at an early stage of development with respect to their national RWM programme. The guidance will be focused on RD&D relating to planning and implementing a national radioactive waste management programme. It will be developed in such a way that it capitalises the experience and know-how gained by organisations having such responsibility in Member-States with advanced programmes.

The target end-user of the guidance will be primarily programme owners and managers (i.e. WMOs, and TSOs) responsible for planning and implementing RD&D at national level. Such guidance will also be of use and interest to other interested stakeholders, such as representatives of civil society and experts knowledgeable in governance and involvement of civil society.

The set of guidance developed shall be comprehensive for the purpose of the users, and unnecessary overlap shall be avoided, which includes complementary to existing IAEA, NEA and any other relevant documentation in the public domain.

Approach

The approach adopted for this WP consists of pursuing and complementing the work initiated previously with the PLANDIS Guide . This Guide was prepared at the request of the Commission in the context of the EURATOM coordination and support action SecIGD2 (Secretariat for IGD-TP). It provides a framework of broad programme activities and related RD&D activities at different stages of a waste disposal programme, from the view point of a WMO. PLANDIS will be used as the starting point for WP2. Thereby, in addition to establishing a broader framework for planning and operating an RD&D programme in support of geological disposal, the scope is widened to include relevant RD&D needs for pre-disposal, as well as disposal solutions tailored to smaller inventories. Other areas where the need for R&D is identified may be added along with implementation of the work programme.

Description of work and role of partners

WP12 - Guidance [Months: 1-60]

SÚRAO, BEL V, JSI, JRC, PURAM, SSTC NRS, SURO

Task 1 - Updating the PLANDIS Guide and Quality Management Procedure

Start: Month 1 – End: Month 12 - Task Leader: [SÚRAO]

Task Contributors: [JSI (EIMV)] [PURAM] [SSTC NRS] [SURO,] [JRC] [BEL V] [EURAD Experts] [External experts, if required]

Total PM: 18

First step consists of updating the PLANDIS Guide in order to ensure consistency with EURAD Founding Documents (Vision, SRA, Roadmap). More precisely, the PLANDIS Guide will be revised, adjusted and complemented to be consistent with terminologies used in EURAD Founding Documents (Vision, Strategic Research Agenda, Roadmap) and to be aligned with EURAD SRA scientific themes/topics and with the successive phases of a RWM programme as elaborated in the Roadmap.

As PLANDIS was developed by the IGD-TP, it was focussed on the perspectives of implementation by a WMO, therefore a second important part of this update will be to include the perspectives of implementation from the TSOs. The outcome will be the updated version of the PLANDIS Guide “RD&D Planning for Radioactive Waste Management: Guidance for small and early-stage Programmes” (PLANMAN Guide), considering feedback from review process (Deliverable 12.1).

The development of the PLANMAN Guide will also include the drafting of a clear quality management procedure for how it has been developed, which can be used in subsequent years (and updated and modified to reflect learning) as future Guides are developed (Deliverable 12.2).

The substantial involvement of the WP organizations reflects the importance of the work, being the basis for the entire subsequent establishment of the detailed guidance. Additional involvement of experts from the Consortium and possibly

external experts will ensure that all types of interest (especially small inventories, early stage programmes, particular waste inventory challenges, etc.) are considered.

Task 2 - Developing and updating a prioritised list of guidance topics by contribution to the Roadmap exercise

Start: Month 16 – End: Month 29 - Task Leader: [PURAM]

Task Contributors: [JSI (EIMV)] [SÚRAO] [SSTC NRS] [SURO] [JRC]

Total PM: 8,3

The EURAD Roadmap describes generic framework and the PLANMAN Guide is to be seen as an “umbrella document” that will need further more detailed guidance. In order to plan and structure that work, a list of such guides is established together with implementation priorities and updated on an annual basis (Deliverable 12.3). This list will be based on analysis of existing Guidance document and identifying Missing Guidance Documents (Deliverable D12.7) and list of prioritized topics for future guidance documents (Deliverable D12.5).

The KM Guidance WP Team together with the PMO propose on an annual basis (from Year 2) to the Bureau/ General Assembly the Guidance Documents’ Editorial Plan for the year to come, i.e. the specific Guidance Documents that shall be established and issued in priority., to be updated on an annual basis).

An important input to the editorial plan will be priorities identified by the competence/SoK/guidance mapping exercise to be completed by the PMO (see WP1) at initiation of the Joint Programme.

Task 3 - Development of Guidance Documents

Start: Month 19 – End: Month 60 - Task Leader: [SÚRAO]

Task Contributors: [JSI (EIMV)] [PURAM] [SSTC NRS] [SURO] [JRC] [EURAD Experts] [External experts, as required]

Total PM: 74

The development of the Pilot guidance document will also test the Quality management procedure developed as Delivery D12.2. The Pilot guide will be developed as Deliverable 12.4.

In accordance with the approved annual plans, the detailed Guidance drawing upon the PLANMAN Guide is supervised by Editorial Board and developed by team of experts(s) composed of:

- Individuals experienced in RD&D planning in more advanced programmes;
- Representatives of early stage programmes and small inventory programmes, including representatives of the WP 12 Team organizations;
- Experts involved with the completion and delivery of RD&D plans for National Programmes;
- Target end-users of the Guide Documents, represented by experts working in organisations from countries with early-stage programmes and small inventory programmes.

Thereby, the efforts for the WP contributors to organize and coordinate the document development process is declared in the WP. The actual drafting and expert input is provided by the respective editorial boards. During the editorial process, preview of the draft Guide shall be performed by target end-users in order to obtain constructive feedback on content and usability. Peers of RD&D planning and implementation, especially from experienced programmes, shall provide review feedback of the draft Guidance Documents. EURAD Mandated Actors (especially WMOs, TSOs), shall provide endorsement of the Guidance Document prior to publication.

Dedicated workshops will be considered where beneficial for supporting the editorial process.

Delineation of PLANMAN is updated on an annual basis (Deliverable 12.5, updated annually)

Along with the workprogramme, the PLANMAN Guide and the subsequent detailed Guidance will be subject review and testing. Reporting on the outcome of this process will start after the third year, and be updated on an annual basis.

The delineation process shall not be finalized after EURAD first phase, but at the end of EURAD-1 there is one overall reporting on the generation of Guidance with the final status of the PLANMAN Guide, its detailed Guidance as achieved, and the processes for establishing the Guidance (Deliverable 12.6).

Participation per Partner

Partner number and short name	WP12 effort
3 - BEL V	4.00
22 - JSI	0.00

Partner number and short name	WP12 effort
EIMV	22.00
23 - JRC	3.50
35 - PURAM	15.30
40 - SSTC NRS	19.00
42 - SÚRAO	20.50
43 - SURO	16.00
Total	100.30

List of deliverables

Deliverable Number ¹⁴	Deliverable Title	Lead beneficiary	Type ¹⁵	Dissemination level ¹⁶	Due Date (in months) ¹⁷
D12.1	KM Guidance - PLANMAN Guide - Updated version of the PLANDIS Guide consistent with the EJP Roadmap and including perspectives of the TSOs needs (PLANMAN Guide)	42 - SÚRAO	Report	Public	12
D12.2	KM Guidance - Quality management procedure for PLANMAN development (incl. review and approval procedure)	42 - SÚRAO	Report	Public	12
D12.3	KM Guidance - approved list of prioritized topics for further guidance documents and selection of one topic for the development of a pilot guide	42 - SÚRAO	Report	Public	22
D12.4	KM Guidance - Development of the Pilot Guide	42 - SÚRAO	Report	Public	29
D12.5	KM Guidance - Updated list of prioritized topics for future guidance documents	42 - SÚRAO	Report	Public	29
D12.6	KM Guidance - Final report on the PLANMAN Guide and the subsequent detailed Guidance,	42 - SÚRAO	Report	Public	60

List of deliverables

Deliverable Number¹⁴	Deliverable Title	Lead beneficiary	Type¹⁵	Dissemination level¹⁶	Due Date (in months)¹⁷
	overall conclusions and recommendations				
D12.7	KM Guidance - Contribution to the EURAD Roadmap Gap Analyses – Identifying Existing and Missing Guidance Documents	42 - SÚRAO	Report	Public	25

Description of deliverables

Deliverable 12.1 - PLANMAN Guide - Updated version of the PLANDIS Guide consistent with EURAD Roadmap and including perspectives of the TSOs needs (PLANMAN Guide) (Month 12) Lead: [SÚRAO]

Deliverable 12.2 – Quality management procedure for PLANMAN development (incl. review and approval procedure) (Month 12) Lead: [SÚRAO]

Deliverable 12.3 – KM Guidance - Approved list of prioritized topics for further guidance documents and selection of one topic for the development of a pilot guide (Month 22) Lead: [SÚRAO]

Deliverable 12.4– KM Guidance - Development of the Pilot Guide (Month 29) Lead: [SÚRAO]

Deliverable 12.5 - KM Guidance - Updated list of prioritized topics for future guidance documents (Month 29) Lead: [SÚRAO]

Deliverable 12.6 - KM Guidance - Final report on the PLANMAN Guide and the subsequent detailed Guidance, overall conclusions and recommendations (Month 60) Lead: [SÚRAO]

Deliverable 12.7 – KM Guidance - Contribution to the EURAD Roadmap Gap Analyses – Identifying Existing and Missing Guidance Documents (Month 25) Lead [SÚRAO]

D12.1 : KM Guidance - PLANMAN Guide - Updated version of the PLANDIS Guide consistent with the EJP Roadmap and including perspectives of the TSOs needs (PLANMAN Guide) [12]

KM Guidance - PLANMAN Guide - Updated version of the PLANDIS Guide consistent with the EJP Roadmap and including perspectives of the TSOs needs (PLANMAN Guide)

D12.2 : KM Guidance - Quality management procedure for PLANMAN development (incl. review and approval procedure) [12]

KM Guidance - Quality management procedure for PLANMAN development (incl. review and approval procedure)

D12.3 : KM Guidance - approved list of prioritized topics for fourther guidance documents and selection of one topic for the development of a pilot guide [22]

Change of title "Approved schedule for delineation of the PLANMAN Guide in-line with the PMO-developed competence matrix and approved Editorial Plan for Year 1" into "Approved list of prioritized topics for fourther guidance documents and selection of one topic for the development of a pilot guide" Change of due date : Month10 to Month22

D12.4 : KM Guidance - Development of the Pilot Guide [29]

Change of title : "Quality management procedure and methodology for developing the detailed delineation guidance of PLANMAN" into "Development of the Pilot Guide" Change of due date : 12 to 29

D12.5 : KM Guidance - Updated list of prioritized topics for future guidance documents [29]

Change of title from "Delineated version of the PLANMAN Guide after Year 1" into "Updated list of prioritized topics for future guidance documents" Change of due date : 24 to 29

D12.6 : KM Guidance - Final report on the PLANMAN Guide and the subsequent detailed Guidance, overall conclusions and recommendations [60]

KM Guidance - Final report on the PLANMAN Guide and the subsequent detailed Guidance, overall conclusions and recommendations

D12.7 : KM Guidance - Contribution to the EURAD Roadmap Gap Analyses – Identifying Existing and Missing Guidance Documents [25]

Contribution to the EURAD Roadmap Gap Analyses – Identifying Existing and Missing Guidance Documents

Schedule of relevant Milestones

Milestone number ¹⁸	Milestone title	Lead beneficiary	Due Date (in months)	Means of verification
MS1	EURAD Kick-off meeting (General Assembly n°1)	1 - ANDRA	1	EURAD Kick-off meeting (General Assembly n°1)
MS10	KM Guidance - Editorial meeting for the update of PLANDIS	42 - SÚRAO	2	KM Guidance - Editorial meeting for the update of PLANDIS
MS12	EURAD EJP Newsletters	1 - ANDRA	3	EURAD EJP Newsletters (Due date : M3 and then every quarter)
MS30	EURAD General Assembly n°2	1 - ANDRA	7	EURAD General Assembly n°2
MS41	KM Guidance - Editorial Plan for PLANMAN Delineation Year 2	42 - SÚRAO	7	KM Guidance - Editorial Plan for PLANMAN Delineation Year 2
MS42	EURAD Annual Work Plan 2	1 - ANDRA	9	EURAD Annual Work Plan 2
MS80	KM Guidance - Editorial boards meetings for the PLANMAN delineation guides	42 - SÚRAO	13	KM Guidance - Editorial boards meetings for the PLANMAN delineation guides
MS81	EURAD General Assembly n°3 + EURAD Annual Meeting 1	1 - ANDRA	13	EURAD General Assembly n°3 + EURAD Annual Meeting 1
MS85	EURAD Periodic Report 1	1 - ANDRA	14	EURAD Periodic Report 1
MS103	EURAD General Assembly n°4	1 - ANDRA	19	EURAD General Assembly n°4
MS109	KM Guidance - Editorial Plan for PLANMAN Delineation Year 3	42 - SÚRAO	19	KM Guidance - Editorial Plan for PLANMAN Delineation Year 3
MS112	EURAD Annual Work Plan 3	1 - ANDRA	21	EURAD Annual Work Plan 3
MS136	EURAD General Assembly n°5 + EURAD Annual Meeting 2	1 - ANDRA	25	EURAD General Assembly n°5 + EURAD Annual Meeting 2
MS140	EURAD Periodic Report 2	1 - ANDRA	26	EURAD Periodic Report 2
MS153	EURAD General Assembly n°6	1 - ANDRA	31	EURAD General Assembly n°6
MS160	KM Guidance - Editorial Plan for PLANMAN Delineation Year 4	42 - SÚRAO	31	KM Guidance - Editorial Plan for PLANMAN Delineation Year 4
MS162	EURAD Annual Work Plan 4	1 - ANDRA	33	EURAD Annual Work Plan 4

Schedule of relevant Milestones

Milestone number¹⁸	Milestone title	Lead beneficiary	Due Date (in months)	Means of verification
MS185	EURAD General Assembly n°7 + EURAD Annual Meeting 3	1 - ANDRA	37	EURAD General Assembly n°7 + EURAD Annual Meeting 3
MS189	EURAD Periodic Report 3	1 - ANDRA	38	EURAD Periodic Report 3
MS199	EURAD General Assembly n°8	1 - ANDRA	43	EURAD General Assembly n°8
MS205	KM Guidance - Editorial Plan for PLANMAN Delineation Year 5	42 - SÚRAO	43	KM Guidance - Editorial Plan for PLANMAN Delineation Year 5
MS206	EURAD Annual Work Plan 5	1 - ANDRA	45	EURAD Annual Work Plan 5
MS222	EURAD General Assembly n°9 + EURAD Annual Meeting 4	1 - ANDRA	49	EURAD General Assembly n°9 + EURAD Annual Meeting 4
MS224	EURAD Periodic Report 4	1 - ANDRA	50	EURAD Periodic Report 4
MS234	EURAD General Assembly n°10	1 - ANDRA	55	EURAD General Assembly n°10
MS240	EURAD General Assembly n°11 + EURAD Annual Meeting 5	1 - ANDRA	60	EURAD General Assembly n°11 + EURAD Annual Meeting 5
MS241	EURAD Periodic Report 5	1 - ANDRA	60	EURAD Periodic Report 5 (Due date: 60+2)

Work package number ⁹	WP13	Lead beneficiary ¹⁰	38 - SCK•CEN
Work package title	Training & Mobility		
Start month	1	End month	60

Objectives

Objectives

The objectives of the Training and Mobility WP are:

- To compose a diverse portfolio of tailored basic and specialized training courses under the umbrella of a “School of Radioactive Waste Management”, newly created under EURAD-1, taking stock of and building upon already existing initiatives (i.e. IAEA and NEA) and creating new initiatives to bridge the identified gaps. The end-users are defined as professionals and potential new professionals at graduated and post-graduated level from EU and non-EU countries (via the IAEA and NEA programmes), and in particular the next generation of experts. Tasks under this WP will include improving access to existing training materials (e.g. training modules developed in association with past and ongoing RD&D projects and EURAD WPs), and providing new training courses and material, both aimed at acquiring both state-of-the-art scientific background and at accessing the vast amount of “tacit” knowledge available within EURAD-1 through targeted hands-on training.
- To organise a mobility programme which provides access to dedicated infrastructures associated with the Mandated Actors/Linked Third Parties within EURAD-1. These mobility actions can be seen either as a complementary action after one or more training course(s) (enabling hands-on training related to the experimental programme executed within EURAD-1) or can be part of the Continuous Personal Development (CPD) of experienced personnel involved in RWM.

Approach

Both the mobility initiative and the training course portfolio will be developed along two tracks, associated with the different needs identified within EURAD.

- In a first track, and following the efforts undertaken to identify knowledge requirements within the Roadmap, specific training/mobility initiatives are developed to suit the specific needs of the end-users at the various phases of RWM programmes according to the Roadmap and following a systematic approach in response to priorities agreed with the General Assembly. The portfolio will be composed of existing (and past) training initiatives that fit EURAD-1 needs and for which the original developer/organiser agrees to be put at the disposal of EURAD-1 portfolio (without losing its identity), and of learning actions specifically developed in the frame of this EURAD-1 to bridge the identified gaps in the existing landscape.

- In a second track, specific training/mobility initiatives will be developed serving the needs identified within the RD&D and SS WPs. The oversight performed by the Training WP will allow 1) to identify the training/mobility needs, scope and opportunities present within these RD&D and SS WPs, and 2) integration of the developed training materials and resources within the Knowledge Platform which will be developed in WP1.

Thereby, “The School of RWM” is an umbrella for the entire catalogue of training/mobility either

- linked to (i.e., organized and “owned” by third partners, could be EURAD Beneficiaries, and to which EURAD provides funding for participation), or
- developed in order to meet needs and fill gaps to what is already available.

With respect to the division into more general training, aimed in particular at next generation of experts, and targeted training aimed in particular at exchange and deepening skills and knowledge between existing experts:

- More general courses, especially those following from a gap analysis in the Roadmap are to be delivered within the frame of a “summer school”, and are scheduled to start after the first EURAD year,
- Targeted training courses making use of existing training from past and on-going EURATOM projects, are best integrated as specific modules at the “summer school”, and
- Targeted training courses, associated with the timing and tasks in the RD&D and SS WPs are to be organized depending on the interaction with, and input from these WPs. It could be organized back-to-back with a particular WP meeting, having all the involved experts gathered, nevertheless being open for participation for interested experts from beyond the specific WP. Such training should be aimed for already during the first EURAD year.

Description of work and role of partners

WP13 - Training & Mobility [Months: 1-60]

SCK•CEN, ANDRA, BEL V, CIEMAT, JSI, JRC, SSTC NRS, SÚRAO, SURO

Task 1 - Identification of the training needs, scope and opportunities from the RD&D and SS WPs

Start: Month 1 – End: Month 22- Task Leader: [SCK•CEN]

Task Contributors: [JRC] [SÚRAO (CTU)] [SSTC NRS] [CIEMAT] [SURO]

Total PM: 2

Within the RD&D and Strategic Studies WPs, specific training needs are present. These training needs need to be identified at the early phase of EURAD initiation by interaction with the WP leaders and coordination teams (Deliverable 13.1). The identified needs should at least encompass 1) the scope of the training needed (basic vs specialised course), 2) the proposed training mode (classroom/hands-on, including mobility needs), 3) the timing of training. This interrogation, which can be done by an easy questionnaire, will allow to provide input for task 3: Training and Mobility Schedule & Priority List.

Task 2 - Improving access to historical and ongoing training modules

Start: Month 1 – End: Month 22- Task Leader: [SCK•CEN]

Task Contributors: [JRC] [SÚRAO (CTU)] [SSTC NRS] [CIEMAT]

Total PM: 3,5

Apart from the training developed within EURAD, we will also link with ongoing or expected training modules developed within ongoing EC H2020 EURATOM projects (like Modern2020, BEACON, MIND, CHANCE) and with existing training modules developed within past EURATOM projects (FP6 and FP7). Also existing initiatives from IAEA or NEA will be taken into account. This will both increase the amount of training materials (and therefore total portfolio) made available within the JP, and at the same time capitalise the efforts made in the past by integrating these efforts into a durable knowledge platform which will be developed within EURAD.

In order to achieve this goal, a mapping exercise will be performed within the first year of EURAD, in coordination with the PMO Task mapping exercise (Deliverable 13.2). The mapping will include (at least):

- Scope of the training course (including content, learning outcomes, duration, etc.)
- Course material availability (textbook, transparencies, exercises, etc.)
- Practical information (when was the course given, how many participants, feedback from the participants if available, etc.)

After the mapping, the generated info has to be translated to the Roadmap and the knowledge requirements identified therein. This will include how identified and available training material addresses knowledge requirements priorities (Deliverable 13.3), and whether changes or adaptations might be required in order to better suit the needs identified within the Roadmap.

Task 3 - Training and Mobility Schedule & Priority List

Start: Month 1 – End: Month 24 - Task Leader: [SCK•CEN]

Task Contributors: [Andra] [JRC] [SÚRAO (CTU)] [SSTC NRS] [CIEMAT] [SURO]

Total PM: 2,55

Drawing from the outputs of Task 1 and KM Coordination Work carried out by the PMO, an annual training schedule and priority list shall be developed to prioritise scope and resources within the Training WP. Such a priority list would indicate on an annual basis the resources allocated, the targeted audience and the trainers who will be involved (Deliverable 13.4).

Task 4 - Implementation of Training Courses

Start: Month 7 – End: Month 60 Task Leader: [SCK•CEN]

Task Contributors: [Andra] [SÚRAO (CTU)] [JRC] [SSTC NRS] [CIEMAT] [SURO] [Bel V]

Total PM: 48,73

Different formats of training (classroom, distance learning, practical exercises in laboratories, URLs, ...) will be organised within EURAD-1, at appropriate levels targeting the needs of the end-users and having proper learning outcomes in line with the desired competence building. This includes:

- A first set of training modules envisages the basic relevant scientific and technical concepts supporting RWM applications. They intend to bring participants' knowledge and skills to a harmonized elementary level suitable for tackling the RD&D objectives brought forward within the R&D and Strategic Studies Work Packages and/or the knowledge requirements within the Roadmap. These training courses will include experts (Procured by the Knowledge Management Coordinator (PMO), from either the Organisations participating in EURAD or External Experts). Formats of training may include face-to-face courses, webinars or MOOCs (massive open online courses), depending on the audience, the training subject and the needs identified.
- Specialized training modules including hands-on training will connect those familiar with the basic scientific concepts with the state of the art in setting up experiments, achieving the maximum benefits out of experiments, and familiarising with modelling codes used to interpret and simulate experimental outcomes. These learning activities will be led by experts in the relevant domains and will aid in accessing the knowledge available outside existing documents

and textbooks (referred to as “tacit”, “implicit” or “collective” knowledge). They will be conducted in a classroom environment or at the work floor (laboratories, underground research facilities, ...). Distant training relying on available technology and tools can also be included (distant visual assistance, augmented learning, etc.).

The training programme within EURAD-1 will be developed taking into account the Systematic Approach to Training as defined by the IAEA (e.g., IAEA Guidebook on Nuclear Power Plant Personnel Training and its Evaluation, Technical Reports Series No. 380, 1996). This Approach consists of a cycled implementation with the following steps:

- Evaluation of functional scientific/technical competences required at the different phases and for the different themes identified within the Roadmap for implementation of a radioactive waste management RD&D programme, through to geological disposal (using the outputs of the Competency Matrix to be completed by the PMO at EURAD launch as key input).
- Design of a training programme based on a translation of competences into learning objectives.
- Development of training materials to meet learning objectives.
- Implementation of the training.
- Evaluation of the training effectiveness, which feeds back into step 1.

Quality criteria will be developed by which existing training initiatives can be appreciated in order to be taken up within the training portfolio of EURAD-1 (Deliverable 13.5).

For the training course (Deliverable 13.6) developed based on the needs identified within the RD&D Work Packages and the Strategic Studies Work Packages (see Task 1) a strong interaction is pursued, both in identifying suitable training courses which could strengthen and enforce the scientific community involved in the different scientific and technical themes addressed within these Work Packages, and in the preparation and execution of new training modules, where experts identified within EURAD Work Packages will be appointed to develop and deliver the training. The corresponding budgets will be allocated and made available to the organisations delivering training (additionally to the budgets already foreseen within these Work Packages).

All training modules developed or supported within EURAD-1 will be grouped under the umbrella of the “School of Radioactive Waste Management”, in order to provide a coherent and internally consistent portfolio which could substantially contribute in the short and long term to the maintenance of expert capacity in waste management and disposal. Trainings might be grouped into Summer or Winter Schools, possibly organised back-to-back with main conferences or workshops in the domains of EURAD-1.

An update, as well as lessons learnt from the training courses that were organized, will be compiled in a dedicated report (Deliverable D13.9 and D13.13).

To increase the visibility of the School of RWM, a dedicated website is developed by WP13 (<https://euradschool.eu/>). This website contains information on all WP13 activities as well as an overview of the EURAD PhD students, a discussion forum and a list of webinars (see below). A report on the use and visibility (Google Analytics) will be written (Deliverable 13.12). The website will be maintained and updated regularly over the course of EURAD-1.

Due to the change in the way people meet and learn, WP13 started organizing and hosting webinars since the start of the COVID-19 pandemic. These webinars range from informal sessions, such as the Lunch & Learn sessions, to online courses (e.g. Introductory course to EURAD and Radioactive Waste Management). These new activities undertaken by WP13 contribute to Task 4 and therefore, WP13 will report on them in a similar way they will report on the actual training courses that will be organized (Deliverable D13.11 and D13.13). These webinars will be announced through the website of the School of RWM and a library of recordings of previously organized webinars will be available here as well. This library will be maintained for (at the least) the course of EURAD-1.

Close interaction with KM WP1 is envisaged in order to align the training portfolio with the development of the State of Knowledge scope.

Task 5 - Implementation of Mobility Programme

Start: Month 10 – End: Month 60 Task Leader: [SURO]

Task Contributors: [Andra] [SÚRAO (CTU)] [JRC] [SSTC NRS] [CIEMAT] [SCK•CEN] [JSI (EIMV)]

Total PM: 38,89

With the mobility programme, EURAD aims to develop and share competences and knowledge beyond the academic pathways. It will contribute to transferring knowledge and skills related to infrastructure used and management between National Programmes at similar or close stages of development. It will also allow scientists and engineers from early-stage programmes to participate in tutored experimental efforts in laboratories of more advanced programmes. The mobility programme will target both professionals (as scientific visitor to contribute to the Continuous Professional Development) in order to increase their competences in a certain domain (learn by doing) and postgraduate students (by means of internship or thesis work).

The mobility programme will support access to dedicated infrastructure associated with EURAD-1. Such infrastructure is mainly present at the premises of EURAD Beneficiaries, and targets primarily underground research laboratories,

as well as, on a secondary level, dedicated surface laboratories, specific analytical facilities, or computational infrastructure. Besides these “experimental” facilities and infrastructure, also more “desktop”-based interchanges or secondments can be envisaged to enable direct knowledge transfer from one organisation to another.

A first deliverable of the mobility task will be to generate a proposal for the mobility programme responding to the different needs identified within Task 1 and prioritised within Task 3 (Deliverable 13.7). The needs are then converted into mobility measures, specified with respect to target groups, hosting organizations and types of facilities, lengths of mobility engagement and competence and skills enhancement outcomes. For the latter, the mobility programme will identify the expectations and quality requirements for defining, monitoring and assessing the competences and skills acquired (“learning outcomes”, similar to training deliverable). Given the broad set of potential needs and the width of potential mobility measures, within the given boundary conditions the calls will be very open.

The mobility programme (Deliverable 13.8) will be developed in a spirit of complementarity with already existing initiatives (like the ENEN+ Mobility Fund or the NEA Nuclear Education, Skills and Technology (NEST) Framework) or to be developed projects (e.g. within current NFRP-2018-7) which also target facilitating access to dedicated infrastructures and promoting researcher’s mobility. This EURAD-1 focusses on professional end-users (from post-graduate onwards). However, a younger audience of students (MSc) is not to be neglected as they will populate tomorrow’s workforce in RWM. This task will explore the possibility to connect to existing initiatives primarily aiming at this target audience and will set up, if feasible, close collaborations with these initiatives or projects.

The mobility programme will be internally reviewed and the lessons learnt will be written down (Deliverable 13.10 and D13.13). This way, the mobility programme can continue to evolve and improve over the course of EURAD-1.

Participation per Partner

Partner number and short name	WP13 effort
1 - ANDRA	8.64
3 - BEL V	4.00
6 - CIEMAT	9.80
22 - JSI	0.00
EIMV	7.46
23 - JRC	8.23
38 - SCK•CEN	24.75
40 - SSTC NRS	8.45
42 - SÚRAO	0.00
CTU	9.03
43 - SURO	15.31
Total	95.67

List of deliverables

Deliverable Number ¹⁴	Deliverable Title	Lead beneficiary	Type ¹⁵	Dissemination level ¹⁶	Due Date (in months) ¹⁷
D13.1	KM Training - List of training needs from the RD&D and SS WPs	38 - SCK•CEN	Report	Public	3
D13.2	KM Training - Mapping of available course material	38 - SCK•CEN	Report	Public	8

List of deliverables

Deliverable Number¹⁴	Deliverable Title	Lead beneficiary	Type¹⁵	Dissemination level¹⁶	Due Date (in months)¹⁷
D13.3	KM Training - Alignment of the available course material with the Roadmap	38 - SCK•CEN	Report	Public	12
D13.4	KM Training - Priority list and schedule for training/mobility	38 - SCK•CEN	Report	Public	12
D13.5	KM Training - Quality criteria and training specification as a reference guide of requirements and expectations of the training courses to be developed	38 - SCK•CEN	Report	Public	9
D13.6	KM Training - Implementation of first training courses developed and implemented depending on the priorities identified and approved within the EJP	38 - SCK•CEN	Report	Public	13
D13.7	KM Training - Specification document of the content, material, and learning outcomes of mobility training e.g. in relation with a curricular of S/T knowledge acquisition targets	43 - SURO	Report	Public	12
D13.8	KM Training - Development of mobility programme	43 - SURO	Report	Public	13
D13.9	KM Training - Update on training courses organized by EURAD	38 - SCK•CEN	Report	Public	36
D13.10	KM Training - Update on mobility actions organized by EURAD	43 - SURO	Report	Public	36
D13.11	KM Training - Overview of webinars organized in the first three years of EURAD	38 - SCK•CEN	Report	Public	38
D13.12	KM Training - Update on the website of the School of RWM	38 - SCK•CEN	Websites, patents filing, etc.	Public	32

List of deliverables

Deliverable Number¹⁴	Deliverable Title	Lead beneficiary	Type¹⁵	Dissemination level¹⁶	Due Date (in months)¹⁷
D13.13	KM Training - Overview of School of RWM training and mobility activities in EURAD-1	38 - SCK•CEN	Report	Public	60

Description of deliverables

Deliverable 13.1 - KM Training - List of training needs from the RD&D and SS WPs - Month: 3 - Lead: [SCK•CEN].

Deliverable 13.2 - KM Training - Mapping of available course material - Month 8 Lead: [SCK•CEN]

Deliverable 13.3 - KM Training - Alignment of the available course material with the Roadmap - Month: 12 Lead: [SCK•CEN]

Deliverable 13.4 - KM Training - Priority list and schedule for training/mobility - Month 12 Lead: [SCK•CEN]

Deliverable 13.5 - KM Training - Quality criteria and training specification as a reference guide of requirements and expectations of the training courses to be developed - Month 9 Lead: [SCK•CEN]

Deliverable 13.6 - KM Training - Implementation of first training courses developed and implemented depending on the priorities identified and approved within EURAD - Month 13 Lead: [SCK•CEN]

Deliverable 13.7 - KM Training - Specification document of the content, material, and learning outcomes of mobility training e.g. in relation with a curricular of S/T knowledge acquisition targets - Month: 12 Lead: [SURO]

Deliverable 13.8 - KM Training - Development of mobility programme, depending on the priorities identified and approved within EURAD (see Task 3) - Month: 13 Lead: [SURO]

Deliverable 13.9 - KM Training - Update on training courses organized by EURAD - Month 36 [SCK•CEN]

Deliverable 13.10 - KM Training - Update on mobility actions performed in EURAD - Month 36 [SURO]

Deliverable 13.11 - KM Training - Overview of webinars organized in the first three years of EURAD - Month 38 [SCK•CEN]

Deliverable 13.12 - KM Training - Update on the website of the School of RWM - Month 32 [SCK•CEN]

Deliverable 13.13 - KM Training - Overview of School of RWM training and mobility activities in EURAD-1 - Month 60 [SCK•CEN]

D13.1 : KM Training - List of training needs from the RD&D and SS WPs [3]
KM Training - List of training needs from the RD&D and SS WPs

D13.2 : KM Training - Mapping of available course material [8]
KM Training - Mapping of available course material

D13.3 : KM Training - Alignment of the available course material with the Roadmap [12]
KM Training - Alignment of the available course material with the Roadmap

D13.4 : KM Training - Priority list and schedule for training/mobility [12]
KM Training - Priority list and schedule for training/mobility

D13.5 : KM Training - Quality criteria and training specification as a reference guide of requirements and expectations of the training courses to be developed [9]
KM Training - Quality criteria and training specification as a reference guide of requirements and expectations of the training courses to be developed

D13.6 : KM Training - Implementation of first training courses developed and implemented depending on the priorities identified and approved within the EJP [13]
KM Training - Implementation of first training courses developed and implemented depending on the priorities identified and approved within the EJP

D13.7 : KM Training - Specification document of the content, material, and learning outcomes of mobility training e.g. in relation with a curricular of S/T knowledge acquisition targets [12]
KM Training - Specification document of the content, material, and learning outcomes of mobility training e.g. in relation with a curricular of S/T knowledge acquisition targets

D13.8 : KM Training - Development of mobility programme [13]
 KM Training - Development of mobility programme

D13.9 : KM Training - Update on training courses organized by EURAD [36]
 Update on training courses organized by EURAD

D13.10 : KM Training - Update on mobility actions organized by EURAD [36]
 Update on mobility actions organized by EURAD

D13.11 : KM Training - Overview of webinars organized in the first three years of EURAD [38]
 Overview of webinars organized in the first three years of EURAD

D13.12 : KM Training - Update on the website of the School of RWM [32]
 Update on the website of the School of RWM

D13.13 : KM Training - Overview of School of RWM training and mobility activities in EURAD-1 [60]
 Overview of School of RWM training and mobility activities in EURAD-1

Schedule of relevant Milestones

Milestone number ¹⁸	Milestone title	Lead beneficiary	Due Date (in months)	Means of verification
MS1	EURAD Kick-off meeting (General Assembly n°1)	1 - ANDRA	1	EURAD Kick-off meeting (General Assembly n°1)
MS12	EURAD EJP Newsletters	1 - ANDRA	3	EURAD EJP Newsletters (Due date : M3 and then every quarter)
MS30	EURAD General Assembly n°2	1 - ANDRA	7	EURAD General Assembly n°2
MS42	EURAD Annual Work Plan 2	1 - ANDRA	9	EURAD Annual Work Plan 2
MS70	KM Training - School of RWM – portfolio gathering all training courses developed and implemented depending on the priorities identified and approved within the EJP; Founding of the School	38 - SCK•CEN	12	KM Training - School of Radioactive Waste Management – portfolio gathering all training courses developed and implemented depending on the priorities identified and approved within the EJP; Founding of the School
MS81	EURAD General Assembly n°3 + EURAD Annual Meeting 1	1 - ANDRA	13	EURAD General Assembly n°3 + EURAD Annual Meeting 1
MS85	EURAD Periodic Report 1	1 - ANDRA	14	EURAD Periodic Report 1
MS103	EURAD General Assembly n°4	1 - ANDRA	19	EURAD General Assembly n°4
MS112	EURAD Annual Work Plan 3	1 - ANDRA	21	EURAD Annual Work Plan 3
MS136	EURAD General Assembly n°5 + EURAD Annual Meeting 2	1 - ANDRA	25	EURAD General Assembly n°5 + EURAD Annual Meeting 2
MS140	EURAD Periodic Report 2	1 - ANDRA	26	EURAD Periodic Report 2

Schedule of relevant Milestones

Milestone number¹⁸	Milestone title	Lead beneficiary	Due Date (in months)	Means of verification
MS153	EURAD General Assembly n°6	1 - ANDRA	31	EURAD General Assembly n°6
MS162	EURAD Annual Work Plan 4	1 - ANDRA	33	EURAD Annual Work Plan 4
MS185	EURAD General Assembly n°7 + EURAD Annual Meeting 3	1 - ANDRA	37	EURAD General Assembly n°7 + EURAD Annual Meeting 3
MS189	EURAD Periodic Report 3	1 - ANDRA	38	EURAD Periodic Report 3
MS199	EURAD General Assembly n°8	1 - ANDRA	43	EURAD General Assembly n°8
MS206	EURAD Annual Work Plan 5	1 - ANDRA	45	EURAD Annual Work Plan 5
MS222	EURAD General Assembly n°9 + EURAD Annual Meeting 4	1 - ANDRA	49	EURAD General Assembly n°9 + EURAD Annual Meeting 4
MS224	EURAD Periodic Report 4	1 - ANDRA	50	EURAD Periodic Report 4
MS234	EURAD General Assembly n°10	1 - ANDRA	55	EURAD General Assembly n°10
MS240	EURAD General Assembly n°11 + EURAD Annual Meeting 5	1 - ANDRA	60	EURAD General Assembly n°11 + EURAD Annual Meeting 5
MS241	EURAD Periodic Report 5	1 - ANDRA	60	EURAD Periodic Report 5 (Due date: 60+2)

Work package number ⁹	WP14	Lead beneficiary ¹⁰	1 - ANDRA
Work package title	Ethics requirements		
Start month	1	End month	60

Objectives

The objective is to ensure compliance with the 'ethics requirements' set out in this work package.

Description of work and role of partners

WP14 - Ethics requirements [Months: 1-60]

ANDRA

This work package sets out the 'ethics requirements' that the project must comply with.

List of deliverables

Deliverable Number ¹⁴	Deliverable Title	Lead beneficiary	Type ¹⁵	Dissemination level ¹⁶	Due Date (in months) ¹⁷
D14.1	EPQ - Requirement No. 1	1 - ANDRA	Ethics	Confidential, only for members of the consortium (including the Commission Services)	12
D14.2	EPQ - Requirement No. 2	1 - ANDRA	Ethics	Confidential, only for members of the consortium (including the Commission Services)	12
D14.3	EPQ - Requirement No. 3	1 - ANDRA	Ethics	Confidential, only for members of the consortium (including the Commission Services)	12

Description of deliverables

The 'ethics requirements' that the project must comply with are included as deliverables in this work package.

D14.1 : EPQ - Requirement No. 1 [12]

7.1. Further information about the possible harm to the environment caused by the research and the measures that will be taken to mitigate the risks must be included in the grant agreement, kept on file, specified in the grant agreement. The proposal should consider potential hazards associated with the experimental work, particularly in underground laboratories. It is expected that these are all operated to high safety standards, but this should be confirmed and documentation related to health and safety should be made available on request of EC staff (depending on policy in this area). Such documentation should be stipulated in the grant agreement and produced for a facility before experiments for the project are performed.

D14.2 : EPQ - Requirement No. 2 [12]

7.2. Copies of authorisations for relevant facilities (e.g., security classification of laboratory) must be kept on file and specified in the grant agreement.

D14.3 : EPQ - Requirement No. 3 [12]

7.3. The applicant must demonstrate that appropriate health and safety procedures conforming to relevant local/national guidelines/legislation are followed for staff involved in this project. This must be confirmed in the grant agreement.

Schedule of relevant Milestones

Milestone number ¹⁸	Milestone title	Lead beneficiary	Due Date (in months)	Means of verification

Work package number ⁹	WP15	Lead beneficiary ¹⁰	27 - NAGRA
Work package title	CONTainer CORrosion under Disposal conditions (ConCorD)		
Start month	25	End month	60

Objectives

Even though the feasibility and safety of established container solutions has been demonstrated, recent progress in materials and processes has shown that optimisation of container manufacturing and performance is possible. Widespread interest in repository optimisation exists and relevant projects are ongoing, e.g., WP HITEC and the HotBENT experiment in Grimsel. The systematic exploration of novel materials, while placing existing solutions in a broader context, will provide a solid state-of-the-art for the pursuit of container optimisation according to available geology, disposal concept and regulatory requirements. The testing of alternative container materials, their mechanical structural response and corrosion resistance will also bring new insights into novel technical solutions for container design.

To further increase the knowledge base and reduce remaining uncertainties, WP ConCorD aims to:

Explore the potential of novel/advanced container materials and processes for optimisation of container performance within the engineered barrier system.

Increase/extend the understanding of complex/coupled interfacial processes influencing container performance under repository relevant conditions, with a focus on irradiation-accelerated corrosion, microbial activity and degradation during nearfield transients, at varying scales.

Mechanistic process understanding and development of predictive models, which will incorporate system variability and will lead to improved performance assessments addressing identified safety needs

During and after the end of ConCorD various national programs will be able to evaluate cooperatively the long-term behaviour of container materials to such an extent as to be able to ensure confidence in the performance of engineered barriers. Such progress will particularly benefit early-stage programmes and those with a small inventory. An Expert Review Group will review and provide guidance on the scientific work performed. Emphasis will be given to issues relevant to end user needs and repository implementation, while ensuring that the generation of information is implementable and useful for performance assessment

Description of work and role of partners

WP15 - CONTainer CORrosion under Disposal conditions (ConCorD) [Months: 25-60]

NAGRA, ANDRA, CIEMAT, ChRDI, CNRS, JUELICH, GRS, KIT, SCK•CEN, SÚRAO, VTT

Task 1 – Management

Start: Month 25 – End: Month 60 - Task Leader: [NAGRA]

Total PM: 31,2

The main goal of Task 1 is the overall management of the WP including scientific-technical coordination, preparation of the SotA reports, preparation of training materials, and steering and review of the WP progress from the ERG. In this respect there are significant interactions with all other ConCorD Tasks.

Subtask 1.1 – S/T coordination

Start: Month 25 – End: Month 60 – Subtask Leader: [NAGRA]

Subtask contributors: [GRS], [SCK•CEN], [ANDRA], [CNRS (IMT Atlantique)], [NAGRA (EPFL) (JACOBS)], [SÚRAO (UJV)]

Total PM: 8

The S/T coordination of ConCorD will be performed by the WP Leader [NAGRA] in collaboration with the Subtask Leaders 1.2 [GRS], 1.3 [SCK•CEN] and Task Leaders 2-6 [ANDRA] [CNRS (IMT Atlantique)] [NAGRA (EPFL) (JACOBS)] [SÚRAO (UJV)] constituting the WP Board.

The WP Board will ensure that the WP is progressing according to the agreed planning, milestones and deliverables. The WP Leader is responsible to report the work progress, the WP deliverables and any modifications of the WP work plan to the PMO. This will be done in close consultation with the WP Board. The WP Board will also be responsible to communicate with other WPs and stakeholders in EURAD and beyond. In ensuring scientific excellence, the WP Board is supported by the ERG (Subtask 1.4).

In order to fulfil these aims, the WP Board will have regular meetings at least every 6 months, which will be captured in minutes to be distributed to WP partners and the PMO.

The WP Board will also organise the WP Annual Meetings, which will be arranged with all partners to allow for information exchange, monitoring of work progress, dissemination of results, and interaction with End Users and other stakeholders. Dedicated technical meetings on Task level will be primary aspects, complemented by topical sessions focussing on specific aspects of interest in ConCorD, poster sessions or sessions focusing specifically on young researchers, as required. In addition, virtual task meetings will take place every 6 months, organised by each Task Leader and in presence of 1-2 members of the ERG.

Subtask 1.2: SotA

Start: Month 25 – End: Month 60 – Subtask Leader: [GRS]

Subtask contributors: [ANDRA], [CNRS (IMT Atlantique)], [NAGRA (EPFL) (JACOBS)], [SÚRAO (UJV)] who will be supported by [JUELICH (UFZ)] [VTT] [SÚRAO] [CIEMAT] [KIT] [CNRS] [SCK•CEN] [JUELICH (HZDR)] and international partners NWMO and CSIRO

Total PM: 11,2

The WP ConCorD will prepare an initial state-of-the-art report (SotA) at month 30 (D15.1) with an update at month 60 (D15.2). This will feed into WP Knowledge Management in EURAD-1 and will be communicated to other WPs in EURAD for information exchange organised at Task level. The content of the SotA will mainly reflect the R&D Tasks defined in ConCorD and build up on technical documents prepared at Task level. Consequently, subchapters of the SotA will address

- (i) Novel materials,
- (ii) Corrosion under irradiation
- (iii) Microbial effects
- (iv) Corrosion under transients
- (v) Modelling and integration in PA

An introduction and an outlook will be included, as well as other chapters providing context.

The update of the SotA at Month 60 will reflect the improved knowledge base generated in ConCorD on these topics, implement the newly acquired information into the state-of-the-art and address open issues.

Subtask 1.3: Training materials

Start: Month 30 – End: Month 60 – Subtask Leader [SCK•CEN]

Total PM: 2

Objective: Development of training materials

The WP ConCorD will prepare specific training materials on topics addressed within the WP in close collaboration with the WP KM Training/Mobility. Training materials in the form of lectures will be developed based on the detailed information of the SotA (Subtask 1.2) and this information will be updated at the end of the ConCorD WP. The preparation of the training materials will be led by the respective ConCorD Task leaders (meaning in teams of 2 partners), with support by the WP Leader. In addition, more detailed technical training or practical sessions that cover different modelling tools can be developed depending on the needs of future Training Event organizers. A first training material deliverable (D15.3) is planned for the first year of the WP and an updated deliverable (D15.4) at the end of ConCorD.

Subtask 1.4: Expert Review Group (ERG)

Start: Month 25 – End: Month 60 – Subtask Leader [NAGRA]

Total PM: 0

The ERG has the mandate of oversight, providing steer to the overall programme, and ensuring scientific excellence, achieved through the critical review of deliverables, participation in the WP Annual Meetings, individual task project meetings, and input to the WP Board. Emphasis will be given to issues relevant to end user needs and repository implementation, while ensuring that the generation of information is implementable and useful for performance assessment.

The ERG consists of an external expert as chairperson and 3-4 members from end-users (i.e., WMOs, TSOs). The main role of the ERG, similarly to a typical EUG, is to provide guidance for the five technical tasks (Tasks 2-6) throughout the 3-year duration of ConCorD. This will be achieved by robust and constructive review of experimental plans, progress reports and project presentations at semi-annual and annual project meetings, and participation in the WP Annual Meeting. A formal update will be provided by the ERG at the Annual Meeting each year, but it is expected that more-frequent interactions with the Task Leaders and individual partners will occur throughout the project. Each ERG member will take the lead as the reviewer for one of the five technical ConCorD tasks (and act as a deputy for a second task), as a way of promoting close collaboration with the participating researchers. The ERG will act as external peer reviewers for all of the ConCorD deliverables.

No budget is foreseen for the ERG as it is an in-kind contribution by the members.

Task 2 - Novel materials

Start: Month 25 – End: Month 60 – Task Leader [ANDRA]

Total PM: 159

The main goal of Task 2 is to explore the potential of novel materials and processes for the optimisation of long-term container performance. For the most promising novel materials, the planned experimental studies will contribute to the understanding of corrosion/degradation processes. Depending on the outcome of the experiments planned in Task 2, further characterization of selected promising materials could be undertaken in Task 3. The planned work is organised according to the two main types of materials: ceramic and metallic materials.

Interactions with other ConCorD Tasks:

Task 1: The initial SotA to be produced in Task 1 will include a review of the current state-of-knowledge of novel canister materials, with the results from Task 2 incorporated in the updated version of the SotA at the end of ConCorD.

Task 3: The irradiation studies in Task 3 will include copper-coated samples and other novel canister materials (subject to availability and selection in Task 2).

Task 6: The properties of novel material studied in Task 2 will be used to the extent possible in performance assessment in Task 6. This will allow the evaluation of lifetimes of containers based on novel materials and comparison with traditional solutions.

Subtask 2.1: Ceramic materials and coatings

Start: Month 25 – End: Month 60 – Task Leader [ANDRA]

Subtask Contributors: [ChRDI (KIPT)] [CNRS] [ANDRA (EMSE)]

Objectives: this sub-task aims at studying materials and processes (deposition, sealing) for innovative solutions of ceramic containers and ceramic coatings. For containers made of bulk ceramics, the key properties for long-term performance are fracture toughness and leaching/alteration. For thin coatings, a primary concern would be the presence of porosity or flaws.

For the bulk ceramic option, the most advanced materials are silica-alumina and silicon carbide. [CNRS] and [ANDRA] with in kind contribution of EMSE propose to study sealing materials for silica-alumina containers since data for the ceramic itself already exist. Experiments will be done on core-shell ceramic glasses and their use for sealing by microwave heating. The leaching properties of these materials will be determined as well as the evolution of the mechanical properties of the assemblies before and after leaching in porewater. The work will be done by a Post-Doc. [ChRDI (KIPT)] aims to study composite materials based on SiC doped with Cr. The studies will focus on the use of silicon carbide as enclosure material in the form of canisters, in-liners or encasements. A part of the work will focus on the determination of structure and physico-chemical properties of these new ceramic composites. Furthermore, the development of TiO₂ and CrN coatings by PVD process is foreseen. The same approach of structural and physico-chemical properties determination will be used to identify the best candidates. Corrosion tests are also proposed to select and validate ceramic coatings for SF/HLW containers

Subtask 2.2: Metallic materials and coatings

Start: Month 25 – End: Month 60 – Task Leader [ANDRA]

Subtask contributors: [ChRDI (KIPT)], [VTT], [ANDRA (EMSE)]

Objectives: Study and consider the implementation of innovative solutions for metallic anti-corrosion coatings or optimised bulk metallic options. Studies will focus on material development (alloy composition, coating technology) and initial corrosion tests to identify the benefit of these new solutions.

[KIPT] will study metallic coatings (Ti, Cr and Cu) obtained by PVD (like in Subtask 2.1). The same approach of structural and physico-chemical properties determination will be used to identify the best candidates. Corrosion tests are also proposed to select and validate metallic coatings for SF/HLW containers.

The [ANDRA (in kind contribution of EMSE)] contribution will focus on new copper/alumina composite coatings provided by cold spray technology. The metallic/ceramic composite will allow the use of nitrogen as carrier gas and lead to decreased porosity and improved adhesion (based on recent research on Cu/SiC coatings). After optimisation of the cold spray technology parameters for Cu/Al₂O₃ compositions, corrosion studies will be performed in repository conditions. The results will be compared to those of wrought Cu alloys [VTT] as well as electrodeposited and cold spray copper coatings [NWMO].

The [VTT] proposal focuses on the optimisation of bulk copper alloys for the KBS-3 concept and more specifically on the effect of impurities on corrosion properties. The uptake and diffusion of hydrogen and its interactions with the matrix will be investigated. The possibility of micro-galvanic corrosion due to the presence of impurities will also be studied. The relationship between hydrogen diffusion into the matrix, creep rate and SCC crack growth in sulphide-containing ground water will be assessed by performing complementary experimental testing and molecular dynamics (MD) simulations.

Task 3 - Corrosion under irradiation

Start: Month 25 – End: Month 60 – Task Leader [CNRS (IMT Atlantique)]

Total PM: 120

The main goal of Task 3 is to assess whether irradiation influences the corrosion of canister materials under disposal conditions. The work planned will provide the necessary scientific understanding and relevant experimental data to allow the incorporation of radiation-induced phenomena into performance assessment models (Task 6). To reach this goal, it is necessary to identify what is the critical parameter that determines the irradiation-induced material degradation (Subtask 3.1). This will be combined with irradiation-corrosion experiments under representative disposal conditions mimicking different periods of the typical repository evolution (Subtask 3.2).

Interactions with other ConCorD Tasks:

Task 1: The initial SotA to be produced in Task 1 will include a review of the current state-of-knowledge of irradiation effects on canisters materials, with the results from Task 3 incorporated in the updated version of the SotA at the end of ConCorD.

Task 2: The irradiation studies in Task 3 will include not only bulk copper and carbon steel samples, but also copper-coated samples and other novel canister materials (subject to availability).

Task 4: The [SÚRAO (UJV)] and [CIEMAT] irradiation experiments are fully integrated with the microbial studies in Task 4.

Task 5: The study of the effect of irradiation during the early unsaturated transient conditions is a central component of Task 3 and will provide complementary information to that being developed in Task 5.

Task 6: Irradiated corrosion rates from all partners and the effect of irradiation on the bentonite properties from [CIEMAT] have been identified as key inputs for several modelling studies in Task 6.

Subtask 3.1: Critical irradiation parameter

Start: Month 25 – End: Month 60 – Task Leader [CNRS]

Subtask Contributors: [NAGRA (JACOBS)], [SÚRAO (UJV)], [CNRS]

Objective: Address whether dose rate or total accumulated dose is the critical parameter determining the extent of irradiation-induced degradation

Experiments in simplified model systems that cover 4 orders of magnitude in dose rate leading to total doses spanning 2 orders of magnitude are planned. The experiments will include unirradiated controls and will explore carbon steel, copper and, to a limited extent, novel container materials arising in Task 2. [NAGRA (JACOBS)] will consider a complete range of dose rates (0.1-1000 Gy/h), total doses (1-100 kGy), and exposure periods (1-10,000 h). These experiments will be supplemented by irradiation studies by [SÚRAO (UJV)] at dose rates of 10-100 Gy/h for exposure periods of up to 18 months, for a total absorbed dose of up to 900 kGy. To complement the simple bulk solution environments to be used by [NAGRA (JACOBS)], these experiments will be conducted in the presence of compacted bentonite, with different degrees of saturation, and over a range of temperatures (room temperature to 150°C). Carbon steel corrosion coupons will be used, along with a limited number of other samples of novel materials to enable comparison with the results from other partners. [CNRS] will study the effect of dose rate (in the Gy/h to hundreds of Gy/h range), with a focus on unsaturated systems. The materials to be exposed and the exact environmental conditions will be selected in consultation with other partners with the aim of complementing the other studies.

The outcome of this task will be a definitive statement regarding the relative importance of dose rate and the total dose on the corrosion behaviour of canister materials over a range of environmental conditions. The work at [CNRS] will be done by PhD student.

Subtask 3.2: Irradiation under repository conditions

Start: Month 25 – End: Month 60 – Task Leader [CNRS]

Subtask Contributors: [SÚRAO (UJV)], [CNRS], [CIEMAT] - International Partner NWMO

Objective: Assessment of irradiation-accelerated corrosion of canister materials in realistic environments and irradiation conditions.

The experiments will represent the conditions expected in the repository with the inclusion of buffer materials at different saturation levels, temperature, and redox conditions. The collaboration between partners in this Subtask will provide additional information on the potential influence of

the type of bentonite used,

the nature of the irradiation source,

the effect of saturation, and

the dose rate at which there is no significant effect of irradiation.

(i) The [SÚRAO (UJV)] studies will focus on the use of compacted Ca-Mg bentonite but will also include MX-80 in a limited number of tests for comparison. The range of environments to be used by [CNRS] has yet to be defined in detail but could include compacted bentonite. The nature of the bentonite will affect the pore-water chemistry undergoing irradiation and, therefore, the distribution and nature of radiolytic species that are produced. Energy transfer to the

montmorillonite structure may also induce chemical or structural changes to the bentonite. In this context, [CIEMAT] will examine the chemical and structural changes that occur when a mixture of bentonite and simulated corrosion products (e.g., magnetite, copper oxide, etc.) is irradiated.

(ii) [CNRS] will use a ^{137}Cs gamma source but could also have access to a ^{60}Co source if needed for comparison, which is considered a benefit since ^{137}Cs is the primary gamma emitter in SF. In addition, the studies by the non-European partner NWMO involve the use of actual spent fuel, thus replicating the full energy spectrum to be expected in the repository. If feasible, depending on the details of the irradiation facilities and test vessels available, the effect of irradiation orientation will also be examined.

(iii) The highest gamma dose rates in the repository will correspond to the initial aerobic, unsaturated period. By analogy with atmospheric corrosion, it is reasonable to presume that there exists a minimum relative humidity (RH) below which there is no irradiation-enhanced corrosion due to the absence of sufficient aqueous phase. For slowly-saturating repositories, therefore, it may be possible to claim that there is a minimal effect of irradiation on the corrosion of the canister because the dose rate will have decayed prior to the critical RH being reached at the canister surface. [CNRS] will conduct experiments at various RH values, as well as at different dose rates. NWMO will also conduct irradiation studies under atmospheric conditions.

(iv) The concept of a threshold irradiation dose rate below which there is no significant effect on canister performance is a useful one for supporting the safety case as it may be possible to exclude irradiation effects on this basis. Several studies will include unirradiated control experiments, which will allow a direct comparison with the equivalent irradiated experiments. It is likely that there will be a continuum in the degree of corrosion enhancement by irradiation which will depend on the sensitivity of the technique used to measure the corrosion rate. Nevertheless, it will be possible to determine the significance of the irradiation effects, which may depend on the canister material and its corrosion rate in the absence of irradiation.

The work at [CNRS] and [CIEMAT] will be done by PhD students.

Task 4 - Microbial effects

Start: Month 25 – End: Month 60 – Task Leader [NAGRA (EPFL)]

Total PM: 126

The main goal of this Task is to improve our collective understanding of the role of microbes in corrosion in the context of nuclear waste disposal. Sulfate-reducing bacteria have long been the focus of this type of investigation as their activity is expected to release sulfide. But, a more comprehensive approach that includes molecular tools to probe the microbial community as a whole along with targeted cultivation is needed along with carefully designed experiments to isolate specific factors and document their impact on microbial activity.

In particular, the topics addressed will be (a) how irradiation controls microbial survival in bentonite; (b) the fundamental mechanisms underlying the threshold dry density that inhibits microbial activity; and (c) the role of O_2 persistence in the inhibition of the growth of sulfate-reducing bacteria in bentonite. The insights provided by the proposed work will allow the inclusion of process understanding in adequately bounding the potential impact of microbial activity on corrosion in the bentonite buffer.

Interactions with other ConCorD Tasks:

Task 1: The initial SotA to be produced in Task 1 will include a review of the current state-of-knowledge of microbial processes relevant to corrosion in the context of nuclear waste disposal, with the results from Task 4 incorporated in the updated version of the SotA at the end of ConCorD.

Task 2: Experiments including bulk copper and carbon steel samples, but also copper-coated samples and other novel canister materials (subject to availability) will be included in Task 4.

Task 3: The irradiation experiments run by [SÚRAO (UJV)] and [CIEMAT] in this task will provide samples for microbial studies in Task 4.

Task 5: Microbial growth and activity during early unsaturated transient conditions within will be tackled within Tasks 3 and 4 and will provide complementary information for the interpretation of the work in Task 5.

Task 6: Microbial growth and activity will be constrained by the experiments in Task 4 and will provide key inputs for several modelling studies in Task 6.

Subtask 4.1: Impact of irradiation on microbial viability

Start: Month 25 – End: Month 60 – Task Leader [NAGRA (EPFL)]

Subtask Contributors: [SÚRAO (UJV) (TUL)], [CIEMAT] ([UGR])

Objective: Assess the impact of irradiation coupled to other stressors (heat and water content) on the activity and survival of microorganisms in bentonite in general, and of sulfide-generating microorganisms in particular.

Previous work on irradiation and microorganisms (for instance in MIND) has focused on the role of irradiation on changing the bioavailability of organic carbon in refractory compounds. The goal of this subtask is to evaluate the role of multiple stressors (including irradiation) on the activity and viability of microorganisms in bentonite. The aim is

not necessarily to identify a survivability threshold, but rather to decipher how repository conditions will impact the potential microbial generation of sulfide in bentonite. Of particular interest is the impact of dose rate vs. total dose on microbial activity and survival.

The experimental system consists of compacted bentonite (varying types) in which metal coupons (various types) are embedded and that is subjected to long-term low-dose or short-term high-dose irradiation. This work is embedded within Task 3 and will allow the integration of the impact of irradiation on bentonite and on corrosion to that on microbial community. As mentioned above, both types of experiments will be conducted under variable conditions of dry density, thermal load, and water saturation in order to consider the impact of multiple effects on the survival of microorganisms. Appropriate controls will be included so as to obtain conclusive results. These experiments integrate microbial community characterization with the characterization of the bentonite pre- and post-irradiation. Thus, this represents a complete study allowing the mapping of repository conditions that permit microbial activity to persist and that addresses the impact of dose rate vs total dose on microbial processes.

This sub-task includes interactions with sub-task 3.2 as experiments planned for these two sub-tasks integrate the relevant questions, including the survival of microorganisms, particularly for the [CIEMAT] and [SÚRAO (UJV)] experiments.

[CIEMAT (UGR)] aim to involve PhD students.

Subtask 4.2: Impact of bentonite dry density and particle size on microbial activity

Start: Month 25 – End: Month 60 – Task Leader [NAGRA (EPFL)]

Subtask Contributors: [SCK CEN], [JUELICH (HZDR)], [NAGRA (EPFL)] – International Partners: NWMO, NUMO

Objective: Identify the bentonite characteristic(s) responsible for the control of microbial activity

In this sub-task, bentonite characteristics and their impact on microbial activity will be tackled. It is well established that dry density correlates with microbial survival in bentonite but the underlying mechanism constraining microbial activity is not well understood. Thus, a series of systematic experiments will be carried out with varying dry densities. A cell containing compacted bentonite will be exposed to H₂ and the bentonite microbial biomass measured (through DNA concentration proxy) to establish the dry density threshold at which no growth occurs. Many reactors will be built and numerous experiments will be run in parallel to allow statistical significance and probing a variety of conditions. In addition, the particle size distribution will be varied for the same dry density (by grinding and sieving the bentonite) in order to test the hypothesis that pore size distribution is a determinant of microbial growth. X-ray CT scans will enable post-mortem pore size distribution characterization. Several bentonites (MX-80, Calcigel, and others, time-permitting) will be considered and direct comparison of their performance will be possible. Appropriate controls are planned to constrain the interpretation of the results.

Additionally, a diffusion experiment will be carried out in which electron donor (H₂) will be provided to a pressure cell containing bentonite and metal coupons. The dry density, type of bentonite and metal coupon (carbon steel and copper) will be varied systematically and the experimental end point will be reached when microorganisms from the bentonite are detected at the outlet. Characterization of the rate of metal corrosion and the change in microbial community will provide an understanding of the role of dry density in corrosion.

Together, these two experiments will provide insight into the role of dry density and particle size distribution on microbial activity in bentonite and its impact on corrosion. In addition, NUMO will provide their data on microbial activity in various bentonites, which may be leveraged in comparison to the work above.

The work at [JUELICH (HZDR)] will be done by a Post-Doc and at [NAGRA (EPFL)] by a PhD student.

Subtask 4.3: Impact of bentonite-associated oxygen on microbial activity and viability

Start: Month 25 – End: Month 60 – Task Leader [NAGRA (EPFL)]

Objective: Identify the role of oxygen on SRB activity

Previous work has shown that compacted bentonite exposed to an anoxic environment for up to 5.5 years still harbours a majority of viable aerobes while no sulfate-reducing bacteria are detected by molecular tools (and very few by cultivation). Thus, the hypothesis is that oxygen persists in the pore space and/or on the surface of bentonite, allowing for the persistence of aerobes and inhibiting the growth of anaerobes such as sulfate-reducing bacteria. The goal of this experiment is to evaluate the role of O₂ in shaping microbial activity in bentonite. The experiment is designed to deploy bentonite that has undergone various treatments and in which steel and copper (and other metals or materials) coupons are embedded. The bentonite treatments will result in varying amounts of residual O₂, thus presumably impacting the growth of anaerobic microorganisms. Example bentonite treatments include (a) degassing saturated bentonite by alternating vacuum and N₂ flushes for an extended period (days), (b) storing the dry bentonite under anoxic conditions for 8 months prior to deployment, (c) storing saturated bentonite in 50% O₂ atmosphere, (d) reducing saturated bentonite with a chemical reducing agent prior to use, and (e) sterile bentonite amended with a live culture of aerobes derived from the bentonite. A single bentonite dry density will be selected for all treatments. Four modules will be prepared

using these various forms of bentonite and deployed in the BIC-A borehole for 2 years at least. We will be careful to characterize the initial state of the several types of bentonite in order to compare it to the 2-year time point. The design of the modules will deviate from the current IC-A design in that much smaller bentonite blocks will be considered and will be contained within smaller reactors that will be placed in the current steel modules. The reason for this change of design is that the diffusion length of sulfide and other reducing agents should be relatively small to allow for significant changes to be detected within the bentonite over the period of time allotted for the project. Thus, we will use small cylinders placed in small reactors and place them inside the module but around the periphery (with the center filled with an inert material). After 2 years, we will consider the corrosion rate, the microbial community (persistence of aerobic microorganisms and presence of sulfide-producing microorganisms), and the prevalence of iron sulfide precipitation in the bentonite (by XRF and XANES). The work will be performed by a PhD student.

Task 5 - Corrosion under transients

Start: Month 25 – End: Month 60 – Task Leader [SÚRAO (UJV)]

Subtask Contributors: [SÚRAO (UJV)] [KIT] [GRS] [CIEMAT]

Total PM: 58.4

Objectives: As the durability of waste containers is strongly related to the evolution of the environmental conditions in all phases of the repository lifecycle, the aim of this task is dedicated to corrosion during redox, hydraulic, and thermal nearfield transients. Those transients would lead to chemo-mechanical interactions between the container material or coating (if present), corrosion products and buffer. The effect of evolving redox conditions, chemical conditions, temperature, bentonite saturation and gas evolution, both in laboratory and in-situ will be the main key processes to be studied in order to address existing uncertainties and to provide relevant experimental data to adequately account for these processes in performance assessment (Task 6).

The experiments will be focused on the effect of representative processes, where at least one parameter can change with time. The activities within the task will provide information about the potential effect of (i) redox constraints, (ii) temperature, (iii) the effect of saturation, (iv) gas evolution, and (v) chemical evolution of system.

[GRS] in cooperation with [KIT] will determine the temporal evolution of rate and propagation of corrosion of spheroidal graphite cast iron GGG40 and copper alloy C71500 in contact with bentonite saturated with pore water at typical near field temperatures. The influence of oxidising/reducing conditions on the growth and long-term chemical and mechanical stability of the protective oxide films will be emphasized. The redox topic will be complemented with studies at 30, 50 and 80°C and pressures of 5, 50 and 100 bar, using both accelerated and conventional corrosion techniques. KIT plans a 2-year Post-Doc to be involved in the study who will also, so as support/supervise Master or Bachelor students. The experimental results will be provided to Anphos21 for modelling in Task 6.

[SÚRAO (UJV)] will study the effect of increased temperature (90 °C, 150°C) on accelerated corrosion in Ca-Mg bentonite, also including MX-80 in a limited number of tests for an insight on chemical evolution and its influence on development of the carbon steel canister – bentonite interface. The study is fully integrated with a contribution in Task 3 and 4.

[CIEMAT] will experimentally and theoretically study the impact of hydraulic (water saturation)/redox and thermal transients (ambient temperature and 80°C), altogether with gas evolution, to relate induced metal corrosion with gas/hydraulic and temperature conditions. Both carbon-steel and Cu-based canisters are considered, including both in-situ (LOT and ABM experiments in Äspö URL) and laboratory studies. [CIEMAT] plans to involve a PhD student in the work proposed to evaluate the impact of hydraulic/gas and thermal transients at the canister/bentonite interface. The experimental results will be provided to Anphos21 for modelling in Task 6.

Interactions with other ConCorD Tasks:

Task 1: The initial SotA to be produced in Task 1 will include a review of the current state-of-knowledge of effects of processes in the transient periods, with the results from Task 5 incorporated in the updated version of the SotA at the end of ConCorD.

Task 2: The studies in Task 5 will include not only bulk copper and carbon steel samples, but also cast iron and copper alloys.

Task 3: The [SÚRAO (UJV)] and [CIEMAT] experiments are fully integrated along with irradiation experiments in Task 3.

Task 4: The [SÚRAO (UJV)] and [CIEMAT] experiments are fully supporting microbial experiments in Task 4 and provide them the experimental basis (samples available etc.)

Task 6: Experimental results of [KIT], [GRS] and [CIEMAT] will form important input to modelling activities in Task 6 [KIT (AMPHOS21)]. Corrosion rates partners under defined transient conditions and the effect of them on development of canister – bentonite interface from the [SÚRAO (UJV)] and [CIEMAT] can also form an input into the integration in PA in Task 6.

Task 6 – Integration

Start: Month 25 – End: Month 60 – Task Leader [NAGRA (JACOBS)]

Total PM: 80

The main goal of Task 6 is the synthesis of newly acquired knowledge into a form applicable for container performance assessment considering the specific needs of the safety cases developed by implementors. This will be based on experimental evidence and the modelling of the experimental observations of processes occurring at the container-oxide-buffer interface, which will demonstrate mechanistic understanding and will support container lifetime predictions for traditional and novel materials. The integration of the outputs of the above Tasks will lead to the development of coupled models considering transient thermo-hydro-mechanical-chemical-biological phenomena at a relevant scale. This will be a supporting tool when integrating the container as a barrier in performance assessments, especially when addressing the relevant timescales and the probabilistic nature of the involved phenomena.

Interactions with other ConCorD Tasks:

Task 6 will have close interactions with Tasks 2, 3, 4 and 5 to manage the provision of experimental results as input data to the various corrosion models. This will be managed formally by two workshops at key milestones within the work package. The first will take place midway through Year 1 to inform the modellers of the planned experiments and their expected outputs. The second will take place midway through Year 3 to manage the final transfer of data between experimentalists and modellers and to address any gaps or delays. It is also anticipated that a number of smaller, informal interactions via email and online meetings by video-conference will take place ad hoc to allow steady information exchange between the larger meetings.

Subtask 6.1: Development of modelling tools and evaluation of experimental data

Start: Month 25 – End: Month 60 – Task Leader [NAGRA (JACOBS)]

Subtask Contributors: [KIT (AMPHOS21)] [JUELICH (UFZ)]

Objective: Develop modelling tools to integrate experimental data from other Tasks

[KIT (AMPHOS21)]: Further development of an existing modelling framework to enable coupling geochemical models, solute transport including water radiolysis, heat transfer, variable saturation and electrochemistry. It will be used to rationalize the data generated within the project using advanced numerical tools coupling reactive transport processes, chemical reactions, heat transfer, variably saturated conditions and the electro-chemistry of the corrosion process. In this way, it is intended to increase the system understanding of the interface between bentonite barriers and metals in a geological disposal framework.

[JUELICH (UFZ)]: Development and implementation of conceptual and mathematical formulation for a mechanistic model to simulate canister corrosion (carbon steel) in contact with porous media (bentonite) due to: A) Radiation effects (radiolysis) and anaerobic corrosion B) Microbiological activities in the buffer material.

Subtask 6.2: Integration for PA

Start: Month 25 – End: Month 60 – Task Leader [NAGRA (JACOBS)]

Subtask Contributors: [JUELICH (UFZ)] [ANDRA] [NAGRA (JACOBS)] – International Partner: CSIRO

Objective: Ensure that ConCorD outputs are useful for performance assessment performed by implementors

[JUELICH (UFZ)]: Integrate the complex processes measured in the experimental activities, by bounding and reducing the complexity of the laboratory-scale models that describe them, whilst still capturing the evolution of key processes relevant to predict canister corrosion within repository scales.

[ANDRA]: Simplification of the corrosion models dealing with irradiation and microbial influences developed from the experimental work at the lab scale in Task 3 and Task 4 so that they can be integrated and modelled at the disposal scale to characterise the phenomenological evolution of each disposal concept.

International Partner CSIRO: Perform integrated modelling of container performance under disposal conditions that are likely to be more extreme in terms of temperature, pressure and chemistry than boundary conditions for conventional geological disposal facilities using new knowledge on container performance from previous tasks. Knowledge gained from experimental work will be integrated within the model and applied to one or more relevant disposal concepts.

[NAGRA (JACOBS)]: Integrate the outputs of Task 6 and indirectly Tasks 2,3,4,5 with the broader scientific basis and with ongoing treatment of container degradation in performance assessment, focussing on the provision of technical steer, and evaluation of the implications highlighted by the coupled modelling activities within Task 6 using technical literature and with due consideration of how the relevant processes are treated in safety cases.

Participation per Partner

Partner number and short name	WP15 effort
1 - ANDRA	5.75

Partner number and short name	WP15 effort
IMT/EMSE	50.50
6 - CIEMAT	29.60
UGR	16.00
7 - ChRDI	0.00
KIPT	71.00
8 - CNRS	58.25
IMT Atlantique	3.00
15 - JUELICH	24.60
UFZ	31.00
16 - GRS	15.30
24 - KIT	24.00
AMPHOS 21	32.00
27 - NAGRA	4.00
EPFL	38.00
Jacobs	46.65
38 - SCK•CEN	21.60
42 - SÚRAO	2.00
TUL	21.00
ÚJV	64.00
50 - VTT	16.25
Total	574.50

List of deliverables

Deliverable Number ¹⁴	Deliverable Title	Lead beneficiary	Type ¹⁵	Dissemination level ¹⁶	Due Date (in months) ¹⁷
D15.1	ConCorD - State-of-the-Art	16 - GRS	Report	Public	30
D15.2	ConCorD - SOTA update	16 - GRS	Report	Public	59
D15.3	ConCorD - Training materials	38 - SCK•CEN	Report	Public	35
D15.4	ConCorD - Updated training materials	38 - SCK•CEN	Report	Public	59
D15.5	ConCorD - Report on novel material choices for HLW/ SF containers	1 - ANDRA	Report	Public	36
D15.6	ConCorD - Report on novel materials properties: corrosion/	50 - VTT	Report	Public	59

List of deliverables

Deliverable Number¹⁴	Deliverable Title	Lead beneficiary	Type¹⁵	Dissemination level¹⁶	Due Date (in months)¹⁷
	durability and mechanical performance				
D15.7	ConCorD - Elucidation of critical irradiation parameter	27 - NAGRA	Report	Public	52
D15.8	ConCorD - Synthesis of irradiation results under repository conditions	8 - CNRS	Report	Public	55
D15.9	ConCorD - Experimental set-up and first results on the impact of irradiation, dry density, particle size and O2 on the microbial community	42 - SÚRAO	Report	Public	42
D15.10	ConCorD - Integration of the findings on the impact of irradiation, dry density, particle size, and O2 on the microbial community	15 - JUELICH	Report	Public	59
D15.11	ConCorD - Designation of boundary conditions and experimental approach	42 - SÚRAO	Report	Confidential, only for members of the consortium (including the Commission Services)	30
D15.12	ConCorD - Identification of the effect of transient processes on corrosion	42 - SÚRAO	Report	Public	57
D15.13	ConCorD - Task 6 report on modelling at the disposal scale and the implications for performance assessment	15 - JUELICH	Report	Public	59
D15.14	ConCorD - ConCorD final synthesis report	27 - NAGRA	Report	Public	60

Description of deliverables

- D15.1 - ConCorD - SOTA – Lead [GRS] – Due month: 30
- D15.2 - ConCorD - SOTA update – Lead [GRS] - Due month:59
 - D15.3 - ConCorD - Training materials - Lead [SCK CEN] - Due month:35
 - D15.4 - ConCorD - Updated training materials - Lead [SCK CEN] - Due month:59
 - D15.5 - ConCorD - Report on novel material choices for HLW/ SF containers - Lead [ANDRA] - Due month:36
 - D15.6 - ConCorD - Report on novel materials properties: corrosion/durability and mechanical performance - Lead [VTT] - Due month:59
 - D15.7 - ConCorD - Elucidation of critical irradiation parameter - Lead [NAGRA] - Due month:52
 - D15.8 - ConCorD - Synthesis of irradiation results under repository conditions - Lead [CNRS] - Due month:55

- D15.9 - ConCorD - Experimental set-up and first results on the impact of irradiation, dry density, particle size and O2 on the microbial community - Lead [SÚRAO] - Due month:42
- D15.10 - ConCorD - Integration of the findings on the impact of irradiation, dry density, particle size, and O2 on the microbial community - Lead [JUELICH] - Due month:59
- D15.11 - ConCorD - Designation of boundary conditions and experimental approach - Lead [SÚRAO] - Due month:30
- D15.12 - ConCorD - Identification of the effect of transient processes on corrosion - Lead [SÚRAO] - Due month:57
- D15.13 - ConCorD - Task 6 report on modelling at the disposal scale and the implications for performance assessment - Lead [JUELICH] - Due month:59

D15.1 : ConCorD - State-of-the-Art [30]

State-of-the-Art

D15.2 : ConCorD - SOTA update [59]

ConCorD - SOTA update

D15.3 : ConCorD - Training materials [35]

ConCorD - Training materials

D15.4 : ConCorD - Updated training materials [59]

ConCorD - Updated training materials

D15.5 : ConCorD - Report on novel material choices for HLW/ SF containers [36]

ConCorD - Report on novel material choices for HLW/ SF containers

D15.6 : ConCorD - Report on novel materials properties: corrosion/durability and mechanical performance [59]

ConCorD - Report on novel materials properties: corrosion/durability and mechanical performance

D15.7 : ConCorD - Elucidation of critical irradiation parameter [52]

ConCorD - Elucidation of critical irradiation parameter

D15.8 : ConCorD - Synthesis of irradiation results under repository conditions [55]

ConCorD - Synthesis of irradiation results under repository conditions

D15.9 : ConCorD - Experimental set-up and first results on the impact of irradiation, dry density, particle size and O2 on the microbial community [42]

ConCorD - Experimental set-up and first results on the impact of irradiation, dry density, particle size and O2 on the microbial community

D15.10 : ConCorD - Integration of the findings on the impact of irradiation, dry density, particle size, and O2 on the microbial community [59]

ConCorD - Integration of the findings on the impact of irradiation, dry density, particle size, and O2 on the microbial community

D15.11 : ConCorD - Designation of boundary conditions and experimental approach [30]

ConCorD - Designation of boundary conditions and experimental approach

D15.12 : ConCorD - Identification of the effect of transient processes on corrosion [57]

ConCorD - Identification of the effect of transient processes on corrosion

D15.13 : ConCorD - Task 6 report on modelling at the disposal scale and the implications for performance assessment [59]

ConCorD - Task 6 report on modelling at the disposal scale and the implications for performance assessment

D15.14 : ConCorD - ConCorD final synthesis report [60]

ConCorD - ConCorD final synthesis report

Schedule of relevant Milestones

Milestone number¹⁸	Milestone title	Lead beneficiary	Due Date (in months)	Means of verification
MS247	ConCorD - WP Annual meeting: Kick-off	27 - NAGRA	25	ConCorD - WP Annual meeting: Kick-off
MS253	ConCorD - Subtask 1.2: Editorial Meeting on Drafts for SOTA	16 - GRS	27	ConCorD - Subtask 1.2: Editorial Meeting on Drafts for SOTA
MS254	ConCorD - Task 4 Meeting to finalize experimental design	27 - NAGRA	27	ConCorD - Task 4 Meeting to finalize experimental design
MS263	ConCorD - Task 3: Experimental set-ups and test conditions coordinated	8 - CNRS	30	ConCorD - Task 3: Experimental set-ups and test conditions coordinated
MS264	ConCorD - Task 5 Revision of existing data for the selection of Cu ad Fe-corrosion products (CIEMAT)	6 - CIEMAT	30	ConCorD - Task 5 Revision of existing data for the selection of Cu ad Fe-corrosion products (CIEMAT)
MS265	ConCorD - Task 5 Systems definition and expected data output	24 - KIT	30	ConCorD - Task 5 Systems definition and expected data output
MS270	ConCorD - Task 6 Workshop to inform modellers of planned experiments and expected output	27 - NAGRA	32	ConCorD - Task 6 Workshop to inform modellers of planned experiments and expected output
MS274	ConCorD - Task 4 supply of samples from irradiation experiment for microbial analysis	6 - CIEMAT	36	ConCorD - Task 4 supply of samples from irradiation experiment for microbial analysis
MS275	ConCorD - Task 4 supply of samples from irradiation experiments for microbial analysis	42 - SÚRAO	36	ConCorD - Task 4 supply of samples from irradiation experiments for microbial analysis
MS276	ConCorD - Subtask 2.2: Supply of coatings samples for corrosion and irradiation tests	1 - ANDRA	36	ConCorD - Subtask 2.2: Supply of coatings samples for corrosion and irradiation tests
MS277	ConCorD - Task 5 Preliminary data delivery to modellers (KIT, GRS, CIEMAT)	24 - KIT	36	ConCorD - Task 5 Preliminary data delivery to modellers (KIT, GRS, CIEMAT)
MS278	ConCorD - WP Annual meeting: Year 1	27 - NAGRA	36	ConCorD - WP Annual meeting: Year 1
MS290	ConCorD - Subtask 2.1: Supply of ceramics samples for mechanical testing and leaching	8 - CNRS	42	ConCorD - Subtask 2.1: Supply of ceramics samples for mechanical testing and leaching

Schedule of relevant Milestones

Milestone number¹⁸	Milestone title	Lead beneficiary	Due Date (in months)	Means of verification
MS299	ConCorD - Task 5 Updated data delivery to modellers (KIT, GRS, CIEMAT)	16 - GRS	48	ConCorD - Task 5 Updated data delivery to modellers (KIT, GRS, CIEMAT)
MS300	ConCorD - WP Annual meeting: Year 2	27 - NAGRA	48	ConCorD - WP Annual meeting: Year 2
MS313	ConCorD - Task 5 Final data delivery to modellers (KIT, GRS, CIEMAT)	6 - CIEMAT	54	ConCorD - Task 5 Final data delivery to modellers (KIT, GRS, CIEMAT)
MS314	ConCorD - Task 6 Workshop to update modellers on final experimental results	27 - NAGRA	54	ConCorD - Task 6 Workshop to update modellers on final experimental results
MS320	ConCorD - Task 6 Modelling completed; inputs ready for PA assessment	27 - NAGRA	56	ConCorD - Task 6 Modelling completed; inputs ready for PA assessment
MS321	ConCorD - Subtask 1.2: Editorial Meeting on Drafts for SOTA update	16 - GRS	57	ConCorD - Subtask 1.2: Editorial Meeting on Drafts for SOTA update
MS329	ConCorD - WP Annual meeting: Year 3	27 - NAGRA	60	ConCorD - WP Annual meeting: Year 3

Work package number ⁹	WP16	Lead beneficiary ¹⁰	19 - IRSN
Work package title	Chemo-Mechanical AGIng of Cementitious materials (MAGIC)		
Start month	25	End month	60

Objectives

The MAGIC WP will assess the impact of several simultaneous chemical processes (hydrolysis, multi-ionic attack (i.e. sulfate and magnesium), carbonation) on the mechanical properties of cementitious materials and their evolution. The WP proposes different processes to assess the long-term performance of cement based materials, including a hydraulic transient (re-saturation period with waters from different geological media). It will leverage and build on the advances on past and current European projects (mainly CEBAMA, PREDIS, ACED, DONUT WPs) and explicitly exclude the repetition of activities conducted in these previous or ongoing projects.

The final goal is to obtain an improved understanding of chemo-mechanical ageing of cementitious materials exposed to various representative chemical disturbances coming from the disposal environment. More specifically the project will focus on:

Portland formulations: Further understanding is required to support the use of these materials in geological disposal, particularly to understand their contribution to the overall system performance during the late post-closure timeframe.

Low-pH formulations: Low-pH concrete is an option retained by several Member States as a material for massive plugs for sealing disposal cells, galleries and access shafts to limit the swelling clay disturbance caused by ordinary Portland cement. The knowledge of its mechanical aging behavior, particularly concerning the different perturbations is scarce.

The use of several cement formulations will help to compare their long-term performance under the same conditions.

The main focus of the MAGIC WP is on the evolution of mechanical properties of cementitious material (especially mechanical performance) under exposure to various chemical disturbances. The experimental data and models on degradation mechanisms are essential for the later use in the safety and performance assessment. The performance assessment as a topic is out of WP scope.

Another aspect to be considered in the project is the impact of microbial activity on the evolution of the chemo-mechanical properties of cementitious materials. This WP will design innovative experiments that include microbial activity to identify their potential impact on the chemo-mechanical evolution of cementitious materials in comparison to the same experimental case without microorganisms.

Microbial activity will be considered in this WP as a disturbance in the same way as the chemical disturbances will be investigated.

Particular strength of this project is the mechanical behavior assessment under various hydraulic conditions and chemical degradations (taking into account a potential effect of a microbiological activity). The integration of innovative material characterization and modelling from nano to laboratory and field studies, to full scale (in terms of modelling) is a key issue of the project.

The 3 main objectives of the WP are:

- OBJ1 - To quantify the mechanical multi-scale evolution of cementitious materials under the chemical degradation expected in repository environments. To identify the main reactive pathways at the repository scale during the re-saturation phase and at the saturated conditions.
- OBJ2 - To obtain a reference chemo-mechanical model of Portland and low-pH concrete exposed to relevant disposal environments, considering representative boundary conditions.
- OBJ3 - To estimate the extent of the impact of microbial activity on concrete properties (low-pH and Portland cement) in partially and fully saturated media.

The available experimental studies are short-term compared to the service lifetime of the material in the disposal site. The long-term behavior of cementitious material should therefore be based on model predictions. Particularly challenging are extrapolations of equilibrium processes. Successful description of such phenomena requires a multiscale approach. This involves a periodic mechanic testing program on well-characterized aged samples exposed to chemical disturbances under well controlled conditions:

- Several years of contact with a host rock (various conditions)
- Accelerated (mono or combined) chemical attacks (concrete/cement freshly formulated or drilled from existing underground structures (various conditions combined with or without microbial activity).

Materials, samples, test protocols, will be chosen and mutualized at the WP scale. The choice of the mechanical tests takes into account the scale of the samples as well as the existing loading in the final structure:

- At the nano to micro scale: nano- and micro indentation studies along with corresponding scale dependent material characterization to provide a close link to the chemical state of the system.
- At the meso scale, centimeter to decimeter size samples is used in a way to identify the chemo-mechanical state of the system:
 - o Mechanical parameters (Compressive strength (Rc), Young Modulus (E), triaxial behavior), shear, bending on small beam.
 - o The initial mechanical condition could be also diverse; e.g. samples initially damaged under creep,...
 - o CT-studies of samples under loading and deformation analysis
 - o As far as technically feasible, in situ CT characterization of chemo-mechanical coupling e.g. nondestructive monitoring of chemical evolution under loading.

The chemo-mechanical modelling will be elaborated on the nano to micro scale (scales at which we can identify the chemo-mechanical evolution due to the chemical attack more easily and faster), consolidated on the meso scale with various types of loading, and verified for a few complex tests (compression, traction, triax under tomography or flexion). Subsequently the real scale of the structure will be modelled (upscaling) based on the knowledge from small scale material characterization and modelling.

Description of work and role of partners

WP16 - Chemo-Mechanical AGIng of Cementitious materials (MAGIC) [Months: 25-60]

IRSN, ANDRA, CEA, CIEMAT, CNRS, COVRA, CV REZ, JUELICH, GRS, LEI, PSI, RWM, SCK•CEN, SÚRAO, UHelsinki

Task 1 – Strategy and piloting the WP – SOTA and dissemination

Start: Month 25 – End: Month 60 - Task Leader: [IRSN]

Task contributors: [ANDRA], [IRSN], [COVRA], [SCK-CEN], [SÚRAO (CTU) (TUL)], [PSI], [CVREZ], [JUELICH (UFZ)] + end users only : NAGRA, RWM

Total PM: 18.5

Objectives :

- To organize discussions with end-user group to define the base cases to be processed in the task 4.
- To coordinate and design initial and final SOTA report.
- To ensure the dissemination of knowledge/Training material.
- To support the collective approach in the task 2 and task 3 to generate data sets used in the integration task 4
- To coordinate the WP

Subtask 1-1: WP coordination

Start: Month 25 – End: Month 60

The subtask 1.1 is relative to the scientific and technical coordination of the work package. It takes into account the participation to PMO meetings twice a year.

An important aspect of subtask 1.1 is to ensure information transfer and to support interactions between different Tasks. A strong link is wished between the different tasks. Numerous work package meetings, workshops and general milestones will structured these interactions.

Two adjacent meetings are planned :

- Kick-off meeting planned at the start of the project including a discussion between experimentalists and modellers, chemists, microbiologists and mechanics to define requirements for modelling approaches and expected experimental input and support discussion on the specifications of the representative systems
- Closure meeting at the end of the project

Three work package meetings are planned:

- M31 including task meetings and a first workshop
- M43 including task meetings
- M55 including task meetings

Following workshops or interaction meetings are planned

- WS1: workshop with PMO and task leaders to define base cases for task 4 (modelling).

- WS2: (adjacent to the annual work package meeting) – workshop on model concepts, and parameters based on expected experimental results in T2 and T3 on coordination of information exchange between experiments and models within and between scales and on scale transitions of data, model approaches and model results.
- WS3: (adjacent to the annual WP meeting) – Workshop dedicated to update the new experimental data (from new and on-going experiments) for modelling refinement in Task 4. Separated Working Groups: nano/micro – meso and macroscales.
- WS4: on criteria definition in the ST1-4 to evaluate the level of interest and uses of the experimental data in models developments.
- WS5: (adjacent to the annual WP meeting) Workshop with two objectives:
 - o Part 1/ In terms of research development: Identify gaps remaining and propose next steps to improve the understanding of the link between chemistry and mechanics to model the long term evolution of cementitious materials in disposal conditions.
 - o Part 2/ In terms of safety: Define the methodology to use the different results and developments highlighted in the work package in safety assessment analyses for geological disposal.

Subtask 1-2 (ST1-2) : State of the Art (SOTA)

Start: Month 25 – End: Month 58

The goal of this subtask is to compile and evaluate the initial and final SOTA about:

- o The key processes controlling the chemical evolution of cementitious materials placed in deep disposals environments;
- o The multiscale mechanical behaviours linked to the disturbances imposed in both types of disposals;
- o The existing knowledge on the chemo-mechanical approach in parallel applications.

The following parameters and conditions will be researched in the literature review for integration process in the Task 4:

- o In terms of chemistry, leaching/hydrolysis, carbonation (atmospheric and under water), magnesium, saline and sulphate attacks associated to microbial activity will be included in the overview for interaction with host rock, ground waters, salted waters or in unsaturated conditions.
- o In terms of mechanics, Young modulus, compressive strength, carbonation shrinkage and swelling (linked to sulphate attacks) will be included in the review.

An important effort will be done at this stage to identify the gap allowing to link the chemical behaviour evolution of cementitious materials to the mechanical one. A constant updating of this SOTA with data coming from T2 and T3 by a specific Working Group will be supported by the creative of an interactive data platform available for all partners involving in the WP.

Subtask 1-3 (ST1-3): Training materials

Start: Month 44 – End: Month 60

This subtask will have to coordinate and to assemble all training materials for the work package on the main elements to model the long term chemo-mechanical evolution of concrete in surface and geological disposals.

Subtask 1-4 (ST1-4): Experiments and numerical models analysis loop – permanent feedback.

Start: Month 27 – End: Month 60 - Task Leader:

In relation with the subtask 1-2, the same WG (composed also by End Users) will have to animate and articulate the knowledge development all along the WP duration. The objective will be to maintain a constant effort of interaction between modellers and experimenters, but also between the different specialities (mechanic, chemistry, microbiology). The Interactive Data Platform on Cement IDPC, will be the key tool to build a robust and safe relation between partners. It will ensure a transparent transfer of data and new results.

The objective of this WG will be to:

- o Define rules to fill the IDPC and to manage the information put inside.
- o Animate discussions between partners in different tasks
- o Ensure that the information provided by T2 and T3 is consistent with the needs identified by modellers in the Task 4.
- o Determine criteria and use them to evaluate, at the end of the WP, the level of interest and uses of the experimental data in models developments.

Task 2 - Chemo-Mechanical evolution of cementitious materials at the meso/macroscale

Start: Month 25 – End: Month 60 – Task Leader [ANDRA]

Task contributors: [ANDRA (LMDC)], [SÚRAO (CTU) (UJV) (TUL)] [CVREZ], [CNRS (ULille)], [PSI (EMPA)], [SCK-CEN], [JUELICH], [COVRA], [GRS]

Total PM: 133,4

Task 2 is dedicated to study the chemo-mechanical behaviour at the macro scale taking into account the cement/aggregate structural behaviour. This scale permits the consolidation of the processes characterized and analysed in the nano/micro scale (task 3), and their respective description by simulation of the behaviour on the full]

The integrated partner proposals focus on experimental studies proposing a set of on-going and new experiments with a selection of mortar/concrete samples in contact with various solutions and atmospheres (CO₂), which are representative of different host rocks, with or without microbial activity. The main objective will be to identify the chemical/textural changes (mineralogical evolutions, chemical changes, porosity, transfer properties) and their impact on the mechanical properties (Young modulus, compressive/tensile strengths, creep, etc). These data will be used as input for the chemo-hydro-mechanical modelling to be performed in task 4, spanning from the sample scale to the structure scale.

The selected subtasks covers different perturbation scenarios occurring in different life stages of the disposal structures. Chemical perturbations such as carbonation, multi-ionic attack (with/without coupling), leaching (with/without carbonation) and corrosion under loading due to mechanical pathways followed or not followed by carbonate precipitation, as well as microbial activity in different environments are studied.

Special attention was given to the sample conditions and the test program in a way to be able to describe in an acceptable way the different scenarios that may occur in the repository structures. Therefore, different guidance points were selected and integrated into the program:

- Only mortar and concrete samples are included in task 2, cement paste is excluded.
- Ammonium nitrate perturbation was excluded from task 2, because the mechanical degradation is later on difficult to scale in time and to integrate within task 4.
- Different initial mechanical states will be studied to represent the initial mechanical state of the structures (for instance: intact, under creep before and with perturbation, mechanical damage...).
- Different mechanical characterization procedures are studied (R_c, R_t, E, bending, traction on bars...), where geometry considerations (up to metric size) will permit to tackle the mechanical behaviour evolution on a structural level with a representative loading mode and order. When it is possible, cases with perturbation under creep will be performed with a follow up of the chemo/mechanical evolution.
- Sample size is a key factor, and optimization was done between the minimal acceptable sample geometry needed to perform the targeted mechanical tests, and the biggest possible geometry for which chemo/mechanical perturbations could be detected.
- Characterization tests will be carried out on ongoing experiments or new samples manufactured in the laboratory, as well as on samples from underground laboratories (drilled or witness samples).

A chemo/mechanical analysis with and without microorganisms will be carried out to understand the microbial impact on the deviations in mechanical behaviour.

ST2-1 Chemo - Mechanical evolution of unsaturated concrete -

Start: Month 25 – End: Month 60 - Subtask leader: [ANDRA (LMDC)]

Geological repository concrete structures will go through different saturation states during their life cycle including saturated, partially saturated and unsaturated state. For these applications, structural concrete will be either reinforced or not reinforced. This life stage could include the full exploitation period where air carbonation could stay activated, with mechanical loading in particular for the retaining structures (where some are reinforced). Afterwards coupling with chemical/microbial attack will occur. The mechanical loading (if existing) will induce stresses and strains that damage the structures, and create new pathways to accelerate other chemical or microbial effects.

Task 2-1 work will allow to study the mechanical evolution due to the effect of corrosion (through mechanical degradation with / without carbonation) on the reinforced concrete structure (up to 1m length) under loading ([ANDRA (LMDC)] and [CNRS (ULille)] proposal). The following different initial boundary conditions and corrosion pathways will be studied: with/without loading, with/without mechanical degradation, and with/without carbonation.

[COVRA] will share their experimental results on the compressive strength of certified concrete strength as a function of the saturation degree and analysis.

Carbonation will be studied with the following different initial cases and conditions: carbonation on mortar and concrete, with [ANDRA (LMDC)] or without [CNRS (ULille)] reinforcement (after corrosion due to mechanical damage pathways), with [CNRS (ULille)] or without [CNRS (ULille)] initial loading (creep) or mechanical damage, and with mechanical structural test program (R_c, R_t, triaxial, and bending [CNRS (ULille)]). Later a coupling with corrosion of reinforced concrete is done for [ANDRA (LMDC)] and [CNRS (ULille)] proposals. Links for the presented scenarios are provided within task 3, in particular for the joint Andra, [ANDRA (LMDC)] and [CNRS (ULille)] proposal in which task 2 samples will be later on analysed in task 3 (for instance, corrosive material deformation analysis after a pull-out test). Subsequently, the data will be acquired to consolidate the upscaling and the structural modelling. The aim is also to quantify the debonding process of rebars affecting the behaviour of concrete under stress conditions.

Other links will be done with the ongoing task 3 in situ sampling proposals, including unsaturated conditions which may occur in particular cases, large panel of pre-aged samples or existing experiments.

ST2-2 Chemo - Mechanical evolution of saturated concrete

Start: Month 25 – End: Month 60 - Subtask leader: [ANDRA]

Saturation of the concrete structures can occur in different life stages of the disposal facility depending on the structure design and site hydraulic state and evolution. Structure cementitious material will be exposed to in situ water; the latter can activate perturbations like hydrolysis, multi-ionic attack (i.e. sulphate and magnesium), and carbonation. Those perturbations can be coupled or not with other initial chemo/mechanical state (unsaturated conditions) or loading effects (like mechanical damage, creep).

In this subtask, three perspectives are presented in a way to assess the chemo/mechanical evolution. A first group of partners propose to characterize the evolution by monitoring or testing buried or drilled existing samples on ongoing experiments (with different conditions) and in contact with the host rock or metallic existing structures. It is the case of [PSI (Empa)], or potentially [Andra]. In particular, [PSI (Empa)] propose to study existing pre-aged samples exposed to Opalinus clay pore water, derived from ongoing large-scale experiments. Andra can also have saturated existing conditions in a deep repository (mainly in the extrados side of cored concrete lining samples, for instance on the shaft, to be confirmed after drilling). If this is the case, chemo/mechanical analysis will be conducted and compared to other URL cases.

The second group of proposals consist of conducting new sets-of experiments. The proposal of [SÚRAO (CTU) (UJV) (TUL)] and [CVREZ] will focus on the evolution of chemo/mechanical behaviour of a low-pH concrete under artificial ageing conditions through chemical multi-ionic and microbial attack (task 2-3), using witness samples stored in Bukov URL (humid air) as reference material. The proposal of [COVRA] [FZJ] and [SCK-CEN] focuses on the evolution of chemical/mechanical behaviour of a low-pH as well as high pH concrete under artificial ageing conditions through chemical multi-ionic attack since 2016 and microbial attack (task 2-3). In total four different environments, all representative of the deep geological repository, are considered (sterilized water, bentonite suspension, underground water).

A third perspective is on including structural disposal characteristics into the perturbation analysis. This process can offer a more complex mechanical validation test for the simulation (Task 4). [ANDRA (LMDC)] and [CNRS (ULille)], together with task 2-1, 3 and 4 propose to analyse the effect of the Callovo-Oxfordien in-situ water (disposal level) and accelerated carbonation (by cycle of immersion) perturbations, by conducting a panel of beam flexion tests with different initial cases (corroded mechanical pathway, with/without creep). [GRS] and [JUELICH (HZDR)] (flow analysis) proposed to investigate in a new experiment the concrete/host rock chemo/mechanical properties and time evolution of a low pH concrete sealing interface due to the effect of water percolation (Konrad solution - Na, K, Ca, Mg, Cl, SO₄, C). Links will be done with task 2-3, where microbial degradation can be characterized and studied in the existing samples, and coupled with the new experiments. The same reference tests in task 2-3 could be compared later with the above-described proposals.

ST2-3 Chemo - Microbial impact on chemo-mechanical evolution of concrete

Start: Month 25 – End: Month 60 - Subtask leader: [JUELICH (HZDR)]

The chemo-mechanical evolution of concrete can be influenced by microbial activity, e.g. by increased precipitation of secondary mineral phases and consequent alteration and dissolution of cement minerals. The presence of cracks increases the possibility of microbial activity in the concrete system, in which the size of the pores determines if microbial life could occur. In case that microbial life is present, the self-sealing of concrete by precipitation of minerals such as calcite can then be enhanced. In concretes with pores of a diameter that is larger than about 0.2 µm, e.g. some type of porous mortars, the microbial activity is not restricted by pore space. Microbial activity can thus induce a change in the chemo-mechanical bulk properties. An example of the determination of a mechanical bulk property that is used in this subtask is a destructive mechanical test (compressive strength) with a size of the samples that is many times larger than the size of the aggregates.

In this subtask, the impact of microbial activity is assessed by comparing concrete samples exposed to solutions with and without microorganisms and the resulting effects on the mechanical and chemical properties are determined. Concrete was made with OPC cement as well as OPC blended with slag or micro silica. Both types of concrete have been prepared several years before the start of MAGIC WP and some of them are already mechanically characterised without chemical and microbiological perturbations. Concrete and mortar samples are currently exposed to these solutions or their exposure will start in MAGIC. The investigations of concrete that is envisaged to be used in a deep geological disposal facility hosted in granitic rock using bentonite as an engineered barrier is performed by [SÚRAO (TUL) (CTU) (UJV)] and [CVREZ]. [COVRA], [JUELICH] and [SCK-CEN] jointly investigate the chemo-mechanical stability of concrete in consideration of the microbial activity under aerobic and anaerobic conditions. These types of concrete are planned to be used in a disposal facility in poorly indurated clay. The diffusion values of dissolved species such as sulphate and bicarbonate in bentonite and in poorly indurated clay are larger than in concrete which makes these experiments representative for the chemical evolution of concrete in granitic and poorly indurated clay under deep geological disposal conditions. The slag blended with OPC cement can be fly ash which is a by-product from coal power plants or blast furnace slag which is a by-product from steel fabrication. In the first case, the concrete lacks redox sensitive species and is therefore slightly oxidizing after manufacturing. Concrete made with pure OPC cement

or OPC cement blended with micro silica is also slightly oxidizing. In the second case, the concrete contains pyrite and is therefore reducing after fabrication. In both investigations concrete with an oxidizing and reducing signature is included. Mechanical, chemical and microbiological characterisations will be performed at the start of MAGIC, after different periods of exposure and towards the end of MAGIC.

[SCK-CEN] also performs mechanical, chemical and microbiological characterisations of samples taken from low-permeability high-pH concrete wedge-blocks, especially at the concrete-clay interface, which have been exposed to Boom Clay since 2003 in the HADES underground research laboratory. The provided data can be used for modelling in task 4.

A wide range of chemical perturbations is covered in subtask 2.3 :

- fresh water either from poorly indurated clay in the underground research facility in Belgium or from cracks in granite in the underground facility in the Czech Republic;

- saline as seawater for poorly indurated clays considered in the Dutch disposal programme for deep geological disposal.

An increase in concrete strength may be expected for concrete exposed to fresh water since the ingress of bicarbonate and the subsequent precipitated calcite have a larger strength than the reacted cement mineral. In addition, the porosity can be reduced with this reaction also leading to a larger concrete strength. The expected changes in concrete strength for concrete exposed to more saline environments is more difficult to forecast. Here, the precipitated minerals within concrete as a result of the ingress of magnesium are considered as non-bonding that is expected to result in a reduction of the concrete strength. The ingress of chlorine may also result in Friedel-salt precipitation which reduces the porosity of the concrete and this reduction in porosity might result in an increase of the mechanical strength of concrete. In addition, calcite precipitation can occur.

Task 3 - Chemo-Mechanical evolution of cementitious materials at the nano/microscale

Start: Month 25 – End: Month 60 – Task Leader [PSI]

Task contributors: [ANDRA (LMDC)], [PSI (EMPA)], [CNRS (ULille)], [SCK-CEN], [IRSN], [JUELICH (HZDR)], [UHelsinki], [CEA], [IRSN (MINES PARIS TECH)], [SÚRAO (CTU) (TUL)], [CVREZ], [RWM (UNIMAN)], [CIEMAT (UGR)].

Total PM: 189.3

Task 3 is dealing with the Chemo-Mechanical evolution of cementitious materials at the nano- and microscale. The studies are focused on the evolution of microstructure, in situ condition and mechanical stability of OPC, low-pH cement and model materials (paste) subjected to external perturbation such as leaching, carbonation, and multi-ionic attack, microbial activity and swelling of corrosion products at saturated and partially saturated conditions.

The analysis will be performed based on small fragments of witness samples and on samples from in situ and ex situ reactive transport studies of accelerated cement degradation by non-destructive characterization of microstructure, porosity and water saturation using x-Ray CT, ultrasonic techniques and complementary destructive 2D Chemo-Bio-Mechanical investigations. Systematic inclusion or exclusion of microorganisms will be used to gauge their impact at nanoscale.

Mechanical testing of cement stability under accelerated degradation scenario and characterization of crack initiation and propagation will be performed based on loading tests with tri-axial and R_c measurements coupled to online 3D analyses by μ -CT from the nano- to microscale. Pore scale microstructure evolution modelling will be used to evaluate the role of chemical and microbial processes on mechanical strength of cementitious material.

The task will provide experimental data for conceptualisation of models linking the microstructure of cement paste their evolution under chemical-microbial degradation and mechanical properties of cementitious material, These data and concepts will serve for calibration and validation of numerical models describing chemical mechanical and microbial degradation of cement & concrete to be developed in Task 3 and in Task 4.

To maximise the output and use the synergies between the activities of different research groups the studied material are limited to OPC and low pH cements undergoing to selected chemical attacks and microbial attacks. In particular for the microbial studies, a specific attention will be paid to the low pH conditions.

SubTask 3.1: 3D Microstructure & Mechanical characterization

Start: Month 25 – End: Month 60 - Subtask leader: [CNRS (ULille)]

This subtask is devoted to 3D destructive (cracking) and semi-non-destructive chemo-mechanical (viscoelastic) characterisation of microstructure and mechanical testing. These activities include classical mechanical tests (uniaxial and tri-axial compression, creep) combined with X-ray micro-tomographic monitoring and sonic/ultrasonic viscoelastic measurements.

Several complementary aspects will be considered in this subtask. The first one is the 3D characterization of microstructural degradations of cement and concrete samples due to chemical (carbonation, leaching and corrosion) and microbial attacks. The principal technique adopted is the X-ray micro-tomographic imaging. The emphasis will be put on the evolution of degraded zone, the distribution of micro-cracks around interfaces aggregates-matrix, armature-

matrix) and inside matrix. The second aspect is about the characterization of mechanical properties of degraded samples. Microscopic mechanical tests (uniaxial and triaxial compression, creep) will be performed on small size samples with X-ray micro-tomographic monitoring. 3D full strain fields of samples will be determined by using Digital Volume Correlation (DVC) method. The emphasis will be put on the non-uniform distribution and localization of local strains, and mechanically induced micro-crack, in correlation with materials heterogeneities and chemo-microbial degradations. Averaged macroscopic strain-stress relations will also be determined. Effective elastic properties, compression strength and creep deformation rate will be evaluated for different samples, and the effects of chemo-microbial degradations on these properties will be identified. These studies will be performed by [CNRS (ULille)] on OPC and reinforces concrete samples in collaboration with Andra and [ANDRA (LMDC)] providing the sample materials. Further tests will be performed by [CNRS (ULille)] on the samples provided by [SCK CEN] subjected by microbial activity, Nonlinear Elastic Wave Spectroscopies (NEWS) and Coda Wave Interferometry (CWI) offer state-of-the-art methods for non-destructively measuring linear (needed for computational models validation) and nonlinear (visco-elastic moduli (proxy variables of microstructural features as micro-cracks, delaminations of interfaces and dissolution pores)). These techniques allow detecting the appearance/evolution of cracks at sub-micrometer scale. Thus, they are complementary to the most advanced high resolution x-CT methods. Empa and PSI will investigate pre-aged small scale samples of OPC-paste/clay interfaces using a dedicated cell designed and optimized for in situ, non-destructive simultaneous characterization of the microstructure (by X-ray CT and neutron imaging at SINQ, PSI) and of the visco-elastic properties (by ultrasonic and quasi-static measurements). The spectrum of investigated chemo-mechanical degradation processes will include carbonation, chemo-mechanical couplings related to precipitation of secondary minerals and biofilm in small pores and cracks, their swelling and respective potential crack nucleation at saturated (and/or) partially saturated conditions.

SubTask 3.2: 3D Microstructure modelling (MBC)

Start: Month 25 – End: Month 60 - Subtask leader: [PSI]

This subtask comprises pores scale modelling of microstructure cement paste microstructure evolution under chemical and microbial activity. Modelling is primary focused on the Lattice Boltzmann based simulations of leaching and precipitation in cement paste in presence and without microbial activity. These simulations will provide macroscopic parameters for the reactivity of the cementitious materials and macroscopic models used in Task 4. Evolution of the microstructure will be used to explain changes in the mechanical properties of materials under chemical attacks. The starting point for the modelling are 3D- CT data and 2D microbial-chemical information obtained in subtasks 3.1 and 3.3. The main objective of this subtask is to develop a chemo-mechanical model of combined dissolution precipitation processes in cement under microbial-chemical-mechanical attacks at a pore scale with spatial resolution of $\approx 1 \mu\text{m}$. This aim will be targeted by [SCK-CEN] and [PSI] extending an existing state of the art Lattice-Boltzmann based pore scale reactive transport model to simulate chemical evolution based on a given boundary condition and material microstructure and composition. One of the main challenges in the high resolution modelling in the computationally expensive speciation simulation. The improvement of the model will be done on the one hand by simplifying chemical description and taking into account most relevant chemical and microbial processes either by considering simplified system chemistry or using neural networks for geochemical calculations. The last approach is technically very promising but extensive training of the network on the large datasets for specific chemical formulation of cement system and the chemical and microbial attack.

The calculated evolution of microstructure will be used to estimate the changes in mechanical properties of the cementitious materials and to evaluate the main parameters controlling its mechanical properties. Role of microbial activity will be evaluated by comparing the results obtained in presence of biofilms and in sterile conditions. It is expected the biofilm will modify the chemical reactivity of mineral surfaces and hydraulic properties of pore space (clogging) and contribute to mechanical swelling. The formation of the secondary mineral phases or their dissolution is captured by the micro-scale Lattice-Boltzmann models used by [PSI] and [SCK-CEN]. In particular [PSI] and [JUELICH (HZDR)] will be working on description cement reactivity in presence /absence of biofilms based on CT-microstructure data provided by [SCK-CEN], [JUELICH (HZDR)], [RWM (UNIMAN)].

Obtained microstructure at a given point in time is transferred to the FEM structural model, where each phase gets assigned its own mechanical parameters. By comparing different degradation states, the effects of combined microbial - chemical attack on mechanical behaviour of cement pastes can be analysed. The result of the micromechanical model are the transport and elastic properties of the representative volume element obtained via a standard numerical homogenization scheme.

Prediction from the microscale model could be compared against micromechanical tests carried out under Task 2. This task provides direct information to those partners who are looking for chemo-mechanical cement paste data in order to upscale transport and mechanical properties for use in macroscale simulations.

SubTask 3.3: 2D Bio-Chemo-Mechanical characterization

Start: Month 25 – End: Month 60 - Subtask leader: [SCK CEN]

This subtask is focused 2D Bio-Chemo-Mechanical characterization of samples aimed to complement studies performed in subtask 3.1 with chemical information about the composition of mineral phases, characterisation of microbial activity and the direct observation of mechanical properties by nano- and micro- indentation techniques. Microbial activity on cementitious materials can result in an increased precipitation of secondary mineral phases followed by an alteration and dissolution of cement minerals. Cracks enable microorganisms to migrate in the concrete system and to form biofilms along the surfaces. As such, microorganisms can influence the chemo-mechanical behaviour of concrete at a small scale. These data are necessary for the interpretation and conceptualisation of data obtained in the Subtask 3.1 and also serve as input to the Subtask 3.2.

This subtask will focused partly on the micromechanical properties of degraded cementitious material, by nano-indentation measurements. A Berkovitch tip intends the material, the analysis of the indentation depth and the related load allows the estimation of the local young modulus and hardness of the material. In the case of heterogeneous materials as concrete, a grid of measurements is required to determine the distribution of mechanical properties in the material.

Deconvolution methods can be next performed on the mechanical distribution to highlights the main phases of cementitious material. If the resolution of the grid is enough refined, these main phases would corresponded to the mineralogical phases (C-S-H, Portlandite...). In addition, the deconvolution method provides quantitative information of the phases formed in the cementitious matrix.

When the cement material is in contact with aggressive solution, nano-indentation measurements can be apply to estimate the change of mechanical properties. However, to get a global understanding of the consequences of mineralogy and microstructure evolution due to chemical attack on the mechanical properties of the cement material, the Nano-indentation has to be coupled with others technics. For instance, the mineralogy changes can be estimated by SEM-EDS or XRD. Microstructure evolution measured thanks to μ tomography. Nano-indentation measurements in the same zone will then allow an estimation of the mechanical consequences due to both mineralogical changes and pore structure evolution.

The impact of microbial activity is assessed by comparing concrete samples exposed to solutions with and without microorganisms and the resulting effect on the mechanical and chemical properties are determined at the microscale. Percolation and batch experiments with OPC CEM I and low-pH hardened cement paste will be performed with different water solutions supplemented with suitable carbon sources representative to in situ conditions. The outflow will also be sampled regularly to follow up the changes in chemical and biological compositions of the pore solution. Microbial diversity in the pore waters will be identified by culture-independent and culture-dependent methods. In addition, each partner uses several techniques to study biofilms on the cement paste and the link with chemo-mechanical degradation will be studied.

[SCK-CEN] will use OPC CEM I and conditions representative for Boom Clay. The alteration in microstructure and mineralogy of degraded cement pastes due to combined chemo-bio-mechanical degradation will be quantified. [SCK-CEN] will collaborate with [CIEMAT (UGR)], who will perform STEM/HAADF and EEM/RS microscopy to analyse the samples at nanoscale. Moreover, [CNRS (ULille)] will perform triaxial compression tests on some samples (subtask 3.1). Results can be used for calibration and validation of multi-scale models in Task 4. Furthermore, these samples will also be used to quantify the mechanical evolution at macroscale, which can be linked with Task 2.

[JUELICH (HZDR)] will study CEM I and low-pH hardened cement paste exposed to calcareous solution or synthetic calcareous solution. These experiments will be modelled and interpreted by [JUELICH (HZDR)] and [PSI] in the subtask 3.3. [JUELICH (HZDR)] will cooperate with [IRSN] who will perform nano-indentation tests on the samples to link the influence of microbial activity to the mechanical evolution. Selected nano and micro indentation test will be conducted by PSI for the post-mortem analysis of samples used in ultrasonic studies by Empa.

[RWM (UNIMAN)] will assess the impact of microbial metabolism on the structure and properties of low pH cement using high pH microbial inocula, and electron donors/acceptors representative of host porewaters. A cross-disciplinary approach will be applied to quantify microbial colonisation of low pH cement and identify the extent and impact of microbial metabolism. This will include the development and application of 3D X-ray CT and 2D-3D image correlation techniques to monitor in situ changes. They will generate data for modelling by other MAGIC partners e.g. the impact on microbial processes on local swelling or other changes in microstructure, and the impacts of these processes on material properties.

Studying the impact of different pore waters each harboring a different microbial community enables a more robust and reliable interpretation of the obtained data. This enables a better estimation of the possible influence of microbial activity on concrete in relevant in situ conditions.

[IRSN] will perform crossed characterizations in chemistry (SEM-EDS, XRD,...) and micromechanics (nanoindentation mapping) through the degradation zone in model materials (C-S-H paste), OPC and low pH cements,

subjected to interaction with calcareous water (with magnesium) to link and quantify the loss of mechanical properties with chemical and microstructural changes (with UHELSINKI). The model material approach will allow to acquire data at the phase scale (C-S-H or C-S-H + portlandite). (SÚRAO (CTU)) will perform mineralogical mechanical (nanoindentation) characterisation of low pH cement subject to inter-action with Ca-Mg rich bentonite water. [CEA]-[IRSN (MINES ParisTech)] will perform mineralogical and XCT characterisation of model materials (C-S-H samples) and OPC paste samples subject to carbonation attack in unsaturated media. These data are essential for the modelling performed in task 4.

SubTask 3.4: Conceptualization and upscaling of data and models

Start: Month 25 – End: Month 60 - Subtask leader: [CNRS (ULille)]

This subtask is introduced to conceptualise and link the knowledge obtained in the experimental subtask 3.1 & 3.3 the modelling activities 3.2. The data and model conceptualisation in the subtask 3.4 provide link with larger scale experimental activities in task 2 and the modelling in task 4.

Based on the analysis of experimental data obtained from the subtasks 3.1 and 3.3, and numerical modelling in the subtask 3.2 quantitative relations will be established between effective mechanical properties (elastic, compression strength, creep, damage) and microstructural evolutions (porosity, calcium dissolution, calcite generation, corrosion product) induced by chemo-microbial processes. From the 3D analysis of microstructural evolutions, we shall identify the pertinent materials scales to be considered and the key microstructural parameters to be used to represent such evolutions and materials heterogeneities. These results will provide the basic input data for the formulation of micro-mechanical models based on different types of upscaling techniques (analytical or numerical). This task will require the integrative knowledge of partners working in the Subtasks 3.1-3.2 namely [CNRS (ULille)], [PSI], [SCK-CEN].

Task 4 - Modelling of the chemo-mechanical evolution of cementitious materials in disposal environments – Integrated task

Start: Month 25 – End: Month 60 – Task Leader [JUELICH (UFZ)]

Task contributors: [JUELICH (UFZ)], [CIEMAT (CSIC)], [LEI], [ANDRA (LMDC)], [CEA], [IRSN (Mines Paris Tech)], [PSI], CNRS (ULille)]

Total PM: 170.2

The broad objective of Task 4 is to obtain long-term reference chemo-mechanical models of Portland and low-pH concrete degradation exposed to relevant disposal environments, considering representative boundary conditions. Main chemical perturbation considered by all partners in Task 4 is carbonation with application in geological disposal. In order to achieve the mentioned objective integration of new knowledge generated in the meso/macro (Task 2) and nano/micro scale (Task 3) in a multi-scale modelling approach is performed.

ST4-1 Chemo-mechanical numerical coupling development at micro-scale

Start: Month 25 – End: Month 60 - Subtask leader: [CEA]

[IRSN (MINES ParisTech)] and [CEA] will work in coupling the reactive transport code HYTEC, developed in [IRSN (MINES ParisTech)], and the Finite Element code CAST3M, developed in [CEA]. A sequential approach to coupling HYTEC with a geo-mechanical algorithm will be investigated. HYTEC will provide the relevant parameters (i.e. porosity evolution, fluid pressure, mineral reaction rates) to be used within the CAST3M. The later will compute the stress evolution and potential fractures appearances and shrinkage and will yield information to HYTEC to create a new mesh and distribution of properties to model the evolutions of geo-mechanical properties. Numerical development will be driven by [CEA] and [IRSN (MINES ParisTech)] and the needs to simulate carbonation of concrete under disposal conditions. For this reason, the numerical tool and modelling results will be compared to existing X-CT scans.

[JUELICH (UFZ)] will develop a micro-scaled Hydro-Mechanical-Chemical (HMC) coupled model that can handle chemical reactions and the subsequent material dissolution and/or precipitation due to hydration or degradation (i.e. carbonation) of cementitious materials. The mechanical and hydraulic properties (e.g. Young's modulus, permeability, diffusivity) are made dependent both on the void space and the chemical component concentration. Knowledge generated within EURAD-DONUT, dealing with chemo-mechanical processes is of special interest and will be incorporated in MAGIC. The chemo-mechanical coupling at the micro-scale will be done and implemented within the existing finite element platform (www.OpenGeoSys.org) mainly developed and coordinated at [JUELICH (UFZ)]. Experimental data described in the literature or provided by partners of Task 2 and Task 3 will be used by [JUELICH (UFZ)] in collaboration with [CIEMAT (CSIC)] to calibrate and test the numerical framework developed. The numerical method can be applied to both Portland- (CEM I) and low-pH-cement concrete. Decision on priorities on the material will be made based on the needs of the consortium.

[PSI] in collaboration with [JUELICH (UFZ)], will implement an interface for transferring the material parameters from pore scale Lattice Boltzmann simulations performed in Task 3 into the THM-codes (e.g. OpenGeoSys). Of

particular interest is interplay of carbonation, role of bio-films and estimation of mechanical stresses due to precipitation of corrosion products in saturated and partially saturated conditions. The studies will be performed on OPC model structures. Communication between pore-level codes and large scale THM codes, will be automated using the neural network framework for process coupling, recently developed at [PSI].

ST4-2. Upscaling methods from nano to micro to REV

Start: Month 25 – End: Month 60 - Subtask leader: [CIEMAT (CSIC)]

[CIEMAT (CSIC)] will develop a software-agnostic (able to work with a variety of numerical codes, including OpenGeoSys) workflow multi-scale method. In this development, Reduced Order Models (ROM) for the aggregate-scale HMC models (developed by [JUELICH (UFZ)] in ST4-1) will be built following the Proper Orthogonal Decomposition (POD), and the aggregate -scale ROM will be then up-scaled to a continuum scale to finally extrapolate the method to the field scale. The multi-scale framework will be used by CSIC and [JUELICH (UFZ)] to perform numerical simulations of multi-scale hydro-chemo-mechanical behaviour of cementitious materials (concrete) under repository conditions. The framework will be tailored to handle large-scale computations with multi-scale algorithms to ensure a balanced trade-off between computational performance and physical accuracy. As in ST4-1 chemical attack will be mainly based on carbonation simultaneously occurring with the hydration of the cement in the concrete. The integration between the micro- and large-scale processes and the multi-scale algorithm will be tested first against available experimental data at the laboratory scale. The experimentally-validated computational tool will then be employed for field-scale simulations and forecasts (see ST4-3)

[CNRS (ULille)] will develop an analytical multiscale model framework for studying the mechanical evolutions of concrete materials under chemical degradation. The formulation of the multi-scale model is based on analytical homogenization techniques. Three materials scales will be considered: i) intra-particle, ii) inter-particles pores and iii) aggregates. The proposed model will be able to provide the estimation of macroscopic elastic properties, plastic or strength criteria, as functions of mineralogical compositions and micro-structural parameters (porosity, volume fraction of aggregates, etc.). The effects of chemical degradation are taken into account through the micro-structural changes such as porosity variation, solid calcium dissolution, calcite production by carbonation. Mechanically and chemically induced micro-cracks are also involved in the model. In the homogenization-based multi-scale model, the macroscopic properties which are functions of local constituent properties will be partially identified by direct experimental measurements at the nano/micro-scale such as nano-indentation and a machine learning based numerical methods (see Task 3). Finally, the proposed multi-scale model, together with the identified constituent parameters, will be validated with laboratory tests performed in Task 2 and 3 and other laboratory tests realized in previous studies of [ANDRA].

ST4-3. Chemo-mechanical processes in safety structures (subtask leader: [ANDRA (LMDC)])

Start: Month 25 - End: Month 60

LMDC will collaborate with [JUELICH (UFZ)] to integrate the chemical evolutions of the concrete matrix during carbonation and contact with underground water in a macroscopic scale chemo-mechanical finite element model; this integration will be based on upscaling of [JUELICH (UFZ)] model for the chemical aspect and [CNRS (ULille)] model for the mechanical one. Next [Andra (LMDC)] will develop a simplified model of rebar corrosion based on its own experience. In the resulting RC homogenized chemo mechanical model, the concrete matrix integrates results of homogenization at lower scale ([JUELICH (UFZ)] and [CNRS (ULille)]), specifically the consideration of matrix porosity evolution due to mineral precipitation or dissolution, (in relation with X ray tomography results in Task 3 at [CNRS (ULille)] and previous models of evolution of mechanical properties in relation with chemical state and the de-passivation of rebars. The resulting tool will be a finite element model able to consider chemo mechanical evolutions of matrix, rebars and interfaces between them. The model will be simplified until it will be usable at structural scale, in 3 dimensions, to study different aging scenarios of reinforced concrete in nuclear wastes repositories. The simplified model will be implanted in the finite element software Castem (developed by CEA).

The model will be tested on corroded beams 40 years old available at LMDC, and after this validation stage, will be used to study an aging scenario of reinforced concrete structures envisioned by Andra for a underground nuclear waste repositories. The simulation will include the short-term behavior during construction, the exploitation phase with concrete drying and atmospheric carbonation of the tunnel intrados during 120 years, the re-saturation of tunnel's extrados with underground water at low pressure, and the long-term re-saturation with the rising of underground water and soil pressures. The model will consider the long-term behavior of the concrete matrix, the modelling of chemical damage of concrete and of steel reinforcements, the degradation of interface between concrete and rebars, all of thus to assess the durability of Andra's structures.

[LEI] will contribute to testing and benchmarking the model abstraction developed by [JUELICH (UFZ)] and [CIEMAT (CSIC)] in subtask 4-2. In that case scenarios tested will be related to concrete structures representative for geological

disposal. Modelling tools like COMSOL Multiphysics, PHREEQC, PHAST, etc. and supercomputer are available at LEI Nuclear Engineering Laboratory).

Participation per Partner

Partner number and short name	WP16 effort
1 - ANDRA	14.00
UT3/LMDC	62.30
5 - CEA	19.30
6 - CIEMAT	0.00
CSIC	50.86
UGR	4.30
8 - CNRS	0.00
ULille	55.80
9 - COVRA	4.25
11 - CV REZ	12.80
15 - JUELICH	8.00
HZDR	30.80
UFZ	36.80
16 - GRS	17.92
19 - IRSN	33.30
MINES ParisTech	17.10
25 - LEI	7.30
34 - PSI	23.80
EMPA	12.80
37 - RWM	0.00
UNIMAN	33.05
38 - SCK•CEN	21.30
42 - SÚRAO	2.50
CTU	15.30
TUL	10.80
ÚJV	12.25
48 - UHelsinki	4.70
Total	511.33

List of deliverables

Deliverable Number¹⁴	Deliverable Title	Lead beneficiary	Type¹⁵	Dissemination level¹⁶	Due Date (in months)¹⁷
D16.1	MAGIC - T1- Initial State of the Art on the chemo-mechanical evolution of cementitious materials in disposal conditions	19 - IRSN	Report	Public	36
D16.2	MAGIC - T1- Updated State-of-the-art report & Summary of major conclusions from the work package	19 - IRSN	Report	Public	58
D16.3	MAGIC - T2- Report on selected experiments for assessing the evolution of concrete, their mechanical safety functions and performance targets	9 - COVRA	Report	Public	30
D16.4	MAGIC - T2 – Technical report on the results of the selected experiments for assessing the evolution of the studied types of concrete	1 - ANDRA	Report	Public	55
D16.5	MAGIC - S/T 3-4 - Initial synthesis of experimental data for calibration and validation of macroscopic models in Task 4.	8 - CNRS	Report	Public	53
D16.6	MAGIC - S/T 3-3 - Report on Bio-Chemical processes controlling microstructural evolution and mechanical strength	38 - SCK•CEN	Report	Public	56
D16.7	MAGIC - T3 - Report on micro scale chemo-mechanical modelling of leaching and carbonation and parameters upscaling	34 - PSI	Report	Public	56
D16.8	MAGIC - S/T 4-1 – 4/2 -Chemo-mechanical numerical coupling development and up-scaling methods	15 - JUELICH	Report	Public	44
D16.9	MAGIC - S/T 4-3 Chemo-mechanical	1 - ANDRA	Report	Public	56

List of deliverables

Deliverable Number ¹⁴	Deliverable Title	Lead beneficiary	Type ¹⁵	Dissemination level ¹⁶	Due Date (in months) ¹⁷
	processes in safety structures				

Description of deliverables

D16.1 - MAGIC - T1- Initial State of the Art on the chemo-mechanical evolution of cementitious materials in disposal conditions. – Lead [IRSN] - Due month: 36

- D16.2 - MAGIC - T1- Updated State-of-the-art report & Summary of major conclusions from the work package - Lead [IRSN] - Due month: 58
- D16.3 - MAGIC - T2 on selected experiments for assessing the evolution of concrete, their mechanical safety functions and performance targets - Lead [COVRA] - Due month: 30
- D16.4 - MAGIC - T2 – Technical report on the results of the selected experiments for assessing the evolution of the studied types of concrete - Lead [ANDRA] - Due month: 55
- D16.5 - MAGIC - S/T 3-4 - Initial synthesis of experimental data for calibration and validation of macroscopic models in Task 4. – Lead [CNRS] - Due month: 53
- D16.6 - MAGIC - S/T 3-3 on Bio-Chemical processes controlling microstructural evolution and mechanical strength – Lead [SCK-CEN] - Due month: 56
- D16.7 - MAGIC - T3 on micro scale chemo-mechanical modelling of leaching and carbonation and parameters upscaling - Lead [PSI] - Due month: 56
- D16.8 - MAGIC - S/T 4-1 – 4/2 -Chemo-mechanical numerical coupling development and up-scaling methods – Lead [JUELICH] Due month: 44
- D16.9 - MAGIC - S/T 4-3 Chemo-mechanical processes in safety structures – Lead [ANDRA] - Due month: 56

D16.1 : MAGIC - T1- Initial State of the Art on the chemo-mechanical evolution of cementitious materials in disposal conditions [36]
MAGIC - T1- Initial State of the Art on the chemo-mechanical evolution of cementitious materials in disposal conditions

D16.2 : MAGIC - T1- Updated State-of-the-art report & Summary of major conclusions from the work package [58]
MAGIC - T1- Updated State-of-the-art report & Summary of major conclusions from the work package

D16.3 : MAGIC - T2- Report on selected experiments for assessing the evolution of concrete, their mechanical safety functions and performance targets [30]
MAGIC - T2- Report on selected experiments for assessing the evolution of concrete, their mechanical safety functions and performance targets

D16.4 : MAGIC - T2 – Technical report on the results of the selected experiments for assessing the evolution of the studied types of concrete [55]
MAGIC - T2 – Technical report on the results of the selected experiments for assessing the evolution of the studied types of concrete

D16.5 : MAGIC - S/T 3-4 - Initial synthesis of experimental data for calibration and validation of macroscopic models in Task 4. [53]
MAGIC - S/T 3-4 - Initial synthesis of experimental data for calibration and validation of macroscopic models in Task 4.

D16.6 : MAGIC - S/T 3-3 - Report on Bio-Chemical processes controlling microstructural evolution and mechanical strength [56]
MAGIC - S/T 3-3 - Report on Bio-Chemical processes controlling microstructural evolution and mechanical strength

D16.7 : MAGIC - T3 - Report on micro scale chemo-mechanical modelling of leaching and carbonation and parameters upscaling [56]
MAGIC - T3 - Report on micro scale chemo-mechanical modelling of leaching and carbonation and parameters upscaling

D16.8 : MAGIC - S/T 4-1 – 4/2 -Chemo-mechanical numerical coupling development and up-scaling methods [44] MAGIC - S/T 4-1 – 4/2 -Chemo-mechanical numerical coupling development and up-scaling methods
D16.9 : MAGIC - S/T 4-3 Chemo-mechanical processes in safety structures [56] MAGIC - S/T 4-3 Chemo-mechanical processes in safety structures

Schedule of relevant Milestones

Milestone number ¹⁸	Milestone title	Lead beneficiary	Due Date (in months)	Means of verification
MS248	MAGIC - WP- Kick off meeting	19 - IRSN	25	MAGIC - WP- Kick off meeting
MS249	MODATS Web pages in EURAD website	1 - ANDRA	25	MODATS Web pages in EURAD website
MS255	MAGIC - T2 – Kick off meeting	1 - ANDRA	27	MAGIC - T2 – Kick off meeting
MS258	MAGIC - T3 – Kick off meeting	34 - PSI	28	MAGIC - T3 – Kick off meeting
MS259	MAGIC - T4- Kick off meeting	15 - JUELICH	29	MAGIC - T4- Kick off meeting
MS266	MAGIC - T1- Creation of the Interactive Data Platform on Cement IDPC (support to be determined – excel file a minima)	19 - IRSN	30	MAGIC - T1- Creation of the Interactive Data Platform on Cement IDPC (support to be determined – excel file a minima)
MS267	MAGIC - T3- Initial SOTA Discussion & TOC definition	8 - CNRS	30	MAGIC - T3- Initial SOTA Discussion & TOC definition
MS269	MAGIC - T1- Annual WP meeting n°1 + WS 2 on coordination between modellers and experimenters – Base case definition to model in the Task 4 on reference geological disposal context in Member States (end user contribution)	19 - IRSN	31	MAGIC - T1- Annual WP meeting n°1 + WS 2 on coordination between modellers and experimenters – Base case definition to model in the Task 4 on reference geological disposal context in Member States (end user contribution)
MS273	MAGIC - T3 – Report on the work plan and selected experimental conditions	34 - PSI	33	MAGIC - T3 – Report on the work plan and selected experimental conditions
MS279	MAGIC - T4- Contribution to the modelling part in the initial SOTA	1 - ANDRA	36	MAGIC - T4- Contribution to the modelling part in the initial SOTA
MS287	MAGIC - T2- Experiment feedback	38 - SCK•CEN	41	MAGIC - T2- Experiment feedback
MS292	MAGIC - WP- Annual WP meeting n°2 + WS 3 on experimental data update	19 - IRSN	43	MAGIC - WP- Annual WP meeting n°2 + WS 3 on experimental data update

Schedule of relevant Milestones

Milestone number¹⁸	Milestone title	Lead beneficiary	Due Date (in months)	Means of verification
MS301	MAGIC - T1- Training materials definition.	19 - IRSN	48	MAGIC - T1- Training materials definition.
MS302	MAGIC - T1- ST1-4 – WS4 on criteria definition in the ST1-4 to evaluate the level of interest and uses of the experimental data in models developments	1 - ANDRA	48	MAGIC - T1- ST1-4 – WS4 on criteria definition in the ST1-4 to evaluate the level of interest and uses of the experimental data in models developments
MS315	MAGIC - T3- Update of TOC for final SOTA	8 - CNRS	54	MAGIC - T3- Update of TOC for final SOTA
MS316	MAGIC - T4 – Workshop on modelling results from the micro scale to the safety structure with End Users and partners	6 - CIEMAT	54	MAGIC - T4 – Workshop on modelling results from the micro scale to the safety structure with End Users and partners
MS319	MAGIC - WP- Annual WP meeting n°3 + WS 5 on gaps remaining + methodology to use results	19 - IRSN	55	MAGIC - WP- Annual WP meeting n°3 + WS 5 on gaps remaining + methodology to use results
MS322	MAGIC - T2- Contribution to the final SOTA	1 - ANDRA	57	MAGIC - T2- Contribution to the final SOTA
MS323	MAGIC - T4- Contribution to the SOTA updates with Task 4 results	15 - JUELICH	57	MAGIC - T4- Contribution to the SOTA updates with Task 4 results
MS330	MAGIC - WP- Closure meeting	19 - IRSN	60	MAGIC - WP- Closure meeting

Work package number ⁹	WP17	Lead beneficiary ¹⁰	1 - ANDRA
Work package title	MOnitoring equipement and DAta Treatment for Safe repository operation and staged closure (MODATS)		
Start month	25	End month	60

Objectives

The overall objective of the proposed MODATS R&D WP is to evaluate, develop and describe methods and technologies, and to provide the means to measure, treat, analyse and manage data in a consistent manner. The ambition of the project is to address the detailed questions regarding monitoring data that have been identified, but not resolved in previous EC projects. At the end of the WP, a series of tools, methods and guidance documents on, and examples of how, data acquisition, management and treatment can be undertaken during operation will be available for programmes to use in designing monitoring programmes for specific repositories. To facilitate meeting this ambition, the WP will work on real data sets from recent full-scale URL experiments, referred to as the MODATS Reference Experiments. The WP will include five such experiments from which data will be analysed.

Description of work and role of partners

WP17 - MOnitoring equipement and DAta Treatment for Safe repository operation and staged closure (MODATS) [Months: 25-60]

ANDRA, CEA, CNRS, CV REZ, JUELICH, IRSN, JSI, NAGRA, ONDRAF/NIRAS, POSIVA, PSI, RWM, SKB, SSTC NRS, VTT

Task 1 – Project Management

Start: Month 25 – End: Month 60 - Task Leader: [ANDRA]

Task contributors: [NAGRA], [POSIVA], [SKB], [SSTC], [VTT (GSL)]

Total PM: 18,5

Objectives of the task: The main objective of this task is to ensure an effective, smooth and high-quality implementation of the MODATS WP. Specifically, this involves:

- Communication and integration between partners and the entire EURAD consortium.
- Monitoring of the work package progress and outputs (indicators/deliverables) against the project work plan.
- Maintaining up-to-date information on EURAD website.

Subtask 1.1: S/T coordination

Start: Month 25 – End: Month 60 - Subtask Leader: [ANDRA]

Subtask contributors: [NAGRA], [POSIVA], [SKB], [SSTC], [VTT (GSL)]

The Coordination Team (Andra, GSL) will ensure:

- Scientific/ technical coordination of the work package.
- WP progress according to the agreed specifications, milestones and planning.
- Scientific excellence at all steps.
- Interfacing with the EURAD Bureau and PMO to fulfil contractual obligations and to communicate all management information (report work progress, deliverables and eventual modifications of the WP work plan to the PMO).
- Delivery of deliverables and milestones.
- Interfacing with other WP leaders as foreseen in this work plan.
- Information transfer between different (sub)tasks.
- Coordination of the organization of consortium meetings (kick-off meeting, work package meetings, Steering Committee meetings, task leaders' meetings...) in collaboration with the partners.
- Internal communication of the project through a private Extranet (Project Place) in order to facilitate exchanges between partners.

An Executive Board will be established and composed of partners participating in task 1. It will be in charge of:

- Ensuring the coordination of scientific work within the consortium: following up the project work plan including provision of deliverables at the agreed deadlines and informing the PMO of the proposed actions in case of deviations.
- Facilitating the interaction with the others WPs, the EURAD Bureau and PMO.
- Coordinating the preparation of technical reports to be submitted at the end of each reporting period (intermediate periodic reports and final report).

Subtask 1.2: State of the Art (SOTA)

Start: Month 25 – End: Month 58 – Subtask Leader: [ANDRA]

Subtask contributors: [VTT (GSL)]

An initial version of the SOTA will be prepared at the beginning of the WP (6 months after the beginning of the project). In the final stage of the WP, the SOTA report will be updated integrating the key findings of the R&D tasks in this WP and relevant findings from other WPs.

The SOTA will be the first reference document of the project in monitoring field.

Task 2 - Data Treatment for Increased Confidence in Repository Monitoring

Start: Month 25 – End: Month 58 – Task Leader [VTT (GSL)] [NAGRA]

Task contributors: [ANDRA], [JUELICH (UFZ)], [IRSN (MUTADIS)], [JSI (EIMV)], [ONDRAF (EURIDICE)], [POSIVA], [PSI], [RWM], [SKB], [SSTC NRS]

Total PM: 164,70

The overarching goals of monitoring in a radioactive waste repository are to provide information to support decision making and to strengthen understanding of some aspects of system behaviour. Although we expect to collect significant quantities of data during repository monitoring few detailed methods exist that address how these data will strengthen system understanding, especially given that repository monitoring will be spatially and temporally limited. Repository monitoring also presents challenges related to evaluation of multi-modal data, i.e. data that is measured by different sensors, resulting in a range of independent parameters, at different locations and at varying spatial and temporal sampling. These data need to be evaluated in a coherent way that considers the specifics of sensors and their spatial relationships and allows for the identification of anomalies related to sensor ageing and malfunction, outside influences, and deviations of the repository system from expected behaviour. This task aims to consolidate the implementation strategy for monitoring systems in repository facilities by developing methods through which confidence can be demonstrated in the acquired data and its analysis and benefits derived for repository implementation.

The questions that have been identified and the perceived knowledge gaps, that will be tackled in this task are as follows:

- What is practically required to further develop monitoring technologies so that they are ready to be applied in an operating repository with confidence?
- How can monitoring data acquisition, treatment and management provide additional support and confidence in the post-closure safety case?
- What are the steps in data treatment, analysis and management that can enhance confidence in monitoring results?
- How should data be organised, summarised and categorised (data reduction), and analysed and compared to predictions?
- Are there techniques and approaches to harmonising and storing large quantities of data on-line that could provide value to monitoring of the multi-barrier system through novel concepts such as artificial intelligence and machine learning?
- Should data management evolve from techniques used to build site descriptive models?
- What are the general principles that govern data management, verification, and comparison to predictions?
- What are the requirements on the structure and content of quality assurance during sensor emplacement and data acquisition for an operating repository?
- What is the impact of sensor interaction with the host medium on the monitoring results, and how can the quality of monitoring results be ensured over extended periods?

Guided by these identified knowledge gaps, the project partners will develop new methods for data QA/QC, data management, data analysis and visualization leading towards the development of Digital Twins that can be used to follow the evolution of a repository system via monitoring and make reliable predictions on its future development. This will support the decision-making process through increased confidence in the integrated monitoring system.

The work in Task 2 will be based on the experience gained from implementation of several full-scale emplacement experiments and the datasets that were collected. Our Reference Experiments for the MODATS project are the following (project partners utilizing a dataset in parenthesis, leads in bold): FE (Nagra; PSI, UFZ), AHA1605 (Andra,), Prototype Repository II (SKB, VTT), POPLU (POSIVA, VTT), PRACLAY (EURIDICE).

Deliverables of this task will include software development products leveraging prior investments by the project partners and funding agencies and to be distributed to the community through open access licence agreements. This will ensure that the work performed in this task will have a lasting impact and will benefit future monitoring efforts.

Task 2 is subdivided into five sub-tasks with project partners typically involved in several sub-tasks: (1) to ensure the integration of Sub-task-sub-task-level results within Task 2, (2) to develop the comprehensive work flow necessary for their advancement in data analysis, spanning the scope of several sub-tasks, and (3) to interact with the project team to facilitate collaboration and joint developments.

POSIVA is in the implementation phase for a HLW repository, and has practical experience on implementing monitoring activities. They will provide information from the implemented monitoring programme viewpoint and needs related to

the repository operation. They will use that background to steer and guide the R&D planned by the other organisations in Task 2. POSIVA will support the reporting and will participate in the review of the deliverables.

Subtask 2.1 - Monitoring Programme Experience and Future Needs

Start: Month 25 – End: Month 48 - Subtask leader: [VTT (GSL)] [NAGRA]

Subtask contributors: [Andra], [ONDRAF (EURIDICE)], [POSIVA], [RWM], [SKB], [PSI]

Total PM: 29,0

Objectives: Integration of Task 2 sub-tasks (principally through a series of workshops) and production of Task 2 report; development of descriptions of the reference experiments; identify and describe lessons from monitoring of URL experiments to provide lessons for repository monitoring design and safety case implications, and which will feed into R&D in Task 2; develop guidance on Quality Assurance Project Plans (QAPPs); and identify future technology development needs based on the R&D in the project (within and beyond MODATS).

Description:

This task will ensure integration of Task 2 activities and ensure that the R&D undertaken is relevant to repository monitoring, as planned by WMOs and required by regulators. This task will also ensure that the R&D outcomes are made relevant to repository monitoring programmes, and will provide outcomes ready to use within these programmes. Integration of Task 2 will be facilitated through a series of workshops. GSL will plan, organise, facilitate and report these workshops. The workshops will provide a platform for identifying the detailed research questions to be addressed in Tasks 2.2-2.4, provide a platform for identifying common lessons from the R&D activities, and will allow the broader context of monitoring to be considered in the project (through sharing of information on programme-specific developments in repository monitoring). The workshop objectives and structure are presented in Table 1.

Andra (AHA1605), Nagra (FE), POSIVA (POPLU), SKB (Prototype Repository II) and EURIDICE (PRACLAY) will provide thoroughly documented datasets and experiment descriptions that can be utilized by other project partners for implementation of their data processing and modelling steps and could serve as a benchmark case for the individual concepts proposed and developed by the MODATS partners.

GSL will coordinate and deliver a structured survey of monitoring aspects of selected previous URL experiments, to understand lessons that can support specific goals of the MODATS WP. Survey objectives will include: understanding of the justification for selecting monitoring parameters, consideration of redundancy, diversity and representativeness in monitoring technologies and sensor locations; experience with quality assurance plans and their use through the experiment lifecycle (e.g. how was the issue of reliability addressed as the monitoring sensor performance changed); how data from the experiment was managed and the lessons related to data management; methods implemented to use monitoring data for calibration of models; and what were the lessons from decommissioning (e.g. were interactions between the sensor and the experiment materials and host rock identified, and, if so, what were the implications for monitoring result reliability). The survey will be used to provide inputs into guidance developed in the project on data quality control, data management and comparison with modelling results.

GSL and EURIDICE will lead the development of a guidance document on the production of QAPPs for repository monitoring. The guidance will be produced by analysing and communicating the quality assurance approaches adopted in the MODATS Reference Experiments, regulatory requirements, recommendations and best international practices related to quality assurance, and then comparing and contrasting this information in a structured project workshop. Information from the URL Case Studies will be provided in the workshop, and will augment the information from the MODATS Reference Experiments and analysis of regulatory requirements, recommendations and best international practices. The outcome of the workshop will be the basis for production of the guidance document, which will be developed iteratively with input from the participating REs, WMOs and TSOs.

RWM and GSL will lead identification of the future R&D development needs for different programmes moving forward. RWM and GSL are particularly well placed to develop the data requirements aspect of this task due to the ongoing work in the RWM programme, which focusses on the development of the RWM strategy, the identification of monitoring parameters using an adapted version of the Modern2020 Screening Methodology, and the development of a structured review of monitoring technologies.

RWM and GSL will use information collated during the ongoing RWM project, the survey of URL experiments, the MODATS Reference Experiments, and the development of monitoring requirements in the MoDeRn and Modern2020 projects to elaborate data requirements for repository monitoring. This will be compared to the RWM information on repository monitoring technologies and a Technology Development Roadmap will be produced that defines the required steps to ensure that the required technologies are available for the implementation of repository monitoring when needed. The starting points will be. The following information will be tabulated: the parameters monitored, technologies used for monitoring the parameter (including diversity in monitoring technologies), the frequency of measurement, accuracy requirements, precision requirements, and modelling capability for understanding the results. The modelling information available for comparison purposes will also be tabulated. For each parameter, key uncertainties will be recorded, e.g. does recording a reliable measurement require a particular contact between the sensor and the medium measured.

The information collated will be considered in a workshop, which will compare and contrast different approaches for each parameter between the MODATS Reference Experiments. At this stage information will be used from the URL State-of-the-Art, from other existing compilations and from the experience of the End User Group, who will also attend the workshop.

The outcome from this activity will be an analysis of data requirements, identification of the state of development of technologies, and identification of any outstanding technology issues that need to be addressed before implementation of repository monitoring programmes commence. The work will be undertaken in the third year of the WP to build on work undertaken independently by RWM and GSL, and developments in repository technology in Task 3 of the MODATS WP.

In this task, GSL will lead the development of a Task 2 report that will pull together the various R&D activities and evaluate the current status with respect to data acquisition, treatment, management and application for repository monitoring.

Subtask 2.2 Data Management

Start: Month 25 – End: Month 54 - Subtask leader: [NAGRA]

Subtask contributors: [Andra], , [JUELICH (UFZ)], [ONDRAF (EURIDICE)], [SKB], [VTT]

Total PM: 27

Objectives: A key component of successful monitoring is a data management system that allows efficient acquisition, storing, and curation of data and metadata. Subtask 2.2 will develop guidance on and continue the development of databases for monitoring data and provision of the data to support enhanced system understanding. Essential aspects to be addressed are: 1) achieving future proof data management systems providing access to data for decades to come, 2) definition of the data to be stored (raw vs. processed data) and interpretations, and 3) supplying data to modelling and developments of Digital Twins (Link to subtasks 2.3 & 2.4).

Measurement data is always prone to errors due to, e.g., sensor fouling, calibration drifts, data transfer problems, and configuration errors in data acquisition. To facilitate reliable analysis results, all measurement data has to be curated. Data errors have to be detected and handled. This is carried out by both statistical tests (e.g. measurement readings stuck on a constant value) and deployment of a priori physics-based knowledge (e.g. mass and energy balances). To make computed results traceable, all data curation steps are based on QA/QC procedures and recorded in a version control system.

Description:

Nagra will expand their data management FEIS system that was specifically built for the FE (Full-scale Emplacement) experiment at the Mont Terri URL. This system collects data from a vast array of sensors in near real-time and relates measurements with sensor specification as well as its spatial position within the experiment setup. They will build on the experience gained with FEIS and extend it to allow handling of modelling data and to develop a processing workflow for reconciliation of measured data with the modelling output from various model realisations and of different numerical codes. We consider this an important first step towards combined evaluation of monitoring and modelling data or the utilisation of digital twins. This requires development of a conceptual workflow that includes steps such as the definition of quality control measures of both the measured and the modelled data, interpolation of values computed at grid nodes to the actual location of the respective sensors, incorporation of uncertainties in the measurements and sensor locations and other factors.

VTT will focus on data quality assurance. The work will start by addressing the “low-hanging fruit” detectable by statistical testing (e.g., changes in data correlation structure). More advanced data quality assurance will be based on metadata and known physical relations (with e.g., data reconciliation). VTT will define together with the other partners the data management plan and the data system architecture, which contain the requirements and guidelines for the raw data storage and handling, data acquisition from various sensor systems, data systems (databases and other means to store and use the data) and data management principles. This work, to be continued in sub-task 2.3, includes the definition of the common repository data anthology and common metadata definitions (e.g. sensor type, accuracy, measurement unit, sensor characteristics, location, ...) to ensure commensurable sensor measurement and modelled data comparison between various repositories. As a starting point, they will take existing datasets provided by the partners (for example datasets from the POPLU Experiment implemented in DOPAS by POSIVA and PROTOTYPE REPOSITORY by SKB) and analyse the existing data in order to start creating the repository data anthology and metadata catalogue for the data harvested by the data acquisition.

UFZ will continue the development of OpenGeoSys (OGS) and its data management module OGS DataExplorer. It already contains a large variety of standard interfaces to CAD, GIS, VTK, etc. allowing the integration of existing geological and geotechnical data and sensor metadata (i.e. coordinates) in a data repository or database. Data obtained by monitoring (i.e. sensors) or by the installation companies of the FE experiment will be collected and stored in OGS DataExplorer. Collected data in surfaces will be converted into VTK unstructured grids to facilitate the integration and

comparison with models. Any nodal property contained in a file will be transferred into VTK scalar arrays which will be available for visualisation and further processing within OpenGeoSys models.

EURIDICE will present the development history, including ongoing work, on the data acquisition process of the HADES URL and related monitoring activities, such as regional boreholes and low-level radwaste implementation (to make a link with a final disposal context, albeit not geological, but which will become relevant in section 2.5). This includes new ideas on automated raw data processing and validation. In addition, the security steps that are currently being implemented, along with new IT approaches to ensure long-term stability on data transfer and storage, will be presented. A practical illustration of the data management approach will be performed through two software tools developed in house ("LabTool", a LIMS application, and "GSIS" - GeoScientific Information System, a GIS type application). These examples show methods on how to take care of the URL monitoring data spanning several decades, with particular attention given to data validation and presentation tools.

Andra will present the GEOSCIENTIFIC DATA ACQUISITION AND MANAGEMENT SYSTEM (SAGD) in the URL. Particular method and illustration for the HA demonstrator will be presented in order to contribute to the guidance.

Sub-Task 2.3 Development of Enhanced Understanding through Integration of Monitoring Data and Models

Start: Month 28 – End: Month 58 - Subtask leader: [NAGRA]

Subtask contributors: [ANDRA], [JUELICH (UFZ)], [ONDRAF (EURIDICE)], [POSIVA], [PSI], [SKB], [VTT]

Total PM: 39

Objectives: Subtask 2.3 develops the methodology for the data-driven assessment of repository safety and integrity. The methodology will address analysis of multi-modal data covering a large spectrum of phenomena and available instrumentation. A key aspect in producing reliable support for the assessment is to deploy a priori knowledge in addition to measured data. This knowledge is needed in both data quality assurance (see subtask 2.2) and in refining analysis results. The methodology will be defined as a set of guidelines describing the data analysis process and software tools supporting this process.

Description:

EURIDICE will give an example of how experimental data have improved and confirmed our understanding of the disposal system (not limited to the PRACLAY Reference Experiment). Based on their current method of interpretation of the data, they are developing a method on how to incorporate modelling results into their data monitoring system to change it into a decision making or optimization tool. The modelling includes blind predictions (to assist the design and operation of the test), as well as interpretation and back-analysis of the monitoring data.

Andras contribution will be linked to the work performed in sub-task 2.4. A data-driven model (DDM) should be initiated from a compilation of "pertinent" temperature monitoring data collected throughout existing in-situ HA demonstrator's underground repository laboratory (URL). The DDM will be compared to existing physics-based model (PBM)

Assessing the long-term safety of the disposed waste requires the combination of analysis results covering many different phenomena. VTT aims to develop a modular data processing and analysis scheme, where data is fused, processed and analysed in layers. Starting from the bottom layer, sets of measurements related to each location and each phenomenon will be created. For each group, a model combining physics-based and data-driven elements will be created, e.g. by using physics-based knowledge as optimization constraints when identifying some of the model parameters from measurement data. In each module, the corresponding model will be utilised in data validation and pre-processing, such as filtering, and refining the data to a higher abstraction level. The output from each module will include both indications of any detected anomalies and data that is reduced and refined for use in the next layer of models. Models on higher layers will analyse larger scale phenomena, combining data from multiple modules on lower layers.

Nagra's contribution to sub-task 2.3 will be closely linked to their work performed in 2.2. They will evaluate the monitoring data in conjunction with the outputs of the system evolution provided by numerical models. The work will be geared towards gleaning additional information from the monitoring through joint interpretation with modelling results. The limitations of the models of the physical system with numerical codes will have to be considered as part of this package, such as limited incorporation of coupled processes, unresolved heterogeneity in the physical system and others. The proposed work is closely linked to the EURAD HITEC project and Nagra's internal Modelling Task Force, both of which include a comparison of THM tools, calibration, and full-scale prediction.

PSI In order to fulfil the monitoring requests for a repository a comprehensive monitoring database has to be defined taking into account all processes and their related parameters that might change during a repository-monitoring phase. Spatial and temporal data density have to be assessed and an interface between monitoring data and data from different models for THM(C) processes has to be defined (same data format) to allow detailed comparison of distributed experimental data and related model data. This includes a decision on which data and which models should be used, including assessment of uncertainties due to spatial interpolation/ measurement errors and errors induced by model simplifications or unknown heterogeneities as well as sensor lifetime and expected system evolution. This means that for a reduced set of THM(C) processes and parameters, a database for monitoring and modelling parameters will

be defined (as far as possible), overlaps and gaps will be identified, site specific default parameter values might be defined too, to allow reasonable comparison of monitoring and model data. In the case of the FE experiment, a process model describing the temperature evolution in the near field will be used to predict the spatial temperature evolution taking into account material parameter uncertainties, e.g. heat conductivity coefficient, porosity, etc. and their spatial distribution in order to estimate the range of calculated temperature distributions due to process parameter uncertainties. These parameter uncertainties are estimated from measurements (e.g. porosity variation in the EDZ), expected system evolution (e.g. minimum and maximum water saturation or longer term geochemical evolution), or uncertainties in the heat conductivity coefficient. This parameter uncertainty space will be sampled within a statistical framework, yielding process model input parameter for calculation of the temperature distribution in the near field and results in the calculation of temperature distribution around the HLW canister (heater, in case of the FE-experiment). This temperature distribution will be used to compare monitored temperatures in space and time and can be used to identify “monitoring data outliers” according to initially defined (known) parameter uncertainties, i.e. a data filter for monitoring data when comparing the with pre-calculated temperature clouds for different parameter uncertainties and stored in a model database. This database will be used in 2.4 for learning purposes of the digital twin. UFZ will develop concepts to quality control the recorded measurements in the FE experiment or the other MODATS datasets. These will be based on statistical analysis and machine learning previously used to analyse and model the data. These QC steps will be incorporated in their data management module.

Sub-Task 2.4 Development of the Digital Twin

Start: Month 28 – End: Month 58 - Subtask leader: [NAGRA]

Subtask contributors: [ANDRA], [JUELICH (UFZ)] [POSIVA], [PSI], [SKB], [JUELICH (UFZ)], [VTT]

Total PM: 42.5

Objectives: In sub-task 2.4 different approaches towards the application of digital twins will be developed by the partners. These incorporate the prerequisite steps taken and developed throughout sub-tasks 2.1-2.3. Specifically, the QC steps and workflows developed for proper comparison of monitoring and model data in Task 2.3 will be crucial to the successful implementation of digital twins. The digital twins will be prototyped and demonstrated based on available datasets and of selected phenomena and processes implemented in the PBM.

Together with the experts involved in Task 3.4, it will be assessed if any potential interactions between sensors and the multi-barrier system could be identified by means of machine learning and sophisticated data analytics. During the last year of the project, when results of the research activities in Task 3 are available, an evaluation will provide insights into the extent to which digital twins can be enhanced by the novel technologies developed in task 3 and the new knowledge gained.

Description:

VTT, together with other contributors will define a software platform for implementing the methodology developed in sub-Tasks 2.2 and 2.3. The platform to be prototyped and demonstrated supports arranging models of different phenomena in layers, as described in sub-Task 2.3. When presenting data, the modules on the highest layer will give an overall view. Starting from this view, the users can navigate to more detailed information produced by models on lower layers. For traceability, data processing steps are recorded and stored in a version control system, so that any previous computation can be returned to for evaluation and justification of computed results. Digital twins of selected processes will be implemented.

UFZ is modelling the FE experiment already with the same tool which will be further developed within MODATS. This will help model calibration according to measured and monitored data. Living digital models (digital twins) will integrate artificial intelligence, machine learning and software analytics with spatial network graphs that will change as their physical “real-life” counterparts evolve. In addition, the 3D visualisation module will be enhanced with interactive graphics elements improving the basis for decision making. For example, monitoring information related to a) claystone properties obtained by electrical resistivity tomography, interval velocity measurements, b) climatic conditions (air humidity, temperature, atmospheric pressure, c) pore-pressure by a mini-piezometer, d) deformation by extensometer, laser-scan, convergence, tiltmeter and saturation by taupe measurements, NRM and evapometer could be integrated along with other measurements to develop further the digital twin.

PSI In a first step, a digital twin for the FE experiment will be developed, which will allow predictions of near-field processes and the assessment of the consistency of monitoring and model data, with the aim of an enhanced system and process understanding in the near-field. In the next step, the digital twin will be used to reproduce and learn from the available experimental and monitoring data from the FE experiment and related model data from sub-task 2.3 to calibrate the digital twin. 3D parameter information, e.g. homogeneous/ heterogeneous distributions for porosity, saturation, compaction, and related heat conductivity parameters, or the temperature distribution along the heater, feeds the digital twin to yield temperatures at different sensor locations to be compared with monitoring data as a function of time. In a further step, the digital twin is used to mimic FE experimental scenarios with assumptions on, e.g. longer term changes of material properties around the heater in order to predict the longer term evolution of the system compared to the

real FE experimental duration. Future applications of the tool to repository evolution during construction and operation are envisaged. The digital twin allows prediction of temperature distribution and evolution for a longer time than the FE-experiment time, “learned” from the FE-experiment duration, but also allows validation of specific ongoing near-field processes, or correct operation of individual sensors. Such an assessment of the quality of the monitoring data with respect to the model data and vice versa provides an improvement of the overall understanding of the monitoring data, including their uncertainty range. 2.4 has to be performed in close cooperation with PSI sub-task 2.3 with respect to a common data interface.

Andra plan to lay the foundations for the development of a hybrid twin demonstrator applied to the HA cell case study in the clay concept. The combination of the DDM and PBM (see sub-task 2.3) produces a nominal hybrid model that affords the opportunity, once twined with the real monitored object, to evaluate the conformity of its evolution and/or to highlight deviations. Deviations can be used with different aims: (i) continuous improvement of the nominal hybrid model; (ii) qualification/disqualification of the new collected data (device malfunctioning, noise) and (iii) identifying critical scenarios to empower decision making. The ambition is to have a first prototype of a Hybrid Twin combining nominal models and the data-driven modelling of bias for the considered scenario for the HA cell and the HA module (means 2 cells possibly).

Sub-Task 2.5 Enhanced System Understanding, Multi-Party Dialogue

Start: Month 25 – End: Month 57 - Subtask leader: [IRSN]

Subtask contributors: [ANDRA], [JUELICH-UFZ] [IRSN (Mutadis)] (NTW)], [JSI (EIMV)], [ONDRAF (EURIDICE)], [PSI], [SKB], [SSTC NRS]

Total PM: 27,2

Objectives: The purpose of this contribution (sub-task 2.5) is to develop an integrated vision of how the monitoring devices and corresponding data production will contribute to develop a shared understanding of the repository system along with the decision-making process from the early phase of authorisation, to subsequent implementation phases, closure and post-closure.

More specifically, this sub-task will address how monitoring data are used to address the evolution of the safety case, depending on the point of view (operator, decision maker, public). It also questions how differences in perception can lead to potential different decisions.

It is intended here to create the conditions for a sound and fair “3+1 parties” dialogue and mutual understanding between the three EURAD categories of organisation (WMO, TSO and RE) and the EURAD Civil Society Group (that will be mediated by CS Experts according to the specific EURAD Double Wing methodology - see the EURAD DEPLOYMENT PLAN and EURAD deliverable D.1.13 List of members of the Civil Society group). The purpose is to highlight how the points of view and types of reasoning may differ. This ultimately makes it possible to address the question of how to approach the link between measurement and the installation of the safety case.

Whereas monitoring is to be developed in order to address uncertainty, the contribution of this sub-task includes a specific linkage with the UMAN project that provides context to understand uncertainty management and safety case review in geological disposal. The project will involve participants, having already a shared level of understanding of such decision-making context (e.g. the understanding of what the safety case is about), as it is already foreseen in projects, such as UMAN.

Methodology

The process will involve a “3+1 team” of researchers and CS experts, contributing to two successive workshops aiming at the production of a synthesis document. The sub-task is not intended to perform an exhaustive review dialogue on all aspects dealt with in task 2, but rather to experiment such dialogue on a selected number of meaningful issues (for all parties) involved by Data Treatment, in the frame of MODATS project.

The “3+1 parties” will first conduct a preparatory phase (Year 1) where they shall establish a common platform of the shared goals and ambition of the dialogue, identifying key challenges and topics, according to the opportunities provided by the MODATS Reference Experiments. A few examples that compare data to predictions and evaluate significance to system understanding and improvement will be selected and discussed. This preparatory phase includes a review of the MoDeRn2020 D5.2 Final Stakeholder Guide as a basis for achieving this common platform.

The sub-task then involves an original process of interaction comprising two successive (Year 2 and Year 3) workshops for which each of the “3+1 categories” of actors prepares (beforehand) a keynote point of view on the topics selected in the common platform, which leads to actor interaction. The first workshop will start the dialogue on an enlarged basis of 10 additional participants from MODATS and UMAN. It will be achieved with a face-to face meeting, possibly in the vicinity of MODATS plenary meetings.

The second workshop (on a remote basis) will allow the finalisation of the work and conclusions (on the basis of previous exchanges) and possible discussions that could lead to additional questions to those already put on the table to date.

Organisation

The lead and coordination of this sub-task will be ensured by IRSN, especially by creating links between partners (for information exchange) during the MODATS project.

Under the coordination of MUTADIS, the shared platform will be constructed by one representative, who will be in charge of the feedback from each college, to allow the preparatory phase.

During two workshops, the link between MODATS experiments, data and the understanding of what data are relevant for, depending of each partner point of view, will be shared and discussed, in order to establish a common vision about global system understanding and improvement, in the frame of the safety case.

Year 1

- Gathering information on the development of Task 2 and Task 3 in year 1, providing the “3+1 parties” with corresponding information (notably during the annual ICS workshop to be held early 2022, organised by PMO 8).
- Establishing (as 1st Sub-Task 2.5 milestone report) the “3+1 common platform” shared goals and ambition of the dialogue:
 - identifying key challenges and topics according to the opportunities provided by the MODATS Reference Experiments,
 - selecting a few datasets to compare to predictions,
 - and evaluating significance to system understanding and improvement.

Year 2

- First MODATS 3+1 Dialogue Workshop (PRESENTIAL), aiming at the development of mutual understanding and when possible common views on the key challenges and topics identified in the platform, based on the preliminary development of Task 2.
- Further gathering information on the MODATS Task 2 and Task 3 developments in year 2 and their potential contribution to meet the identified challenges.
- Providing the CS Group with corresponding information (during the annual ICS workshop to be held early 2023, organised by PMO 8)
- Compiling the first MODATS “3+1 Dialogue Workshop” results into a 2nd Sub-Task 2.5 milestone report.

Year 3

- Second MODATS “3+1 Dialogue Workshop” (REMOTE MEETING) addressing complementary challenges and topics that have been recognised in the development of MODATS, while finalising the work and conclusions of the sub-task.
- Compiling the second MODATS “3+1 Dialogue Workshop” results into a Sub-Task 2.5 Deliverable.

Task 3 - Novel and Optimised Monitoring Technology for Repository Monitoring

Start: Month 25 – End: Month 57 - Task leader: [ANDRA]

Total PM: 191

The requirements on sensing methods to monitor waste repositories are quite unique. Monitoring must not interfere with EBS integrity and jeopardize the long-term safety of a repository.

The MoDeRn Project successfully developed and analysed the capabilities of monitoring technologies for future repository use in the fields of measurement techniques and probes, data transmission methods and energy supply. The Modern2020 project accelerated technological development of a tailored system for geological disposal in a way that was not seen before in order to move from the state-of-the-art to the proof of concept and demonstration phase. With this ambition, Modern2020 explored a large number of innovative methods and techniques for developing useful tools and assessing the monitoring strategies in an appropriate way.

Objectives: New and emerging sensing methods may change the paradigm of how to monitor waste repositories. In order to push forward what is possible in terms of monitoring, it is crucial to stay abreast with the technological development to apply and adapt emerging technologies to waste repository monitoring and develop new technologies that are suitable for the specific requirements of repository monitoring. In addition, we develop new methods that extract signals from the data through signal processing, joint inversion schemes and other techniques that are specific to the monitoring methods. In Task 3, we will:

1. Research and further develop innovative sensors and geophysical techniques to measure and infer parameters that are difficult to obtain for long-term monitoring.
2. Develop and qualify optical sensors to get them ready to be used in the initial phase of the development of the geological disposal for temperature and strain measurement.

Develop methods to investigate the impact of monitoring technology on the performance of a range of disposal systems.

Sub-Task 3.1 Geophysics & Innovative Sensors

Start: Month 25 – End: Month 57 - Subtask leader: [ANDRA]

Subtask contributors: [JUELICH (GFZ)], [IRSN], [NAGRA (ETH)], [POSIVA]

Total PM: 73

This sub-task will be focussed on the development of geophysical methods, new sensor development and their testing and application in experimental setups.

For monitoring of radioactive waste repositories, knowledge of the spatial and temporal variations of key parameters, such as temperature, pressure, moisture, porosity, etc. is envisaged. In principle, this can be obtained with a sensor network, in which all these parameters can be measured directly. However, this imposes challenges. First, the placement of the sensors could have an impact on the passive safety of the multi-barrier system. Furthermore, the placement of a sensor may locally disturb the embedding material, and the measurements may be therefore not representative. Finally, the sensor data corresponds to point information only, which may be not representative for the entire volume of interest. With geophysical methods the problems mentioned above can be addressed. They can be performed in a non-destructive fashion. Therefore, the integrity of the barriers remains unaffected, and the embedding material is not disturbed locally. Most importantly, repeated geophysical measurements allow spatial and temporal changes to be monitored over larger volumes.

Unfortunately, geophysical methods also suffer from some deficiencies. Firstly, they are often ambiguous, that is, several subsurface models explain the data equally well. Depending on the method(s) employed, they can offer only limited spatial and/or temporal resolution. Finally, geophysical methods yield physical material properties, such as elasticity parameters, density, or electrical conductivities, and it is not straightforward to translate these material properties to parameters of interest (i.e., temperature, pressure, etc.).

To address the problem of ambiguity, joint differential inversions can be applied. Here, several geophysical data types are inverted simultaneously, whereby additional constraints are supplied. They can either include structural similarity constraints (anomalous features that maybe evolve over time, will likely manifest themselves in several physical material parameters), or the different physical material properties can be related to each other via empirical relationships (e.g. Archie's law). The latter would also allow the direct retrieval of some relevant parameters, like porosity. The translation of physical material properties to relevant geotechnical parameters of interest requires comprehensive measurements using dense sensor networks, combined with suitable geophysical experiments. Out of these datasets, it is possible to establish appropriate constitutive relationships.

In this task, ETH Zürich and Nagra will develop novel tools to:

- a) set up joint inversion of various geophysical data to better constrain the model parameters,
- b) establish suitable constitutive relationships between relevant geotechnical parameters and physical material properties,
- c) identify other constraints that can be supplied (e.g., geological a priori information), and
- d) combine all constraints and constitutive parameter relationships in the joint inversion schemes.

This project will involve (i) algorithmic developments and tests with synthetic data and (ii) application of the new methodology to the Mont Terri full-scale emplacement (FE) experiment.

Given the tight time frame of this WP, it may be necessary to restrict the analysis to the most important parameters such as temperature, pressure and moisture content, but the algorithms to be developed should be sufficiently general, such that it can be extended to additional parameters.

Results from Task 3.1 will offer quantitative and exciting means for combining the goals of Task 2 (data treatment) and Task 3 (monitoring technology). Ultimately, this research is expected to provide optimized monitoring setups for radioactive waste repositories, in which geophysical experiments are combined with in situ sensors.

(activity is frozen until Eurad Bureau make a decision on the Budget) IRSN will continue the development of monitoring the properties of a bentonite buffer during its saturation using the spectral induced polarization (SIP) method. SIP is a geophysical method that is sensitive to the ability of porous materials to store reversible electrical charges. SIP offers an extension to the classical direct current conductivity/resistivity method to image not only the saturation of the porous media in water but also to identify the physical and chemical properties such as the pore water chemical composition and the influence of bacterial activity. The method is based on the electrical double layer coating grain surfaces, which is important in clay material due to the high specific surface values and cation-exchange capacity of clay minerals. This method has previously been applied on clay rocks and has shown promising results in imaging their water content and mineral composition. In addition, the method is also sensitive to the presence of fractures (mineralised or open). Finally, thanks to the development of new physical modes it is now possible to link the parameters stemming from SIP to the permeability of the media, which constitutes a new and innovative method to image through time the permeability of porous and fractured soils or rocks.

In this task we wish to apply this method to characterise the evolution of two bentonite buffers implemented at the Tournemire URL during the Modern2020 project. The two buffers differ in their composition. One (ERT) is a bentonite based granular material, whereas the other (LTRBM) is made of a pre-compacted bentonite and sand mixture. The two buffers are hydrated artificially and are equipped with numerous sensors that measure continuously the temperature, pore and total pressure, relative humidity, suction, conductivity, resistivity and pH. The buffers are located in a large borehole and confined by the means of a cement plug. In addition, four electrical boreholes were drilled around each buffer to implement a non-invasive electrical monitoring network.

This task will be structured around three main points: (i) modelling of electrical resistivity data acquired during the Modern2020 project; (ii) theoretical and numerical aspects including the effects of the double layer for bentonite clay minerals (smectite), building a macroscopic SIP bentonite model, (iii) experimental aspects including the petrophysical and textural characterisation of the ERT and LTRBM mock-ups and defining their SIP and (iv) field testing of the method on two large-scale in situ tests (ERT and LTRBM).

GFZ Potsdam, in collaboration with IRSN will lead the implementation of a new thermo-hydro-mechanical loading experiment at the Tournemire URL, France called CHENILLE (Coupled beHaviour undErstaNdIng of fauLts: from the Laboratory to the fiELd). The overall objective of this experiment is to create a dataset that will enable identification and characterization of the physical processes resulting from thermal and fluid loading on a pre-existing fault zone. The project aims at carrying out thermally controlled (temperatures ranging from 15 to 150°C) in situ gas injection in a fault accessible from the galleries. A heating system will be installed around an injection borehole to allow a precise and controlled incremental increase of the thermal load. Monitoring will focus on passive and active seismic methods. In addition, the boreholes will be equipped with fibre optic cables for distributed temperature measurement. The injection borehole will be equipped with an injection probe, allowing for pressure monitoring, one point measurement of temperature (for reference), and 3D relative deformation between the two ends of the injection chamber (3-4 m). While the in situ instrumentation is co-funded via internal budget of the institute, in the frame of this task we propose to realize the geophysical monitoring of this experiment.

Crack formation detection is challenging in clay-rich material due to the high attenuation of the soft rocks. Moreover, the expected sub-cm scale of fractures imposes use of the highly-sensitive acoustic emission (AE) sensors that are able to record high frequency signals with dominant frequencies up to 100 kHz and at high sampling rates up to 500 kHz. Owing to the expected unfavourable geology and attenuation conditions, the AE sensors will be installed in sub-horizontal boreholes of 76 mm diameter in the direct proximity (distance < 5 m) of the injection point. Side-view installation of AE sensors will be preferred to improve the coupling quality and reduce the number of boreholes with up to 4 sensors in a single borehole. In addition to AE sensors, two high-frequency sensitive accelerometers (ACCs) will be co-located and used for cross-calibration of AE sensors.

A controlled seismic experiment is planned, using coupled magnetostrictive vibrators to investigate the structural environment, in particular the complex fault network surrounding the tunnel lab. The fault structure is composed of a main brecciated and foliated core zone of up to two meters thickness and a damage zone of complex geometry made up of subsidiary faults. The results of the active seismic survey will assess the position of eventual damage occurrence and will be used to cross-validate fibre optic and passive seismic observations. In addition, the experiment will be equipped with fibre optic cables for temperature measurements. This work will be carried out as part of Task 3.3.

Novel time series analysis applied to passive seismic monitoring with the goal of automatically analysing, locating and classifying seismic events will be led by POSIVA. They have been monitoring the bedrock stability of the Olkiluoto site using microseismic monitoring since 2002. The analysis of microseismic observations consists of analysing and classifying recorded seismic waves. This analysis permits POSIVA to locate and recognize several types of events at Olkiluoto, for example blasts, microearthquakes, rock falls, connected to raise boring and miscellaneous events. Each event class has its own typical seismic signatures which can be used to classify them. The analysis work is performed using software by Institute of Mine Seismology (IMS).

Currently the microseismic analysis work is completed manually for all Olkiluoto's events. Most of the analysed data are from blasts during tunnel excavation. POSIVA is also investigating the possibility to use mechanical excavation technology (for example TBM) which also produce a characteristic seismic wave that could be analysed automatically. An automatization approach based on speech recognition technology could be a possibility to investigate. Seismic waves are sinusoids and seismic analysis is based on recognition of P- and S-waves which are used to determine the location of the seismic event. Using AI can be helpful to pick the wave forms which are typical for explosions.

POSIVA has recognised the need for faster analysis: an automated locating of the seismic signals facilitates the analysis of common seismic events, such as blasts. Also, POSIVA has recognized that the automated locating of a blast requires additional R&D and testing on seismic software tools to succeed. The particularity of the Olkiluoto site and limited number of seismic stations make the task difficult. POSIVA will provide the datasets from stations to be further analysed and this requires a software application for existing seismic analysis. The role of POSIVA is the coordination of the work and the participation to the planning of the work and use own personnel work effort for interpretation and analysis. The software modification is planned to be subcontracted.

Furthermore, POSIVA will develop new methods for digital mapping of leakages. It is envisaged that water inflow will be monitored over long periods in crystalline rock environments. Current mapping methods are based on manual acquisition and analysis. As a consequence, results may be subject to bias. In addition, the work is time consuming and cannot be undertaken frequently, which restricts in-depth analysis of, for example, the annual variation in response to changes of weather and ventilation. Therefore, a rapid, efficient and reliable method is needed to be able to conduct leakage surveys. In addition, the use of data could be combined to the models and the visualisation methods could be

improved. POSIVA will conduct a literature survey on different methods and select the most appropriate method to be tested in ONKALO® in Olkiluoto and analyse the outcome.

Sub-Task 3.2 - Advancement of Fibre-Optic Methods

Start: Month 25 – End: Month 57 - Subtask leader: [ANDRA]

Subtask contributors: [CEA], [CNRS (UJean Monnet - LHC)] [CVREZ], [JUELICH (GFZ)], [NAGRA]

Total PM: 104

Optical fibre sensors (OFS) are exceptional tools, as they enable distributed measurements, providing data over their entire extent. Moreover, optical fibre's small size reduces the invasiveness of measurements. Furthermore, the sensing units do not contain electronics and can be exposed to the harsh repository conditions during the operating period. In sub-task 3.2, the promising developments seen in the application of fibre optic sensing methods will be further developed. While some of these techniques have already been explored successfully for repository monitoring in MoDeRn and Modern2020, fibre optic sensing sees a fast-paced development and a continuous stream of innovation. Here we focus on new sensing capability, qualifying optical fibres for various monitoring technologies and glean additional insights from distributed measurements of temperature and deformation.

Important development has been performed in the past to get suitable radiation tolerant optical fibre and design sensitive external coating to measure strain and temperature in the near field of high-level disposal cells. Andra, UJean Monnet-LHC and CVREZ have decided to join efforts to develop a sensing cable that is capable of measuring both strain and temperature under radiation, and also improve data treatment and analysis procedures for the metallic disposal cell prototype. The ambition of this task is to qualify the OFS sensing cable as a possible product to monitor geological disposal. Based on the previous results in Modern2020 and FINESSE project. The cable developed by Andra will use multivariate analysis to permit the best understanding of the physics involved in the fibre degradation and cable coating degradation through RIA, nonlinear measurements (Raman, Brillouin, Rayleigh) and mechanical analysis. The qualification will be also performed under Neutron environment in a way to get a unique qualification process to this product. We expect that effort will result in a cable design and measuring performance suitable for monitoring High level waste cells.

Fibre-optic strain sensing was already identified in the MoDeRn project as a suitable monitoring technique and first tests were performed in the Modern2020 project. Aspects that could not be covered yet were advanced analysis techniques, detailed comparisons of different sensor types and measurement techniques, and the evaluation of possible time-dependent effects of the sensor performance from ageing. Nagra plans to use the existing instrumentation of the TS experiment at the Mont Terri URL to further improve the application and analysis of fibre-optic strain sensing under repository-like conditions. They will continue the periodic measurements of circumferential strains in three cross sections of different tunnel support systems, performed since late 2018. Two shotcrete-supported sections and one steel-supported section were instrumented with 3 different types of fibre-optic distributed strain sensing cables as well as FBG (Fibre Bragg Grating) sensors and fibre-optic temperature compensation cables. The fibre-optic distributed strain and temperature sensors were measured with Brillouin and Rayleigh technologies. In addition, the cross sections were also monitored by conventional convergence measurements.

Advanced data processing and analysis techniques for detailed quantification of the strain distribution and an evaluation of sensors and sensing technologies will be applied to the data set covering late 2018 through to 2022:

- Measurement results and performance of three distributed strain sensing technologies (spontaneous and stimulated Brillouin, as well as Rayleigh scattering) will be compared in detail for (a) total strain, (b) qualitative patterns of distributed strain, (c) spatial resolution, (d) overall functionality and (e) effects specific to each sensing technology. The data sets offer a unique opportunity to develop advanced data processing and analysis techniques, because the entire spectrum of fibre-optic sensing methods is applied.
- Advantages and challenges of different distributed sensor designs including a comparison of the strain results obtained.
- A general performance comparison between distributed sensors (Brillouin and Rayleigh) vs. point sensors (FBG). In addition, a comparison of the fibre-optic results with the conventional convergence measurements will be done.
- Evaluation of possible time-dependent effects and properties of the sensors in regards to long-term performance for repository monitoring.

We expect that this effort will result in a detailed determination of high-resolution distributed strain within the tunnel support system, allowing for assessment of the tunnel deformation in space and time under conditions representative of a repository, as well in recommendations for the selection of adequate fibre-optic strain monitoring methods for monitoring experts of other WMO, TSO or research organisations.

Distributed temperature sensing (DTS) will be used by GFZ Potsdam in their combined thermal and hydro-mechanical loading experiment to be installed at the Tournemire URL. The project aims at carrying out a thermally controlled (with temperatures ranging from 15 to 150°C) in situ gas injection experiment in one of the faults accessible from the galleries. A heating system will be installed around an injection borehole to allow a precise and controlled incremental increase of

the thermal load. In addition to active and passive seismic methods (see Task 3.1), Temperature fibre optic monitoring will be installed in the four boreholes of 20 m length, containing the heating systems (4 m long) as well as in the 30 m long injection borehole. DTS technology enables borehole temperature monitoring to study hydrogeological processes at unprecedentedly high frequency and spatial resolution. The objective of this sub-task is to test our ability to install DTS equipment, perform this measurement type under extreme conditions, including the complete temperature range from 15 to 150°C, and compare the results to others techniques. In addition to the fundamental knowledge that this project will provide, it will lead to a significant improvement in current measurement methods in clay-rich material thanks to the combination of several geophysical techniques and complementary sensors, and more broadly in the context of monitoring underground installations at high temperature levels in complex geological environments.

Fibre optic methods are also a promising technology for chemical sensing. The measurement of pH is a parameter that can give lots of information about the processes involved for different stages of the disposal phase. The common way to measure pH is to use electrochemical techniques. However, there are several drawbacks, which make the use of pH electrodes difficult or even impossible for the target applications. Measurements with electrodes can generally be biased by electromagnetic fields, changing flow velocity of the test solution or solutes such as heavy metals, proteins or hydrogen sulphide, etc... During long-term measurements, small variations of pH are difficult to observe, since the electrode signal drifts with time. The dependence of the liquid junction potential on the composition and concentration of the sample can be a further source of error. pH detection in small sample volumes or high-resolution pH detection in heterogeneous systems requires miniaturisation of the working electrode and sometimes also the reference electrode, which involves complex fabrication procedures. CEA will develop an optical pH sensors based. This technology uses an optical fibre on which an acid-base indicator has been deposited using specific grafting techniques. The technique relies on the change in the absorption spectrum of the acid-base indicator when pH changes. Over the last 10 years, CEA has improved the grafting process considerably leading to a greater robustness, patenting it as Graftfast™. Previously the technology development had focussed on acidic and alkaline pH values, while they are not applicable to the neutral pH range expected for many materials in the EBS. The proposed research and development focus on improving the grafting process, improvements to the optical design and finally testing in Andra's URL at Bure.

Subtask 3.3 - Interactions between Sensors and the Multi-Barrier System

Start: Month 31 – End: Month 57 - Subtask leader: [ANDRA]

Subtask contributors: [RWM], [SSTC NRS], [VTT (GSL)]

Total PM: 14

Placement of sensors within the multi-barrier system will result in interactions between the sensor and the medium in which it is embedded. For example, placement of a sensor within a bentonite buffer could cause geometrical anomalies that lead to a lowering of bentonite density. The EURAD SRA Theme 5 topic calls for an activity “to investigate the impact of monitoring technology on the performance of a range of disposal systems”. This sub-task directly addresses that requirement.

In this sub-task the potential for sensors to interact with the multi-barrier system will be researched to ensure confidence in the data collected from different technologies and to understand the influence that the sensor may have on the multi-barrier system. The sub-task will be addressed through FEP analysis that will consider monitoring technologies identified in Task 2.2, using the following process:

- An inventory of materials and geometries of monitoring sensors will be developed for a range of example technologies.
- The potential thermal, hydro, mechanical, chemical, gas and radionuclide migration interactions between the sensors and the materials in which they could be placed will be identified through expert workshop discussions and application of databases from previous studies.
- The potential implications of monitoring on the performance of the multi-barrier system will be ascertained through a combination of scoping calculations, expert elicitation and argumentation.

RWM and GSL will jointly undertake the FEP analysis which will form the basis for the research activities, in particular identifying a common set of technologies and sensors to be evaluated, a set of type engineered barriers systems under consideration across Europe, and preparing an integration report that draws conclusions on the interactions that can be used as a reference document moving forward.

SSTC NRS will examine the sources of hardness and evaluate the impacts of the harsh environment on the requirements for long-term monitoring on sensor equipment. Within sub-task 3.2, it is envisaged that MODATS will “develop systems capable of monitoring the multi-barrier system remotely ...”. It is evident that such systems will ensure monitoring of different parameters, characterizing the state of different barriers of the geological repository. Each sensor of the monitoring system shall perform monitoring functions in case of external impacts under the environmental conditions envisaged by the design. The monitoring system shall be robust and durable with limited possibility for maintenance and repair. Here, we propose to analyse:

- possible environmental impacts on sensors taking into account the designed sensor lifetime;
- possibilities for re-calibration or drift compensation, for maintenance or redundancy measurement.

According to our evaluation, requirements for the sensors in regards to the following characteristics will be defined:

- resistance to external impacts (thermal, chemical, mechanical, radiation, etc.);
- reliability and durability of sensors and limitations for maintenance

Task 4 - Communication and Project Synthesis

Start: Month 25 – End: Month 60 - Subtask leader: [SSTC NRS]

Subtask contributors: [ANDRA] [NAGRA], [POSIVA], [SKB], [VTT (GSL)]

Total PM: 43,50

Objectives of the task: The overall objective of this work package is to spread excellence and disseminate knowledge and results, obtained within the MODATS WP, and to integrate this into the KM system developed in the EURAD project. Dissemination of project results will be mainly targeted to the radioactive waste management community and wider stakeholders in accordance to activities in relation to CSO group (Sub-Task 2.5). Thus, target audiences can be divided in three main groups (without being exhaustive at this stage):

i) Scientific and technical stakeholders (IGD-TP, WMOs, SITEX, TSOs, research and innovation projects, universities, Master and PhD Students, engineering companies international experts, IAEA, NEA, European Technology platforms, EC, etc.)

ii) Local Stakeholders (specific attention will be paid to make sure our research and communication actions do not interfere with communication plans and any other activities from the concerned national waste management agencies particularly in regards to the issue of deep geological disposal and

iii) The public at large (experts, policy makers, local authorities, local public and local information/advisory groups, etc.)

Description

The activities within this task will cover the following main issues:

1. Interaction with KM WPs.
2. Develop communication tools, principally webpages dedicated to the WP inside the <https://www.ejp-eurad.eu/> website. Biannual newsletters will be generated.
3. Project synthesis.

Sub task 4.1: Interaction with KM Work Packages

Start Month 25 – End Month 58 – Subtask Leader: SSTC NRS

The three KM WPs are responsible for the selection prioritisation, coordination and production of their respective output (SoK, guidance documents and training and mobility activities) with the input from all EURADs WPs and identified end-user needs. Dissemination of guidance documents, after the review process, is the responsibility of WP1 (PMO). Therefore, the Sub-Task 4.1 will not cover these activities. The proposed scope of work covers, in particular, the following:

- Identification of MODATS needs with regard to KM activities;
- Regular communication with KM WPs;
- Development of proposals on integration of the MODATS results into KM systems.

The MODATS WP will interact with the Knowledge Management WPs to contribute to the up-to-date knowledge in monitoring for geological disposal. Timely and efficient interaction with the KM WPs would benefit the implementation of MODATS tasks, as well as the dissemination of MODATS results within the EURAD community and to wider audiences. There will be following links with the specific KM WPs:

Link to WP11 (SoK):

The scope of MODATS is connected to a series of domains of the Goal Breakdown Structure (GBS) –Theme 3 (EBS), Theme 7 (Safety Case), but also with other themes and domains.

- Within sub-task 4.1, the domains that could provide benefit to the WP MODATS tasks will be identified. Position papers addressing the relevance of MODATS to a particular SoK will be developed as well as Domain Insight documents that will serve as a useful contribution to the activities on the prioritization of SoK documents (GBS domains for which SoK documents are created on a first-priority basis). The prioritization itself will be developed within WP11 (SoK),
- The MODATS WP outcomes will be integrated into the State of Knowledge (SoK) system, being developed in the framework of EURAD KM WP11. Within this sub-task 4.1, there will be proposals developed on the information to be integrated into specific SoK documents. Effective communication and coordination with the WP11 team will be required.

Link to WP 12 (Guidance):

Interaction with WP12 during development of Guidance documents, envisaged in MODATS Task 2. This will include, in particular:

- development of proposals regarding possible integration of Guidance documents developed within MODATS Task 2 into WP12 guidance system (set of guidance) and appropriate communication with WP12 team;

- development of proposals on the use of MODATS outcomes for development of other Guidance documents within WP12;
- Determination of possibilities for use of WP12 outcomes (guidance) for MODATS needs.

In the course of implementation, there will be coordination of WP12 with MODATS Tasks 2 and 3.

Link to WP 13 (Training and Mobility):

Activities will contain involvement of MODATS (both participants and activities) in the training and mobility performed within WP13.

This interaction will include:

- dissemination and clarification of information about available training and mobility among MODATS participants, especially among PhD and PostDoc students;
- lecturing at the training courses on topics related to monitoring (if requested by the WP13 team).
- providing support for both intra-WP and cross-WP mobility activities, organised by WP13, in case if such activities are related to MODATS;
- for intra-WP mobility within MODATS, evaluation of submitted applications by the assigned members of the Steering Committee;
- regular communication with WP13 team;
- providing feedback from the mobility activities to WP13 team.

On the results of the interaction with KM Work Packages, a report will be prepared (D17.8), where the main outcomes and lessons learnt will be presented.

Subtask 4.2: Develop communication tools of the MODATS project,

Start month 25 – End month 60 – Subtask leader: SSTC NRS

MODATS webpages on Eurad website

A MODATS section will be set up on <https://www.ejp-eurad.eu/> website at the start of the project and will provide initial information on the project (presentation, scope, partners, work packages, etc.) for the wider audience. The dedicated web pages (D4.1) will be regularly updated with on-going activities, public reports, publications, events (meeting, workshops, etc.).

Each partner of the WP will have to provide a short description about the MODATS work on their own website with a link to the dedicated MODATS website.

Newsletters

Content for EURAD newsletters (general information, news and events) will be prepared for the wider audience

External presentation

MODATS results will also be presented during EURAD events, the annual IGD-TP Exchange Forum and events where the interest is demonstrated.

A plan for dissemination will be outlined at the same time as the WP description (these two documents will help partners to disseminate the results outside the WP).

The dissemination activities will be collated in a table following the progress of the project, year 1 and year 2; Tables will be considered as milestones for better visibility. The final status will be included in the synthesis report

Subtask 4.3 - Project synthesis

Start Month 48 – End Month 60 – Subtask leader: SSTC NRS

A synthesis document will be produced during the last year of the WP implementation. It will analyse and integrate MODATS results into a comprehensive report. An abstract for a wider audience will also be produced. The project synthesis will mainly be based on Task 2 and Task 3 reports.

Participation per Partner

Partner number and short name	WP17 effort
1 - ANDRA	56.00
5 - CEA	27.00
8 - CNRS	0.00
UJean Monnet	7.00
11 - CV REZ	31.00

Partner number and short name	WP17 effort
15 - JUELICH	0.00
GFZ	27.00
UFZ	35.50
19 - IRSN	15.60
MUTADIS	5.60
22 - JSI	0.00
EIMV	8.00
27 - NAGRA	15.00
ETH	28.00
32 - ONDRAF/NIRAS	0.00
EURIDICE	9.50
33 - POSIVA	14.50
34 - PSI	28.50
37 - RWM	6.00
39 - SKB	10.50
40 - SSTC NRS	45.00
50 - VTT	23.00
GSL	25.00
Total	417.70

List of deliverables

Deliverable Number ¹⁴	Deliverable Title	Lead beneficiary	Type ¹⁵	Dissemination level ¹⁶	Due Date (in months) ¹⁷
D17.1	MODATS – Initial State-of-the-art	1 - ANDRA	Report	Public	32
D17.2	MODATS – Final State-of-the-art	1 - ANDRA	Report	Public	58
D17.3	MODATS - Lessons from URL Experiments	50 - VTT	Report	Public	36
D17.4	MODATS - Guidance on Quality Assurance Project Plans (QAPPs)	50 - VTT	Report	Public	48
D17.5	MODATS - Enhanced System Understanding, Multi-Party Dialogue	19 - IRSN	Report	Public	57
D17.6	MODATS - Task 2 Integrated Report: Data Treatment for Increased	50 - VTT	Report	Public	58

List of deliverables

Deliverable Number¹⁴	Deliverable Title	Lead beneficiary	Type¹⁵	Dissemination level¹⁶	Due Date (in months)¹⁷
	Confidence in Repository Monitoring				
D17.7	MODATS - Synthesis Report on Innovative and Enhanced Equipment for Repository Monitoring	1 - ANDRA	Report	Public	57
D17.8	MODATS - Interaction of the MODATS WP with EURAD Knowledge Management Work Packages – Synthesis Report	40 - SSTC NRS	Report	Public	58
D17.9	MODATS - Final report Monitoring Equipment and Data Treatment for Safe Repository Operation and Staged Closure	50 - VTT	Report	Public	60

Description of deliverables

- D17.1 - MODATS – Initial State-of-the-art - Lead [Andra] – Due month: 32
- D17.2 - MODATS – Final State-of-the-art - Lead [Andra] – Due month: 58
- D17.3 - MODATS - Lessons from URL Experiments – Lead [VTT] – Due month: 36
- D17.4 - MODATS - Guidance on Quality Assurance Project Plans (QAPPs) – Lead [VTT] – Due month: 48
- D17.5 - MODATS - Enhanced System Understanding, Multi-Party Dialogue - Lead [IRSN] – Due month: 57
- D17.6 - MODATS - Task 2 Integrated Report: Data Treatment for Increased Confidence in Repository Monitoring – Lead [VTT] – Due month: 58
- D17.7 - MODATS - Synthesis Report on Innovative and Enhanced Equipment for Repository Monitoring - Lead [Andra] – Due month: 57
- D17.8 - MODATS - Interaction of the MODATS WP with EURAD Knowledge Management Work Packages – Synthesis Report – Lead [SSTC NRS] – Due month: 58
- D17.9 - MODATS - Final report Monitoring Equipment and Data Treatment for Safe Repository Operation and Staged Closure - Lead [VTT] – Due month: 60

D17.1 : MODATS – Initial State-of-the-art [32]

MODATS – Initial State-of-the-art

D17.2 : MODATS – Final State-of-the-art [58]

MODATS – Final State-of-the-art

D17.3 : MODATS - Lessons from URL Experiments [36]

MODATS - Lessons from URL Experiments

D17.4 : MODATS - Guidance on Quality Assurance Project Plans (QAPPs) [48]

MODATS - Guidance on Quality Assurance Project Plans (QAPPs)

D17.5 : MODATS - Enhanced System Understanding, Multi-Party Dialogue [57]

MODATS - Enhanced System Understanding, Multi-Party Dialogue

D17.6 : MODATS - Task 2 Integrated Report: Data Treatment for Increased Confidence in Repository Monitoring [58]

MODATS - Task 2 Integrated Report: Data Treatment for Increased Confidence in Repository Monitoring

D17.7 : MODATS - Synthesis Report on Innovative and Enhanced Equipment for Repository Monitoring [57]
MODATS - Synthesis Report on Innovative and Enhanced Equipment for Repository Monitoring

D17.8 : MODATS - Interaction of the MODATS WP with EURAD Knowledge Management Work Packages – Synthesis Report [58]
MODATS - Interaction of the MODATS WP with EURAD Knowledge Management Work Packages – Synthesis Report

D17.9 : MODATS - Final report Monitoring Equipment and Data Treatment for Safe Repository Operation and Staged Closure [60]
MODATS - Final report Monitoring Equipment and Data Treatment for Safe Repository Operation and Staged Closure

Schedule of relevant Milestones

Milestone number ¹⁸	Milestone title	Lead beneficiary	Due Date (in months)	Means of verification
MS250	MODATS - Minutes of WP Board meeting 1	50 - VTT	26	MODATS - Minutes of WP Board meeting 1
MS251	MODATS - Minutes of Task 2 Workshop 1	50 - VTT	26	MODATS - Minutes of Task 2 Workshop 1
MS256	MODATS Project Description	40 - SSTC NRS	27	MODATS Project Description
MS257	MODATS - Interaction with EURAD Knowledge Management Work Packages: Activity Plan	40 - SSTC NRS	27	MODATS - Interaction with EURAD Knowledge Management Work Packages: Activity Plan
MS268	MODATS - Description of the MODATS Reference Experiments (Final)	1 - ANDRA	30	MODATS - Description of the MODATS Reference Experiments (Final)
MS271	MODATS - Minutes of Task 2 Workshop 2	50 - VTT	32	MODATS - Minutes of Task 2 Workshop 2
MS280	MODATS - Lessons from URL Experiments	50 - VTT	36	MODATS - Lessons from URL Experiments
MS283	MODATS - Minutes of WP Board meeting 2	50 - VTT	37	MODATS - Minutes of WP Board meeting 2
MS286	MODATS - Definition of DDM Test Cases	50 - VTT	39	MODATS - Definition of DDM Test Cases
MS288	MODATS - Minutes of Task 2 Workshop 3	1 - ANDRA	41	MODATS - Minutes of Task 2 Workshop 3
MS296	MODATS - Minutes of Task 2 Workshop 4	50 - VTT	46	MODATS - Minutes of Task 2 Workshop 4
MS297	MODATS - Development of Understanding Workflow: Activity Plan	27 - NAGRA	47	MODATS - Development of Understanding Workflow: Activity Plan
MS303	MODATS - Guidance on Quality Assurance Project Plans	50 - VTT	48	MODATS - Guidance on Quality Assurance Project Plans

Schedule of relevant Milestones

Milestone number¹⁸	Milestone title	Lead beneficiary	Due Date (in months)	Means of verification
MS305	MODATS - Minutes of WP Board meeting 3	50 - VTT	49	MODATS - Minutes of WP Board meeting 3
MS311	MODATS - Minutes of Task 2 Workshop 5	50 - VTT	53	MODATS - Minutes of Task 2 Workshop 5
MS317	MODATS - Data Management – Lessons Learned for Repository Monitoring	15 - JUELICH	54	MODATS - Data Management – Lessons Learned for Repository Monitoring
MS318	MODATS - Comparison of DDMs with PBMs	34 - PSI	54	MODATS - Comparison of DDMs with PBMs
MS324	MODATS - Future Needs Memo: Final	37 - RWM	57	MODATS - Future Needs Memo: Final
MS325	MODATS - Development of Understanding Workflow Memo	27 - NAGRA	57	MODATS - Development of Understanding Workflow Memo
MS326	MODATS - Synthesis of Lessons Learned on Data Treatment for Increased Confidence in Repository Monitoring from the MODATS Reference Experiments	50 - VTT	57	MODATS - Synthesis of Lessons Learned on Data Treatment for Increased Confidence in Repository Monitoring from the MODATS Reference Experiments
MS327	MODATS - Synthesis Report on Innovative and Enhanced Equipment for Repository Monitoring: Final Report	1 - ANDRA	57	MODATS - Synthesis Report on Innovative and Enhanced Equipment for Repository Monitoring: Final Report
MS328	MODATS - Task 2 Integrated Report: Data Treatment for Increased Confidence in Repository Monitoring	50 - VTT	58	MODATS - Task 2 Integrated Report: Data Treatment for Increased Confidence in Repository Monitoring
MS331	MODATS - Minutes of WP Board meeting 4	50 - VTT	60	MODATS - Minutes of WP Board meeting 4
MS332	MODATS - Interaction of the MODATS WP with EURAD Knowledge Management Work Packages – Synthesis Report: Final Report	40 - SSTC NRS	60	MODATS - Interaction of the MODATS WP with EURAD Knowledge Management Work Packages – Synthesis Report: Final Report

1.3.4. WT4 List of milestones

Milestone number ¹⁸	Milestone title	WP number ⁹	Lead beneficiary	Due Date (in months) ¹⁷	Means of verification
MS1	EURAD Kick-off meeting (General Assembly n°1)	WP1, WP10, WP11, WP12, WP13, WP2, WP3, WP4, WP5, WP6, WP7, WP8, WP9	1 - ANDRA	1	EURAD Kick-off meeting (General Assembly n°1)
MS2	ACED Kick-off meeting (WPM1)	WP2	38 - SCK•CEN	1	ACED Kick-off meeting (WPM1)
MS3	DONUT Kick off - WP Meeting 1	WP4	1 - ANDRA	1	DONUT Kick off - WP Meeting 1
MS4	FUTuRE Kick-off meeting (WPM1)	WP5	15 - JUELICH	1	FUTuRE Kick-off meeting (WPM1)
MS5	Kick-off GAS WP Meeting 1	WP6	32 - ONDRAF/NIRAS	1	Kick-off GAS WP Meeting 1
MS6	Kick-off HITEC WP Meeting 1	WP7	50 - VTT	1	Kick-off HITEC WP Meeting 1
MS7	KM SoK - launch of screening exercise (task 1)	WP11	15 - JUELICH	1	KM SoK - launch of screening exercise (task 1)
MS8	ACED Specifications of representative disposal cell systems and links with and between model approaches and expected experimental results M1.1.1	WP2	38 - SCK•CEN	2	ACED Specifications of representative disposal cell systems and links with and between model approaches and expected experimental results M1.1.1
MS9	ROUTES Kick-off meeting (ROUTES WPM1)	WP9	19 - IRSN	2	ROUTES Kick-off meeting (ROUTES WPM1)
MS10	KM Guidance - Editorial meeting for the update of PLANDIS	WP12	42 - SÚRAO	2	KM Guidance - Editorial meeting for the update of PLANDIS
MS11	ACED Task 2 workshop 1	WP2	38 - SCK•CEN	3	ACED Task 2 workshop 1
MS12	EURAD EJP Newsletters	WP1, WP10, WP11,	1 - ANDRA	3	EURAD EJP Newsletters (Due date : M3 and then every quarter)

Milestone number¹⁸	Milestone title	WP number⁹	Lead beneficiary	Due Date (in months)¹⁷	Means of verification
		WP12, WP13, WP2, WP3, WP4, WP5, WP6, WP7, WP8, WP9			
MS13	ROUTES Questionnaire	WP9	19 - IRSN	3	ROUTES Questionnaire
MS14	KM SoK - List of Demonstration cases	WP11	4 - BGE	7	KM SoK - List of Demonstration cases
MS15	KM SoK - list of criteria for selecting demonstration cases	WP11	4 - BGE	4	KM SoK - list of criteria for selecting demonstration cases
MS16	ACED - note on the specific experimental conditions at the steel/clay material interface, parameters and modelling approaches	WP2	38 - SCK•CEN	6	ACED - note on the specific experimental conditions at the steel/clay material interface, parameters and modelling approaches with detailed information on set-ups and work flow, variables to measure and a dismantling and characterization plan. It will also define the link between the experiments and the model approaches (also input to general workshop 1, and MS31)
MS17	CORI Technical Report - Task 2 State-of-art report on organic degradation by radiolytic and hydrolytic processes	WP3	24 - KIT	6	CORI Technical Report - Task 2 State-of-art report on organic degradation by radiolytic and hydrolytic processes.
MS18	CORI Technical Report- Task 3 with (i) Final documentation of the systems to be studied and (ii) State-of-art summary on organic-cement-interactions	WP3	24 - KIT	6	CORI Technical Report- Task 3 with (i) Final documentation of the systems to be studied and (ii) State-of-art summary on organic-cement-interactions.
MS19	CORI Technical Report- Task 4 with (i) Final documentation of the systems to be studied and (ii)	WP3	24 - KIT	6	CORI Technical Report- Task 4 with (i) Final documentation of the systems to be studied and (ii) State-

Milestone number¹⁸	Milestone title	WP number⁹	Lead beneficiary	Due Date (in months)¹⁷	Means of verification
	State-of-art summary on organic-cement-interactions				of-art summary on organic-cement-interactions
MS20	GAS Task 2.2 Experimental set-ups, geometries and boundary conditions	WP6	32 - ONDRAF/NIRAS	6	GAS Task 2.2 Experimental set-ups, geometries and boundary conditions
MS21	UMAN Draft D10.5 as input to Task 2, Task 4, Task 5 and other subtasks of Task 3	WP10	3 - BEL V	6	UMAN Draft D10.5 as input to Task 2, Task 4, Task 5 and other subtasks of Task 3
MS22	UMAN Preliminary list of uncertainties from UMAN subtask 3.3 as input to Subtask 4.2	WP10	3 - BEL V	6	UMAN Preliminary list of uncertainties from UMAN subtask 3.3 as input to Subtask 4.2
MS23	UMAN Preliminary list of uncertainties from subtask 3.4 as input to Subtask 4.2	WP10	3 - BEL V	6	UMAN Preliminary list of uncertainties from subtask 3.4 as input to Subtask 4.2
MS24	UMAN Identification of the different actors across the various programme phases including a first characterization of their roles and interests (Draft D10.10)	WP10	3 - BEL V	6	UMAN Identification of the different actors across the various programme phases including a first characterization of their roles and interests (Draft D10.10)
MS25	UMAN Composition of the pluralistic stakeholder group for Seminar 1	WP10	3 - BEL V	6	UMAN Composition of the pluralistic stakeholder group for Seminar 1
MS26	SOTA from RD&D CORI WP as input to UMAN T3.2	WP10, WP3	24 - KIT	6	SOTA from RD&D CORI WP as input to UMAN T3.2
MS27	SOTA from RD&D FUTuRE WP as input to UMAN T3.3	WP10, WP5	15 - JUELICH	6	SOTA from RD&D FUTuRE WP as input to UMAN T3.3
MS28	HITEC/GAS training n°1 on multi-physical coupling in geomechanics (especially THM and Gas coupling issues)	WP6, WP7	50 - VTT	6	HITEC/GAS training n°1 on multi-physical coupling in geomechanics (especially THM and Gas coupling issues)
MS29	SOTA from RD&D SFC WP as input to UMAN T3.5	WP10, WP8	39 - SKB	6	SOTA from RD&D SFC WP as input to UMAN T3.5
MS30	EURAD General Assembly n°2	WP1, WP10,	1 - ANDRA	7	EURAD General Assembly n°2

Milestone number¹⁸	Milestone title	WP number⁹	Lead beneficiary	Due Date (in months)¹⁷	Means of verification
		WP11, WP12, WP13, WP2, WP3, WP4, WP5, WP6, WP7, WP8, WP9			
MS31	ACED Experimental data as a first input for modelling and information exchange towards other scales M1.1.2	WP2	38 - SCK•CEN	7	ACED Experimental data as a first input for modelling and information exchange towards other scales M1.1.2
MS32	ACED WP meeting 2 + Workshop 1	WP2	38 - SCK•CEN	7	ACED WP meeting 2 + Workshop 1
MS33	CORI Start of experimental RD&D programme (task 2, 3 and 4)	WP3	24 - KIT	7	CORI Start of experimental RD&D programme (task 2, 3 and 4)
MS34	DONUT WP Meeting 2	WP4	1 - ANDRA	7	DONUT WP Meeting 2
MS35	GAS WP Meeting 2	WP6	32 - ONDRAF/NIRAS	7	GAS WP Meeting 2
MS36	HITEC WP Meeting 2	WP7	50 - VTT	7	HITEC WP Meeting 2
MS37	ROUTES Workshop 1 on Radioanalytical characterisation of radioactive waste and waste with complex/toxic properties (T3.1)	WP9	19 - IRSN	7	ROUTES Workshop 1 on Radioanalytical characterisation of radioactive waste and waste with complex/toxic properties (T3.1)
MS38	ROUTES Workshop 1 on disposal options for SIMS (T5.1)	WP9	19 - IRSN	7	ROUTES Workshop 1 on disposal options for SIMS (T5.1)
MS39	ROUTES workshop on European experience in developing shared solutions for RWM	WP9	19 - IRSN	7	ROUTES workshop on European experience in developing shared solutions for RWM
MS40	UMAN Draft deliverable D10.2 as input to Tasks 4 and 5	WP10	3 - BEL V	7	UMAN Draft deliverable D10.2 as input to Tasks 4 and 5
MS41	KM Guidance - Editorial Plan for PLANMAN Delineation Year 2	WP12	42 - SÚRAO	7	KM Guidance - Editorial Plan for PLANMAN Delineation Year 2
MS42	EURAD Annual Work Plan 2	WP1, WP10,	1 - ANDRA	9	EURAD Annual Work Plan 2

Milestone number¹⁸	Milestone title	WP number⁹	Lead beneficiary	Due Date (in months)¹⁷	Means of verification
		WP11, WP12, WP13, WP2, WP3, WP4, WP5, WP6, WP7, WP8, WP9			
MS43	ACED Identification of integration and upscaling strategies M1.1.3	WP2	38 - SCK•CEN	9	ACED Identification of integration and upscaling strategies M1.1.3
MS44	GAS State-of-the-art chapter on diffusion and gas sorption in clayey materials as an input to D6.1	WP6	32 - ONDRAF/NIRAS	9	GAS State-of-the-art chapter on diffusion and gas sorption in clayey materials as an input to D6.1
MS45	GAS State-of-the-art chapter on advective gas transport in clayey materials as an input to D6.1	WP6	32 - ONDRAF/NIRAS	9	GAS State-of-the-art chapter on advective gas transport in clayey materials as an input to D6.1
MS46	GAS State-of-the-art chapter on gas-induced impacts on barrier integrity including pathway closure and sealing processes as an input to D6.1	WP6	32 - ONDRAF/NIRAS	9	GAS State-of-the-art chapter on gas-induced impacts on barrier integrity including pathway closure and sealing processes as an input to D6.1
MS47	HITEC experimental progress report	WP7	50 - VTT	9	HITEC experimental progress report
MS48	HITEC Task 2.1 and Task 2.2 Experimental test plan (Combined with MS62)	WP7	50 - VTT	9	HITEC Task 2.1 and Task 2.2 Experimental test plan (Combined with MS62)
MS49	HITEC Selection of benchmark exercises for task 2.3	WP7	50 - VTT	9	HITEC Selection of benchmark exercises for task 2.3
MS50	FUTuRE Report on set-up of experiments – Task 2.1	WP5	15 - JUELICH	10	FUTuRE Report on set-up of experiments – Task 2.1
MS51	FUTuRE Report on set-up of experiments – Task 2.2	WP5	15 - JUELICH	10	FUTuRE Report on set-up of experiments – Task 2.2

Milestone number¹⁸	Milestone title	WP number⁹	Lead beneficiary	Due Date (in months)¹⁷	Means of verification
MS52	FUTuRE Report on set-up of experiments – Task 2.3	WP5	15 - JUELICH	10	FUTuRE Report on set-up of experiments – Task 2.3
MS53	FUTuRE Report on set-up of experiments – Task 3	WP5	15 - JUELICH	10	FUTuRE Report on set-up of experiments – Task 3
MS54	UMAN Preliminary list of uncertainties from subtask 3.5 as input to Subtask 4.2	WP10	3 - BEL V	10	UMAN Preliminary list of uncertainties from subtask 3.5 as input to Subtask 4.2
MS55	ACED T3.1 - distribution of experimental samples to partners	WP2	38 - SCK•CEN	12	ACED T3.1 - distribution of experimental samples to partners
MS56	CORI First Annual WP Meeting (including technical meetings on Task level)	WP3	24 - KIT	12	CORI First Annual WP Meeting (including technical meetings on Task level)
MS57	CORI Technical Report- Task 4 (i) Radionuclide retention on CSH or CASH or AFm/AFt in the presence of organics, (ii) Radionuclide retention on HCP in the presence of organics	WP3	24 - KIT	12	CORI Technical Report- Task 4 (i) Radionuclide retention on CSH or CASH or AFm/AFt in the presence of organics, (ii) Radionuclide retention on HCP in the presence of organics.
MS58	GAS Task 3 – interim experimental design report comprising a revised detailed work programme of subtasks 3.1, 3.2 and 3.3	WP6	32 - ONDRAF/NIRAS	12	GAS Task 3 – interim experimental design report comprising a revised detailed work programme of subtasks 3.1, 3.2 and 3.3
MS59	GAS SOTA chapter on gas-induced impacts on model-based interpretation including a survey of previous research programmes and a screening of gas-related FEP lists as an input to D6.1	WP6	32 - ONDRAF/NIRAS	12	GAS State-of-the-art chapter on gas-induced impacts on model-based interpretation including a survey of previous research programmes and a screening of gas-related FEP lists as an input to D6.1
MS60	GAS SOTA chapter drawing an overview of the conceptualizations of gas migration through geological disposal systems and related processes, at the scale of a repository	WP6	32 - ONDRAF/NIRAS	12	GAS State-of-the-art chapter drawing an overview of the conceptualizations of gas migration through geological disposal systems and related processes, at the scale of a repository and how these can

Milestone number¹⁸	Milestone title	WP number⁹	Lead beneficiary	Due Date (in months)¹⁷	Means of verification
	and how these can be translated into models				be translated into models as an input to D6.1
MS61	GAS Technical Note defining a generic repository configuration, sets of parameters, conditions and relevant indicators	WP6	32 - ONDRAF/NIRAS	12	GAS Technical Note defining a generic repository configuration, sets of parameters, conditions and relevant indicators on which sub-task 4.2 will test various evaluation approaches
MS62	HITEC Task 2.1 and Task 2.2 Experimental test plan (Combined with MS48)	WP7	50 - VTT	12	HITEC Task 2.1 and Task 2.2 Experimental test plan (Combined with MS48)
MS63	HITEC Task 3.3 - Mathematical models – description of models and plan for improvements (Description of conceptual models and tools, plan for the models improvement)	WP7	50 - VTT	12	HITEC Task 3.3 - Mathematical models – description of models and plan for improvements (Description of conceptual models and tools, plan for the models improvement)
MS64	SFC Task 2.3 Characteristics of irradiated material to be characterised	WP8	24 - KIT	12	SFC Task 2.3 Characteristics of irradiated material to be characterised
MS65	ROUTES WPM2	WP9	19 - IRSN	12	ROUTES WPM2
MS66	ROUTES Workshop on Case studies on shared development and use of technologies and facilities	WP9	19 - IRSN	12	ROUTES Workshop on Case studies on shared development and use of technologies and facilities
MS67	UMAN Recommendations for future RD&D, strategic study and KM activities for the 2nd wave of EURAD-1	WP10	3 - BEL V	12	UMAN Recommendations for future RD&D, strategic study and KM activities for the 2nd wave of EURAD-1
MS68	Materials to be discussed in UMAN Seminar 1	WP10	3 - BEL V	12	Materials to be discussed in UMAN Seminar 1
MS69	UMAN Mapping of the stakes related to the outcomes of Task 2 and Subtask 3.1 from a civil society point of view for the 1st Task 5 seminar	WP10	3 - BEL V	12	UMAN Mapping of the stakes related to the outcomes of Task 2 and Subtask 3.1 from a civil society point of view for the 1st Task 5 seminar

Milestone number¹⁸	Milestone title	WP number⁹	Lead beneficiary	Due Date (in months)¹⁷	Means of verification
MS70	KM Training - School of RWM – portfolio gathering all training courses developed and implemented depending on the priorities identified and approved within the EJP; Founding of the School	WP13	38 - SCK•CEN	12	KM Training - School of Radioactive Waste Management – portfolio gathering all training courses developed and implemented depending on the priorities identified and approved within the EJP; Founding of the School
MS71	Methodology for ICS activities assessment	WP1, WP10, WP9	19 - IRSN	12	Methodology for ICS activities assessment
MS72	ACED Workshop 2 – Joint workshop with GAS and DONUT	WP2	38 - SCK•CEN	13	ACED Workshop 2 – Joint workshop with GAS and DONUT (Month 13 - 18)
MS73	FUTuRE WPM2	WP5	34 - PSI	13	FUTuRE WPM2 - Change of Lead: 34 - PSI (instead of 15. JUELICH)
MS74	UMAN WP meeting 1	WP10	3 - BEL V	13	UMAN WP meeting 1
MS75	UMAN Draft D10.3 as input to Task 3	WP10	3 - BEL V	13	UMAN Draft D10.3 as input to Task 3
MS76	UMAN Draft D10.7 as input to Task 4 and 5	WP10	3 - BEL V	13	UMAN Draft D10.7 as input to Task 4 and 5
MS77	UMAN Seminar 1	WP10	3 - BEL V	13	UMAN Seminar 1
MS78	KM SoK - Initial draft QA plan	WP11	40 - SSTC NRS	4	KM SoK - Initial draft QA plan
MS79	KM SoK - proposal to the General Assembly for future work	WP11	4 - BGE	24	KM SoK - proposal to the General Assembly for future work
MS80	KM Guidance - Editorial boards meetings for the PLANMAN delineation guides	WP12	42 - SÚRAO	13	KM Guidance - Editorial boards meetings for the PLANMAN delineation guides
MS81	EURAD General Assembly n°3 + EURAD Annual Meeting 1	WP1, WP10, WP11, WP12, WP13, WP2, WP3, WP4, WP5, WP6, WP7, WP8, WP9	1 - ANDRA	13	EURAD General Assembly n°3 + EURAD Annual Meeting 1

Milestone number¹⁸	Milestone title	WP number⁹	Lead beneficiary	Due Date (in months)¹⁷	Means of verification
MS82	ICS Workshop 1	WP1, WP10, WP9	19 - IRSN	13	ICS Workshop 1
MS83	GAS WP Meeting 3 jointly organised with the WP HITEC	WP6, WP7	32 - ONDRAF/NIRAS	13	GAS WP Meeting 3 jointly organised with the WP HITEC
MS84	HITEC WP Meeting 3 jointly organised with the WP GAS	WP6, WP7	50 - VTT	13	HITEC WP Meeting 3 jointly organised with the WP GAS
MS85	EURAD Periodic Report 1	WP1, WP10, WP11, WP12, WP13, WP2, WP3, WP4, WP5, WP6, WP7, WP8, WP9	1 - ANDRA	14	EURAD Periodic Report 1
MS86	CORI Technical Report- Task 3 (i) Organic retention on cement hydrates (AFm, AFt, CSH/ CASH), (ii) Organic retention on hardened cement pastes (HCP), (iii) Effect of iron on organic sorption in cementitious systems	WP3	24 - KIT	14	CORI Technical Report- Task 3 (i) Organic retention on cement hydrates (AFm, AFt, CSH/CASH), (ii) Organic retention on hardened cement pastes (HCP), (iii) Effect of iron on organic sorption in cementitious systems
MS87	KM SoK - updated QA procedure documents	WP11	40 - SSTC NRS	19	KM SoK - updated QA procedure documents
MS88	ROUTES up-to-date overview per country on the use of waste acceptance criteria (WAC) in Member-States, hereby focusing on the use of WAC as a tool for waste cycle management	WP9	19 - IRSN	15	ROUTES up-to-date overview per country on the use of waste acceptance criteria (WAC) in Member-States, hereby focusing on the use of WAC as a tool for waste cycle management
MS89	UMAN Compiled and reviewed information about possible management options for site and geosphere	WP10	3 - BEL V	15	UMAN Compiled and reviewed information about possible management options for site and geosphere related uncertainties as input to Subtask 4.3

Milestone number¹⁸	Milestone title	WP number⁹	Lead beneficiary	Due Date (in months)¹⁷	Means of verification
	related uncertainties as input to Subtask 4.3				
MS90	ROUTES Workshop 2 on Radioanalytical characterisation of radioactive waste and waste with complex/toxic properties (T3.1)	WP9	19 - IRSN	16	ROUTES Workshop 2 on Radioanalytical characterisation of radioactive waste and waste with complex/toxic properties (T3.1)
MS91	ROUTES Workshop 2 on disposal options for SIMS (T5.1)	WP9	19 - IRSN	16	ROUTES Workshop 2 on disposal options for SIMS (T5.1)
MS92	UMAN Preliminary list of uncertainties from subtask 3.2 as input to Subtask 4.2	WP10	3 - BEL V	16	UMAN Preliminary list of uncertainties from subtask 3.2 as input to Subtask 4.2
MS93	KM SoK - start of broad SoK implementation	WP11	4 - BGE	25	KM SoK - start of broad SoK implementation
MS94	ACED - GAS - DONUT Joint Workshop - 1	WP2, WP4, WP6	32 - ONDRAF/NIRAS	16	ACED - GAS - DONUT Joint Workshop
MS95	ACED Task 2 workshop 2	WP2	38 - SCK•CEN	18	ACED Task 2 workshop 2
MS96	ACED T4.1 - Simulation results as basis for ACED T4.2 and T4.3	WP2	38 - SCK•CEN	18	ACED T4.1 - Simulation results as basis for ACED T4.2 and T4.3
MS97	CORI Technical Report - Task 2 Hydrolytic/radiolytic degradation of organics: description of first results on hydrolytic and radiolytic organic degradation and identification of released species	WP3	24 - KIT	18	CORI Technical Report - Task 2 Hydrolytic/radiolytic degradation of organics: description of first results on hydrolytic and radiolytic organic degradation and identification of released species
MS98	CORI Technical Report- Task 4 (i) Radionuclide transport in HCP in the presence of organics, (ii) Radionuclide speciation under alkaline conditions in presence of organics	WP3	24 - KIT	18	CORI Technical Report- Task 4 (i) Radionuclide transport in HCP in the presence of organics, (ii) Radionuclide speciation under alkaline conditions in presence of organics.

Milestone number¹⁸	Milestone title	WP number⁹	Lead beneficiary	Due Date (in months)¹⁷	Means of verification
MS99	GAS - Task 2.1 Experimental progress report	WP6	32 - ONDRAF/NIRAS	18	GAS Task 2.1 Experimental progress report
MS100	GAS Task 2.2 - Experimental progress report	WP6	32 - ONDRAF/NIRAS	18	GAS Task 2.2 Experimental progress report
MS101	UMAN Draft D10.8 as input to Task 4 and 5	WP10	3 - BEL V	18	UMAN Draft D10.8 as input to Task 4 and 5
MS102	Composition of the pluralistic stakeholder group for UMAN Seminar 2	WP10	3 - BEL V	18	Composition of the pluralistic stakeholder group for UMAN Seminar 2
MS103	EURAD General Assembly n°4	WP1, WP10, WP11, WP12, WP13, WP2, WP3, WP4, WP5, WP6, WP7, WP8, WP9	1 - ANDRA	19	EURAD General Assembly n°4
MS104	ACED WP meeting 3	WP2	38 - SCK•CEN	19	ACED WP meeting 3
MS105	DONUT WP Meeting 3	WP4	1 - ANDRA	19	DONUT WP Meeting 3
MS106	GAS WP Meeting 4	WP6	32 - ONDRAF/NIRAS	19	GAS WP Meeting 4
MS107	HITEC WP Meeting 4	WP7	50 - VTT	19	HITEC WP Meeting 4
MS108	UMAN Workshop 1 on management options and preferences of different actors regarding site and geosphere related uncertainties	WP10	3 - BEL V	19	UMAN Workshop 1 on management options and preferences of different actors regarding site and geosphere related uncertainties
MS109	KM Guidance - Editorial Plan for PLANMAN Delineation Year 3	WP12	42 - SÚRAO	19	KM Guidance - Editorial Plan for PLANMAN Delineation Year 3
MS110	ROUTES Workshop 3 on Radioanalytical characterisation of radioactive waste and waste with complex/toxic properties (T3.1) +Workshop 1 on Characterization and	WP9	19 - IRSN	20	ROUTES Workshop 3 on Radioanalytical characterisation of radioactive waste and waste with complex/toxic properties (T3.1) +Workshop 1 on Characterization and

Milestone number¹⁸	Milestone title	WP number⁹	Lead beneficiary	Due Date (in months)¹⁷	Means of verification
	segregation of legacy waste (T3.2)				segregation of legacy waste (T3.2)
MS111	UMAN Draft D10.9 as input to Task 4 and 5	WP10	3 - BEL V	20	UMAN Draft D10.9 as input to Task 4 and 5
MS112	EURAD Annual Work Plan 3	WP1, WP10, WP11, WP12, WP13, WP2, WP3, WP4, WP5, WP6, WP7, WP8, WP9	1 - ANDRA	21	EURAD Annual Work Plan 3
MS113	UMAN Compiled and reviewed information about possible management options for uncertainties related to the human aspects as input to Subtask 4.3	WP10	3 - BEL V	21	UMAN Compiled and reviewed information about possible management options for uncertainties related to the human aspects as input to Subtask 4.3
MS114	DONUT Intermediate report describing numerical method improvement and their transferability in numerical tools	WP4	1 - ANDRA	22	DONUT Intermediate report describing numerical method improvement and their transferability in numerical tools
MS116	DONUT Intermediate report describing improvement and implementation of scale transition methods improvement and their application for multiscale simulations	WP4	1 - ANDRA	22	DONUT Intermediate report describing improvement and implementation of scale transition methods improvement and their application for multiscale simulations
MS117	DONUT Intermediate report describing numerical developments realized to treat uncertainty	WP4	1 - ANDRA	22	DONUT Intermediate report describing numerical developments realized to treat uncertainty
MS118	UMAN Compiled and reviewed information about possible management options for uncertainties related to spent fuel as input to Subtask 4.3	WP10	3 - BEL V	23	UMAN Compiled and reviewed information about possible management options for uncertainties related to spent fuel as input to Subtask 4.3

Milestone number¹⁸	Milestone title	WP number⁹	Lead beneficiary	Due Date (in months)¹⁷	Means of verification
MS119	ACED T4.3 - Definition of calculation cases and parameter ranges	WP2	38 - SCK•CEN	24	ACED T4.3 - Definition of calculation cases and parameter ranges
MS120	CORI Second Annual WP Meeting (including technical meetings on Task level)	WP3	24 - KIT	24	CORI Second Annual WP Meeting (including technical meetings on Task level)
MS121	CORI Technical Report - Task 2 Identification/ quantification of soluble organic species generated by degradation of organic matter	WP3	24 - KIT	24	CORI Technical Report - Task 2 Identification/ quantification of soluble organic species generated by degradation of organic matter: description and discussion of results acquired about identification of soluble species generated by radiolysis/hydrolysis.
MS122	GAS Task 2.1 Modelling progress report.	WP6	32 - ONDRAF/NIRAS	24	GAS Task 2.1 Modelling progress report
MS123	GAS Task 2.2 Modelling progress report	WP6	32 - ONDRAF/NIRAS	24	GAS Task 2.2 Modelling progress report
MS124	GAS Tasks 3.1 and 3.2 experimental progress report	WP6	32 - ONDRAF/NIRAS	24	GAS Tasks 3.1 and 3.2 experimental progress report
MS125	GAS Task 3 – Progress report describing Modelling / concepts, codes and validation workflows	WP6	32 - ONDRAF/NIRAS	24	GAS Task 3 – Progress report describing Modelling / concepts, codes and validation workflows
MS126	SFC Task 2.1 Workshop – 24	WP8	39 - SKB	24	SFC Task 2.1 Workshop – 24
MS127	ROUTES WPM3	WP9	19 - IRSN	24	ROUTES WPM3
MS128	Materials to be discussed in UMAN Seminar 2	WP10	3 - BEL V	24	Materials to be discussed in UMAN Seminar 2
MS129	Mapping of the stakes related to the outcomes of UMAN Tasks 2, 3 and 4 from a civil society point of view for the 2nd Task 5 seminar	WP10	3 - BEL V	24	Mapping of the stakes related to the outcomes of UMAN Tasks 2, 3 and 4 from a civil society point of view for the 2nd Task 5 seminar
MS130	HITEC Task 3.3 - Modelling benchmarks – description	WP4, WP7	50 - VTT	24	HITEC Task 3.3 -Modelling benchmarks – description (Description of calibration

Milestone number¹⁸	Milestone title	WP number⁹	Lead beneficiary	Due Date (in months)¹⁷	Means of verification
	(Description of calibration case, verification cases and benchmarks selected for T3.3 in cooperation with DONUT				case, verification cases and benchmarks selected for T3.3 in cooperation with DONUT
MS131	FUTuRE WPM3	WP5	34 - PSI	25	FUTuRE WPM3 - Change of Lead Beneficiary: 34. PSI (instead of 15. JUELICH)
MS132	ROUTES Workshop on waste management with/without WAC available (T4.2)	WP9	19 - IRSN	25	ROUTES Workshop on waste management with/without WAC available (T4.2)
MS133	UMAN WP meeting 2	WP10	3 - BEL V	25	UMAN WP meeting 2
MS134	UMAN Workshop 2 on management options and preferences of different actors regarding human aspects related uncertainties	WP10	3 - BEL V	25	UMAN Workshop 2 on management options and preferences of different actors regarding human aspects related uncertainties
MS135	UMAN Seminar 2	WP10	3 - BEL V	25	UMAN Seminar 2
MS136	EURAD General Assembly n°5 + EURAD Annual Meeting 2	WP1, WP10, WP11, WP12, WP13, WP2, WP3, WP4, WP5, WP6, WP7, WP8, WP9	1 - ANDRA	25	EURAD General Assembly n°5 + EURAD Annual Meeting 2
MS137	ICS Workshop 2	WP1, WP10, WP9	19 - IRSN	25	ICS Workshop 2
MS138	GAS WP Meeting 5 jointly organised with the WP HITEC	WP6, WP7	32 - ONDRAF/NIRAS	25	GAS WP Meeting 5 jointly organised with the WP HITEC
MS139	HITEC WP Meeting 5 jointly organised with the WP GAS	WP6, WP7	50 - VTT	25	HITEC WP Meeting 5 jointly organised with the WP GAS
MS140	EURAD Periodic Report 2	WP1, WP10, WP11, WP12, WP13,	1 - ANDRA	26	EURAD Periodic Report 2

Milestone number¹⁸	Milestone title	WP number⁹	Lead beneficiary	Due Date (in months)¹⁷	Means of verification
		WP2, WP3, WP4, WP5, WP6, WP7, WP8, WP9			
MS141	CORI Technical Report- Task 3 (i) Organic transport in HCP, (ii) Update on organic retention studies on cementitious materials including iron/calcium effect	WP3	24 - KIT	26	CORI Technical Report- Task 3 (i) Organic transport in HCP, (ii) Update on organic retention studies on cementitious materials including iron/calcium effect
MS142	CORI Technical Report. Update on radionuclide retention studies on cementitious materials in the presence of organics	WP3	24 - KIT	26	CORI Technical Report. Update on radionuclide retention studies on cementitious materials in the presence of organics.
MS143	UMAN Draft 10.6 as input to Task 4 and 5	WP10	3 - BEL V	26	UMAN Draft 10.6 as input to Task 4 and 5
MS144	ROUTES summary of Task 4.2 workshop outcomes on Sharing experience on waste management with/ without WAC available	WP9	19 - IRSN	28	ROUTES summary of Task 4.2 workshop outcomes on Sharing experience on waste management with/without WAC available
MS145	UMAN Compiled and reviewed information about possible management options for uncertainties related to waste inventory as input to Subtask 4.3	WP10	3 - BEL V	28	UMAN Compiled and reviewed information about possible management options for uncertainties related to waste inventory as input to Subtask 4.3
MS146	UMAN Workshop 3 on management options and preferences of different actors regarding SF-related uncertainties	WP10	3 - BEL V	28	Change of "... regarding waste inventory..." into "SF-related uncertainties" New title: UMAN Workshop 3 on management options and preferences of different actors regarding SF-related uncertainties
MS147	Composition of the pluralistic stakeholder group for UMAN Seminar	WP10	3 - BEL V	29	Composition of the pluralistic stakeholder group for UMAN Seminar

Milestone number¹⁸	Milestone title	WP number⁹	Lead beneficiary	Due Date (in months)¹⁷	Means of verification
MS148	ACED Task 2 workshop 3	WP2	38 - SCK•CEN	30	ACED Task 2 workshop 3
MS149	ACED T4.1 - Simulation results as a basis for ACED T4.2 and T4.4	WP2	38 - SCK•CEN	30	ACED T4.1 - Simulation results as a basis for ACED T4.2 and T4.4
MS150	ACED Workshop 4 – Joint workshop with GAS and DONUT	WP2	38 - SCK•CEN	30	ACED Workshop 4 – Joint workshop with GAS and DONUT (Month 30 - 37)
MS151	ROUTES Workshop predisposal routes for the disposal options for SIMS (T5.2)	WP9	19 - IRSN	30	ROUTES Workshop predisposal routes for the disposal options for SIMS (T5.2)
MS152	Last input from ROUTES to UMAN	WP10, WP9	19 - IRSN	30	Last input from ROUTES to UMAN
MS153	EURAD General Assembly n°6	WP1, WP10, WP11, WP12, WP13, WP2, WP3, WP4, WP5, WP6, WP7, WP8, WP9	1 - ANDRA	31	EURAD General Assembly n°6
MS154	ACED WP meeting 4 + Workshop 3	WP2	38 - SCK•CEN	31	ACED WP meeting 4 + Workshop 3
MS155	ACED Updated experimental data, model concepts and parameters as input for modelling and for information transfer towards other scales including update upscaling approach M1.1.4	WP2	38 - SCK•CEN	31	ACED Updated experimental data, model concepts and parameters as input for modelling and for information transfer towards other scales including update upscaling approach M1.1.4
MS156	DONUT WP Meeting 4	WP4	1 - ANDRA	31	DONUT WP Meeting 4
MS157	GAS WP Meeting 6	WP6	32 - ONDRAF/NIRAS	31	GAS WP Meeting 6
MS158	HITEC WP Meeting 6	WP7	50 - VTT	31	HITEC WP Meeting 6
MS159	UMAN Input to Task 5 on management options and preferences of different actors regarding site and	WP10	3 - BEL V	31	UMAN Input to Task 5 on management options and preferences of different actors regarding site and geosphere

Milestone number¹⁸	Milestone title	WP number⁹	Lead beneficiary	Due Date (in months)¹⁷	Means of verification
	geosphere and human aspects related uncertainties				and human aspects related uncertainties
MS160	KM Guidance - Editorial Plan for PLANMAN Delineation Year 4	WP12	42 - SÚRAO	31	KM Guidance - Editorial Plan for PLANMAN Delineation Year 4
MS161	ROUTES Workshop 2 on Characterization and segregation of legacy waste (T3.1)	WP9	19 - IRSN	32	ROUTES Workshop 2 on Characterization and segregation of legacy waste (T3.1)
MS162	EURAD Annual Work Plan 4	WP1, WP10, WP11, WP12, WP13, WP2, WP3, WP4, WP5, WP6, WP7, WP8, WP9	1 - ANDRA	33	EURAD Annual Work Plan 4
MS163	ROUTES Workshop on identification of R&D needs and opportunities of collaboration related to the management of challenging wastes (T4.3)	WP9	19 - IRSN	33	ROUTES Workshop on identification of R&D needs and opportunities of collaboration related to the management of challenging wastes (T4.3)
MS164	UMAN Workshop 4 on management options and preferences of different actors regarding SF-related uncertainties	WP10	3 - BEL V	33	Change of "... regarding SF-related uncertainties" into "waste inventory related uncertainties" New title: UMAN Workshop 4 on management options and preferences of different actors regarding waste inventory related uncertainties
MS165	ACED - GAS - DONUT Joint Workshop	WP2, WP4, WP6	32 - ONDRAF/NIRAS	33	ACED - GAS - DONUT Joint Workshop
MS166	Composition of the pluralistic stakeholder group for UMAN Seminar 4	WP10	3 - BEL V	35	Composition of the pluralistic stakeholder group for UMAN Seminar 4
MS167	ACED T3.2 - Synthesis note on concepts and effective parameters	WP2	38 - SCK•CEN	36	ACED T3.2 - Synthesis note on concepts and effective parameters for approximation

Milestone number¹⁸	Milestone title	WP number⁹	Lead beneficiary	Due Date (in months)¹⁷	Means of verification
	for approximation of chemical evolution of waste packages on disposal cell scale (input to milestone M1.1.5)				of chemical evolution of waste packages on disposal cell scale (input to milestone M1.1.5)
MS168	ACED T3.3 - Synthesis note on concepts and effective parameters for approximation of chemical evolution of waste packages on disposal cell scale (input to milestone M1.1.5)	WP2	38 - SCK•CEN	36	ACED T3.3 - Synthesis note on concepts and effective parameters for approximation of chemical evolution of waste packages on disposal cell scale (input to milestone M1.1.5)
MS169	ACED T4.2 - Demonstration of simulation results with abstracted models	WP2	38 - SCK•CEN	36	ACED T4.2 - Demonstration of simulation results with abstracted models
MS170	CORI Third Annual WP Meeting (including technical meetings on Task level)	WP3	24 - KIT	36	CORI Third Annual WP Meeting (including technical meetings on Task level)
MS171	CORI Technical Report - Task 2 Update of soluble organics species generated by degradation of organic matter: update of results on the identification of soluble organic species generated by radiolysis/hydrolysis	WP3	24 - KIT	36	CORI Technical Report - Task 2 Update of soluble organics species generated by degradation of organic matter: update of results on the identification of soluble organic species generated by radiolysis/hydrolysis
MS172	GAS Task 2.1 Experimental progress report	WP6	32 - ONDRAF/NIRAS	36	GAS Task 2.1 Experimental progress report
MS173	GAS Task 2.2 Experimental progress report	WP6	32 - ONDRAF/NIRAS	36	GAS Task 2.2 Experimental progress report
MS174	GAS Task 4.2 progress report on modelling and evaluation approaches applied to the generic repository derived from the conceptualizations of gas migration through geological disposal systems and related	WP6	32 - ONDRAF/NIRAS	36	GAS Task 4.2 progress report on modelling and evaluation approaches applied to the generic repository derived from the conceptualizations of gas migration through geological disposal systems and related processes, at the scale of a repository

Milestone number¹⁸	Milestone title	WP number⁹	Lead beneficiary	Due Date (in months)¹⁷	Means of verification
	processes, at the scale of a repository				
MS175	SFC Task 2.2 Workshop – 36	WP8	39 - SKB	36	SFC Task 2.2 Workshop – 36
MS176	ROUTES WPM4	WP9	19 - IRSN	36	ROUTES WPM4
MS177	ROUTES Workshop on the feasibility of developing further European shared solutions for waste management from cradle to grave (T6.3)	WP9	19 - IRSN	36	ROUTES Workshop on the feasibility of developing further European shared solutions for waste management from cradle to grave (T6.3)
MS178	Materials to be discussed in UMAN Seminar 3	WP10	3 - BEL V	36	Materials to be discussed in UMAN Seminar 3
MS179	Mapping of the stakes related to the outcomes of UMAN Tasks 2, 3 and 4 from a civil society point of view for the 3rd Task 5 seminar	WP10	3 - BEL V	36	Mapping of the stakes related to the outcomes of UMAN Tasks 2, 3 and 4 from a civil society point of view for the 3rd Task 5 seminar
MS180	ACED Final freeze of data and models mainly for transfer towards other scales M1.1.5	WP2	38 - SCK•CEN	37	ACED Final freeze of data and models mainly for transfer towards other scales M1.1.5
MS181	FUTuRE WPM4	WP5	34 - PSI	37	FUTuRE WPM4 - Change of Lead Beneficiary: 34. PSI (instead of 15. JUELICH)
MS182	UMAN WP meeting 3	WP10	3 - BEL V	37	UMAN WP meeting 3
MS183	UMAN Input to Task 5 on management options and preferences of different actors regarding waste inventory and SF related uncertainties	WP10	3 - BEL V	37	UMAN Input to Task 5 on management options and preferences of different actors regarding waste inventory and SF related uncertainties
MS184	UMAN Seminar 3	WP10	3 - BEL V	37	UMAN Seminar 3
MS185	EURAD General Assembly n°7 + EURAD Annual Meeting 3	WP1, WP10, WP11, WP12, WP13, WP2, WP3, WP4, WP5, WP6,	1 - ANDRA	37	EURAD General Assembly n°7 + EURAD Annual Meeting 3

Milestone number¹⁸	Milestone title	WP number⁹	Lead beneficiary	Due Date (in months)¹⁷	Means of verification
		WP7, WP8, WP9			
MS186	ICS Workshop 3	WP1, WP10, WP9	19 - IRSN	37	ICS Workshop 3
MS187	GAS WP Meeting 7 jointly organised with the WP HITEC	WP6, WP7	32 - ONDRAF/NIRAS	37	GAS WP Meeting 7 jointly organised with the WP HITEC
MS188	HITEC WP Meeting 7 jointly organised with the WP GAS	WP6, WP7	50 - VTT	37	HITEC WP Meeting 7 jointly organised with the WP GAS
MS189	EURAD Periodic Report 3	WP1, WP10, WP11, WP12, WP13, WP2, WP3, WP4, WP5, WP6, WP7, WP8, WP9	1 - ANDRA	38	EURAD Periodic Report 3
MS190	CORI Technical Report- Task 3Update on organic transport studies in HCP	WP3	24 - KIT	38	CORI Technical Report- Task 3Update on organic transport studies in HCP
MS191	CORI Technical Report. Update on radionuclide transport studies in HCP in the presence of organics.	WP3	24 - KIT	38	CORI Technical Report. Update on radionuclide transport studies in HCP in the presence of organics
MS192	ROUTES Note on identification, per country, of R&D needs with respect to the management of challenging wastes	WP9	19 - IRSN	40	ROUTES Note on identification, per country, of R&D needs with respect to the management of challenging wastes
MS193	ACED Task 2 workshop 4	WP2	38 - SCK•CEN	42	ACED Task 2 workshop 4
MS194	ACED T4.2 - Updated simulation results with abstracted models	WP2	38 - SCK•CEN	42	ACED T4.2 - Updated simulation results with abstracted models
MS195	ACED T4.3 - Simulation results and	WP2	38 - SCK•CEN	42	ACED T4.3 - Simulation results and integration towards T1.2

Milestone number¹⁸	Milestone title	WP number⁹	Lead beneficiary	Due Date (in months)¹⁷	Means of verification
	integration towards T1.2				
MS196	CORI End of experimental RD&D programme (Task 2, 3 and 4)	WP3	24 - KIT	42	CORI End of experimental RD&D programme (Task 2, 3 and 4)
MS197	Materials to be discussed in UMAN Seminar 4	WP10	3 - BEL V	42	Materials to be discussed in UMAN Seminar 4
MS198	Mapping of the stakes related to the outcomes of UMAN Tasks 2, 3 and 4 from a civil society point of view for the 4th Task 5 seminar	WP10	3 - BEL V	42	Mapping of the stakes related to the outcomes of UMAN Tasks 2, 3 and 4 from a civil society point of view for the 4th Task 5 seminar
MS199	EURAD General Assembly n°8	WP1, WP10, WP11, WP12, WP13, WP2, WP3, WP4, WP5, WP6, WP7, WP8, WP9	1 - ANDRA	43	EURAD General Assembly n°8
MS200	ACED WP meeting 5 + Workshop 6	WP2	38 - SCK•CEN	43	ACED WP meeting 5 + Workshop 6
MS201	DONUT WP Meeting 5	WP4	1 - ANDRA	43	DONUT WP Meeting 5
MS202	GAS WP Meeting 8	WP6	32 - ONDRAF/NIRAS	43	GAS WP Meeting 8
MS203	HITEC WP Meeting 8	WP7	50 - VTT	43	HITEC WP Meeting 8
MS204	UMAN Seminar 4	WP10	3 - BEL V	43	UMAN Seminar 4
MS205	KM Guidance - Editorial Plan for PLANMAN Delineation Year 5	WP12	42 - SÚRAO	43	KM Guidance - Editorial Plan for PLANMAN Delineation Year 5
MS206	EURAD Annual Work Plan 5	WP1, WP10, WP11, WP12, WP13, WP2, WP3, WP4, WP5,	1 - ANDRA	45	EURAD Annual Work Plan 5

Milestone number¹⁸	Milestone title	WP number⁹	Lead beneficiary	Due Date (in months)¹⁷	Means of verification
		WP6, WP7, WP8, WP9			
MS207	HITEC Final Workshop on Influence of temperature on clay-based material behaviour	WP7	50 - VTT	46	HITEC Final Workshop on Influence of temperature on clay-based material behaviour
MS208	Recommendations of UMAN for future RD&D, strategic study and KM activities for future EURAD implementation phase	WP10	3 - BEL V	46	Recommendations of UMAN for future RD&D, strategic study and KM activities for future EURAD implementation phase
MS209	HITEC/GAS training n°2 on multi-physical coupling in geomechanics (especially THM and Gas coupling issues)	WP6, WP7	50 - VTT	46	HITEC/GAS training n°2 on multi-physical coupling in geomechanics (especially THM and Gas coupling issues)
MS210	ACED Closure meeting	WP2	38 - SCK•CEN	48	ACED Closure meeting
MS211	CORI Fourth and Final WP Meeting (including technical meetings on Task level)	WP3	24 - KIT	48	CORI Fourth and Final WP Meeting (including technical meetings on Task level)
MS212	CORI Electronic data deposit	WP3	24 - KIT	48	CORI Electronic data deposit
MS213	CORI Conclusive Technical Meeting of Task 2 (integrated into the Fourth Annual CORI WP Meeting). Preparation of technical	WP3	24 - KIT	48	CORI Conclusive Technical Meeting of Task 2 (integrated into the Fourth Annual CORI WP Meeting). Preparation of technical
MS214	CORI Conclusive Technical Meeting on Task 3 (integrated into the Fourth Annual CORI WP Meeting). Preparation of technical Deliverable	WP3	24 - KIT	48	CORI Conclusive Technical Meeting on Task 3 (integrated into the Fourth Annual CORI WP Meeting). Preparation of technical Deliverable. (48).
MS215	FUTuRE WPM5	WP5	34 - PSI	48	FUTuRE WPM5 - Change of Lead Beneficiary: 34. PSI (instead of 24. KIT)
MS216	GAS Task 2.1 Modelling progress report	WP6	32 - ONDRAF/NIRAS	48	GAS Task 2.1 Modelling progress report

Milestone number¹⁸	Milestone title	WP number⁹	Lead beneficiary	Due Date (in months)¹⁷	Means of verification
MS217	GAS Task 2.2 Modelling progress report.	WP6	32 - ONDRAF/NIRAS	48	GAS Task 2.2 Modelling progress report
MS218	SFC Task 2.4 Workshop – 48	WP8	39 - SKB	48	SFC Task 2.4 Workshop – 48
MS219	ROUTES WPM5	WP9	19 - IRSN	48	ROUTES WPM5
MS220	GAS Chapter on pathway closure and sealing processes of the WP thematic report on barrier integrity as input to D6.8 (in common with HITEC WP)	WP6, WP7	32 - ONDRAF/NIRAS	48	GAS Chapter on pathway closure and sealing processes of the WP thematic report on barrier integrity as input to D6.8 (in common with HITEC WP)
MS221	GAS WP Meeting 9	WP6	32 - ONDRAF/NIRAS	49	GAS WP Meeting 9
MS222	EURAD General Assembly n°9 + EURAD Annual Meeting 4	WP1, WP10, WP11, WP12, WP13, WP2, WP3, WP4, WP5, WP6, WP7, WP8, WP9	1 - ANDRA	49	EURAD General Assembly n°9 + EURAD Annual Meeting 4
MS223	ICS Workshop 4	WP1, WP10, WP9	19 - IRSN	49	ICS Workshop 4
MS224	EURAD Periodic Report 4	WP1, WP10, WP11, WP12, WP13, WP2, WP3, WP4, WP5, WP6, WP7, WP8, WP9	1 - ANDRA	50	EURAD Periodic Report 4
MS225	GAS Update of the State-of-the-art chapter on diffusion and gas sorption in clayey	WP6	32 - ONDRAF/NIRAS	52	GAS Update of the State-of-the-art chapter on diffusion and gas sorption in clayey materials as an input to D6.2

Milestone number¹⁸	Milestone title	WP number⁹	Lead beneficiary	Due Date (in months)¹⁷	Means of verification
	materials as an input to D6.2				
MS226	GAS Update of the State-of-the-art chapter on advective gas transport in clayey materials as an input to D6.2	WP6	32 - ONDRAF/NIRAS	52	GAS Update of the State-of-the-art chapter on advective gas transport in clayey materials as an input to D6.2
MS227	GAS Chapter on diffusion and retention processes of the WP thematic report on gas transport mechanisms as input to D6.7	WP6	32 - ONDRAF/NIRAS	54	GAS Chapter on diffusion and retention processes of the WP thematic report on gas transport mechanisms as input to D6.7
MS228	GAS Chapter on advective gas transport of the WP thematic report on gas transport mechanisms as input to D6.7	WP6	32 - ONDRAF/NIRAS	54	GAS Chapter on advective gas transport of the WP thematic report on gas transport mechanisms as input to D6.7
MS229	GAS Chapter on gas induced impact of the WP thematic report on barrier integrity as input to D6.8	WP6	32 - ONDRAF/NIRAS	54	GAS Chapter on gas induced impact of the WP thematic report on barrier integrity as input to D6.8
MS230	GAS Chapter on model-based interpretation and synthesis of results of the WP thematic report on barrier integrity as input to D6.8	WP6	32 - ONDRAF/NIRAS	54	GAS Chapter on model-based interpretation and synthesis of results of the WP thematic report on barrier integrity as input to D6.8
MS231	GAS Update of the State-of-the-art chapter on model-based interpretation including a survey of previous research programmes and a screening of gas-related FEP lists as an input to D6.2	WP6	32 - ONDRAF/NIRAS	54	GAS Update of the State-of-the-art chapter on model-based interpretation including a survey of previous research programmes and a screening of gas-related FEP lists as an input to D6.2
MS232	GAS Chapter of the WP thematic report on conceptualisation and evaluation at repository scale	WP6	32 - ONDRAF/NIRAS	54	GAS Chapter of the WP thematic report on conceptualisation and evaluation at repository scale presenting the gas storyboards and the testing of various approaches for the evaluation of gas impact at repository scale in a performance

Milestone number¹⁸	Milestone title	WP number⁹	Lead beneficiary	Due Date (in months)¹⁷	Means of verification
					assessment context (as an input to D6.9)
MS233	GAS Update of the State-of-the-art chapter drawing an overview on the conceptualizations of gas migration through geological disposal systems and related processes, at the scale of a repository	WP6	32 - ONDRAF/NIRAS	54	GAS Update of the State-of-the-art chapter drawing an overview on the conceptualizations of gas migration through geological disposal systems and related processes, at the scale of a repository and how these can be translated into models as an input to D6.2
MS234	EURAD General Assembly n°10	WP1, WP10, WP11, WP12, WP13, WP2, WP3, WP4, WP5, WP6, WP7, WP8, WP9	1 - ANDRA	55	EURAD General Assembly n°10
MS235	ICS Workshop 5	WP1, WP10, WP9	19 - IRSN	55	ICS Workshop 5
MS236	GAS WP Meeting 10	WP6	32 - ONDRAF/NIRAS	56	GAS WP Meeting 10
MS237	GAS Workshop on “Mechanistic understanding of gas transport in clay-based materials”	WP6	32 - ONDRAF/NIRAS	56	GAS Workshop on “Mechanistic understanding of gas transport in clay-based materials”
MS238	GAS Chapter of the WP thematic report 4 on conceptualisation and evaluation at repository scale comparing modelling and evaluation approaches (as an input to D6.9)	WP6	32 - ONDRAF/NIRAS	57	GAS Chapter of the WP thematic report 4 on conceptualisation and evaluation at repository scale comparing modelling and evaluation approaches (as an input to D6.9)
MS239	ROUTES WPM6	WP9	19 - IRSN	60	ROUTES WPM6
MS240	EURAD General Assembly n°11 + EURAD Annual Meeting 5	WP1, WP10, WP11, WP12, WP13, WP2,	1 - ANDRA	60	EURAD General Assembly n°11 + EURAD Annual Meeting 5

Milestone number¹⁸	Milestone title	WP number⁹	Lead beneficiary	Due Date (in months)¹⁷	Means of verification
		WP3, WP4, WP5, WP6, WP7, WP8, WP9			
MS241	EURAD Periodic Report 5	WP1, WP10, WP11, WP12, WP13, WP2, WP3, WP4, WP5, WP6, WP7, WP8, WP9	1 - ANDRA	60	EURAD Periodic Report 5 (Due date: 60+2)
MS242	KM SoK - Specification of the EURAD KM/SoK prototype	WP11	15 - JUELICH	36	KM SoK - Specification of the EURAD KM/SoK prototype
MS243	KM SoK - Update of the SoK experts involvement	WP11	4 - BGE	32	KM SoK - Update of the SoK experts involvement
MS244	KM SoK - Feedback mechanism for Domain Insights, SoK documents and KM Systems –Methods and results	WP11	40 - SSTC NRS	36	KM SoK - Feedback mechanism for Domain Insights, SoK documents and KM Systems –Methods and results
MS245	KM SoK - Implementation status, results, lessons learned and improvements on DI and SoK document production	WP11	4 - BGE	32	KM SoK - Implementation status, results, lessons learned and improvements on DI and SoK document production
MS246	ROUTES - Kick off meeting /Task 8 meeting	WP9	28 - NCSR	25	ROUTES - Kick off meeting / Task 8 meeting
MS247	ConCorD - WP Annual meeting: Kick-off	WP15	27 - NAGRA	25	ConCorD - WP Annual meeting: Kick-off
MS248	MAGIC - WP- Kick off meeting	WP16	19 - IRSN	25	MAGIC - WP- Kick off meeting
MS249	MODATS Web pages in EURAD website	WP16	1 - ANDRA	25	MODATS Web pages in EURAD website

Milestone number¹⁸	Milestone title	WP number⁹	Lead beneficiary	Due Date (in months)¹⁷	Means of verification
MS250	MODATS - Minutes of WP Board meeting 1	WP17	50 - VTT	26	MODATS - Minutes of WP Board meeting 1
MS251	MODATS - Minutes of Task 2 Workshop 1	WP17	50 - VTT	26	MODATS - Minutes of Task 2 Workshop 1
MS252	UMAN - SOTA from the CONCORD WP as input to UMAN Subtask 3.6	WP10	16 - GRS	27	UMAN - SOTA from the CONCORD WP as input to UMAN Subtask 3.6
MS253	ConCorD - Subtask 1.2: Editorial Meeting on Drafts for SOTA	WP15	16 - GRS	27	ConCorD - Subtask 1.2: Editorial Meeting on Drafts for SOTA
MS254	ConCorD - Task 4 Meeting to finalize experimental design	WP15	27 - NAGRA	27	ConCorD - Task 4 Meeting to finalize experimental design
MS255	MAGIC - T2 – Kick off meeting	WP16	1 - ANDRA	27	MAGIC - T2 – Kick off meeting
MS256	MODATS Project Description	WP17	40 - SSTC NRS	27	MODATS Project Description
MS257	MODATS - Interaction with EURAD Knowledge Management Work Packages: Activity Plan	WP17	40 - SSTC NRS	27	MODATS - Interaction with EURAD Knowledge Management Work Packages: Activity Plan
MS258	MAGIC - T3 – Kick off meeting	WP16	34 - PSI	28	MAGIC - T3 – Kick off meeting
MS259	MAGIC - T4- Kick off meeting	WP16	15 - JUELICH	29	MAGIC - T4- Kick off meeting
MS260	ROUTES - Part 8.2.1 meeting 1	WP9	28 - NCSR	30	ROUTES - Part 8.2.1 meeting 1
MS261	UMAN - Preliminary list of uncertainties from UMAN Subtask 3.6 as input to Subtask 4.2 and questionnaire	WP10	3 - BEL V	30	UMAN - Preliminary list of uncertainties from UMAN Subtask 3.6 as input to Subtask 4.2 and questionnaire
MS262	UMAN - SOTA from the MAGIC WP as input to UMAN Subtask 3.6	WP10	8 - CNRS	30	UMAN - SOTA from the MAGIC WP as input to UMAN Subtask 3.6
MS263	ConCorD - Task 3: Experimental set-ups and test conditions coordinated	WP15	8 - CNRS	30	ConCorD - Task 3: Experimental set-ups and test conditions coordinated
MS264	ConCorD - Task 5 Revision of existing data for the selection	WP15	6 - CIEMAT	30	ConCorD - Task 5 Revision of existing data for the selection of Cu ad Fe-corrosion products (CIEMAT)

Milestone number¹⁸	Milestone title	WP number⁹	Lead beneficiary	Due Date (in months)¹⁷	Means of verification
	of Cu and Fe-corrosion products (CIEMAT)				
MS265	ConCorD - Task 5 Systems definition and expected data output	WP15	24 - KIT	30	ConCorD - Task 5 Systems definition and expected data output
MS266	MAGIC - T1- Creation of the Interactive Data Platform on Cement IDPC (support to be determined – excel file a minima)	WP16	19 - IRSN	30	MAGIC - T1- Creation of the Interactive Data Platform on Cement IDPC (support to be determined – excel file a minima)
MS267	MAGIC - T3- Initial SOTA Discussion & TOC definition	WP16	8 - CNRS	30	MAGIC - T3- Initial SOTA Discussion & TOC definition
MS268	MODATS - Description of the MODATS Reference Experiments (Final)	WP17	1 - ANDRA	30	MODATS - Description of the MODATS Reference Experiments (Final)
MS269	MAGIC - T1- Annual WP meeting n°1 + WS 2 on coordination between modellers and experimenters – Base case definition to model in the Task 4 on reference geological disposal context in Member States (end user contribution)	WP16	19 - IRSN	31	MAGIC - T1- Annual WP meeting n°1 + WS 2 on coordination between modellers and experimenters – Base case definition to model in the Task 4 on reference geological disposal context in Member States (end user contribution)
MS270	ConCorD - Task 6 Workshop to inform modellers of planned experiments and expected output	WP15	27 - NAGRA	32	ConCorD - Task 6 Workshop to inform modellers of planned experiments and expected output
MS271	MODATS - Minutes of Task 2 Workshop 2	WP17	50 - VTT	32	MODATS - Minutes of Task 2 Workshop 2
MS272	ROUTES - Part 8.1.2 meeting 1	WP9	29 - NES	33	ROUTES - Part 8.1.2 meeting 1
MS273	MAGIC - T3 – Report on the work plan and selected experimental conditions	WP16	34 - PSI	33	MAGIC - T3 – Report on the work plan and selected experimental conditions
MS274	ConCorD - Task 4 supply of samples from irradiation experiment for microbial analysis	WP15	6 - CIEMAT	36	ConCorD - Task 4 supply of samples from irradiation experiment for microbial analysis
MS275	ConCorD - Task 4 supply of samples from	WP15	42 - SÚRAO	36	ConCorD - Task 4 supply of samples from irradiation

Milestone number¹⁸	Milestone title	WP number⁹	Lead beneficiary	Due Date (in months)¹⁷	Means of verification
	irradiation experiments for microbial analysis				experiments for microbial analysis
MS276	ConCorD - Subtask 2.2: Supply of coatings samples for corrosion and irradiation tests	WP15	1 - ANDRA	36	ConCorD - Subtask 2.2: Supply of coatings samples for corrosion and irradiation tests
MS277	ConCorD - Task 5 Preliminary data delivery to modellers (KIT, GRS, CIEMAT)	WP15	24 - KIT	36	ConCorD - Task 5 Preliminary data delivery to modellers (KIT, GRS, CIEMAT)
MS278	ConCorD - WP Annual meeting: Year 1	WP15	27 - NAGRA	36	ConCorD - WP Annual meeting: Year 1
MS279	MAGIC - T4- Contribution to the modelling part in the initial SOTA	WP16	1 - ANDRA	36	MAGIC - T4- Contribution to the modelling part in the initial SOTA
MS280	MODATS - Lessons from URL Experiments	WP17	50 - VTT	36	MODATS - Lessons from URL Experiments
MS281	ROUTES - Internal memorandum with results of Part 8.1.1 for final report D 9.1E	WP9	28 - NCSR	37	ROUTES - Internal memorandum with results of Part 8.1.1 for final report D 9.1E
MS282	UMAN Draft D10.18 as input to workshop and Tasks 4 and 5	WP10	3 - BEL V	37	UMAN Draft D10.18 as input to workshop and Tasks 4 and 5
MS283	MODATS - Minutes of WP Board meeting 2	WP17	50 - VTT	37	MODATS - Minutes of WP Board meeting 2
MS284	ROUTES - Part 8.2.1 meeting 2	WP9	43 - SURO	38	ROUTES - Part 8.2.1 meeting 2
MS285	UMAN - Workshop on the significance and characterization of near-field uncertainties	WP10	3 - BEL V	39	UMAN - Workshop on the significance and characterization of near-field uncertainties
MS286	MODATS - Definition of DDM Test Cases	WP17	50 - VTT	39	MODATS - Definition of DDM Test Cases
MS287	MAGIC - T2- Experiment feedback	WP16	38 - SCK•CEN	41	MAGIC - T2- Experiment feedback
MS288	MODATS - Minutes of Task 2 Workshop 3	WP17	1 - ANDRA	41	MODATS - Minutes of Task 2 Workshop 3
MS289	ROUTES - Draft report on Evaluation of existing predisposal routes for SIMS with regard to disposal options	WP9	28 - NCSR	42	ROUTES - Draft report on Evaluation of existing predisposal routes for SIMS with regard to disposal options

Milestone number¹⁸	Milestone title	WP number⁹	Lead beneficiary	Due Date (in months)¹⁷	Means of verification
MS290	ConCorD - Subtask 2.1: Supply of ceramics samples for mechanical testing and leaching	WP15	8 - CNRS	42	ConCorD - Subtask 2.1: Supply of ceramics samples for mechanical testing and leaching
MS291	UMAN - Compiled and reviewed information about possible management options for near-field related uncertainties	WP10	3 - BEL V	43	UMAN - Compiled and reviewed information about possible management options for near-field related uncertainties
MS292	MAGIC - WP- Annual WP meeting n°2 + WS 3 on experimental data update	WP16	19 - IRSN	43	MAGIC - WP- Annual WP meeting n°2 + WS 3 on experimental data update
MS293	UMAN - Composition of the pluralistic stakeholder group for UMAN Seminar 5	WP10	3 - BEL V	44	UMAN - Composition of the pluralistic stakeholder group for UMAN Seminar 5
MS294	ROUTES - Part 8.2.2 meeting 3	WP9	28 - NCSR	45	ROUTES - Part 8.2.2 meeting 3
MS295	UMAN - WS5 - Management options and preferences of different actors regarding near-field related uncertainties	WP10	3 - BEL V	45	UMAN - WS5 - Management options and preferences of different actors regarding near-field related uncertainties
MS296	MODATS - Minutes of Task 2 Workshop 4	WP17	50 - VTT	46	MODATS - Minutes of Task 2 Workshop 4
MS297	MODATS - Development of Understanding Workflow: Activity Plan	WP17	27 - NAGRA	47	MODATS - Development of Understanding Workflow: Activity Plan
MS298	ROUTES 1st workshop: SIMS and LIMS interaction (Part 8.2.3)	WP9	29 - NES	48	ROUTES 1st workshop: SIMS and LIMS interaction (Part 8.2.3)
MS299	ConCorD - Task 5 Updated data delivery to modellers (KIT, GRS, CIEMAT)	WP15	16 - GRS	48	ConCorD - Task 5 Updated data delivery to modellers (KIT, GRS, CIEMAT)
MS300	ConCorD - WP Annual meeting: Year 2	WP15	27 - NAGRA	48	ConCorD - WP Annual meeting: Year 2
MS301	MAGIC - T1- Training materials definition.	WP16	19 - IRSN	48	MAGIC - T1- Training materials definition.
MS302	MAGIC - T1- ST1-4 – WS4 on criteria	WP16	1 - ANDRA	48	MAGIC - T1- ST1-4 – WS4 on criteria definition in the

Milestone number¹⁸	Milestone title	WP number⁹	Lead beneficiary	Due Date (in months)¹⁷	Means of verification
	definition in the ST1-4 to evaluate the level of interest and uses of the experimental data in models developments				ST1-4 to evaluate the level of interest and uses of the experimental data in models developments
MS303	MODATS - Guidance on Quality Assurance Project Plans	WP17	50 - VTT	48	MODATS - Guidance on Quality Assurance Project Plans
MS304	UMAN - WP meeting 4	WP10	3 - BEL V	49	UMAN - WP meeting 4
MS305	MODATS - Minutes of WP Board meeting 3	WP17	50 - VTT	49	MODATS - Minutes of WP Board meeting 3
MS306	ROUTES - Internal memorandum with results of Part 8.2.1 for final report D 9.22	WP9	43 - SURO	52	ROUTES - Internal memorandum with results of Part 8.2.1 for final report D 9.22
MS307	UMAN - Mapping of the stakes related to the outcome of subtasks 3.6, 4.2 & 4.3 as input to UMAN Seminar 5	WP10	3 - BEL V	52	UMAN - Mapping of the stakes related to the outcome of subtasks 3.6, 4.2 & 4.3 as input to UMAN Seminar 5
MS308	UMAN - Materials to be discussed in UMAN Seminar 5	WP10	3 - BEL V	52	UMAN - Materials to be discussed in UMAN Seminar 5
MS309	ROUTES - 2nd workshop: SIMS and LIMS interaction (Part 8.2.3)	WP9	21 - IST ID	53	ROUTES - 2nd workshop: SIMS and LIMS interaction (Part 8.2.3)
MS310	ROUTES - Draft summary report on analysis, assessment and evaluation of disposal options for SIMS (taking into account both potential disposal options and predisposal routes) including Annex: 2 case studies on typical waste pathways	WP9	28 - NCSR	53	ROUTES - Draft summary report on analysis, assessment and evaluation of disposal options for SIMS (taking into account both potential disposal options and predisposal routes) including Annex: 2 case studies on typical waste pathways
MS311	MODATS - Minutes of Task 2 Workshop 5	WP17	50 - VTT	53	MODATS - Minutes of Task 2 Workshop 5
MS312	UMAN - 5th UMAN Seminar	WP10	3 - BEL V	54	UMAN - 5th UMAN Seminar
MS313	ConCorD - Task 5 Final data delivery to modellers (KIT, GRS, CIEMAT)	WP15	6 - CIEMAT	54	ConCorD - Task 5 Final data delivery to modellers (KIT, GRS, CIEMAT)

Milestone number¹⁸	Milestone title	WP number⁹	Lead beneficiary	Due Date (in months)¹⁷	Means of verification
MS314	ConCorD - Task 6 Workshop to update modellers on final experimental results	WP15	27 - NAGRA	54	ConCorD - Task 6 Workshop to update modellers on final experimental results
MS315	MAGIC - T3- Update of TOC for final SOTA	WP16	8 - CNRS	54	MAGIC - T3- Update of TOC for final SOTA
MS316	MAGIC - T4 – Workshop on modelling results from the micro scale to the safety structure with End Users and partners	WP16	6 - CIEMAT	54	MAGIC - T4 – Workshop on modelling results from the micro scale to the safety structure with End Users and partners
MS317	MODATS - Data Management – Lessons Learned for Repository Monitoring	WP17	15 - JUELICH	54	MODATS - Data Management – Lessons Learned for Repository Monitoring
MS318	MODATS - Comparison of DDMs with PBMs	WP17	34 - PSI	54	MODATS - Comparison of DDMs with PBMs
MS319	MAGIC - WP- Annual WP meeting n°3 + WS 5 on gaps remaining + methodology to use results	WP16	19 - IRSN	55	MAGIC - WP- Annual WP meeting n°3 + WS 5 on gaps remaining + methodology to use results
MS320	ConCorD - Task 6 Modelling completed; inputs ready for PA assessment	WP15	27 - NAGRA	56	ConCorD - Task 6 Modelling completed; inputs ready for PA assessment
MS321	ConCorD - Subtask 1.2: Editorial Meeting on Drafts for SOTA update	WP15	16 - GRS	57	ConCorD - Subtask 1.2: Editorial Meeting on Drafts for SOTA update
MS322	MAGIC - T2- Contribution to the final SOTA	WP16	1 - ANDRA	57	MAGIC - T2- Contribution to the final SOTA
MS323	MAGIC - T4- Contribution to the SOTA updates with Task 4 results	WP16	15 - JUELICH	57	MAGIC - T4- Contribution to the SOTA updates with Task 4 results
MS324	MODATS - Future Needs Memo: Final	WP17	37 - RWM	57	MODATS - Future Needs Memo: Final
MS325	MODATS - Development of Understanding Workflow Memo	WP17	27 - NAGRA	57	MODATS - Development of Understanding Workflow Memo
MS326	MODATS - Synthesis of Lessons Learned	WP17	50 - VTT	57	MODATS - Synthesis of Lessons Learned on Data

Milestone number¹⁸	Milestone title	WP number⁹	Lead beneficiary	Due Date (in months)¹⁷	Means of verification
	on Data Treatment for Increased Confidence in Repository Monitoring from the MODATS Reference Experiments				Treatment for Increased Confidence in Repository Monitoring from the MODATS Reference Experiments
MS327	MODATS - Synthesis Report on Innovative and Enhanced Equipment for Repository Monitoring: Final Report	WP17	1 - ANDRA	57	MODATS - Synthesis Report on Innovative and Enhanced Equipment for Repository Monitoring: Final Report
MS328	MODATS - Task 2 Integrated Report: Data Treatment for Increased Confidence in Repository Monitoring	WP17	50 - VTT	58	MODATS - Task 2 Integrated Report: Data Treatment for Increased Confidence in Repository Monitoring
MS329	ConCorD - WP Annual meeting: Year 3	WP15	27 - NAGRA	60	ConCorD - WP Annual meeting: Year 3
MS330	MAGIC - WP- Closure meeting	WP16	19 - IRSN	60	MAGIC - WP- Closure meeting
MS331	MODATS - Minutes of WP Board meeting 4	WP17	50 - VTT	60	MODATS - Minutes of WP Board meeting 4
MS332	MODATS - Interaction of the MODATS WP with EURAD Knowledge Management Work Packages – Synthesis Report: Final Report	WP17	40 - SSTC NRS	60	MODATS - Interaction of the MODATS WP with EURAD Knowledge Management Work Packages – Synthesis Report: Final Report

1.3.5. WT5 Critical Implementation risks and mitigation actions

Risk number	Description of risk	WP Number	Proposed risk-mitigation measures
1	Risk: Poor communication, non-adherence to PMO good practice, or lack of quality control results in a negative impact to EURAD progress and timely implementation of safe radioactive waste management Risk consequence: Lack of confidence or loss of credibility in EURAD	WP1, WP10, WP11, WP12, WP13, WP15, WP16, WP17, WP2, WP3, WP4, WP5, WP6, WP7, WP8, WP9	Risk actioner: PMO Mitigation measure: PMO includes clear ToR, range of competence with individuals experienced in scientific coordination, who hold a good overview of RWM, and who represent and understand the views of different Actor perspectives
2	Risk: Lack of understanding of contractual agreements, liabilities, or roles and responsibilities between the EC, Mandated Organisations (Beneficiaries) or Linked 3rd parties results in dispute or negative impact to EURAD Risk consequence: Lack of confidence or loss of credibility in EURAD	WP1, WP10, WP11, WP12, WP13, WP15, WP16, WP17, WP2, WP3, WP4, WP5, WP6, WP7, WP8, WP9	Risk actioner: PMO Mitigation measure: Clear consortium agreement, ToR (and governance scheme) and financial reporting procedures (in accordance with good practice for procurement and financial project management)
3	Risk: Delay in getting information/data/ contributions from team (internal contributions) or inputs from Actors, interested stakeholders or expert reviewers (external contributions). Lack of support from Task contributors due to illness/holidays/competing requirements. Lack of communication and progress updates. Risk consequence: Delay to work or inefficient working	WP1, WP10, WP11, WP12, WP13, WP15, WP16, WP17, WP2, WP3, WP4, WP5, WP6, WP7, WP8, WP9	Risk actioner: WP Leaders Mitigation measure: Clear ToR and follow good practice with respect to project management and progress reporting
4	Risk: Delay in getting information/data/ contributions from team (internal contributions) or inputs from Actors, interested stakeholders or expert reviewers (external contributions). Lack of support from Task contributors due to illness/holidays/competing requirements. Lack of communication and progress updates. Risk consequence:	WP1, WP10, WP11, WP12, WP13, WP15, WP16, WP17, WP2, WP3, WP4, WP5, WP6, WP7, WP8, WP9	Risk actioner: Task Leaders Mitigation measure: Clear ToR and follow good practice with respect to project management and progress reporting

Risk number	Description of risk	WP Number	Proposed risk-mitigation measures
	Delay to work or inefficient working		
5	Risk: Mis-use of EURAD IP (data, systems, tools, documents, knowledge). Risk consequence: Potential loss of public confidence	WP1, WP10, WP11, WP12, WP13, WP15, WP16, WP17, WP2, WP3, WP4, WP5, WP6, WP7, WP8, WP9	Risk actioner: All Mitigation measure: Adherence to quality management system procedures, adopt good practice with respect to data management, quality and version control and apply industry standard security measures (for example, security marking documents appropriately if commercial in confidence and/or draft)
6	Risk: Lack of support from personnel due to illness/holiday/competing requirements Risk consequence: Delays in programme schedule	WP1, WP10, WP11, WP12, WP13, WP15, WP16, WP17, WP2, WP3, WP4, WP5, WP6, WP7, WP8, WP9	Risk actioner: All Mitigation measure: Regular dialogue across EURAD teams, including PMO, Bureau, and other boards. Management teams will promote a culture of open and transparent working and provide opportunities to obtain constructive feedback to continuously improve EURAD based on experience and community feedback.
7	Experimental risk : Failure of experimental setup or infrastructure	WP15	Risk actioner: WP leader / Tasks leader Mitigation measure : Involving high quality infrastructure and teams and planning realistic and well-designed experiments and procedures. Close collaboration and communication between laboratories to exploit overlaps in equipment/ expertise.
8	Risk: Experimental findings from Tasks 2,3, 4 and 5 are not available for integration within Task 6 by the required deadlines. Experimental findings are not suitable for integration within repository scale models	WP15	Risk actioner: All WP15 Mitigation measure: 2 workshops have been scheduled to coordinate information transfer between the tasks. This sets a deadline and gives the option to take remediate action if work is behind schedule. A close collaboration between the experimentalists and the laboratory scale modelers has already been established and will support the timely delivery of the required information. If necessary, data from literature will be sourced to fill in any gaps caused by unforeseen delays to the experimental work.
9	Risk: Development of digital twin will not be complete	WP17	Risk actioner : WP leader and Task leader (task 2) Mitigation measure: The target is to develop and evaluate the benefit of such tools for the decision-making process. The exercise will proceed with 1-2 parameters in a way to be achievable during the period. Different approaches will be followed, we cannot imagine all would fail. The development, even if it is partial, should be sufficient to draw conclusion in this project.

1.3.6. WT6 Summary of project effort in person-months

	WP1	WP2	WP3	WP4	WP5	WP6	WP7	WP8	WP9	WP10	WP11	WP12	WP13	WP14	WP15	WP16	WP17	Total Person/ Months per Participant
1 - ANDRA	100	11.80	10.40	2.50	2	15	13.70	0	6.40	9.33	3.40	0	8.64	✓	5.75	14	56	258.92
· IMT/EMSE	0	0	0	0	0	0	0	0	0	0	0	0	0		50.50	0	0	50.50
· UT3/LMDC	0	0	0	0	0	0	0	0	0	0	0	0	0		0	62.30	0	62.30
· BRGM	0	19.60	13.40	34.50	30.50	0	16.70	0	0	0	0	0	0		0	0	0	114.70
2 - ARAO	0	0	0	0	0	0	0	0	1.20	0	0	0	0		0	0	0	1.20
3 - BEL V	6	5	0	0	0	0	0	0	0.30	12.90	4	4	4		0	0	0	36.20
4 - BGE	0	0	0	0	0	3.58	13.70	0	0	6.50	50.80	0	0		0	0	0	74.58
5 - CEA	0	56	35.40	0	23	0	15	10.90	0	0	0	0	0		0	19.30	27	186.60
· EDF	0	6.50	0	9.50	0	9.50	10.50	0	0	0	0	0	0		0	0	0	36
· Orano	0	0	0	0	0	0	0	0	6.30	0	0	0	0		0	0	0	6.30
6 - CIEMAT	0	19.50	44.40	0	53	26	37	160.27	7	3.50	1.15	0	9.80		29.60	0	0	391.22
· CSIC	0	0	30	0	0	0	0	0	0	0	0	0	0		0	50.86	0	80.86
· UPC	0	0	0	0	0	19	48.50	0	0	0	0	0	0		0	0	0	67.50
· UGR	0	0	0	0	0	0	0	0	0	0	0	0	0		16	4.30	0	20.30
· IDOM	0	0	0	0	0	0	0	14.21	0	0	0	0	0		0	0	0	14.21
· UAM	0	31	0	0	0	0	6	0	0	0	0	0	0		0	0	0	37
· UPM	0	0	0	0	0	0	0	48	0	0	0	0	0		0	0	0	48
7 - ChRDI	0	0	0	0	0	0	0	4.50	0	0	0	0	0		0	0	0	4.50
· KIPT	0	0	0	0	0	0	48	0	0	0	0	0	0		71	0	0	119
· SIIGNASU	0	0	0	0	0	0	21	0	0	0	0	0	0		0	0	0	21
8 - CNRS	14	14	44	39	86	15.30	50	71.10	0	0	0	0	0		58.25	0	0	391.65
· UOrléans	0	0	16	0	0	0	0	0	0	0	0	0	0		0	0	0	16

	WP1	WP2	WP3	WP4	WP5	WP6	WP7	WP8	WP9	WP10	WP11	WP12	WP13	WP14	WP15	WP16	WP17	Total Person/ Months per Participant
· ULille	0	0	0	31	0	0	0	0	0	0	0	0	0		0	55.80	0	86.80
· ULorraine	0	6	0	0	0	50.70	33	0	0	0	0	0	0		0	0	0	89.70
· UMontpellier	0	0	0	0	0	0	0	8	0	0	0	0	0		0	0	0	8
· UGrenoble	0	0	0	0	31	39.70	0	0	0	0	0	0	0		0	0	0	70.70
· UNice	0	0	0	6	0	0	0	0	0	0	0	0	0		0	0	0	6
· UJean Monnet	0	0	0	0	0	0	0	0	0	0	0	0	0		0	0	7	7
· IMT Atlantique	0	12	0	0	0	0	0	0	0	3.50	0	0	0		3	0	0	18.50
· UPoitiers	0	0	0	0	7	35.20	0	0	0	0	0	0	0		0	0	0	42.20
9 - COVRA	0	10.50	0	0.60	0	2.75	0	0	4.40	1.50	0	0	0		0	4.25	0	24
· TU Delft	0	0	0	0	0	17.50	0	0	0	0	0	0	0		0	0	0	17.50
10 - FTMC	0	0	20	0	0	0	0	3.83	3.10	2	0	0	0		0	0	0	28.93
11 - CV REZ	0	0	12	0	0	0	0	0	0	0	0	0	0		0	12.80	31	55.80
12 - Dekom	0	0	0	0	0	0	0	0	2.40	0	0	0	0		0	0	0	2.40
13 - EEAE	0	0	0	0	0	0	0	0	3.50	0	0	0	0		0	0	0	3.50
14 - ENRESA	0	1	0	4.80	0	0	2.10	1.39	0	2.50	0	0	0		0	0	0	11.79
15 - JUELICH	0	10.80	19	17	31	0	0	0	6	0	0	0	0		24.60	8	0	116.40
· GFZ	0	0	0	0	0	0	0	0	0	0	0	0	0		0	0	27	27
· HZDR	0	0	8	14.50	48	0	0	36	0	3.30	36	0	0		0	30.80	0	176.60
· UFZ	0	29	0	27.50	0	12	0	0	0	0	0	0	0		31	36.80	35.50	171.80
16 - GRS	0	0	0	18.70	10.40	11	0	0	3.10	6.40	0	0	0		15.30	17.92	0	82.82
17 - IAE	0	0	0	0	0	0	0	0	1.10	0	0	0	0		0	0	0	1.10
18 - INCT	0	0	0	0	0	0	0	0	6	0	0	0	0		0	0	0	6
19 - IRSN	7.20	26	0	24	0	40	0	0	9.59	7.10	0	0	0		0	33.30	15.60	162.79
· MUTADIS	4.10	0	0	0	0	0	0	0	0	12.80	0	0	0		0	0	5.60	22.50

	WP1	WP2	WP3	WP4	WP5	WP6	WP7	WP8	WP9	WP10	WP11	WP12	WP13	WP14	WP15	WP16	WP17	Total Person/ Months per Participant
· MINES ParisTech	0	26	0	0	0	0	0	0	0	0	0	0	0		0	17.10	0	43.10
· NTW	13.80	0	0	0	0	0	0	0	5.90	4.90	0	0	0		0	0	0	24.60
20 - IST	0	0	0	0	0	0	0	0	4.80	0	0	0	0		0	0	0	4.80
21 - IST ID	0	0	0	0	0	0	0	0	4.80	0	0	0	0		0	0	0	4.80
22 - JSI	0	0	26.40	0	0	0	0	10.80	2.20	1.50	0	0	0		0	0	0	40.90
· ZAG	0	38	0	0	0	0	0	0	0	0	0	0	0		0	0	0	38
· EIMV	2.20	0	0	0	0	0	0	0	8.40	5.30	0	22	7.46		0	0	8	53.36
23 - JRC	15	0	0	0	0	0	0	63.48	0	0	0.20	3.50	8.23		0	0	0	90.41
24 - KIT	0	0	47.90	0	47	0	0	19.34	0	2.70	0	0	0		24	0	0	140.94
· Uni Mainz	0	0	24	0	25	0	0	0	0	0	0	0	0		0	0	0	49
· PEL	0	0	0	0	0	0	0	2.10	0	0	0	0	0		0	0	0	2.10
· AMPHOS 21	0	0	21.40	0	0	0	0	0	0	0	0	0	0		32	0	0	53.40
· Uni Potsdam	0	0	12	0	0	0	0	0	0	0	0	0	0		0	0	0	12
· BAM	0	0	0	0	0	0	0	30	0	0	0	0	0		0	0	0	30
· BGR	0	0	0	0	0	13	9	0	0	0	0	0	0		0	0	0	22
· Uni Clausthal	0	0	0	0	0	0	0	0	0	5.50	0	0	0		0	0	0	5.50
25 - LEI	0	11	0	5	0	6.50	10	7	2.30	3.70	0	0	0		0	7.30	0	52.80
26 - MTA EK	0	11	0	0	21	0	0	22	0	0	0	0	0		0	0	0	54
· SORC	0	0	0	12	0	0	0	0	0	0	0	0	0		0	0	0	12
27 - NAGRA	0	0	0	0	0	9	3.40	8.84	0	4.20	0	0	0		4	0	15	44.44
· ETH	0	0	0	0	0	0	0	0	0	0	0	0	0		0	0	28	28
· ZHAW	0	0	0	0	0	12	0	0	0	0	0	0	0		0	0	0	12
· CIMNE	0	0	0	0	0	34	0	0	0	0	0	0	0		0	0	0	34
· EPFL	0	0	0	0	0	32	0	0	0	0	0	0	0		38	0	0	70

	WP1	WP2	WP3	WP4	WP5	WP6	WP7	WP8	WP9	WP10	WP11	WP12	WP13	WP14	WP15	WP16	WP17	Total Person/ Months per Participant
· UBERN	0	54	0	0	0	0	0	0	0	0	0	0	0		0	0	0	54
· Jacobs	0	0	0	0	0	0	0	0	0	0	0	0	0		46.65	0	0	46.65
28 - NCSR	0	0	0	0	0	0	0	0	7.40	0	0	0	0		0	0	0	7.40
· DMT	0	0	0	0	0	0	0	0	11.30	0	0	0	0		0	0	0	11.30
29 - NES	0	0	0	0	0	0	0	0	5.97	0	0	0	0		0	0	0	5.97
30 - NJF	0	0	0	0	0	0	0	0	1.90	0	0	0	0		0	0	0	1.90
31 - NRG	0	0	0	5	0	0	0	0	0.30	3.80	0	0	0		0	0	0	9.10
32 - ONDRAF/ NIRAS	0	0	0	0	0	6.50	0	0	5.90	2.50	0	0	0		0	0	0	14.90
· ULiège	0	0	0	0	0	45.80	40.50	0	0	0	0	0	0		0	0	0	86.30
· EURIDICE	0	0	0	0	0	0	4.90	0	0	0	0	0	0		0	0	9.50	14.40
33 - POSIVA	0	0	0	0	0	0	2.50	0	0	0	0	0	0		0	0	14.50	17
· Envirocase	0	0	0	0	0	0	0	0	0	3	0	0	0		0	0	0	3
34 - PSI	0	18	13	18	81.95	24	0	30.10	0	5.33	0	0	0		0	23.80	28.50	242.68
· EMPA	0	0	11	0	0	0	0	0	0	0	0	0	0		0	12.80	0	23.80
35 - PURAM	0	0	0	0	0	0	0	0	0	0	0	15.30	0		0	0	0	15.30
36 - RATEN	0	0	17	0	22	0	0	0	4	8.40	0	0	0		0	0	0	51.40
37 - RWM	14	0	0	0	0	3.50	10.90	0	0	3	0	0	0		0	0	6	37.40
· UNIMAN	0	0	0	0	0	0	0	0	0	0	0	0	0		0	33.05	0	33.05
38 - SCK•CEN	0	41.50	18.30	26	12.25	31.40	0	15.54	1.30	5.40	0	0	24.75		21.60	21.30	0	219.34
39 - SKB	0	0	0	0	0	0	9	54.72	1.70	0	0	0	0		0	0	10.50	75.92
· UU	0	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0
40 - SSTC NRS	0	0	0	0	0	0	0	3.12	10.50	5	31	19	8.45		0	0	45	122.07
41 - STUBA	0	0	0	0	0	0	0	0	3.60	1.70	0	0	0		0	0	0	5.30
42 - SÚRAO	0	1.50	4.60	6.50	1	4.50	11	0	1.90	5.10	0	20.50	0		2	2.50	0	61.10

	WP1	WP2	WP3	WP4	WP5	WP6	WP7	WP8	WP9	WP10	WP11	WP12	WP13	WP14	WP15	WP16	WP17	Total Person/ Months per Participant
· CTU	0	0	40	35	0	36	54	0.44	0	0	0	0	9.03		0	15.30	0	189.77
· TUL	0	0	0	45	0	0	0	0	0	0	0	0	0		21	10.80	0	76.80
· IGN	0	0	0	64	0	0	0	0	0	0	0	0	0		0	0	0	64
· ÚJV	0	29	42	10	31	12.50	10	0	0	0	0	0	0		64	12.25	0	210.75
· CU	0	0	0	19	0	0	45	0	0	0	0	0	0		0	0	0	64
43 - SURO	0	0	0	0	0	0	0	0	10.70	3.60	0	16	15.31		0	0	0	45.61
44 - TNO	0	0	0	0	14	0	0	0	0	0	0	0	0		0	0	0	14
45 - TS Enercon	0	0	0	18.55	0	0	0	0	0.30	1.20	0	0	0		0	0	0	20.05
46 - TUS	0	0	0	4	0	0	0	16.97	4.90	5	0	0	0		0	0	0	30.87
47 - UCyprus	0	0	4	0	0	0	0	0	1.30	0	0	0	0		0	0	0	5.30
48 - UHelsinki	0	0	0	0	18	0	28	0	0	0	0	0	0		0	4.70	0	50.70
· TUT	0	0	0	20	0	0	0	0	0	0	0	0	0		0	0	0	20
· JYU	0	0	0	0	0	0	28	0	0	0	0	0	0		0	0	0	28
· GTK	0	0	0	0	0	0	6	0	0	0	0	0	0		0	0	0	6
· Aalto	0	0	0	0	0	6	0	0	0	0	0	0	0		0	0	0	6
49 - UKRI	0	0	0	0	0	93.66	77.30	0	0	0	0	0	0		0	0	0	170.96
50 - VTT	0	27	0	0	0	0	28.50	10	0	2.93	0	0	0		16.25	0	23	107.68
· GSL	0	0	0	0	0	0	0	0	8.60	2.50	0	0	0		0	0	25	36.10
51 - VUJE	0	0	0	0	0	0	0	0	2	0	0	0	0		0	0	0	2
Total Person/ Months	176.30	515.70	534.20	517.65	595.10	667.59	693.20	652.65	172.36	157.59	126.55	100.30	95.67		574.50	511.33	417.70	6508.39

1.3.7. WT7 Tentative schedule of project reviews

No project reviews indicated

1. Project number

The project number has been assigned by the Commission as the unique identifier for your project. It cannot be changed. The project number **should appear on each page of the grant agreement preparation documents (part A and part B)** to prevent errors during its handling.

2. Project acronym

Use the project acronym as given in the submitted proposal. It can generally not be changed. The same acronym **should appear on each page of the grant agreement preparation documents (part A and part B)** to prevent errors during its handling.

3. Project title

Use the title (preferably no longer than 200 characters) as indicated in the submitted proposal. Minor corrections are possible if agreed during the preparation of the grant agreement.

4. Starting date

Unless a specific (fixed) starting date is duly justified and agreed upon during the preparation of the Grant Agreement, the project will start on the first day of the month following the entry into force of the Grant Agreement (NB : entry into force = signature by the Commission). Please note that if a fixed starting date is used, you will be required to provide a written justification.

5. Duration

Insert the duration of the project in full months.

6. Call (part) identifier

The Call (part) identifier is the reference number given in the call or part of the call you were addressing, as indicated in the publication of the call in the Official Journal of the European Union. You have to use the identifier given by the Commission in the letter inviting to prepare the grant agreement.

7. Abstract

8. Project Entry Month

The month at which the participant joined the consortium, month 1 marking the start date of the project, and all other start dates being relative to this start date.

9. Work Package number

Work package number: WP1, WP2, WP3, ..., WPn

10. Lead beneficiary

This must be one of the beneficiaries in the grant (not a third party) - Number of the beneficiary leading the work in this work package

11. Person-months per work package

The total number of person-months allocated to each work package.

12. Start month

Relative start date for the work in the specific work packages, month 1 marking the start date of the project, and all other start dates being relative to this start date.

13. End month

Relative end date, month 1 marking the start date of the project, and all end dates being relative to this start date.

14. Deliverable number

Deliverable numbers: D1 - Dn

15. Type

Please indicate the type of the deliverable using one of the following codes:

R	Document, report
DEM	Demonstrator, pilot, prototype
DEC	Websites, patent filings, videos, etc.
OTHER	
ETHICS	Ethics requirement
ORDP	Open Research Data Pilot
DATA	data sets, microdata, etc.

16. Dissemination level

Please indicate the dissemination level using one of the following codes:

- PU Public
- CO Confidential, only for members of the consortium (including the Commission Services)
- EU-RES Classified Information: RESTREINT UE (Commission Decision 2005/444/EC)
- EU-CON Classified Information: CONFIDENTIEL UE (Commission Decision 2005/444/EC)
- EU-SEC Classified Information: SECRET UE (Commission Decision 2005/444/EC)

17. Delivery date for Deliverable

Month in which the deliverables will be available, month 1 marking the start date of the project, and all delivery dates being relative to this start date.

18. Milestone number

Milestone number: MS1, MS2, ..., MSn

19. Review number

Review number: RV1, RV2, ..., RVn

20. Installation Number

Number progressively the installations of a same infrastructure. An installation is a part of an infrastructure that could be used independently from the rest.

21. Installation country

Code of the country where the installation is located or IO if the access provider (the beneficiary or linked third party) is an international organization, an ERIC or a similar legal entity.

22. Type of access

- TA-uc if trans-national access with access costs declared on the basis of unit cost,
- TA-ac if trans-national access with access costs declared as actual costs, and
- TA-cb if trans-national access with access costs declared as a combination of actual costs and costs on the basis of unit cost,
- VA-uc if virtual access with access costs declared on the basis of unit cost,
- VA-ac if virtual access with access costs declared as actual costs, and
- VA-cb if virtual access with access costs declared as a combination of actual costs and costs on the basis of unit cost.

23. Access costs

Cost of the access provided under the project. For virtual access fill only the second column. For trans-national access fill one of the two columns or both according to the way access costs are declared. Trans-national access costs on the basis of unit cost will result from the unit cost by the quantity of access to be provided.

Table of history of changes from proposal

Annex 1 - Part A

[illegible]

List of milestones and deliverables updated accordingly to modifications in WP7 HITEC: 2 milestones merged into 1 milestone (MS48 and MS62) Change of Lead Beneficiary for D7.6: Andra instead of CNRS	WP7	March 2021
Summary of project effort in person-months revised to take into account the changes fixed into personnel costs due to the integration of subcontractings: WP4 DONUT - TS ENERCON (Beneficiary 45): -1,45 PM WP6 GAS - UKRI (Beneficiary 49): -14,11 PM WP7 HITEC - UKRI (Beneficiary 49): -7,50 PM	WP4 WP6 WP7	March 2021
Changes to integrate activities for Knowledge Management and Programme Management Office work packages for years 3, 4 and 5 : - Description of work (WP11 /12 and 13) - List of deliverables (WP11 /12 and 13) - List of Milestones (WP11) - Summary of project effort in person-months WP 1 PMO : + 6 PM Bel V (Beneficiary 3) – Bureau + 6,5 PM CNRS – IMT Atlantique (Beneficiary 8) – PMO + 4,2 PM IRSN (Beneficiary 19) – PMO + 3,10 PM IRSN – NTW (Beneficiary 19) – Involvement in MODAT’s WP + 6,5 PM RWM (Beneficiary 37) – PMO WP11 State-of-Knowledge : +51,8 PM WP12 Guidance : + 36 PM WP13 Training and Mobility : + 36,92 PM and integration of a line for mobility actions (+220 257,80 € secured under WP13 leader’s budget (SCK CEN))	WP 1 WP11 WP12 WP13	April 2021
Changes to integrate second wave workpackages : Update of WP description, PMs per partner, new deliverables, new milestones for ROUTES and UMAN to integrate the extensions WP9 Routes Extension: +25,06 PM WP10 UMAN Extension: +23,59 PM Creation of new work packages : WP Description, PMs per partner, deliverables, milestones, risks for WP15 ConCorD, WP16 MAGIC and WP17 MODATS	WP9 WP10 WP15 WP16 WP17	April 2021

Annex 1 - Part B

Page	Description of the change	Date
pp. 7-8	Section 1.2 has been revised with extended information about Key Performance Indicators and Risk Register.	26/04/2019
p.15	Section 1.4.4 has been revised to indicate that strong synergies with IAEA and any other international organisations shall be established for joint development and implementation of actions related to Knowledge Management and Strategic Studies with subsequent Memorandum of Understanding.	26/04/2019

p.6, 15, 41 and 42	Section 1.1.4, section 1.4.4 and section 3.2 have been revised in order to clarify the definition and role of the CS group and the CS experts and the procedures and criteria for selection of representatives from the CSOs should be defined.	03/05/2019
p.22	Section 3 (introduction), it is now specified that specific attention/emphasis on Strategic Studies shall be paid for the second wave.	26/04/2019
p.42	Section 3.2 has been revised to reinforce the strong scientific/technical leader with recognized high level contribution in the field of radioactive waste management.	26/04/2019
p.46	Section 3.4.2 – it has been clarified that the distribution of EC contribution between the different types of activities shall not be capped. It can be subject to modification after approval by the General Assembly	26/04/2019
p.3	Section 1, reference to EURAD Sciences network added p.3	08/03/2019
p.14	Section 1.4.3 has been revised to clarify that the IAEA phases plus the added phase 0 used in the Roadmap are of a general nature and are each applicable to several waste streams and waste types.	08/03/2019
pp.15-16	Section 1.4.4 has been revised: - To mention that SOTA reports will be completed in-line with international good practice (incl. communication of the existing knowledge gaps in the context of safety). This will be done in a general or generic way, without direct reference to specific safety assessments, safety cases or national programmes. - To remove reference to KM platform (recommendation 17) - To revise Interaction with Civil Society in RD&D WPs	08/03/2019
p.19	Section 2.2.1: reference to KM platform removed (recommendation 17)	08/03/2019
pp.22-28	Section 3: has been complemented with statements that explain in a concise manner ‘what’ and ‘why’ paragraphs for each of the RD&D and SS WPs and to explicitly demonstrate the link with EURAD Roadmap/SRA. It has also been revised to take into account the modification in the interactions with CS.	08/03/2019
p.28	Sections 3.1.d has been revised to address recommendation n°20	08/03/2019
p.35	Section 3.1.2 has been revised. The figure 9: Timing of WP5-FUTuRE has been changed to take into account the correct start date: Month 25 (instead o Month 13) for the task 1.3	18/09/2020
p.42	Section 3.2 has been revised to indicate that regulators’ representatives (through WENRA, ENSREG) will be invited to join the EAB, to address recommendation n°24	08/03/2019

p. 48-59-	In Section 3.4.4 the repartition of the other direct costs have been added/modified for some beneficiaries - Andra: due to the sum of the costs for “travel”, “equipment”, “other goods and services” which exceeded 15% of its personnel costs. - NRG: 19 000 € have been deducted under other direct costs due to its withdrawal from ACED WP - For SCK-CEN: 19 700 € have been added in other goods and services due to NRG withdrawal from ACED WP - For SÚRAO: 2 000 € have been deducted in other goods and services due to UJV withdrawal from Task 4 of ACED WP	18/09/2020
p. 59	Section 3.4.5 the detailed allocated budget per WP and per Participant has been revised to take into account: - NRG withdrawal from ACED WP and UJV (Linked Third Party of SURAO) from task 4 of ACED WP and the reallocation of the activities to the other partners - Typo error for ENRESA PM efforts under SFC WP has been corrected (1,39 PM instead of 2,39 PM)	18/09/2020
p. 202	Section 4.1 have been revised to take into account NRG withdrawal from ACED WP	18/09/2020
p. 233	Section 4.1 have been revised to take into account UJV (Linked Third Party of SURAO) withdrawal from task 4 of ACED WP	18/09/2020
p. 296	Section 4.2 has been revised to take into account the change of the status of UU (initially linked third party of SKB): Uppsala University (UU) will provide contributions to EURAD against payment, as third party to SKB. The in-kind contributions will not be used on SKB’s premises.	18/09/2020
pp. 297-298	Section 4.2 has been revised to take into account UJV (Linked Third Party of SURAO) withdrawal from task 4 of ACED WP	18/09/2020
pp31-56	Section 3.1 has been revised to include second wave workpackages and their process of selection and development 3.1.1 addition of description of new RD&D WPs and implication of civil society in WPs (3.1.1 b / 3.1.1 c / 3.1.1 e), and addition of paragraph explaining the selection and development process of the second wave 3.1.2 Timing : Workpackages PMO, ROUTES and UMAN Gantt updated to include the second wave work Addition of 3 new Gantt for WP ConCorD, MAGIC and MODATS Modification of the Trame Gantt for WP 11 (SoK), WP12 (Guidance), WP13 (Training/Mobility) to take into account the deployment of the activities for year 3, 4, 5	April 2021
p57	The figure presenting the governance in section 3.2 has been updated to include 2 nd wave WPs	April 2021
pp64-	Section 3.4 :	April 2021

119	3.4.3 The graph of distribution allocated budget between the different type of eligible costs has been updated to include 2nd wave WPs costs Section 3.4.4 has been revised to include costs linked to the second wave work-packages 3.4.5 Detailed allocated budget per WP and per participant updated to include all changes listed in this table 3.4.6 Update of the table of not allocated budget (secured under Coordinator budget)	
pp120-313	Section 4.1 has been revised to include missing information in “Description of main tasks in EURAD-1” for the following Beneficiaries: TS ENERCON in WP10 UMAN UKRI in WP7 HITEC	March 2021
pp314-373	Section 4.2 has been revised to include subcontractor(s) for the following Beneficiaries: TS ENERCON in WP4 DONUT (Task 4) UKRI in WP6 GAS (Task 2) UKRI in WP7 HITEC (Task 2)	March 2021
pp120-313	Section 4.1 has been changed to include information related to the second wave workpackages in “Description of main tasks in EURAD-1” for the following Beneficiaries : Andra, Bel V, BGE, CEA, CIEMAT, ChRDI, CNRS-Subatech, COVRA, CVREZ, Dekom, EEAE, Juelich, GRS, INCT, IRSN, IST-LPSR, IST-ID, JS, KIT, LEI, NAGRA, NCSRD, NES, NJF, ONDRAF/NIRAS, POSIVA, PSI, RATEN, RWM, SCK-CEN, SSTC, SKB, STUBA, SURAO, SURO, TUS, UCY, UH and VTT	April 2021
pp314-373	Section 4.2 has been changed to include information related to the second wave workpackages for the following Beneficiaries : Addition of subcontractors : ANDRA, NAGRA, NCSRD, POSIVA and SKB. Addition of a new LTP: ANDRA, CIEMAT, CNRS, Juelich, NAGRA and RWM Addition of an in-kind contribution : ANDRA Addition of International Partners : NAGRA Addition of tasks to existing LTPs: CIEMAT, ChRDI, CNRS, Juelich, IRSN, JS, KIT, NAGRA, NCSRD, PSI, SURAO and VTT	April 2021

Annex 2 – Changes in the Estimated budget

In the Amendment 847593-27:

WP2 – ACED:

The Dutch Waste Management Organisation COVRA and NRG both intended to contribute to the Work Package ACED in EURAD. However, when comparing the final EURAD proposal to the Dutch programme, it became clear that two Dutch contributions in one work package was not balancing well with the Dutch programme. It was decided that COVRA would focus on ACED and ROUTES, while NRG focusses on DONUT and UMAN, i.e. NRG has withdrawn from ACED.

Also, UJV is not able to contribute to Task 4 or being the subtask responsible for Task 2.2. IRSN becomes the subtask responsible for Task 2.1 and BEL-V of Task 2.2. There is no co-task leader for Task 2 anymore.

Overview of the modifications due to these changes in contribution:

Task 2

Change in sub-task responsible organizations:

The contribution of NRG in task 2.1 will be performed by SCK CEN.

The contribution of NRG in task 2.2 will be performed by Mines ParisTech.

Task 3

Subtask responsible for Task 3.3: UFZ (instead of NRG)

The contribution of NRG in Task 3.3 on waste package scale modelling will be performed by UFZ and SCK CEN

Task 4

The contribution of UJV in task 4.1 will be performed by UFZ.

The contribution of NRG in task 4.1 will be performed by UFZ and Mines ParisTech.

The contributions of NRG in task 4.2 will be performed by UFZ and Mines ParisTech.

WP	Organisation	Direct costs						Estimated Costs costs of in-kind contributions not used on premises
		Personnel costs	Travel	Other goods and services	Equipment	Large research infrastructure	TOTAL	
WP2 ACED	3. BEL V	+10 700,00					+10 700,00	
WP2 ACED	15. JUELICH - UFZ	+117 800,00					+117 800,00	
WP2 ACED	19. IRSN - Mines ParisTech	+28 000,00					+28 000,00	
WP2 ACED	31. NRG	-220 000,00	-11 000,00	-8 000,00			-239 000,00	
WP2 ACED	38. SCK-CEN	+92 800,00		+19 700,00			+112 500,00	
WP2 ACED	42. SÚRAO - ÚJV	-28 000,00		-2 000,00			-30 000,00	
TOTAL		+1 300,00	-11 000,00	+ 9 700,00			0,00	

WP8 - SFC:

Change of the status of UU (SKB's LTP) from linked third party into in-kind contribution against payment.

WP	Organisation	Total direct costs costs					Indirect costs	TOTAL	Estimated Costs of in-kind contributions not used on premises
		Personnel costs	Travel	Other goods and services	Equipment	Large research infrastructure			
WP8 SFC	39. SKB	+341 041,75	+21 250,00	+25 000,00			0	+387 291,75	+387 291,75
WP8 SFC	- UU	-272 833,40	-17 000,00	-20 000,00			-77 458,35	-387 291,75	

In the Amendment 847593-35 :

Integration of subcontractings for TS ENERCON (Beneficiary 45) and UKRI (Beneficiary 49):

		Total direct costs costs						Subcontracting
WP	Organisation	Personnel costs	Travel	Other goods and services	Equipment	Large research infrastructure	TOTAL	
WP4 DONUT	45. TS ENERCON	- 5 496,00					-5 496,00	+6 870,00
WP6 GAS	49. UKRI-BGS	-61 065,00					-61 065,60	+76 332,00
WP7 HITEC	49. UKRI-BGS	-30 532,80					-30 532,80	+38 166,00

Integration of activities for years 3, 4 and 5 for PMO and KM work packages

		Total direct costs costs						Subcontracting
WP	Organisation	Personnel costs	Travel	Other goods and services	Equipment	Large research infrastructure	TOTAL	
WP1 PMO	1- Andra							+518 377,50
	3. Bel V	+ 42 000,00					+ 42 000,00	
	8- CNRS (IMT Atlantique)	+ 91 000,00					+91 000,00	

	19 – IRSN	+42 000,00					+42 000,00	
	19- IRSN (NTW)	+ 26 815,00	+5 000,00				+ 31 815,00	
	37- RWM	+ 46 644,00					+46 644,00	
TOTAL		+248 459,00	+5 000,00				+253 459,00	+518 377,50
WP11 SoK	1-Andra	+ 4 000,00					+4 000,00	
	3-Bel V	+ 28 000,00					+28 000,00	
	4- BGE	+262 128,00					+262 128,00	
	6- CIEMAT	+ 1 775,60					+1 775,60	
	15- JUELICH (HZDR)	+92 400,00					+ 92 400,00	
	23- JRC	+ 2 084,80					+2 084,80	
	40- SSTC NRS	+18 900,00					+18 900,00	
TOTAL		+409 288,40					+409 288,40	
WP12 Guidance	3- Bel V	+28 000,00					+28 000,00	
	22- JSI (EIMV)	+63 600,00					+63 600,00	
	35- PURAM	+12 000,00					+12 000,00	
	42- SURAO	+18 000,00					+18 000,00	
	40- SSTC	+18 900,00					+18 900,00	
	43- SURO	+24 600,00					+24 600,00	
TOTAL		+165 100,00					+165 100,00	
WP 13 Training and Mobility	1-Andra	+33 900,00					+33 900,00	
	3- Bel V	+28 000,00					+28 000,00	
	6- CIEMAT	+15 758,45					+15 758,45	
	23- JRC	+25 593,60					+25 593,60	

	22- JSI (EIMV)	+13 038,00					+13 038,00	
	42- SURAO (CTU)	+10 335,90					+10 335,90	
	38- SCK-CEN	+113 675,25					+113 675,25	
	40- SSTC	+ 5 670,00					+5 670,00	
	43- SURO	+21 771,00					+21 771,00	
	TOTAL	+267 742,20					+267 742,20	

Integration of costs for Strategic Studies extension (second wave)

WP	Organisation	Total direct costs costs						Subcontracting
		Personnel costs	Travel	Other goods and services	Equipment	Large research infrastructure	TOTAL	
WP9 ROUTES	1-Andra	+ 10 000,00	+1 400,00				+11 400,00	
	6- CIEMAT	+ 1 760,00	+1 400,00				+3 160,00	
	9- COVRA	+5 120,00	+1 400,00				+6 520,00	
	12- Dekom	+3 480,00	+1 400,00				+4 880,00	
	13- EEAE	+1 600,00	+1 400,00				+3 000,00	
	16- GRS	+ 7 690,10	+1 400,00				+9 090,10	
	18- INCT	+1 200,00	+1 400,00				+2 600,00	
	19- IRSN	+4 875,00	+1 400,00				+6 275,00	
	19- IRSN (NTW)	+8 000,00	+1 400,00				+9 400,00	

	21- IST-ID	+2 200,00	+1 400,00	+1 700,00			+5 300,00	
	20-IST	+2 760,00	+1 400,00				+4 160,00	
	22-JSI	+5 075,00	+1 400,00				+6 475,00	
	22-JSI (EIMV)	+8 000,00	+1 400,00				+9 400,00	
	25- LEI	+2 000,00	+1 400,00				+3 400,00	
	28- NCSRD	+11 250,00	+1 400,00				+12 650,00	
	28- NCSRD (DMT)	+40 330,00	+1 400,00				+41 730,00	
	29-NES	+11 260,15	+1 400,00	+1 660,00			+14 320,15	
	30- NJF	+857,08	+1 400,00				+2 257,08	
	32- ONDRAF/NIRAS	+6 164,40	+1 400,00				+7 564,40	
	36- RATEN	+2 200,00	+1 400,00				+ 3 600,00	
	40- STTC NRS	+3 150,00	+1 400,00				+4 550,00	+3 625,00
	41- STUBA	+1 480,00	+1 400,00				+2 880,00	
	43- SURO	+16 400,00	+1 400,00				+17 800,00	
	47- UCY	+2 513,60	+1 400,00				+3 913,60	
	50- VTT (GSL)	+13 750,00	+1 400,00				+15 150,00	
TOTAL		+173 115,33	+35 000,00	+3 320,00			+211 435,33	+3 625,00
WP10 UMAN	1-Andra	+12 870,00	+3 500,00				+16 370,00	
	3-Bel V	+20 330,00	+ 3 625,00	+2 000,00			+25 955,00	
	4-BGE	+8 890,00	+1 875,00				+10 765,00	
	16-GRS	+19 254,90	+3 500,00				+22 754,90	
	19-IRSN	+12 748,80	+3 500,00				+16 248,80	
	19-IRSN (MUTADIS)	+26 600,00	+3 500,00	+2 000,00			+32 100,00	

	19-IRSN (NTW)	+17 000,00	+3 500,00				+20 500,00	
	24- KIT	+ 1 600,00	+625,00				+2 225,00	
	25- LEI	+1 000,00	+625,00				+1 625,00	
	27- NAGRA	+11 200,00	+1 875,00				+13 075,00	
	32- ONDRAF/NIRAS	+3 082,20	+625,00				+3 707,20	
	34- PSI	+48 326,94	+5 500,00				+53 826,94	
	36- RATEN	+2 420,00	+3 500,00				+5 920,00	
	42- SURAO	+4 720,00	+3 500,00				+8 220,00	
	38- SCK-CEN	+16 322,60	+3 500,00				+19 822,60	
	40- SSTC NRS	+420,00	+625,00				+1 045,00	
	41- STUBA	+740,00	+625,00				+1 365,00	
	43- SURO	+2 460,00	+3 500,00	+5 000,00			+10 960,00	
	46-TUS	+970,00	+625,00				+1 595,00	
	50-VTT	+12 155,00	+3 500,00				+15 625,00	
	TOTAL	+223 110,44	+51 625,00	+9 000,00			+283 735,44	

Integration of second wave workpackages (see 3.4.5 – Detailed allocated budget per Wp and per participant)

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1. Excellence

Following decades of research, development and demonstration (RD&D) in support of the safe management and disposal of radioactive waste, and building on the preparatory work of the recent EC JOPRAD project, a European Joint Programme on Radioactive Waste Management (EURAD) is now proposed to coordinate activities on agreed priorities of common interest between European Waste Management Organisations (WMOs), Technical Support Organisations (TSOs) and Research Entities (REs).

Such Joint Programming will complement National RD&D Programmes, by jointly establishing and carrying out activities jointly where there is added value at the European level. It is the logical next step in deepening collaboration between European actors in the field of radioactive waste management (RWM). It builds on existing and emerging networks of European actors (IGD-TP, SITEX and EuradSciences), preceding coordination and support actions (in particular, SecIGD2, SITEX-II project and JOPRAD).

The vision of the European Joint Programme on Radioactive Waste Management (EURAD) is to achieve:

“A step change in European collaboration towards safe radioactive waste management (RWM), including disposal, through the development of a robust and sustained science, technology and knowledge management programme that supports timely implementation of RWM activities and serves to foster mutual understanding and trust between Joint Programme participants”.

By step-change we mean the next step in deepening of research-cooperation between Member-States with long lasting impacts, and with a significantly more effective and efficient public RD&D funding in Europe.

We will implement a Joint Programme of strategic research and knowledge management activities at the European level, bringing together and complementing national EU Member State programmes of various magnitudes and at various states of advancement in order to ensure cutting edge knowledge creation and preservation in view of delivering safe, sustainable and socially acceptable solutions for the management of radioactive waste across Europe now and in the future.

1.1.Objectives

The Joint Programme will generate and manage knowledge to support EU Member-States with their implementation of the Directive 2011/70/Euratom ([Waste Directive](#)), taking into account the different magnitudes and stages of advancement of member state National Programmes. This will encompass:

- Supporting Member-States in developing and implementing their national RD&D programmes for the safe long-term management of their full range of different types of radioactive waste through participation in the RWM Joint Programme; in particular:
- Consolidating existing knowledge for the safe start of operation of the first geological disposal facilities for spent fuel, high-level waste, and other long-lived radioactive waste, and supporting optimization linked with the stepwise implementation of geological disposal; and
- Enhancing knowledge management and transfer between organisations, Member-States and generations.

From this, these high-level objectives, the Joint Programme has established the following specific objectives:

- a) Develop, maintain and consolidate the scientific and technical basis of safe radioactive waste management;
- b) Address important and complex issues and enable expert networking;
- c) Enhance knowledge management and transfer between organisations, Member-States and generations; and
- d) Engage with Civil Society.

These are each described further below.

1.1.1. Develop, maintain and consolidate the scientific and technical basis of radioactive waste management

The research, development and demonstration (RD&D) carried out in support of safe radioactive waste management (RWM), including disposal, is considered a key component of each National Programme. Given the long timescales and socio-political dimension, RD&D provides primarily the scientific basis for implementing safe RWM solutions, whilst also contributing to building stakeholder trust, public acceptance, and training for next generations of experts.

EURAD consists of collaboratively developing, maintaining and consolidating at the European level the scientific and technical basis of RWM, including disposal.

The scope of EURAD includes scientific and technical activities on RWM from cradle to grave:

- Radioactive waste characterisation and processing (incl. treatment, conditioning and packaging);
- Interim storage of radioactive waste; and
- Disposal solutions – Mainly geological disposal of spent fuel, high-level waste (HLW) and long-lived intermediate level waste (ILW).

Specific RD&D required for near-surface or surface disposal and low-level waste (LLW), will be addressed, and is encompassed within the RD&D needs identified for waste characterisation and processing, interim storage and geological disposal of radioactive waste. Nuclear facility dismantling and decommissioning activities are however excluded, although interfaces, and particularly aspects that impacts final disposal will be considered.

EURAD scope is organised at a strategic level by 7 scientific themes. Each theme is further split into a list of topics and sub-topics (mostly collaborative RD&D, and relevant strategic studies or knowledge management activities), that in-part, or in-full, contribute to the overall European effort to address remaining challenges of RWM, including disposal.

The Joint Programme implements in a collaborative way those aspects of RD&D activities required within national research RWM programmes as well as associated activities where synergy at European level has been identified. The prioritised scope identified is described more fully in the Strategic Research Agenda and will support achievement of the EURAD Vision.

1.1.2. Address important and complex issues and enable expert networking

Complementary to RD&D and in support to the implementation of the Member-States' National Programmes, the Joint Programme shall give the opportunity to participants and expert contributors to network on methodological and strategic issues and challenges that are common to various National Programmes and in direct links with scientific and technical issues:

- Share knowledge and discuss common methodological and strategical challenging issues (strategic studies) that are in close link with scientific, technical and societal aspects on RWM and that are common to various National Programmes;
- Identify the contribution of past and on-going RD&D projects to the resolution of these issues;
- Identify any emerging topics for collaboration that could be addressed within the Joint Programme;
- Take into account emerging science and technology as well as research priorities originating from other programmes (for example results from Horizon 2020 projects or IAEA outputs).

1.1.3. Enhance knowledge management and transfer between organisations, Member-States and generations

It is essential to implement an efficient and integrated Knowledge Management programme at EU level in order to establish, capitalize and transfer the state of scientific and technical knowledge in the field of RWM. Objectives are to:

- Preservation/capitalisation of generated knowledge - Make sure that the publicly financed knowledge generated over the past, ongoing and future RD&D activities is preserved and made accessible.
- Transfer of knowledge towards Member-States with early-stage RWM programmes - Make sure that Member-States with National Programmes at an early-stage of implementation can take advantage of existing knowledge and know-how from the Member-States with advanced National Programmes, primarily to access state of the art, and second to ease access to knowledge developed during previous EC supported RD&D projects.
- Transfer of knowledge between generations - Ensure that the necessary expertise and skills are maintained through generations of experts in view of the long lead-times and operational time-spans (several decades) for RWM, including disposal, by providing training and mobility for researchers.
- Dissemination of knowledge – Disseminate and demonstrate progress, results and added-value of the European Joint Programme to a wider audience.

1.1.4. Engage with Civil Society

The successful implementation of RWM National Programmes relies on both scientific and technical aspects for a sound safety strategy and scientific and engineering excellence and societal (social, legal, ethical, political) aspects.

Civil Society Organisations (CSOs) are not research organisations but have a specific concern on RWM safety and are involved in the perspective of the implementation of the UNECE Aarhus Convention which reinforces the requirements of access to information, public participation in decision-making and access to justice in environmental matters. European programmes therefore undertake work to address these requirements through local and national stakeholder engagement activities to enable Civil Society (representative organisations, e.g. Non-Government Organizations, Local Community Partnerships, etc.) to participate in defining their national RD&D programmes and the evaluation of RD&D results in the perspective of safety.

Interacting with Civil Society is important in this perspective and therefore one objective of the Joint Programme is to allow interactions between WMOs, TSOs, Res and Civil Society Organisations. These interactions will facilitate the translation of scientific/technical results and create the conditions for Civil Society Organisations to express their expectations or views. Such interactions shall improve the mutual understanding on the RD&D needed to develop safe acceptable solutions in the processing and disposal of radioactive waste. It shall also contribute to developing ideas, propositions and methodologies on how to interact with Civil Society on scientific and technical results, how to deal with uncertainties (inherently linked to the long timeframes and numerous processes considered for geological disposal), and on how to interact with Civil Society stakeholders in order to promote mutual benefit of the available knowledge, based on cooperation and sharing.

1.2.Evaluation of objectives

Section 6.2 of the Founding Documents describes the processes planned for Evaluation.

At the WP level - To assess EURAD outputs, early affects and long-term impacts, monitoring and evaluation criteria will be constructed that will serve as the basis for the development of a set of key performance indicators (KPI). Such KPIs shall help measuring outcomes and impacts towards the phases of the Roadmap and in terms which can also be assessed by decision makers (EC, Programme Owners). These KPIs are built in close consultation and collaboration with the Joint Programme participants and will align with objectives

within the scientific Themes, and prioritized RD&D, strategic studies and knowledge management activities presented in the Strategic Research Agenda. This will be managed by the PMO, together with each work package. The set of KPI will be included in the Quality Management Plan (Deliverable 1.1).

At the Programme level – By mandating organisations to participate, Member-States demonstrate that EURAD has an EU-added value beyond their National Programme. As the Joint Programme is not working in direct support for implementation of RWM operations or geological disposal, it is the responsibility of the National Programmes to evaluate outputs and results with respect to their own needs (towards implementation). As part of this, towards the end of EURAD-1, the PMO shall prepare a tool (e.g. questionnaire aligned to the Waste Directive) for getting the views from national programme owners on EURAD impacts during phase 1.

Assessment of quality and scientific excellence can however be shared, and will represent a primary criterion for the evaluation of EURAD results and achievements, and assumes over-riding importance in the first 5-year implementation plan.

The scope of criteria for evaluating the overall Joint Programme (and the individual Work Packages) will include:

- The Joint Programme/Work Package must articulate the overall research vision. To enhance the potential of achieving it, a world-class team of complementary expertise shall have been brought together.
- The Joint Programme/Work Package shall be ambitious, creative, innovative, and address key research challenges. It shall also be sustainable beyond the lifetime of the programme itself.
- A strong scientific case for support must be demonstrated by the Joint Programme/Work Package with the proposed research set into the context of the current state of knowledge and other work under way in the field.
- The outputs of the Joint Programme/Work Package shall result in a major impact on the research area beyond the immediate project, resulting in an appreciably raise in the international profile of European radioactive waste RD&D.
- The Joint Programme/Work Package shall clearly demonstrate the methods intended to be used to attain the stated objectives and describe clearly how appropriate they are for the planned activity and their scientific or technical feasibility. Where there is not a detailed methodological plan for the whole period of the implementation plan, the proponents shall explain how the research objectives for the latter years will be identified.
- The Joint Programme/Work Package shall identify the most significant challenges to achieving the stated objectives and explain how these will be addressed.
- The Joint Programme/Work Package must show clearly how meaningful, independent peer review will be integrated on a timely basis within the overall implementation plan.

In addition, the PMO will actively maintain and monitor a Risk Register to document those risks identified within each Work Package that may impact the overall performance of the EJP. With respect to the WPs that require significant coordination and strategic oversight to ensure consistency and continued support by each College), it is anticipated that a key risk will be raised that relates to meeting the needs of safety assessment end-users with a focus on generic methodologies (exact wording to be agreed). This risk will be managed through identified mitigation measures to be developed and continuously monitored together with the WP Leader, Key WP Contributors from each College, and the PMO.

1.3.Relation to the work programme

EURAD falls into EURATOM WP2018 – Topic NFRP-2018-6, that calls for the establishment of a European Joint Research Programme in the field of radioactive waste management in order to complement the national efforts in view of delivering safe, sustainable and publicly acceptable solutions for the management of radioactive waste across Europe now and in the future.

By fostering and strengthening RD&D collaboration and by making existing knowledge easily available to end users, EURAD shall enable cutting-edge knowledge creation and preservation and effective use of resources and shall help the RWM community facing the following challenges over the coming years:

- The implementation of the first geological disposal facilities by the more advanced programmes;
- The harmonisation of practices fostered by European initiatives such as [WENRA](#), EC [Waste Directive](#), EC [Nuclear Safety Directive](#), and [Aarhus Convention](#), etc.;
- The development and update of early stage programmes to start a disposal siting and licensing process, taking benefit of the experience gained by advanced programmes;
- The establishment of the State-of-Knowledge and its transfer to end users;
- The availability of competencies, research infrastructures and programmes to accompany the implementation and contribute to optimizing the management, including the disposal, of radioactive waste; and
- The necessity of creating a multi-decennial research and knowledge management perspective, considering the more than 100 years process between siting, licensing, operation and closure of a typical geological disposal programme.

1.4.Concept and methodology

The proposed overall concept described in this section is based on the EURAD Founding Documents that deliver the common Vision, Strategic Research Agenda (including Knowledge Management), Roadmap, Deployment Plan and Governance Scheme that will guide cooperative research and investments in the field over the coming decades in Europe. See EURAD ‘Founding Documents’ that are attached as an Appendix to the Part B.

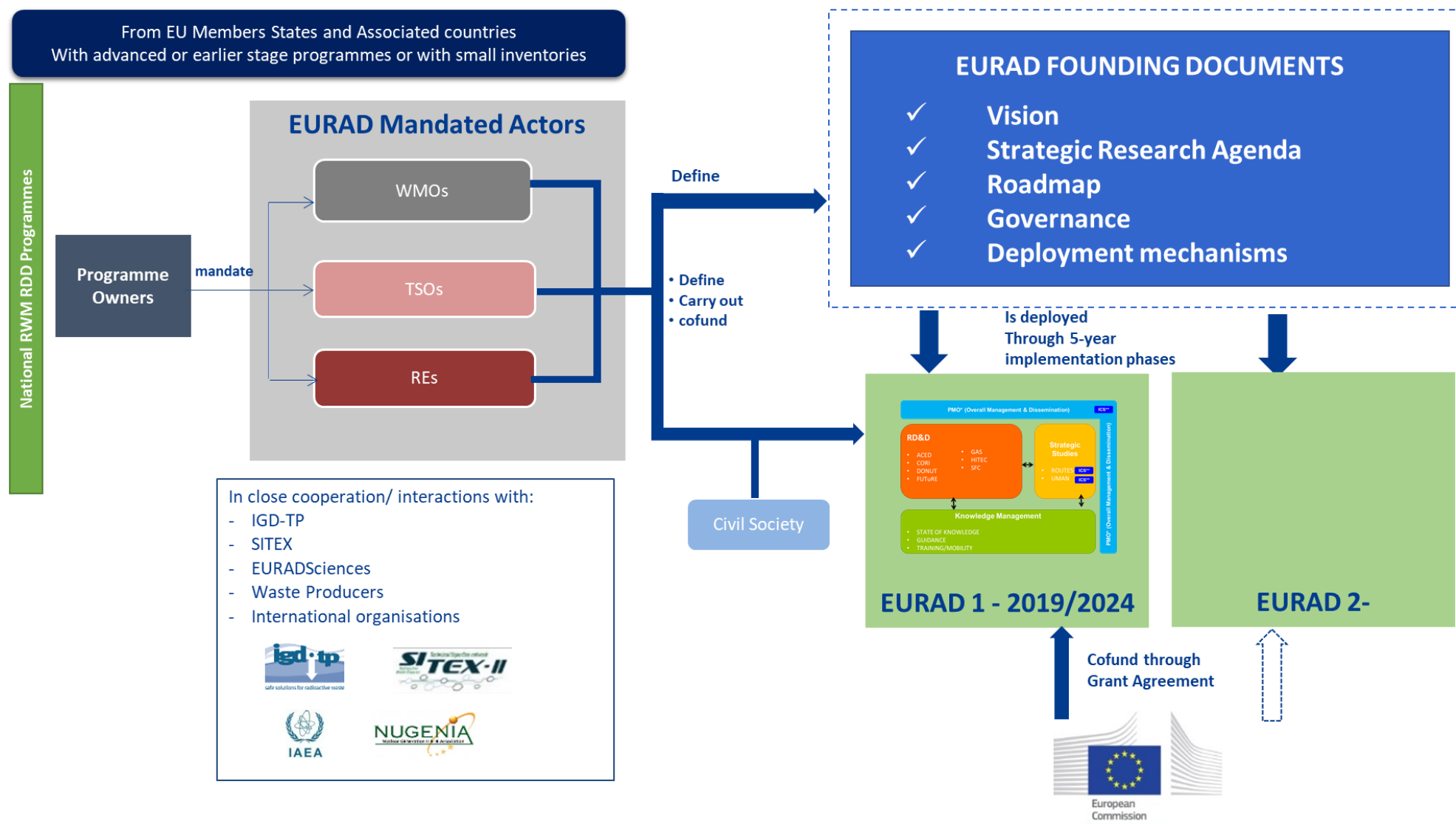


Figure 1– Overall scheme of the European Joint Programme on Radioactive Waste Management (EURAD)

1.4.1. Participants

EURAD participants are those organisations with scientific and technical responsibilities and a national mandate for RD&D and innovation programmes in the field of radioactive waste management that endorse EURAD Vision and that are willing to share the EURAD Founding Documents (Vision, Strategic Research Agenda, Roadmap, Deployment Plan and Governance - added as an Appendix to this Part B) and positively support its implementation.

After extensive consultation of the Member-States National Programmes and the research community, the EURATOM JOPRAD project identified three distinct categories of organisation with scientific and technical responsibilities and a national mandate for research in RWM:

- **Waste Management Organisations (WMOs)** whose mission covers the management and disposal of radioactive waste,
- **Technical Support Organisations (TSOs)** carrying out activities aimed at providing the technical and scientific basis for notably supporting the decisions made by a national regulatory body and
- **Research Entities (REs)** which are involved in RD&D in RWM under the responsibility of Member-States

Participants can call for Linked Third Parties to carry out part of the work plan. A Linked Third Party is an organisation to which a Participant has a pre-existing legal relationship (options are: Memorandum of Understanding, agreement, contract, affiliation, joint research unit...) which is not based on a contract for the purchase of goods works or services.

For full details on EURAD Consortium, see Section 3.6.

1.4.2. Strategic Research Agenda

EURAD Strategic Research Agenda (SRA) has been developed in a stage-wise manner, Step 1 - taking over entirely the scope developed within the Programme Document developed under EC JOPRAD Project [1] and Step 2 – enhanced with a small number of additional needs identified by ongoing EC projects and approved for inclusion between the key contributors of the JP.

The SRA is set up as a dynamic and living document that shall be updated periodically in order to integrate outcomes of RD&D activities as well as any emerging collaboration needs identified by the RWM community during the implementation phases of the Joint Programme.

We anticipate that there will be regular ‘soft’ updates to make minor edits and additions. This will be consolidated and extended by periodic extensive updates to coincide with future Work Package developments (for example during identification and prioritisation of the scope of future EURAD implementation phase) where it is anticipated that significant changes may result to take account of learning from EURAD-Phase 1. Thereby, the SRA, Roadmap and Work Package scope and methodologies may align with experience feedback, particularly with respect to the JP governance scheme and how criteria are used to identify evolving needs of the Member-States, and how the WMOs, TSOs and REs contribute to this process.

The SRA provides a description of scientific and technical activities and knowledge management needs of common interest between the Joint Programme participants. These activities are grouped into a number of

¹ [JOPRAD - Towards a Joint Programming on Radioactive Waste Disposal](#): EC project that completed initial preparatory work for the potential setting up of Joint Programme on radioactive waste management and disposal. JOPRAD identified the scientific and technical basis of a future joint Programme in the [D4.4 Programme Document](#) together with considerations for a financing and governance scheme, published in the [D3.2 Conditions for Implementing a Joint Programme](#).

scientific themes and based upon the scope established by the EC JOPRAD Project. The SRA Themes, are illustrated below in Figure 2. Although all technical in nature, Theme 1 is an overarching theme, Themes 2-5 are predominantly focussed on fundamental science, engineering, and technology, and Themes 6 and 7 include aspects more of an applied science and integration focus. Each Theme is also summarised below.

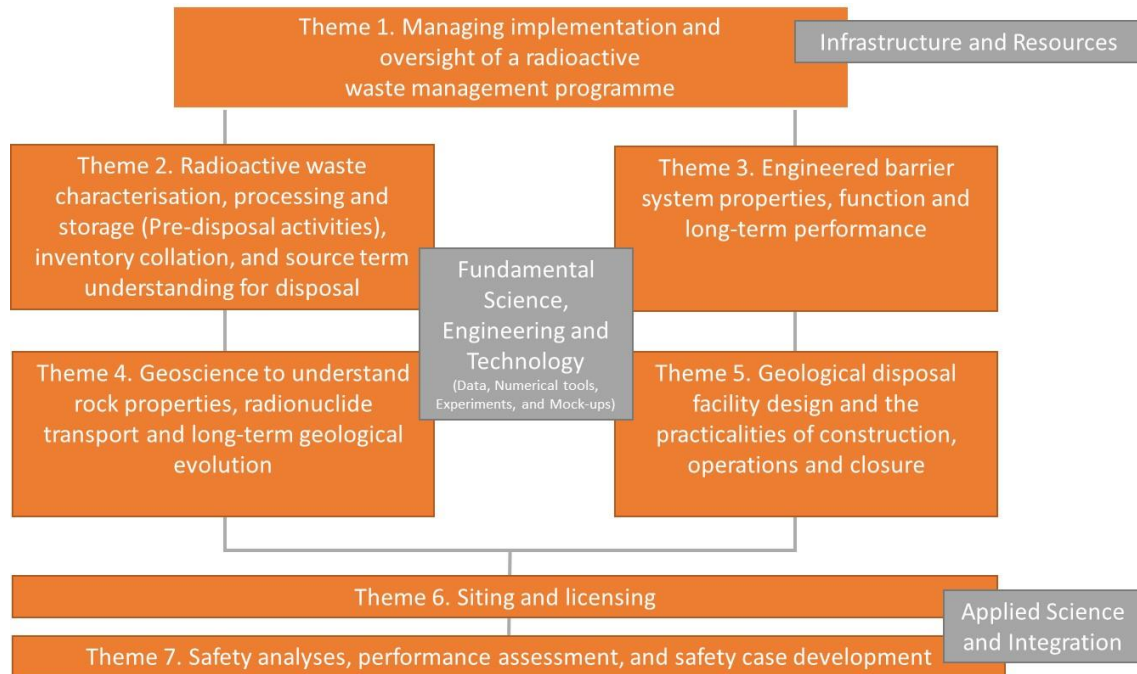


Figure 2 - The 7 Scientific Themes of the Joint Programme

Theme 1: Managing implementation and oversight of a radioactive waste management programme

Implementation of a national radioactive waste management programme, including geological disposal, requires a strong technical foundation of national policy to provide a legal framework, a long term vision, appropriate regulatory oversight, funding, organisational infrastructure and sound management systems and processes and frequent exchange among stakeholders. For programmes in the early phase of establishing national policy or developing a waste management programme, there is international entities support (IAEA, NEA) and EU-wide good practice and lessons learned that can be used to facilitate implementation of suitable organisational structures and strategic decision making.

Theme 2: Radioactive waste characterisation, processing and storage (Pre-disposal activities), and source term understanding for disposal.

This involves characterizing the various waste types (requiring activation calculations, evaluation of contamination carry-over, development of waste treatment and packing technology, etc.), evolution of waste matrix properties during extended interim storage times, developing waste acceptance criteria and developing model predictions about future waste. This also includes development of sufficient interim storage capacity. Source term and radionuclide release mechanisms need to be assessed for different waste forms/waste packages considering the interaction of the various interfaces with the disposal environment. In this broad area of work much information is already available or can be acquired through co-operation. Where remaining issues remain, they are often site and design specific.

Theme 3: Engineered barrier system properties, function and long-term performance.

Engineered barriers (overpack, buffer, backfill, seals, etc.) are in a broad sense comparable in many programmes and much basic information is already available today as there have been many European and international project to-date. Existing needs can be further developed through continued co-operation, which includes the provision of utilising available Underground Research Laboratories (URL) to conduct large-scale demonstration and verification testing. However, at a National Programme level some specific development work is often necessary to improve the understanding of the system of engineered barriers, optimise it or adapt it to the specific situation at hand. Remaining research issues concern in particular cementitious and to a lesser degree clay-based materials.

Theme 4: Geoscience to understand rock properties, radionuclide transport and long-term geological evolution.

Geoscience focussing on host rocks representative of the broad range of geologies to understand long-term geological evolution (and stability), and on the detailed understanding of the relevant properties and behaviour of different types of host rocks. This includes the transport properties of radionuclides and fluids, redox phenomena, coupled phenomena to address facility-induced disturbances, and the impact of gases). This also includes the demonstration and verification that the important coupled geomechanical, thermal, hydrological and chemical phenomena are sufficiently well understood to allow for long term assessment of void space closure, fluid movement and behaviour of the material interfaces, in some cases through full scale experiments in an URL. The broad area of geoscience will require significant activities that are specific to each country (especially regional geology but also the details of specific rocks), but with respect to the properties of rocks, much can be learned from other programmes working on similar rocks and may involve co-operative projects in URLs.

Theme 5: Facility design and the practicalities of construction, operations and closure.

Facility design (covering early conceptual design during early programme phases, right through to detailed design for construction, operation and closure). In the area of geomechanics and excavation, much can be learned from the tunnelling and mining industries and the corresponding science and technology developments. The current focus is on the demonstration of waste transport and engineered barrier emplacement techniques, and to perform demonstration tests under real 1:1 scale and active conditions. URLs and/or rock characterisation facility experiments, incl. monitoring activities often focus on demonstrating that technical aspects of facility construction and operation are suited for their purpose.

Theme 6: Siting and licensing.

The selection of a site (or sites) and licensing for a geological disposal facility is clearly the most important challenge to the successful implementation of long-term management of radioactive wastes. Site characterisation (exploration of geometrical aspects, rock layers, structures, and characterisation of key rock properties), acquiring site parameters through the use of geophysical techniques, hydraulic and geochemical measurements in boreholes and seismic investigations will contribute to the selection of the preferred site. As part of the full development of the selected site, underground testing will be required to allow detailed in-situ confirmation (and/or refinement) of some of the critical data on rock properties and state parameters before and during the construction of the repository. Site selection policies and procedures, regulatory arrangements and licensing requirements vary between Member-States, reflecting inter alia the socio-political context, geological factors, and the waste inventory. In this broad area of work a large part is of national focus and much can be learned from science and technology e.g. developed for hydro-carbon exploration, but also the wealth of information available from radioactive waste management programmes and from previously existing URLs must be considered. For URL-experiments, significant technology developments have been made (testing tools, sensors, etc.) that are essential for underground testing at repository sites. This area is very much suited for co-operation.

Theme 7: Performance assessment, safety analyses and safety case development.

For safety analyses (methodology, numerical tools, compiling all the information and data, drawing the conclusions), a wealth of information is already available. The development of the safety case and the task of integrating all the necessary information will always be specific to the system evaluated and thus, in this area, each country must develop its own capabilities in interaction with the various local stakeholders, however, confidence building requires often international exchange and the help of experienced experts from elsewhere. Common issues include typically the exchange on the treatment of uncertainties. There is a need to recognise the need for independence between those supporting and managing safety case development and those supporting or managing the regulatory review and scrutiny of a safety case, this applies to all the SRA Themes, but especially relevant to Theme 7.

1.4.3. Roadmap

The SRA is further complemented by a Roadmap that describes the totality of scope of the Joint Programme and its relevance to radioactive waste management (including disposal) programmes at different stages of maturity. The Roadmap effectively provides a framework upon which to organise the scientific and technical activities of the SRA, enabling programmes to ‘click-in’, and to access active work or future plans. It also provides a framework for future periodic assessment of the Joint Programme, and to evaluate future priorities and new work packages as new knowledge is acquired or as new needs are identified.

A Roadmap, with clear objectives, linking the Joint Programme activities (as listed in the SRA) to milestones typical of different phases of a radioactive waste management (RWM) programme has been developed (focussed on those planning for disposal). The Roadmap relates to Joint Programme Founding Documents (and was not addressed by the preparatory work carried out in the EC JOPRAD project). It draws from the IAEA work (see, [IAEA Planning and Design Considerations for Geological Repository Programmes of Radioactive Waste](#)). The IAEA definitions of recognised phases of a waste disposal programme (and their associated major objectives) are used to provide the Roadmap framework:

- Phase 0: Policy, framework and programme establishment*;
- Phase 1: Site evaluation and site selection;
- Phase 2: Site characterisation;
- Phase 3: Facility construction;
- Phase 4: Facility operation and closure;
- Phase 5: Post-closure.

*Note that the IAEA phases used in the Roadmap are of a general nature and are each applicable to several waste streams and waste types. Furthermore, phase 0 was not covered by IAEA-TECDOC-1755, but added to capture pre-disposal (waste treatment and processing) and interim storage and to recognise the needs of Member-States who are in the process of establishing a waste management programme.

The Roadmap demonstrates the totality of scope of the Joint Programme and its relevance to waste management and disposal programmes at different stages of maturity. The Roadmap effectively provides a framework upon which to organise the scientific priorities of the SRA, enabling users and programmes to ‘click-in’, and to access existing knowledge and active work or future plans. It also provides a framework for future periodic assessment of the Joint Programme, and to evaluate future priorities and new work packages as new knowledge is acquired or as new needs are identified.

The Roadmap comprises 7 theme-specific tables showing how identified activities of the Joint Programme SRA relate to different Phases of implementation and typical Waste Management Programme objectives for each theme. The SRA tasks are flagged (🟡) to illustrate those being addressed in-part or in-full by scope of active EC-funded projects, including those of the Joint Programme. Tasks that will be addressed in future work of the Joint programme are also flagged (🔵).

The Roadmap tables will be used throughout the Joint Programme as a tool to support the management of the SRA in reviewing progress, updating on how new work should be prioritised (importance and urgency) and communicating completed, ongoing and future work activities to those interested in our work.

1.4.4. Deployment Mechanisms

Deployment activities

EURAD Vision, SRA and Roadmap will be delivered through **5-year implementation phases** according to the EJP Cofund Instrument. The Work Plan of an implementation phase is broken down into a set of Work Packages, Tasks and Sub-Tasks. To deliver against EURAD objectives, four different types of Work Package (WP) have been adopted, as well as specific cross-cutting tasks - interactions with Civil Society and providing access to knowledge/results – that will be directly embedded in specific WPs. These are each described below.

Table 1: Deployment Mechanisms to be used by the EURAD

Type of WP	Type of actions	Type of deliverables
Collaborative RD&D WPs	Activities aiming at developing and consolidating scientific and technical knowledge. Activities shall be a balance between those with a direct link to operational RD&D (direct links with implementation of deep geological disposal or other waste management route as well as safety concerns) and prospective RD&D (short and long-term experiment and/or modelling works to demonstrate the robustness of the waste management concepts, to increase understanding and predictability of the impact of fundamental processes and their couplings or to maintain scientific excellence and competences throughout the stepwise long-term management of radioactive waste).	State-of-the-art ² (initial and update), S/T deliverables, reports, demonstrator, pilot, prototype, plan designs, software, technical diagram...
Strategic Studies WPs	Actions consisting of enabling experts and specialists to network on methodological/ strategical issues and advance significant challenges that are common to various National Programmes and that are in direct link with scientific and technical issues.	Position paper (e.g. emerging needs for future RD&D/Strategic Studies/KM activities), report on generic methodologies, best practices...
Knowledge Management WPs	Actions consisting of developing State of Knowledge; developing descriptive methodological guidance and developing/delivering Training modules and mobility measure.	State-of-knowledge documents; Guidance documents, Training delivery and materials...
Programme Management Office WP	Day-to-day administrative, financial and legal management, reporting exercises, interactions with EC, communication and dissemination activities, administration of JP website, Extranet, Scientific and technical coordination/integration of the overall JP (monitoring EURAD progress)	Management tools, Periodic reports, financial statements, website, platforms...

Synergies with international organisations

Strong synergies with IAEA and any other international organisations shall be established for joint development and implementation of actions related to Knowledge Management and Strategic Studies with subsequent Memorandum of Understanding.

² SOTA reports, where specified for all EURAD WPs, will be completed in-line with international good practice. This will include communication of the existing knowledge gaps in the context of safety. This will be done in a general or generic way, without direct reference to specific safety assessments, safety cases or national programmes. It is the responsibility of the National Programmes to evaluate outputs and results with respect to their own needs (towards implementation) as specified in Section 6.2 of the EURAD Founding Documents and section 1.2 of the Part B.

Interaction with Civil Society – cross cutting component

As described in the Vision Document, one objective of EURAD is to allow innovative ways for close interactions between experts from WMOs, TSOs and REs and Civil-Society (CS) Organisations. Based on model of pluralistic interactions between them developed and tested under previous projects (SITEX-II, JOPRAD, Modern2020), EURAD proposes a framework for interaction with CS that consists in:

- Translating scientific/technical results for communication to CS group at the annual workshops CS and by extension to the public;
- Gathering CS views on future EURAD activities;
- Improve the mutual understanding on the RD&D needed to develop safe acceptable solutions in the processing and disposal of radioactive waste ;
- Develop propositions on how to interact with CS on scientific and technical results, how to deal with uncertainties (inherently linked to the long timeframes and numerous processes considered for geological disposal), and on how to interact with CS stakeholders in order to promote mutual benefit of the available knowledge, based on cooperation and sharing.

To do so, the EURAD has the ambition to establish interaction activities with a group of representatives of civil society organisations (**the CS group**). The composition of the CS group³ will be launched at inception of EURAD via an open call relayed by EURAD consortium to CS organisations such as local communities having interest in RWM (local association, local Committee of Information, local partnership), national or European CS Organisations taking part in interactions in the field of RWM at national or European level. The candidates shall demonstrate evidence of a standing engagement in the follow-up of RWM activities. Each participant of the CS group will approve the principle of participating in EURAD ICS activities as described in the EURAD Terms of Reference.

The interactions with the CS group will be facilitated by Civil Society facilitators (**the CS experts**), working for Linked Third Parties to mandated actors in the Joint Programme, having a long-term engagement on RWM and/or having skills/experience on the involvement of Civil Society in scientific and technical issues. The CS experts will interact with the institutional experts from the WMOs, TSOs and REs in order to understand the field of study and to prepare interactions with the CS group. The process will enable CS group to express their views on the RD&D needed to develop safe solutions in the processing and disposal of radioactive waste. The CS experts will work in an organised process together with representatives from WMOs, TSOs and REs.

1.5.Ambition

The ambition of EURAD is to establish an inclusive, transparent, leading edge scientific and goal oriented, entirely new approach on European collaboration towards safe and timely implementation of radioactive waste management, including disposal. This will, foster mutual understanding and trust between Joint Programme participants as well as other stakeholders.

A cornerstone is the development of a robust and sustained **state-of-the-art science and technology programme**, established to complement National R&D programmes, and to carry out activities of high common interest between WMOs, TSOs and REs where there is added value at the European level. Such Joint programme will allow improved integration of the fundamental scientific understanding for all concepts related to the safe and environmentally sound disposal of long-lived radioactive waste and spent nuclear fuel in geological disposal sites within Europe, including corresponding pre-disposal activities. It supports research needs of advanced and early stage programmes and will assure access to advanced research infrastructure for coordinated implementation within scientific excellence and leading edge research on basic components and generic processes and their couplings and upscaling, oriented towards site-specific complex systems understanding of long-term repository evolution and safety. The EURAD Strategic Research Agenda, originating from research needs of high common interest established by the EC JOPRAD project, contains a

³ Each candidate shall demonstrate evidence of a standing engagement in the follow-up of RWM activities (for a period of at least 3 years in the RWM field). Each participant should be willing to attend (at least twice a year) a programme of meetings where facilitated interactions with the JP participants will be organised.

broad spectrum of scope and prioritised activities that will lead to an improved scientific basis for geological disposal, and the safe treatment, packaging and storage of radioactive waste across Europe.

As disposal programmes across Europe advance, and move from conceptual studies to industrialisation and operations, research will continue. Given the inherent long timescales involved, with both licensing of a facility (decades), and the operation of facilities up to closure (centuries), scientific understanding will evolve and technology will advance. It is therefore necessary that any waste management programme remains founded at any given moment on rapidly evolving leading edge science. Our research approach will enable programmes to cope with this fast evolving scientific and technological landscape, regardless of stage of advancement, and allow the waste management concepts to remain credible and strongly efficient throughout the very long phase (>30 yr) between siting and closure of a repository.

Beyond the state-of-the-art, an important, novel and ambitious component of EURAD is to **consolidate efforts across Member-States on Knowledge Management** – this includes access to existing Knowledge (State-of-Knowledge), guiding the development of capability in line with core competencies (Guidance and Training), and improving access to quality tools, resources and communities of practice to share and learn from each other (Dissemination).

As radioactive waste management programmes across Europe are varied, particularly with respect to their level of advancement, a key consideration is ensuring that the right knowledge is available to the right people at the right time. Therefore, within the Joint Programme, we plan to use the Roadmap that has been established to provide a framework for mapping Knowledge requirements at different stages of a waste management programme. It is intended that the Roadmap will serve as a key tool for identifying, structuring, prioritising and managing all Knowledge Management activities in the Joint Programme. This will include future expansion with the required competencies in relation to what is needed to support disposal programme implementation, so that it may be used to determine critical training and guidance needs and as a tool for managing people development. This will enable the Joint Programme Knowledge Management efforts to focus initially on the most critical Knowledge required for Early Stage Programmes (i.e. State of Knowledge, Guidance and Training to support Programme Managers working in support of a National Programme that is at an early stage of development with respect to implementing radioactive waste management) and which can benefit from preparatory work undertaken previously by the IGD-TP SecIGD2 and JOPRAD Projects to understand KM.

Joint Programme Objectives on Knowledge Management are to:

- Develop an approach to comprehensive accessibility to publicly financed knowledge generated over the past, ongoing and future RD&D activities is preserved and made accessible
- Make sure that Member-States with National Programmes at an early-stage of implementation can take advantage of existing knowledge and know-how from the Member-States with advanced National Programmes, primarily to access state of the art, and second to ease access to knowledge developed during previous EC supported RD&D projects .
- In view of the long lead-times and operational time-spans for RWM, provide support to ensuring that the necessary expertise and skills are maintained through generations of experts for ongoing project.
- Disseminate and demonstrate progress, results and added-value of the European Joint Programme to a wider audience.

In addition to generating and managing expertise and scientific-technical knowledge, EURAD will **elaborate upon complex issues and identify new and emerging ones by bringing together all interested actors to jointly conduct Strategic Studies**. Strategic studies are initiated in order to agree upon needs for future activities, including further specific thematic studies or RD&D. This may also be referred to as ‘think-tank’ activities to determine if there is a RD&D need on an emerging issue, if there is a need of a position paper or if it is considered mature and suitable for knowledge management activities.

As part of EURAD-1, there is one Strategic Study on the understanding of uncertainty, risk and safety amongst different actors, including how uncertainty transforms into risk, and how this translates into “safety” for

different actors. This Strategic Study contributes to a common understanding of these phenomena amongst the different actors, including identifying research and innovation that could further bring forward this area.

Another Strategic Study is elaborating upon the need for R&I in order to deal with all the different types of waste in Europe, also “exotic” ones for which there presently is not mature solution available. One specific aspect within this study is R&I needs for dealing with small national inventories, where existing solutions may be inadequate and/or prohibitively expensive, and rely on human and financial resources found in countries with larger programmes. By these initial Strategic Studies, EURAD meets the expectation of extending the areas of activities to identification of R&I needs well beyond the community addressed in former EURATOM framework programmes, namely the strong community of advanced programmes developing geological disposal for spent fuel and high-level waste.

EURAD intends to maintain and **deepen the interaction/cooperation** that have been established since JOPRAD and during the preparation phase of EURAD proposal:

- **Waste Producers**

Waste Producers and those with a pre-disposal waste management remit are engaged via the Nuclear Generation II & III Association (NUGENIA). Although not direct contributors or participants of the Joint Programme, continued engagement via dissemination and consultation will ensure NUGENIA and their dedicated R&D on nuclear fission technologies and predisposal activities, will set a foundation for future collaboration in projects influencing the waste form for final disposal. Waste Producers and Waste Management Organisations /Implementers at a national level are often well-connected and have existing cooperation activities that should support the integration of Waste Producers RD&D needs (that impact disposal), via the WMOs. Waste Producers are often responsible for contributing to financing of disposal facilities.

- **International Organisations**

It is recognised that the scientific basis and public acceptance of RWM solutions, including geological disposal, is a global effort, and that new opportunities may emerge to link to worldwide RD&D efforts. Already the Joint Programme has established close links with the International Atomic Energy Agency (IAEA) from inception to avoid duplication of effort and resources. Such co-operation will continue, e.g. with the establishment of a Memorandum of Understanding, and extend to other organisations, including the Organisation for Economic Co-operation and Development – Nuclear Energy Agency (OECD-NEA), to strategically direct and offer clear added-value to the Joint Programme objective.

2. Impact

2.1.Expected impacts

EURAD will generate and manage knowledge to support EU Member-States with their implementation of the Directive 2011/70/Euratom ([Waste Directive](#)), and more specifically with the development and implementation of their national RD&D programmes for the safe long-term management (including disposal) of their full range of different types of radioactive waste. More specifically, EURAD will:

1. **Support compliance with European regulations** – by supporting Member-States in implementing RD&D, developing skills and providing for transparency in order to develop solutions for their radioactive waste (see, Waste Directive articles 8, 10 and 12.1(f));
2. **Support passive safety of radioactive waste** – by contributing to the responsible and safe management of radioactive waste in Europe, including the safe start of operation of the first geological disposal facilities for high-level and long-lived radioactive waste / spent nuclear fuel as well as improvement, innovation and development of science and technology for the management and disposal of other radioactive waste categories;

3. **Help to gain or maintain public confidence and awareness in radioactive waste management** - by fostering transparency, credibility and scientific excellence;
4. **Support radioactive waste management innovation and optimisation** – by supporting the development of solutions for different waste streams and types and continuously improving and optimising waste management routes and disposal solutions, including identifying needs specific to small inventory programmes with their particular challenges with respect to access to critical mass of expertise and developing appropriate disposal options;
5. **Contribute to addressing scientific/technical challenges and evolving regulatory concerns** – by prioritising activities of high common interest, and creating conditions for cross fertilization, interaction and mutual understanding between different Joint Programme contributors and participants;
6. **Enhance knowledge transfer to early stage programmes** – by providing an opportunity for less advanced programmes, and in particular those in an early stage of geological disposal programme implementation, to benefit from the cross-European integration in radioactive waste management;
7. **Foster efficient use of the RD&D resources at the EU level** - by sharing and advancing existing knowledge, facilities and infrastructure rather than repeating and duplicating efforts; and
8. **Foster a better transfer of knowledge across generations of experts** – by helping to bridge the risk of shortage of the skilled, multidisciplinary human resources and critical infrastructure needed to develop, assess, license and operate RWM facilities, in view of the long lead-times and the intergenerational operational time-spans.

2.2.Measures to maximise impact

2.2.1. Dissemination and exploitation of results

At the inception of EURAD, one of the first task of the Programme Management Office (WP1 Task 6) will be to develop a plan for the dissemination and exploitation of the EURAD results. Such plan for the dissemination and exploitation (PDER) will be a key deliverable that will describe in a concrete and comprehensive manner, the area in which we expect to make an impact, who are the potential users of the results and how we plan to maximise EURAD impacts/results. It should also describe appropriate channels of dissemination and interaction with potential users. This PDER will be agreed between EURAD participants and will be submitted at month 3. It will be then regularly updated during the implementation of EURAD, as Beneficiaries are required to report periodically to the European Commission the concrete dissemination and exploitation activities carried out. At the end of the first implementation phase of EURAD, the final report should include the final version of the PDER that will allow the European Commission to assess the impacts of EURAD activities.

Dissemination shall be based upon:

- **EURAD Annual Meetings;**
- **Peer-reviewed scientific open access publications** in internationally recognized scientific journals;
- **Presenting EURAD scientific-technical results and achievements at scientific-technical conferences/ workshops /forums** addressing the scientific-technical expert community;
- **Presenting EURAD objectives, scope, work programme and main achievements at events where broader stakeholder community and/or decision maker presence**, with the aim of providing confidence in the scientific-technical basis and enhancing awareness of the well-founded progress in the field and its time-horizons;
- **Presenting, at events of inter-European and international platforms, organizations and fora**, exchanging on the EJP and promoting coherent messages and developments within the broader context;

- **Exchanging the scientific-technical basis, the objectives, scope, work planning and achievements with civil society and their representatives**, resulting in out-reach beyond the involved expert community to these key actors for advancement of National Programmes and for policy decision-making.
- **Training/Mobility Programme to be developed as part of EURAD KM Programme of activities**

Within KM Programme of activities, a **diverse portfolio of tailored basic and specialized training courses** will be composed under the umbrella of a “School of Radioactive Waste Management”, newly created under EURAD-1, taking stock of and building upon already existing initiatives (i.e. IAEA and NEA) and creating new initiatives to bridge the identified gaps. The end-users are defined as professionals and potential new professionals at graduated and post-graduated level associated with the organisations participating within EURAD-1, and in particular the next generation of experts. Access to existing training materials (e.g. training modules developed in association with past and ongoing RD&D projects and EURAD WPs) will be improved and new training courses and material provided, both aimed at acquiring both state-of-the-art scientific background and at accessing the vast amount of “tacit” knowledge available within EURAD-1 through targeted hands-on training.

Furthermore, a **mobility programme** shall provide access to dedicated infrastructures associated with the organisations participating within EURAD-1. These mobility actions can be seen either as a complementary action after one or more training course(s) (enabling hands-on training related to the experimental programme executed within EURAD-1) or can be part of the Continuous Personal Development (CPD) of experienced personnel involved in RWM.

The key-mechanism for exploitation of the results are based on the Joint Programme as a facilitator for the different Actors to generate the value that they exploit:

- The EJP contributing by developing and making available knowledge, promoting common understanding with respect to decision-making and policy amongst actors across Europe, promoting mobile cross-European expertise, and providing Guidance on how to implement R&D programmes and knowledge management;
- National decision-makers making use for avoiding unnecessary delay in establishing and implementing the required policy;
- Industry and other involved actors to implement science and technology in a safe and cost-effective manner, making use of knowledge and expertise available across Europe;
- Industry making use of their front-runner position to sell know-how and technology also outside of Europe.

2.2.2. Access policy and Intellectual Property Rights (IPR)

The management of intellectual property generated within EURAD will be regulated by the Consortium Agreement that all partners (Beneficiaries/Linked Third parties) have agreed to finalise before the Grant Agreement is signed.

The Consortium Agreement will set out the rules on IPR matters, including identification of background, access rights and patent issues and its stipulations will be complemented in the dissemination plan that addresses also the exploitation of results. Results generated by EURAD shall be the property of the participants (Beneficiaries/Linked Third parties) generating it. Each participant, duly owner of Results will have to consider its interest and to determine whether to apply for a patent or not.

Any software developed in the framework of EURAD shall be accessible on a royalty-free basis to all EURAD participants (Beneficiaries/Linked Third Parties) for the needs of EURAD implementation, for non-commercial internal research activities and/or its non-commercial industrial activities.

All WP deliverables are made freely available to all participants. Participants, on the other hand, will take care in not revealing information with a potential commercial interest to third parties.

The data (excluding patents and software) arising from the deliverables will be public and will be considered as open-access literature.

Any type of industrialization is not yet the primary goal of EURAD, but the feasibility and reliability demonstrations also provide results that are needed as input for the next step of the innovation cycle towards the industrial scale of processes and tools, such as conditioning, treatment, monitoring..., needed for implementing safe management of radioactive waste..

2.2.3. Communication activities

In parallel of the Dissemination and Exploitation Plan, a Communication Plan will be developed in order to describe the targeted communication measures that will be implemented for promoting EURAD itself and its mains results and findings and demonstrating to a large public how EU funding contributes to tackle scientific/technical and societal challenges in the field of radioactive waste management.

Several communication channels/tools will be developed within EURAD WP1-Programme Management Office:

- A dedicated **EURAD website** that will provide initial information on EURAD Vision, Roadmap, Strategic Research Agenda. It will present EURAD participants, ongoing projects (Work Packages for a wide audience. The website will be regularly updated with on-going activities, public reports, publications, it will also publicised EURAD Annual Meetings, scientific/technical workshops organised within the different WPs, as well as training/mobility programme.
- A **newsletter** that will be regularly published and will aim to keep all interested parties informed on EURAD ongoing activities and main findings, results and outcomes.
- **Communication tools, such as flyer, brochures, posters, rollups, synthesis, video etc.** that may be displayed and/or distributed during workshops, conferences or congresses will be also developed within WP1.
- Publication of articles in non-scientific and non-peer-reviewed publication
- EURAD participants will be encouraged to provide short information about EURAD on their own website with a link towards the official EURAD website.

All communication and dissemination activities will acknowledge support of the HORIZON2020 Euratom programme by displaying the EU emblem and by including the following text: This project has received funding from Euratom research and training programme 2014-2018 under grant agreement No [847593]”.

3. Implementation

According to the EURATOM WP2018 call, the Joint Programme shall remain **flexible** to include **new activities** in order to be as needs-driven as possible; and to allow later **inclusion of new organisations** that would be mandated during the course of an implementation phase.

Under the EURAD first implementation phase (EURAD-1), and for RD&D and Strategic Studies, this flexibility is ensured by allocating about 70% of the available budget to WPs/tasks that shall start at Month 1 (“*first wave*”). The remaining 30% shall be allocated to existing or new WPs/tasks that will be approved by the General Assembly during the course of EURAD-1 and integrated in the Work Plan through the Annual Work Programmes (“*second wave*”). Proposals for second wave of RD&D and Strategic Studies WPs/tasks will emerge as the Joint Programme progresses. These will be considered in an open and transparent manner via the PMO and General Assembly. The EURAD SRA/Roadmap and their updated/extension will support this by providing the framework for performing a structured gap analysis (See Section 1.4 and 3.3.1). Specific attention/emphasis on Strategic Studies shall be paid for the second wave of projects.

For Knowledge Management, the principle of flexibility is ensured by a yearly allocation of KM budget. About 20% of the KM budget will be allocated to tasks that will be implemented in the first year. The KM budget will be then allocated on an annual basis.

This Section 3 provides the overall structure of the work plan and the detailed work description of the “first wave” of activities of EURAD-1, as well as the allocated budget to carry out these activities. At the time of the submission, the budget which is not allocated is secured under the budget of the Coordinator. See Section 3.7 for further details.

3.1. Overall structure of the work plan

EURAD-1 overall structure of the work plan is illustrated in the Figure 3 below.

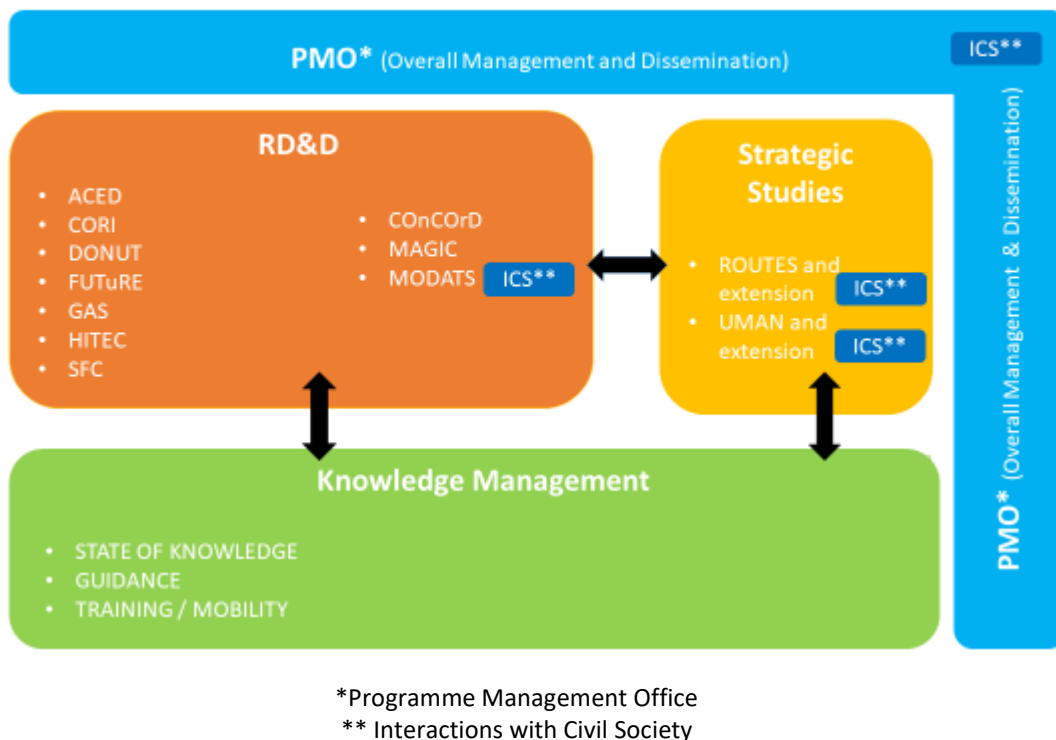


Figure 3 –EURAD-1 overall structure of the work plan

This EURAD-1 overall work plan is the result of a collaborative process between WMOs, TSOs and REs that is fully described in the Annex 3 of the EURAD Founding Documents (see Appendix).

During the preparation phase of EURAD, the WMOs, TSOs and REs collaboratively established the RD&D/Strategic Studies WPs to be launched as a first wave of EURAD-1, respecting the following boundary conditions:

- Each WP shall be in line with EURAD Vision and the JOPRAD Programme Document (Basis of EURAD Strategic Research Agenda). Specifically, each WP has to address mainly topics of high or medium level of common interest from the JOPRAD Programme Document.
- The WPs shall be of common interest by the different categories of actors: REs, TSOs and WMOs.
- The WPs shall avoid (i) duplication of existing international activities (e.g. from NEA or IAEA) and (ii) re-doing what has been done in the past (at national or European level).
- The WPs shall address topics which are not currently addressed by ongoing EC projects. The ongoing EC projects are given on the following figure. The different topics addressed in ongoing EC projects are the following: monitoring (Modern2020), microorganisms (MIND), concrete alteration (Cebama), non-destructive assay methods (CHANCE), waste thermal treatment (THERAMIN), bentonite mechanical evolution (Beacon) and characterization of dismantling waste (INSIDER). The aim of this is to wait for feedback from these ongoing projects before launching any follow up WP within EURAD-1.

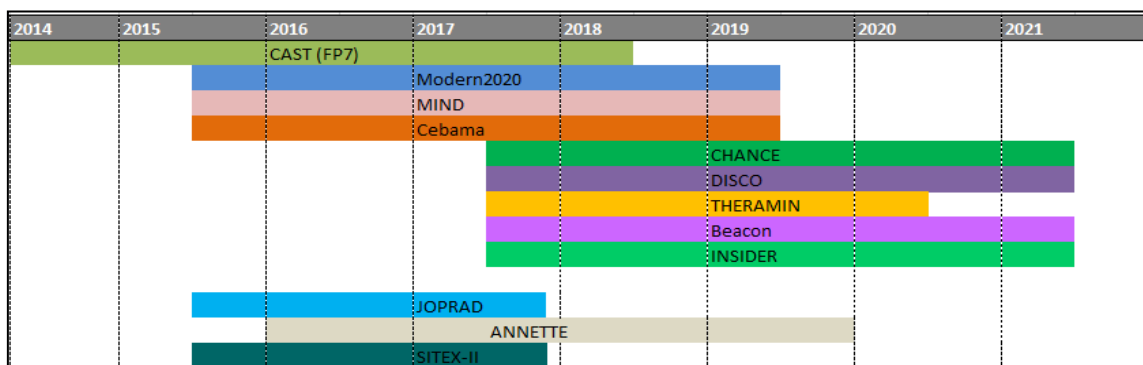


Figure 4 – Overview of ongoing EC EURATOM projects

Implementation of the “second-wave”:

The same boundary conditions applied for the selection of the second wave workpackages.

Each of EURADs three Colleges were asked to propose outline topics for up to 4 new R&D work packages and 2 new or/extended Strategic Studies (StS).

Following an eligibility check (against the agreed criteria, covering notably our shared SRA priorities) and some commonality screening, a ‘Consolidated long list’ of proposals was formed.

It was agreed not to develop all of these ideas into detailed proposals, instead prioritised proposals around common needs have been identified and a ‘short list’ of proposals has been agreed with EURAD’s Colleges.

Proposals were then worked up in more detail and, after review by the Bureau (in close cooperation with the PMO), the final list of WPs has been selected.

The timeline of the selection and development processes of the second wave are presented below.

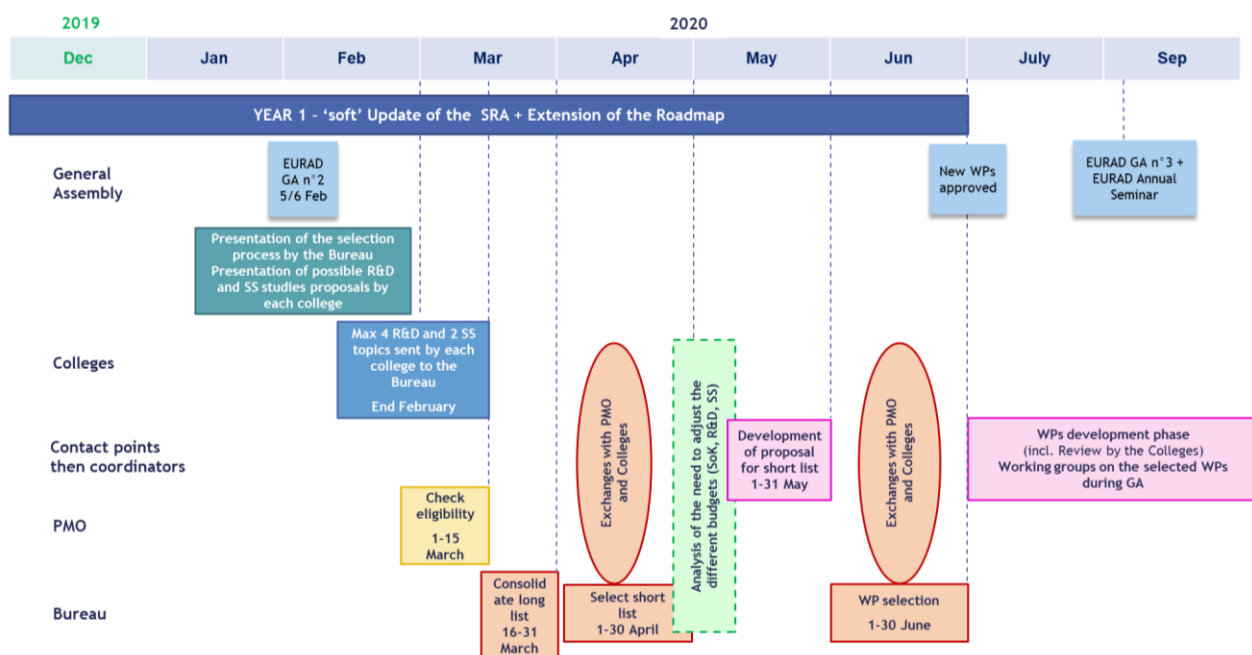


Figure 5 – Timeline selection process 2nd wave

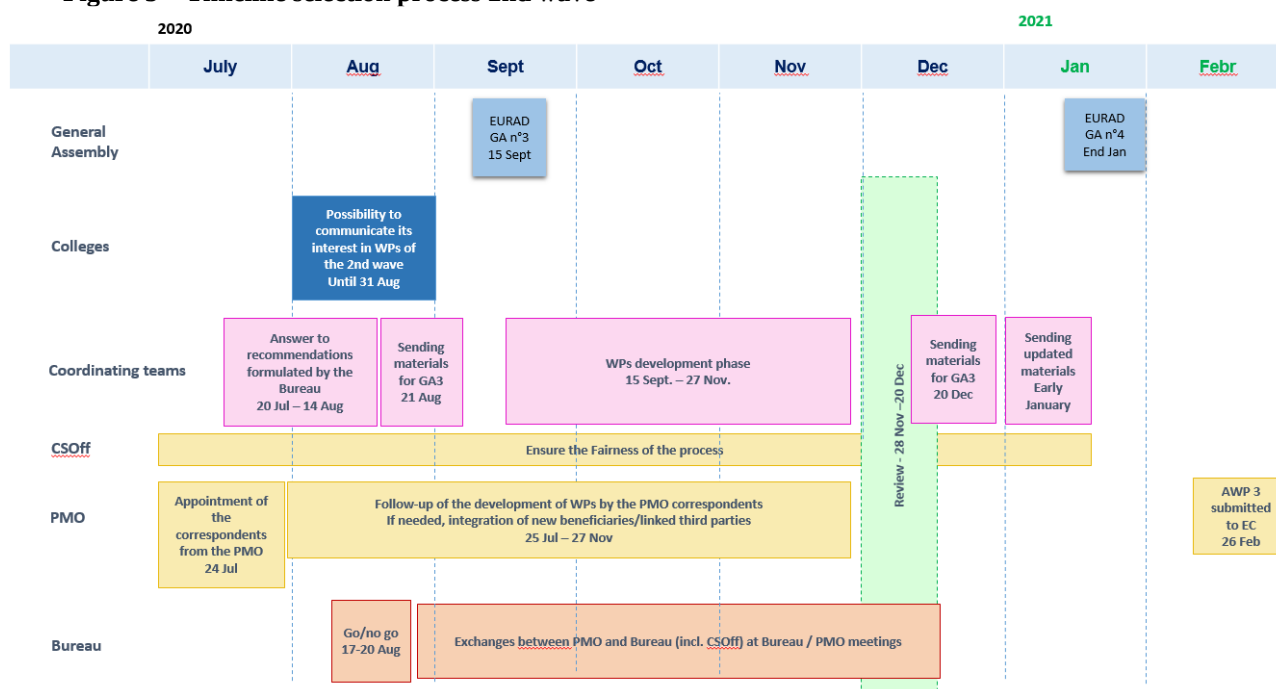


Figure 6 – Timeline development process 2nd wave

3.1.1. Work breakdown structure

EURAD 1 Work Packages (2019-2024)		Indicative Budget	EURAD Strategic Research Objectives	EURAD Beneficiaries			Coordinator
		Total Cost (EC + Beneficiary Contributions)		WMOs	TSOs	REs	
Programme Management Office		6%					
WP1	Administration, Scientific Coordination, Communication and Dissemination	€3.5 M		◆◆	◆	◆◆	ANDRA (France)
Collaborative RD&D		82%					
WP2	Assessment of Chemical Evolution of ILW and HLW Disposal Cells (ACED)	€5.1 M	Multiscale approach and process integration to improve long-term modelling and assessments .	◆◆◆◆◆	◆◆◆◆◆	◆◆◆◆◆ ◆◆◆◆◆	SCK-CEN (Belgium)
WP3	Cement-Organics-Radionuclide-Interactions (CORI)	€4.7 M	Improved understanding of the role of organics (either naturally occurring or as introduced in the wastes) and their influence on radionuclide migration in cement based environments.	◆◆	◆◆◆	◆◆◆◆◆ ◆◆◆◆◆	KIT (Germany)
WP4	Development and Improvement of Numerical Methods and Tools for Modelling Coupled Processes (DONUT)	€3.7 M	Improved understanding of the upscaling of THMC modelling for coupled hydro-mechanical-chemical processes in time and space.	◆◆◆◆	◆◆◆◆◆	◆◆◆◆◆ ◆◆◆◆◆	ANDRA - BRGM (France)
WP5	Fundamental Understanding of Radionuclide Retention (FUTURE)	€4.6 M	Quantification of long-term entrapment of key radionuclides in solid phases to inform reactive transport models and the influence of redox.	◆◆	◆◆◆◆◆	◆◆◆◆◆ ◆◆◆◆◆	FZJ (Germany)
WP6	Mechanistic Understanding of Gas Transport in Clay Materials (GAS)	€5.6 M	To increase understanding and predictability of gas migration in different host rocks.	◆◆◆◆◆ ◆◆	◆◆◆	◆◆◆◆◆ ◆◆◆◆◆	ONDRAF/NIRAS (Belgium)
WP7	Influence of Temperature on Clay-based Material Behaviour (HITEC)	€5.3 M	Improved THM description of clay based materials at elevated temperatures.	◆◆◆◆◆ ◆◆◆◆◆	◆◆	◆◆◆◆◆◆◆	VTT (Finland)
WP8	Spent Fuel Characterisation and Evolution Until Disposal (SFC)	€5.8 M	Reduce uncertainties in spent fuel properties in predisposal phase.	◆◆◆◆◆	◆◆◆◆◆	◆◆◆◆◆ ◆◆◆◆◆	SKB-UU (Sweden)
WP15	CONTainer CORrosion under Disposal conditions (ConCorD)	€4.8 M	Evaluate cooperatively the long-term behaviour of container materials to such an extent as to be able to ensure confidence in the performance of engineered barriers	◆◆◆◆	◆◆	◆◆◆◆	Nagra (Switzerland)
WP16	Chemo Mechanical AGing of Cementitious materials (MAGIC)	€4.2 M	Increase the confidence in Chemo-Mechanical simulations by reducing uncertainties in input data and understanding of key coupled	◆◆◆◆	◆◆◆	◆◆◆◆◆◆◆	IRSN (France)
WP17	Monitoring Equipment and Data Treatment for Safe Repository Operation and Staged Closure (MODATS) *	€4.7 M	Evaluate, develop and describe methods and technologies and to provide the means to measure, treat, analyse and manage data in a consistent manner	◆◆◆◆◆	◆◆◆	◆◆◆◆	ANDRA (France)
Strategic Studies to Address Complex Issues and Expert Networking		7%					
WP9	Waste management routes in Europe from cradle to grave (ROUTES) *	€1.9 M	Waste Management Routes across Europe considering different waste types and their specified endpoints.	◆◆◆◆◆ ◆◆◆◆◆	◆◆◆◆◆ ◆◆◆◆◆	◆◆◆◆◆ ◆◆◆◆◆	IRSN (France)
WP10	Uncertainty Management multi-Actor Network (UMAN) *	€2 M	Further refinement of methods to make sensitivity and uncertainty analyses and the development of a multi-actor network for uncertainty management.	◆◆◆◆◆ ◆◆◆◆◆	◆◆◆◆◆ ◆◆◆◆◆ ◆◆	◆◆◆◆◆ ◆◆◆◆◆	BelV (Belgium)
Knowledge Management		5%					
WP11	KM State-of-Knowledge (SoK)	€1 M	To maintain information, knowledge and records over the long lead- and implementation-timelines of geological disposal programmes, from pre-licensing through to the post-operational phase.	◆◆	◆◆	◆◆	BGE (Germany)
WP12	Guidance	€0.7 M	To identify RD&D and knowledge transfer needs in support of defining pre-licensing activities that can support success in the siting and licensing phase/process.	◆◆	◆◆◆		SURAO (Czech Republic)
WP13	Training & Mobility	€1.2 M	Training and competence maintenance of skills and expertise to support safe radioactive waste management including disposal.	◆◆	◆◆◆	◆◆	SCK-CEN (Belgium)

* Interactions with Civil Society

a. Programme Management Office (Management and Dissemination)

• **WP1 – Programme Management Office**

During EURAD-1, and in addition to its responsibility of administrative, legal and financial management and the coordination of the overall scientific and technical coordination/integration/evaluation of impacts (RD&D, Strategic Studies and KM), the PMO shall support EURAD General Assembly in the exercise that consists of **extending/updating the SRA and the Roadmap**. During EURAD-1, the following extension/updates are anticipated:

- [Year 1] **Roadmap Extension** - Complete EURAD Roadmap with a **Competency Matrix**, to identify competencies for different Actors (WMOs, TSOs and REs) and to **map existing/available SoK, Guidance and Training material** (open access) against Themes of EURAD SRA for different phases of implementation of a RWM programme. This shall support identification of the key need-gaps, which will then be used to prioritise the scope of each of the main KM WPs. This task will be undertaken by the PMO, with inputs from participants of the KM WPs and with oversight and guidance by the appointed Joint Programme Fellows/Experts
- [Year 2] **‘Soft’ update of the SRA/Roadmap** in view of the preparation of the 2nd wave of RD&D and Strategic Studies WPs where it is anticipated that minor edits and additions should be made, e.g. assessing the level of common interest of topics that emerged lately in the process of developing the SRA; identification of emerging RD&D needs and assess level of common interest.
- [Year 4-5] **‘Extensive’ update** of the SRA/Roadmap (exact timing to be adjusted in order to be in line with Euratom work programme) to coincide with preparation and prioritisation of the scope of the potential EURAD2. During this extensive update, it is anticipated that significant changes may result to take account of learning from EURAD-1 and align the Vision, SRA, Roadmap and RD&D, Strategic Studies and KM Work Packages scope and methodologies with how things evolve, particularly with respect to the JP governance scheme and how the criteria used to identify needs of the WMOs, TSOs and REs.

See WP1-PMO description for full details, included related Deliverables.

b. Collaborative RD&D WPs

For the first wave of EURAD-1, the following RD&D WPs have been collaboratively established:

WP2 - Assessment of Chemical Evolution of ILW and HLW Disposal Cells (ACED);

Multiscale approach and process integration to improve long-term modelling and assessments

‘What’

This WP improves the methodology to integrate knowledge on the geochemical processes in and between the materials in a disposal cell for ILW and HLW waste in order to understand and assess the long-term evolution of such complex system. A multi-process and multi-scale modelling framework will enable the assessment of the chemical evolution at various materials interfaces and thermal, hydraulic and/or chemical gradients from the microscale to the disposal cell scale (ILW, HLW) considering the near field environment and the host rock for larger temporal scales. Starting from small-scale process understanding, it seeks to which detail geochemical processes need to be included for representative assessments of the chemical evolution in view of the needs in repository design and safety assessment.

‘Why’

The WP ACED is included already in the first EJP EURAD as it covers an important number of high priority items of the roadmap of EURAD. These are in particular the EBS systems understanding in phase 1 and 2:

- Improved understanding of the interactions occurring at the interfaces between waste packages and different barriers in the disposal system

- Improved description of the spatial and temporal evolution and transformations affecting the porous media and degrading materials in the near field of HLW and ILW disposal systems
- And concerns also the high priority item for phase 1 in performance assessment and systems models
- Improved understanding of the role of physical/chemical processes at different scales and linking bottom-up and top-down approaches in performance assessment

More concrete: the work will allow identifying to which detail and complexity these processes should be incorporated in models for different type of safety and performance related studies. The information gained through study of the more generic but European representative HLW and ILW disposal cells can later be used and adapted for more specific, national disposal cell designs.

The outcomes will impact the safety case in different ways such as with respect to material specifications and establishment of requirements for deposition scenarios. The representative designs are set for ILW and HLW in both crystalline and sedimentary rock types, representing prevailing designs of the WMOs as end-users. The clear interest of the mandated actors in this WP is demonstrated by the fact that the WP work is carried out by a large number of partners, with a good balance between WMO, TSO and RE representatives.

WP3 - Cement-Organic-Radionuclide interactions (CORI);

Improved understanding of the role of organics (either naturally occurring or as introduced in the wastes and their influence on radionuclide migration in cement based environments)

‘What’

This WP aims to develop an in-depth understanding of the interaction of cementitious materials with omnipresent organic matter and with radionuclides. Organic materials are present in some nuclear waste and as admixtures in cement-based materials and can potentially influence the performance of a geological disposal system, especially in the context of low and intermediate level waste disposal. The potential accelerating effect of organic molecules on radionuclide migration is related to the formation of complexes in solution with some radionuclides of interest (actinides and lanthanides) which can (i) increase the radionuclide solubility and (ii) decrease the radionuclide sorption. The WP’s raison d’être is to quantify the organic release issues which can accelerate the radionuclide migration in the context of the post closure phase of geological repositories for ILW and LLW/VLLW, including surface/shallow disposal.

‘Why’

The thematic represented by the WP Cori has been selected for the first phase of the EJP as “improved understanding of the role of organics (either naturally occurring or introduced by the wastes) and their influence on radionuclide migration” was identified as an important subject in theme 4 (Geoscience to understand rock properties, radionuclide transport and long-term geological evolution) phase 1 and 2 of the roadmap. Due to the potential degradation of organic matter, this subject is particularly challenging in cementitious environments. Due to the importance of this subject in national programs, various mandated actors are working already since long time on the issues addressed by this WP (see for instance the meetings of the former TSWG in May 2013, Ghent, Belgium, leading to CEBAMA, or the latter extended discussion on CORI at the IGD-TP EF 6 (2015) in London, UK). Over this entire period, partners were eager to join forces for a strong improvement in scientific understanding allowing assessing long term radionuclide mobility in organic rich cementitious waste disposal environments.

WP4 - Development and Improvement Of Numerical methods and Tools for modelling coupled processes (DONUT);

Improved understanding of the upscaling THMC modelling for coupled hydro-mechanical-chemical processes in time and space

‘What’

This WP will develop and improve specific numerical methods and tools that allow efficient modelling coupled processes, considering (i) the versatility of numerical methods with regards to the various tools used by “end-users”; and (ii) a demonstration of robustness and added-value of developments by benchmark of the methods and tools on representative test cases at large repository time and space scales.

‘Why’

The DONUT WP has been selected for the first phase of EURAD as it will address the following activities identified as a high or medium level of common interest in Theme 7 “Performance assessment, safety case development and safety analyses” of the Roadmap:

- Improved understanding of the upscaling of THMC modelling for coupled hydromechanical-chemical processes in time and space (Phase 1 of the Roadmap).
- Improved understanding and models for the impact of THMC on the behaviour of the host rock and the buffer materials (Phase 2 of the Roadmap).
- Improved multi-scale reactive transport models (Phase 2 of the Roadmap)
- Improved performance assessment tools (Phases 0 and 1 of the Roadmap).
- Further refinement of methods to make sensitivity and uncertainty analyses (Phases 2 and 3 of the Roadmap)
- Improved computing (Phases 3 and 4 of the Roadmap).

Furthermore, by improving the numerical methods and tools that are able to manage multi-physicals coupled processes, the work conducted in this WP is relevant for better description of site evolution and design optimization. Both can be applied to deep geological and near surface radioactive waste disposal. Finally, by providing efficient numerical means for analysis, DONUT will, contribute to abstraction for safety case (quantification of safety margins, detailed assessment of safety functions allocated to components...).

WP5 - Fundamental understanding of radionuclide retention (FUTURE)

Quantification of long-term entrapment of key radionuclides in solid phases to inform reactive transport models and the influence of redox

‘What’

This WP aims at realizing a step change in quantitative mechanistic understanding of radionuclide retention in the repository barrier system, the key mission of any repository for radioactive waste. In consequence, the *raison d’être* of this WP concerns the identification of constraints and the increase in predictability of RN migration properties in “real” clay and crystalline rocks, quantifying the influence of key parameters of the heterogeneous rock/water system such a rock structure, redox interfaces, water saturation, reversibility etc. with the goal to develop multicomponent mechanistic sorption models, fracture and/or pore scale simulations of radionuclides transport in both in crystalline clay rock considering the combined analysis of reactivity, structure, flow field, and RN mobility/retention.

‘Why’

“Radionuclide mobility” has been identified by the mandated actors of WMO, TSO and RE as one of the key themes (4) of the EJP, the SRA and its concretization in the roadmap. It is a key theme in all radioactive waste management countries in Europe, a cornerstone for any proof of safety of nuclear waste disposal concepts. Hence, it was evident to all actors that this theme should also be part of the first EJP, acknowledging that there has been research on the various topics of radionuclide migration for more than 30 years, often funded by the European Commission, but realizing as well that various key themes have not been addressed in previous European projects (e.g. FUNMIG, SKIN, RECOSY) with sufficient depth and with sufficient potential for applicability on the real repository systems in clay or crystalline rock. The results of the project are expected to reduce uncertainties and over-conservatism of current approaches and improve the scientific basis, the realism and credibility for the safety case of deep geological disposal in clay and crystalline rock.

WP6 - Mechanistic understanding of gas transport in clay materials (GAS);

To increase understanding and predictability of gas migration in different host rocks

‘What’

This WP will provide data and develop process-level models to improve mechanistic understanding of transport processes in natural and engineered clay materials, including couplings with mechanical behaviour and impact on the clay properties. Experimental work will determine, for each identified gas transport regime, the conditions under which that regime is possible, in clay materials representative of host rock and clay EBS components. Data will be obtained that are pertinent for low (diffusion) to high (advection) gas transport rates.

Work will also show how knowledge gained from lab and in situ experiments is integrated in the conceptualisation of gas transport through different components of a repository system and how gas could affect (or not) the performance of the system. This will involve (i) development of phenomenological descriptions of gas transport and of its likely consequences at the relevant scale and (ii) testing different approaches to represent the effects of gas at repository scale and bounding its consequences in terms of repository performance.

‘Why’

Theme 4 of the EURAD Roadmap (Geoscience to understand rock properties, radionuclide transport and long-term geological evolution), increasing the understanding of gas migration is a high priority topic. Gas generation and transport is a key issue as it is possible that gas could be generated at a faster rate than it can be removed through clay host rocks (and clay EBS components – Theme 3) without creating discrete, gas-specific pathways through these low-permeability components. In several disposal concepts, the potential for migration of free gas containing radionuclides to the biosphere is an important issue. Consequently, the *raison d’être* of this WP is to answer two key end-users questions:

- How can gas migrate within the repository and which water soluble and volatile radionuclides could be associated with it?
- How and to what extent could the hydro-mechanical perturbations induced by gas affect barrier integrity and performance?

This WP will build on the outcomes of FORGE. Experiments in FORGE revealed complex mechanisms and emphasized the importance of the mechanical control exerted by the porous material on gas transport. It was suggested that this complexity can be addressed as long as one can bound the effects of these mechanisms using simple and robust descriptions for evaluation purposes (e.g. two-phase flow models for gas transient representation at repository scale, identified as a medium priority under Theme 4). A necessary condition for this is that the scientific bases are integrated properly, in a traceable way throughout the system conceptualisation process. Hence, the structure of this WP follows this process, imposing interactions at each step to ensure close cooperation between experimentalists, process modellers and those involved in evaluation of system performance. This should allow the development of robust evaluation approaches that support the expert judgement formulated at the end of FORGE that gas is not a feasibility challenging issue for geological disposal but more a challenge of managing uncertainties.

WP7 - Influence of temperature on clay-based material behaviour (HITEC); and

Improved THM description of clay based materials at elevated temperatures

‘What’

This WP aims to develop and document improved THM understanding of clay based materials (host rock and buffer) exposed to elevated temperatures (>100°C) for extended durations. The WP’s *raison d’être* is to evaluate whether or not elevated temperature limits (of 100-150°C) are feasible and safe for a variety of geological disposal concepts for high heat generating wastes (HHGW).

HITEC will study clay host rock formations (<120°C) and establish the possible extent of elevated temperature damage in the near or far field (e.g. from over pressurisation) and also the consequences of any such damage. The WP will also look at buffer bentonite and determine if temperature influences the buffer swelling pressure, hydraulic conductivity, erosion or transport properties (i.e. inhibits buffer safety functions).

‘Why’

The HITEC WP has been selected for the first phase of EURAD as the activity “Characterise bentonite/clay-based material evolution under specific conditions to provide data on hydro-mechanical, thermal and chemical behaviour” was identified as a high priority subject in theme 3 (EBS properties, function and long-term performance) phases 1-3 of the roadmap. Furthermore, the theme 4 (Geoscience to understand rock properties, radionuclide transport and long-term geological evolution) topic of “Improved understanding of the influence of temperature on radionuclide migration and representation of effects in geochemical models” was also rated as a medium priority activity.

For the disposal of HHGW it is important to understand the consequences of the heat produced on the properties (and their long term performance) of the natural and engineered clay barriers. Most safety cases (for disposal concepts that involve clay) currently involve a temperature limit of 100°C. Being able to tolerate higher temperature, whilst still ensuring an appropriate safety standard, would have significant advantages (e.g. shorter above ground cooling times, more efficient packaging, fewer disposal containers, fewer transport operations, smaller facility footprints etc.).

This WP has the potential to effectively integrate with the parallel SFC RD&D WP (i.e. interrogate the validity of the currently applied thermal limits and also the accuracy of the assumed waste source term).

WP8 - Spent Fuel characterisation and evolution until disposal (SFC);

Reduce uncertainties in spent fuel properties in predisposal phase

‘What’

This WP will develop and document an experimentally verified procedure to accurately determine the source term of irradiated spent fuels. It will also develop characterisation techniques that will allow us to more fully understand the physiochemical evolution of irradiated spent fuels (pellets and cladding) under normal and credible accident scenarios following reactor discharge (i.e. during interim storage (wet and dry), transport to and emplacement in a GDF).

‘Why’

Accurately determining the source term (see “...management of inventory data and uncertainty treatment”) and evolving condition (see “Improved understanding of the impacts of extended storage...”) of spent fuel is fundamental to safety assessment. This is reflected in the fact that both of these Roadmap theme 2 activities are shared high priorities. Parameters such as decay heat and nuclear reactivity (fissile content) need to be known to decide how much fuel can be safely loaded into a disposal container and how closely disposal containers can be emplaced at disposal. In the absence of accurate knowledge there is a risk that these parameters could be too conservatively estimated. Conservatisms would then percolate through container loadings and facility layouts, potentially resulting in substantially more containers than necessary, more transport operations and ultimately a larger facility footprint. This scenario has safety and cost ramifications. Conversely, the alternative is also possible (i.e. optimistic parameters are estimated), which could then be detrimental to safety, i.e. inadvertently breach a thermal or criticality safety limit.

WMOs are particularly interested in the possibility of an NDA technique that could allow swift and accurate corroboration of spent fuel records, prior to fuel containerisation (i.e. potential waste acceptance criteria (WAC), such as a fuel burn-up measurement or a thermal limit acceptance check). WAC is a key thematic area under theme 2 of the EURAD Roadmap and is typically of most interest to more advanced stage programmes (Phase 2 onwards).

This has potential to effectively integrate with the parallel HITEC RD&D WP (i.e. scrutinise actual thermal output and also the validity of currently applied thermal limits).

WP15 - CONtainer CORrosion under Disposal conditions (ConCorD);

Optimise and evaluate the behaviour of materials for disposal containers in view of their long-term barrier performance

‘What’

WP ConCorD will:

- Explore the potential of novel container materials and processes for optimisation of container performance within the engineered barrier system.

- Deepen the understanding of coupled interfacial processes influencing container performance under repository relevant conditions, with a focus on irradiation-accelerated corrosion, microbial activity and degradation during nearfield transients.
- Demonstrate the obtained mechanistic process understanding and develop predictive models leading to more focused performance assessments for addressing identified safety needs.

‘Why’

Even though the feasibility and safety of established container solutions has been demonstrated, recent progress in materials and processes has shown that optimisation of container manufacturing and performance is possible. The systematic exploration of novel materials, while placing existing solutions in a broader context, will provide a solid state-of-the-art for the pursuit of container optimisation according to available geology, disposal concept and regulatory requirements. The deeper understanding of coupled degradation processes of container materials will allow the development of improved assessment tools, which will ensure confidence in the long-term performance of containers and its predictability

WP16 - Chemo-Mechanical AGIng of Cementitious materials (MAGIC);

Increase the confidence in Chemo-Mechanical simulations by reducing uncertainties in input data and understanding of key coupled

‘What’

MAGIC aims to:

- quantify the chemo-mechanical multi-scale evolution of cementitious materials under the chemical degradation expected in repository environments. To identify the main reactive pathways at the repository scale during the re-saturation phase and at the saturated conditions.
- obtain a reference chemo-mechanical model of Portland and low-pH concrete exposed to relevant disposal environments, considering representative boundary conditions.
- estimate the extent of the impact of microbial activity on concrete properties (low-pH and Portland cement) in partially and fully saturated media.

‘Why’

Nowadays, most of the experimental data are limited to the short-term material evolution and the long-term mechanical integrity of the cementitious material remains largely unknown. Following knowledge gaps have been identified:

- What is the impact of various chemical degradation phenomena on the mechanical behavior of massive cementitious materials?
- What is the impact of microbially induced processes in the chemo-mechanical behavior of cementitious materials? Do these processes change the chemical evolution which is expected to occur without microbiological activity?
- How to model the long-term mechanical behavior of cementitious materials during hydraulic transients or fully saturated media with respect to the chemical evolution with and without microbial activity?
- How to achieve a comprehensive model based description of the multi-scale modelling process?

WP17 - MOnitoring equipement and DAta Treatment for Safe repository operation and staged closure (MODATS);

Evaluate, develop and describe methods and technologies, and to provide the means to measure, treat, analyse and manage data in a consistent manner.

‘What’

The ambition of the MODATS WP is to consolidate the implementation strategy for monitoring systems by developing methods through which confidence can be demonstrated in the data acquired and benefits derived for repository implementation. Repository monitoring also presents challenges related to evaluation of multi-modal data, i.e. data that is measured by different sensors, resulting in a range of independent parameters, at different locations and at varying spatial and temporal sampling. The WP will undertake R&D into data acquisition, data management and presentation, and use of data in system understanding. The WP want also to push forward what is possible in terms of monitoring, it is crucial to stay abreast with the technological development to apply and adapt emerging technologies to waste repository monitoring and develop new technologies that are suitable for the specific requirements of repository monitoring.

‘Why’

The MODAT WP covers three main topics of the Eurad Roadmap with two consider as high priority. Monitoring is a broad research area with many aspects. International collaborative research on monitoring has focused activities in a few projects that have typically addressed high-level topics. This research has helped to develop the general principals applying to repository monitoring, and to establish an international community of experts in the subject The work in the MODATS WP would provide a mechanism for this international community to commence the development of the more detailed aspects of monitoring, in particular building confidence in the acquisition, treatment and management of data. By engaging in this work now, the knowledge, experience and expertise of the monitoring community can be used in developing solutions to detailed questions associated with monitoring data. This information will be of use to programmes that are close to the start of operations and less mature programmes just setting out in the repository implementation process. The expected outputs from the WP are captured in the following:

- Learning from the monitoring of URL experiments to provide lessons for repository monitoring design and safety case implications.
- Improving monitoring technologies: especially by measuring challenging monitoring parameters.
- Investigate the impact of monitoring technology on the performance of a range of disposal systems
- Improving data treatment methods and tools (example: digital twin...) in support the elaboration of the monitoring plan.
- Documents and guidances describing a set of case studies of how monitoring data might be validated and enhance system understanding if collected during repository operation.
- Use of monitoring data to support dialogues with stakeholders.

c. Strategic Studies WPs

For the first wave of EURAD-1, the following Strategic Studies WPs have been collaboratively established. These two WPs consist of enabling experts and specialists to network on these methodological/ strategical issues and advance significant challenges that are common to various National Programmes and that are in direct link with scientific and technical issues. Initiated in order to agree upon and define in some detail the needs for future activities, including further specific thematic studies or RD&D at the forefront of science. This may also be referred to as ‘think-tank’ or networking activities to determine if there is a RD&D need on an emerging issue, if there is a need of a position paper or if it is considered mature and suitable for knowledge management activities.

- **WP9 - Waste Management routes in Europe from cradle to grave (ROUTES); and**

Share experience and knowledge on RWM routes between WMOS, TSOs and REs from different countries, with programmes at different stages of development, with different amounts and types of radioactive waste to manage

‘What’

This WP will describe and compare the different approaches to characterisation, treatment and conditioning and to long-term waste management routes between MS (member states). The interested organisations are from different countries, with programmes at different stages of development, with different amounts and types of radioactive waste to manage. In this WP, will be Identified the safety-relevant issues and their R&D needs associated with the waste management routes (cradle to grave), including the management routes of legacy and historical waste. The WP will consider past and present EU projects on the topics of interest and other initiatives carried out at international level such as IAEA, NEA in order not to duplicate the work. The aim of this WP is to identify relevant R&D topics which could be collaboratively launched in the second wave of EURAD.

‘Why’

As noted under the EURAD Roadmap Theme 2 - Radioactive waste characterisation, processing and storage (Pre-disposal activities), and source term understanding for disposal - the pre-disposal activities including radioactive waste characterization, treatment and conditioning as well as storage are considered as high priorities. Moreover, as highlighted in the Roadmap, a sufficient knowledge of the radionuclide and chemical content of the waste is a prerequisite for the development of the complete waste management route.

The common interests addressed in the ROUTES strategic studies are identified in the Roadmap and related to the Theme 2: Inventory collation and forecasting (3.5), the Methodology to define radionuclides inventories (3.6), understanding of the potential for Long-term storage as a management option for disused sealed radioactive sources (3.10), the Management of damaged waste packages and methods for reprocessing aged waste (1.2.4), the Waste acceptance criteria (2.1.6). All these subtopics are related to Roadmap Phase 0 (Policy, Framework & Programme Establishment), except the subtopic WAC which is related to Phase 2 (Site Characterisation) and Phase 3 (Facility Construction).

Consequently, the *raison d’être* of this WP is to provide an opportunity to the organisations of the Member-States to share their experience and to identify common R&D interest on such topics. To this aim, safety-relevant issues and R&D needs associated with the waste management routes (cradle to grave) will be identified, considering waste characterisation, the development of waste acceptance criteria (WAC) prior to the availability of disposal facilities, options for disposal of small waste inventories. In addition to providing an overview of good practices for different steps in radioactive waste management and guidance for research activities, the work package will provide an opportunity to consider sharing of technology and facilities.

- **WP10 - Understanding of uncertainty, risk and safety (UMAN).**

Further refinement methods to make sensitivity and uncertainty analyses and the development of multi-actor network for uncertainty management

‘What’

This WP is dedicated to the management of uncertainties potentially relevant to the safety of different radioactive waste management stages and programmes. It includes various activities such as exchanges on views, practices and uncertainty management options and the review of existing strategies, approaches and tools. Interactions between different types of actors including civil society are central to this WP. These interactions are aimed at meeting the shared objective of fostering a mutual understanding of uncertainty management strategies, approaches and preferences. A particular focus is put on uncertainties in direct link with RD&D WPs and with a high (and where relevant medium) priority subdomain of the SRA for which exchanges of information and experiences and strategic studies have been identified as beneficial by the JP actors themselves. The WP will consider past and present EU projects on the topics of interest and other initiatives carried out at international level such as IAEA and NEA so as to avoid duplicating existing work. The WP will allow identifying the contribution of past and on-going RD&D projects to the overall management of uncertainties as well as remaining and emerging issues associated with uncertainty management that could be addressed in subsequent waves of EURAD.

‘Why’

Decisions associated with radioactive waste management programmes are made in the presence of irreducible and reducible uncertainties. Several choices made on the basis of limited information in early programme phases may also have to be confirmed before or during the construction and operation of the facility. At the end of the process, uncertainties will inevitably remain but it should be demonstrated that these uncertainties do not undermine safety arguments. Hence, the management of uncertainties is a key issue when developing and reviewing the safety case of waste management facilities and, in particular, of waste disposal facilities due to the long-time scales during which the radiotoxicity of the waste remains significant.

As noted under the EURAD Roadmap Theme 1 - Managing implementation and oversight of a radioactive waste management programme - a clear strategy and commitment to involvement of stakeholders is essential to the decision-making process at all stages of a waste management programme. It is also explained that scientific activities associated with a waste management programme (site characterisation, process modelling, safety assessment etc.) are evolving over time leading to new view points and sometimes new uncertainties and they are less predictable in the outcome, duration or resources that may eventually be required. Accounting for such uncertainty has thus become a key part of successful programme planning, and would benefit from continued sharing of methodologies and experience.

Therefore, uncertainty is a cross-cutting issue of the different themes and stages identified in the Roadmap. The term “uncertainty” is also explicitly mentioned in the title of several activities of common interest considered as having a medium or a high priority: Inventory uncertainty (1.1.1), Site uncertainty treatment (3.1), Geological Uncertainties (1.6.2), Uncertainty treatment (2.1.3). Furthermore, RD&D activities are aimed at improving the state-of-knowledge and thus are expected to reduce uncertainties. Understanding the contribution of these activities to the overall uncertainty management is important for the different actors involved in the decision-making process as well as for the identification of future EURAD priorities and activities.

Consequently, the *raison d’être* of this WP is to provide an opportunity to the organisations and different actors of the Member-States to share their experience and views on uncertainty management and to identify emerging needs associated with this topic. The WP will also contribute to understanding the added value of RD&D activities for the safety case and the decision-making process. It also contributes to the vision of EURAD by fostering mutual understanding and trust between Joint Programme participants.

d. Knowledge Management WPs

Under EURAD-1, Knowledge Management is enabled by three permanent WPs that derive directly from EURATOM expectations under WP2018:

- **WP11 - State of Knowledge** - Activities under this WP consist of developing a systematic approach of establishing the state-of-knowledge in the field of RWM research. This shall be done on a stepwise basis: i) establishing of procedures to document the SoK; ii) testing and improving these procedures on a few demonstration topics/sub-topics (of the Roadmap); iii) performing a review on existing tools/platforms and evaluating the added-value of establishing such a platform dedicated to provide access to SoK developed in EURAD.
- **WP12 - Methodological guidance** - Activities under this WP consist of developing a comprehensive suite of instructional guidance documents that can be used by Member-States with RWM programmes that are at an early stage of development with respect to their national RWM programme. Such WP shall pursue and complement the work initiated with the [PLANDIS Guide](#).
- **WP13- Training/mobility** - Activities under this WP consist of developing a diverse portfolio of tailored basic and specialised training courses under the umbrella of a “School of Radioactive Waste Management”, taking stock of and building upon already existing initiatives (i.e. IAEA and NEA) and creating new initiatives to bridge the identified gaps. The end-users are defined as professionals and potential new professionals at graduated and post-graduated level from EU and non-EU countries (via the IAEA and NEA programmes), and in particular the next generation of experts This WP will also

organise a mobility programme to provide access to dedicated infrastructures associated with the Mandated Actors/Linked Third Parties within EURAD. This work will be carried out in close interaction with European networks having a recognised experience in training/mobility in the field of RW

e. Contribution from Civil Society

For the first wave of the EURAD-1, the two Strategic Studies Work Packages have been selected for specific contribution from civil society because they are focusing on generic aspects of radioactive waste management and are of interest for civil society in EU countries:

- SS WP9 - Waste Management routes in Europe from cradle to grave (ROUTES); and
- SS WP10- Understanding of uncertainty, risk and safety (UMAN).

In close collaboration with the WP Boards (WP Leader and task leaders) the role of **CS Experts** (in charge of translating the WP work content and results to the CS group as described in [Section 1.1.4](#)) is to:

- Sketch out and map the key stakes related to the work performed in the different tasks/subtasks of the WPs from a CS point of view in order to translate the work content and the results to the broader CS group and gather its feedback at annual workshops;
- Contribute to the work performed in the tasks/subtasks of the selected WPs and participate in key working meetings of these tasks;
- Raise awareness from the broader CS group on the scientific/technical research issues for radioactive waste management solutions by preparing and animating a specific session dedicated to the selected WPs in the CS annual workshop of EURAD (see above).

Furthermore, under the PMO WP, a **dedicated coordination task** is established to coordinate, support and integrate at the programme level all the interactions activities with Civil Society. This coordination task will consist of providing methodological support for CS interactions with RWM stakeholders: elaboration of material, methodologies, processes and sessions to prepare EURAD participants and CS representatives in order facilitate fruitful interactions, as well as the assessment of the on-going experimental model of Interaction between EURAD participants and Civil Society. This coordination work will also consist notably of organizing yearly a workshop involving the participants of the CS group, the CS Experts together with a panel of experts from WMOs, TSOS and REs participants in EURAD.

In the second wave workpackages, the contribution from Civil Society will continue in the extensions of the Strategic Studies.

A specific subtask has also been added in the RD&D WP MODATS (subtask 2.5) to cover interactions with the Civil Society. The aim of this subtask is develop an integrated vision of how the monitoring devices and corresponding data production will contribute to develop a shared understanding of the repository system along with the decision-making process from the early phase of authorisation, to subsequent implementation phases, closure and post-closure.

3.1.2. Timing of the different work packages and their components

WP1- Programme Management Office (PMO), including Dissemination

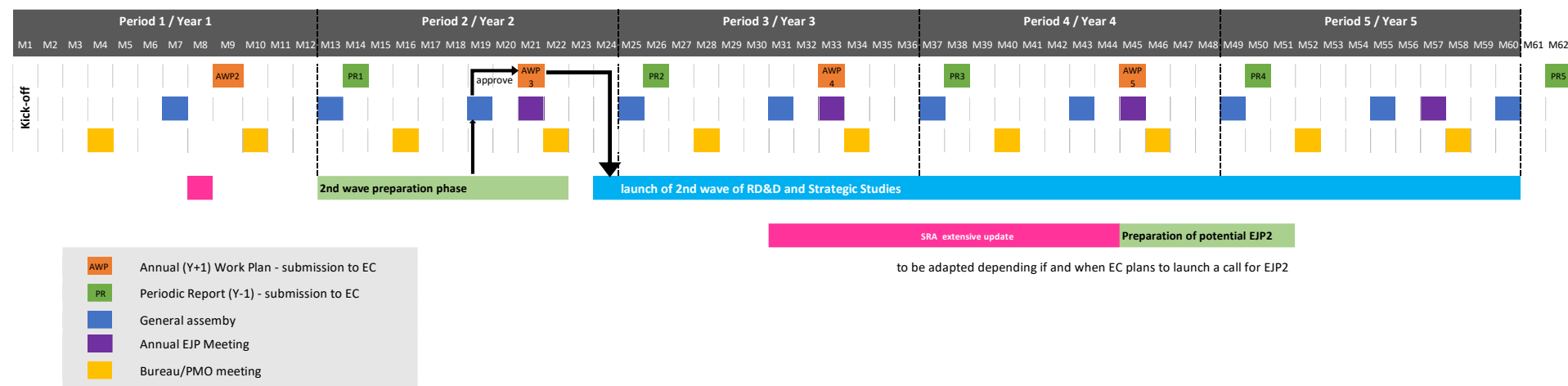
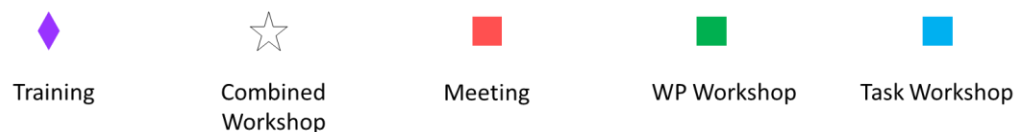


Figure 7 – EURAD Programme Management timing

The breakdown of WPs into tasks and subtasks and the timing of each is included in the diagrams below. Tasks are denoted ‘TX’ and subtasks are denoted as ‘TX.X’. The timing of deliverables is included using notation of ‘DX.X’. The final column shows the extent to which the activities will be complete within the first year, expressed as a percentage.

Legend



WP 2 – Assessment of Chemical Evolution of ILW and HLW Disposal Cells (ACED)

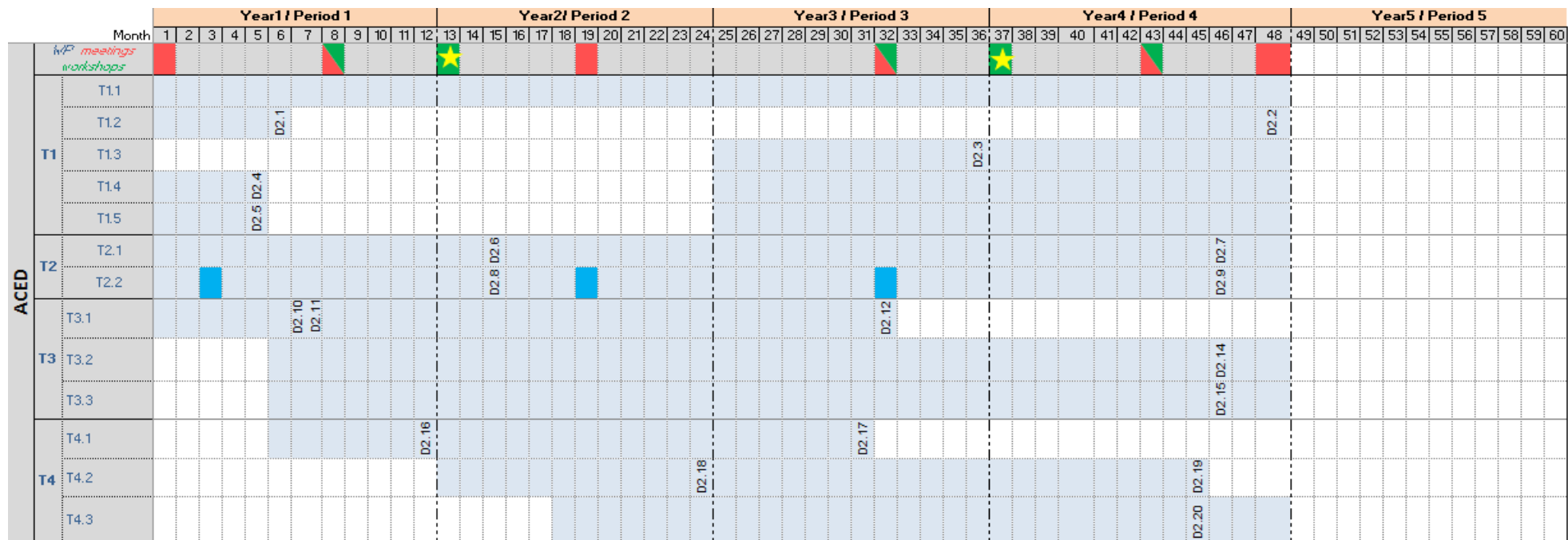


Figure 8 - Timing of WP2-ACED

WP 3 – Cement-Organic-Radionuclide-Interactions (CORI)

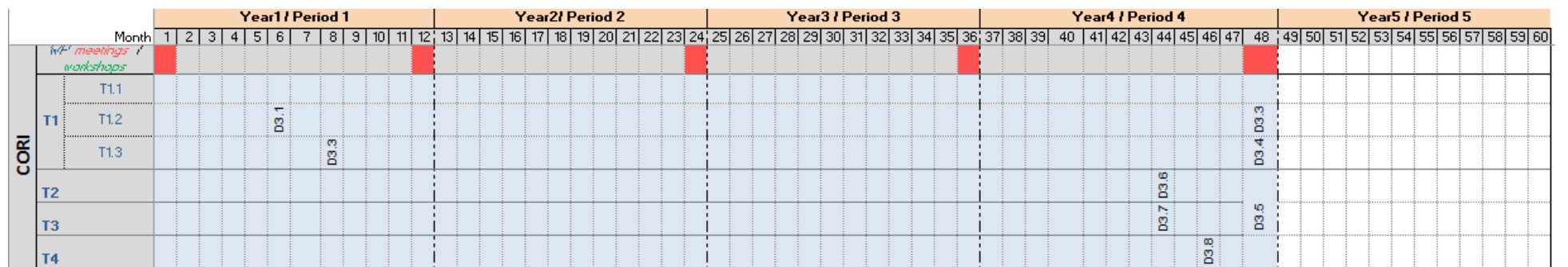


Figure 9- Timing of WP3-CORI

WP 4 – Development/improvement of numerical methods & tools for modelling coupled processes (DONUT)

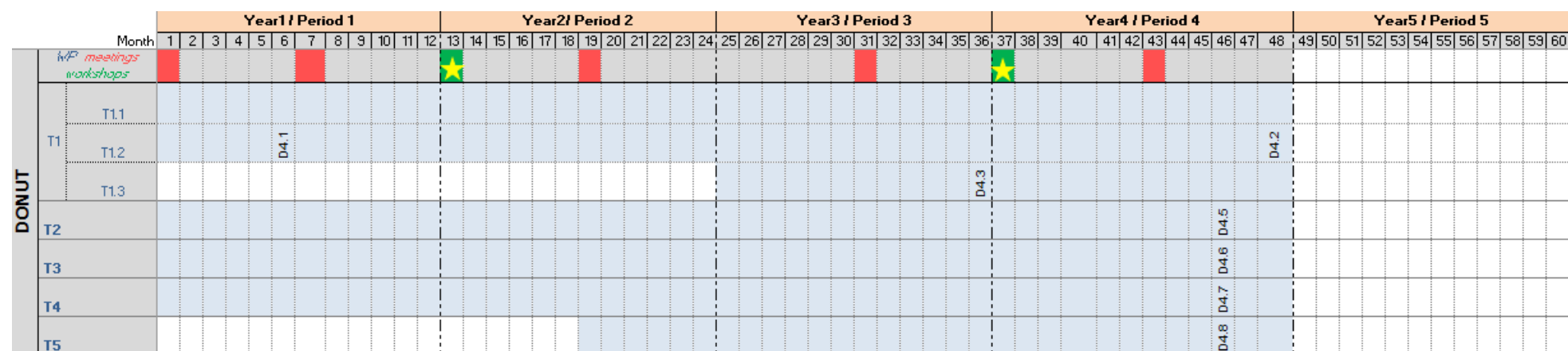


Figure 10 - Timing of WP4-DONUT

WP 5 – Fundamental understanding of radionuclide retention (FUTuRE)

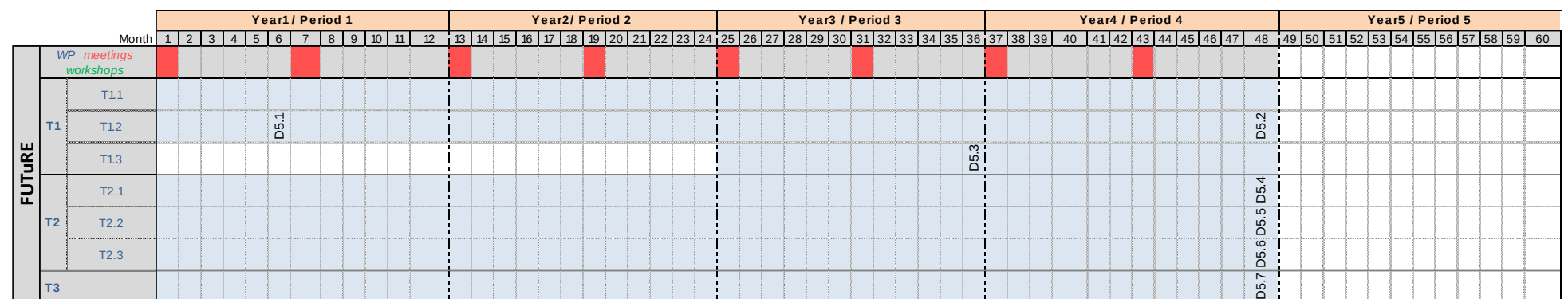


Figure 11 - Timing of WP5-FUTuRE

WP6-Mechanistic understanding of gas transport in clay materials (GAS) and WP7-Influence of temperature on clay-based material behaviour (HITEC)

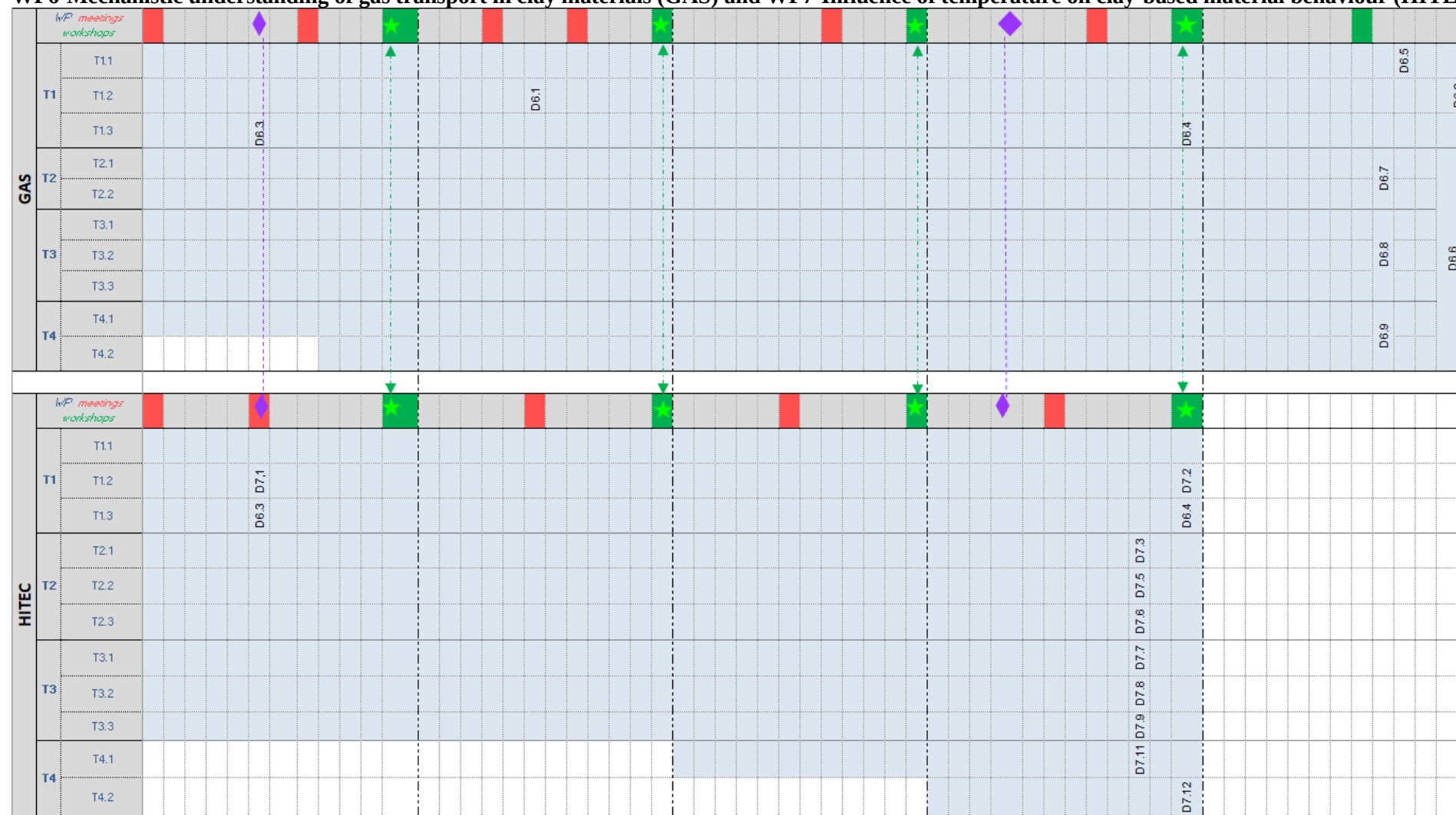


Figure 12 - Timing of WP6-GAS and WP7- HITEC

WP 8 – Spent Fuel Characterization and Evolution Until Disposal (SFC)

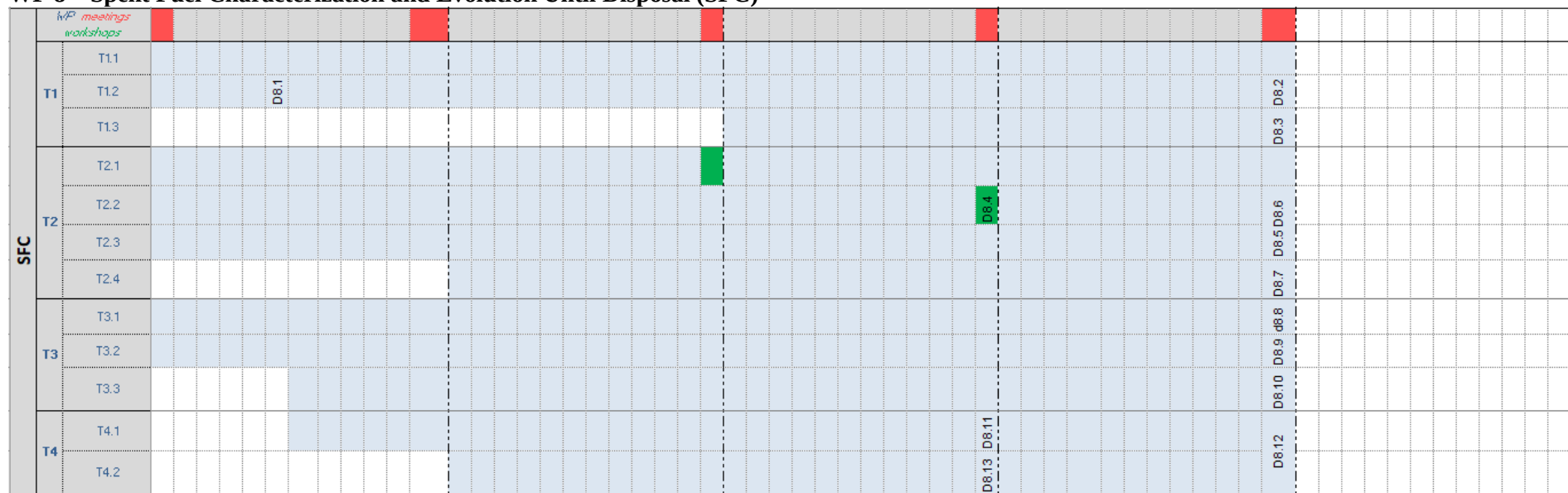


Figure 5 - Timing of WP8-SFC

WP 9 – Waste management routes in Europe from cradle to grave (ROUTES)

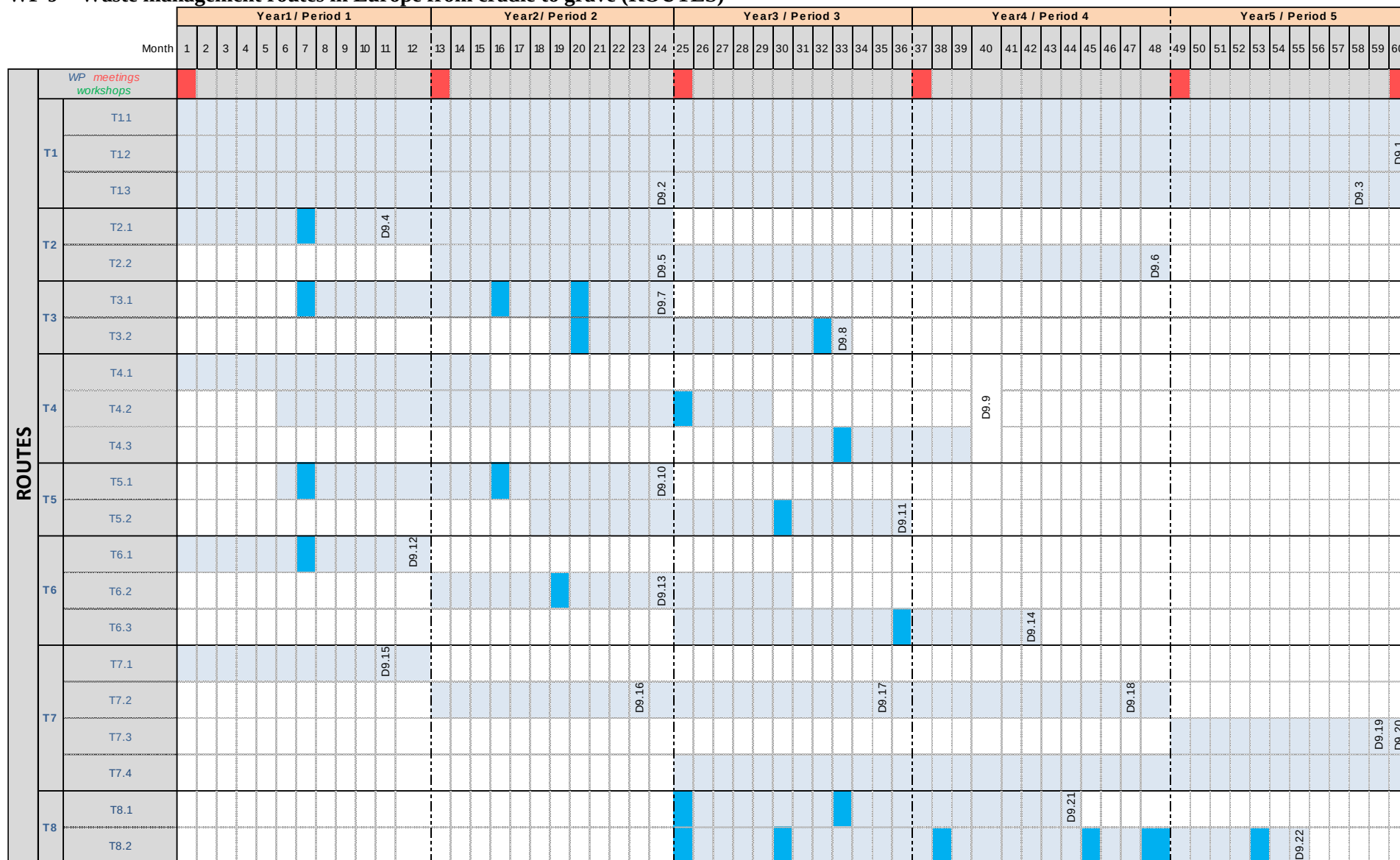


Figure 6 - Timing of WP9-ROUTES

WP10 – Uncertainty Management multi-Actor Network (UMAN)

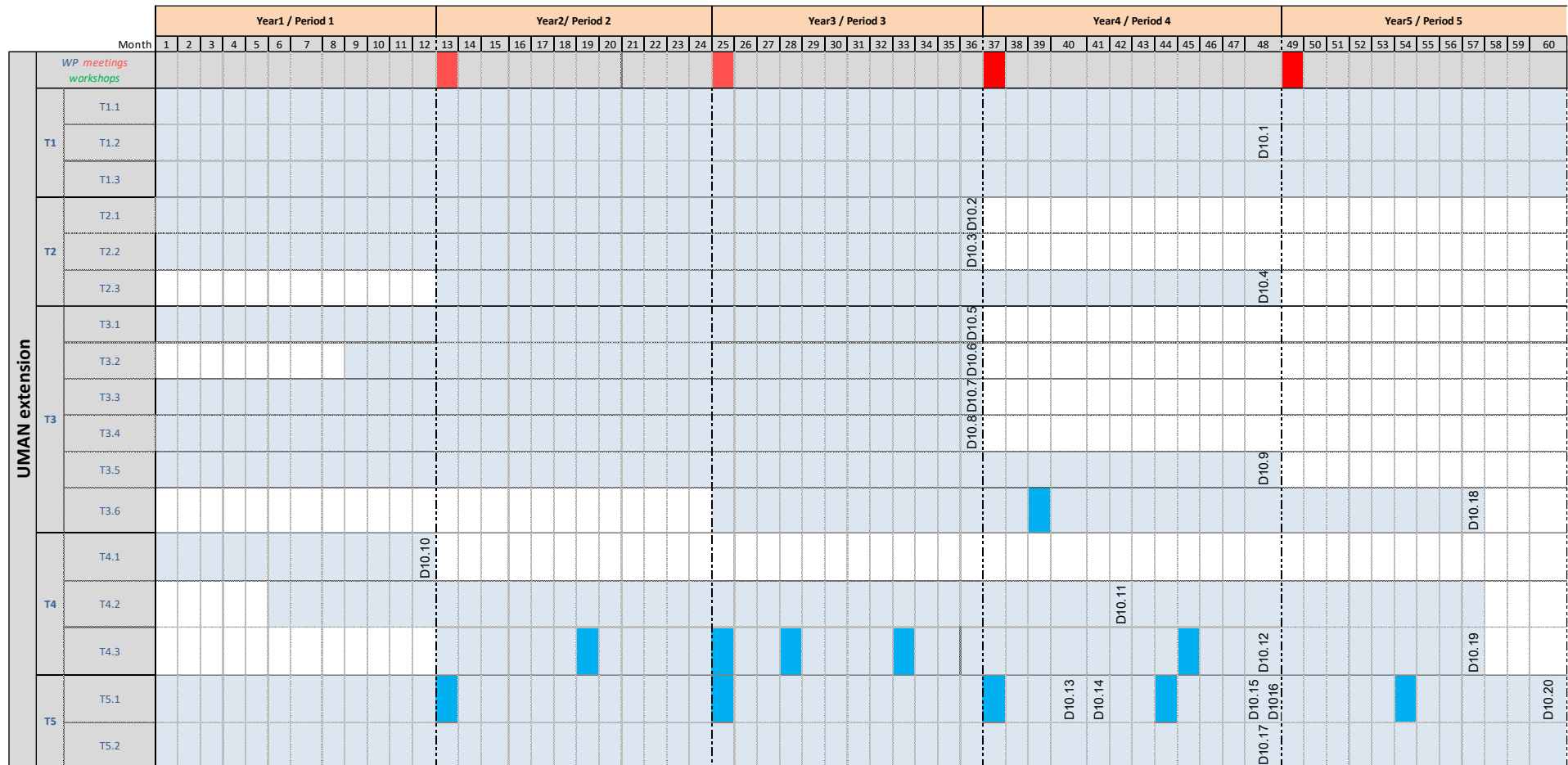


Figure 15 - Timing of WP10-UMAN

WP11 – State-of-Knowledge (SoK)

[illegible]

Figure 16 - Timing of WP11- SoK

WP12 – Guidance

		Year1 / Period 1												Year2/ Period 2												Year3 / Period 3												Year4 / Period 4												Year5 / Period 5											
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
Guidance	T1	D12.1 D11.2																																																											
	T2													D12.3												D12.7												D12.5																							
	T3																									D12.4												D12.6																							

Figure 17 - Timing of WP12-Guidance

WP13 – Training/Mobility

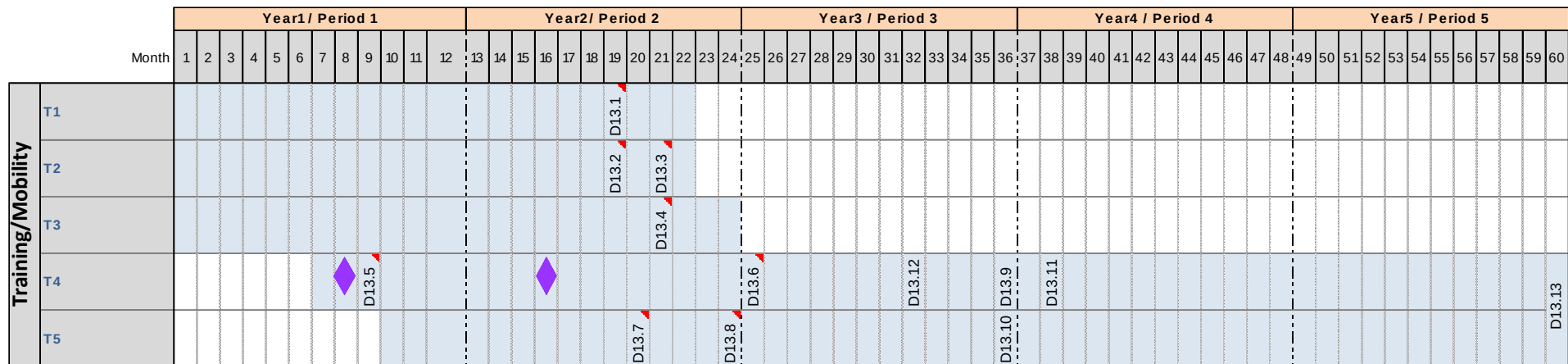


Figure 18 Timing of WP13-Training/Mobility

WP15- Container CORrosion under Disposal conditions (ConCorD)

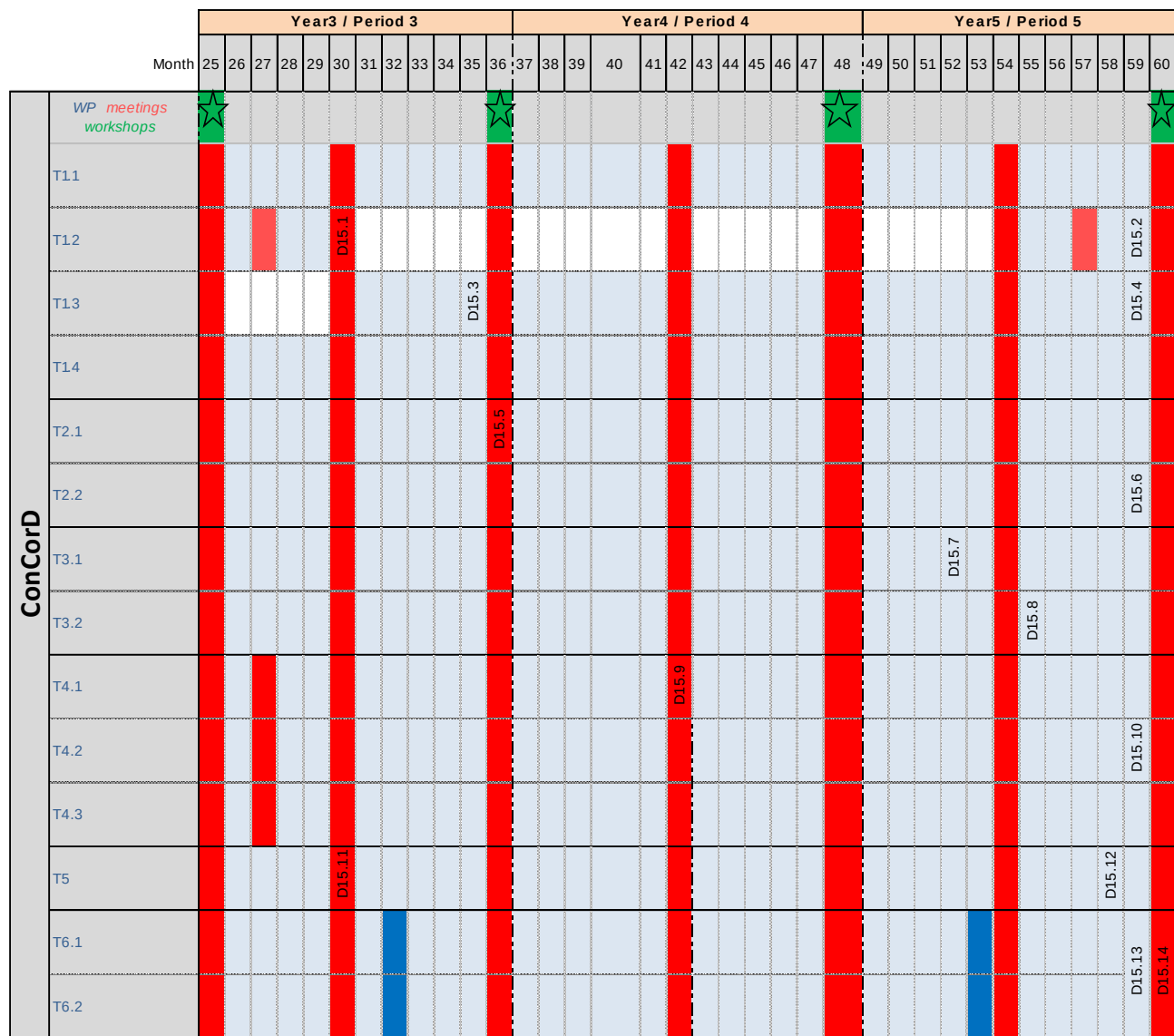
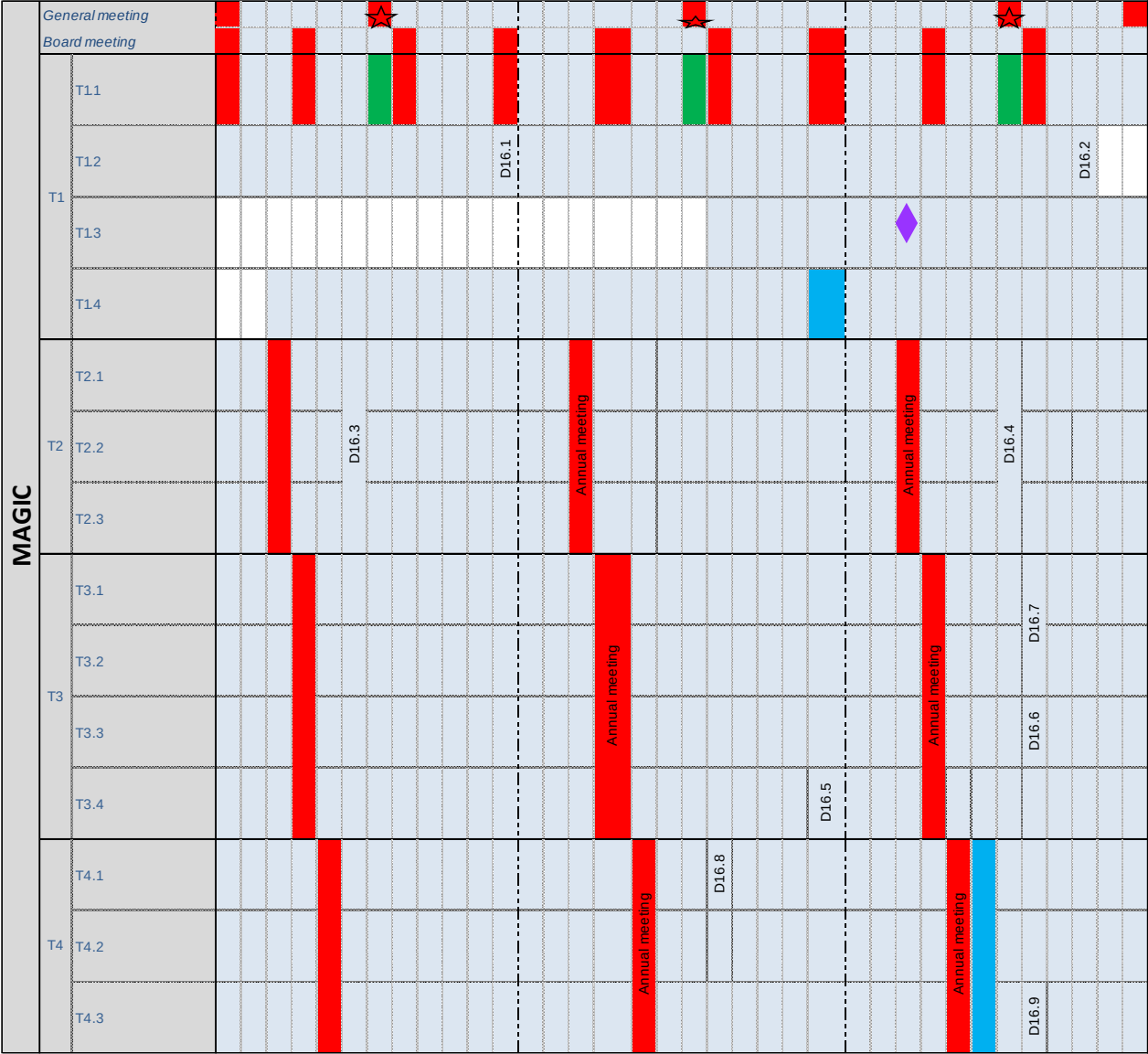


Figure 19 - Timing of WP15 ConCorD

WP16- Chemo Mechanical AGIng of Cementitious materials (MAGIC)



WP17- Monitoring Equipment and Data Treatment for Safe Repository Operation and Staged Closure (MODATS)

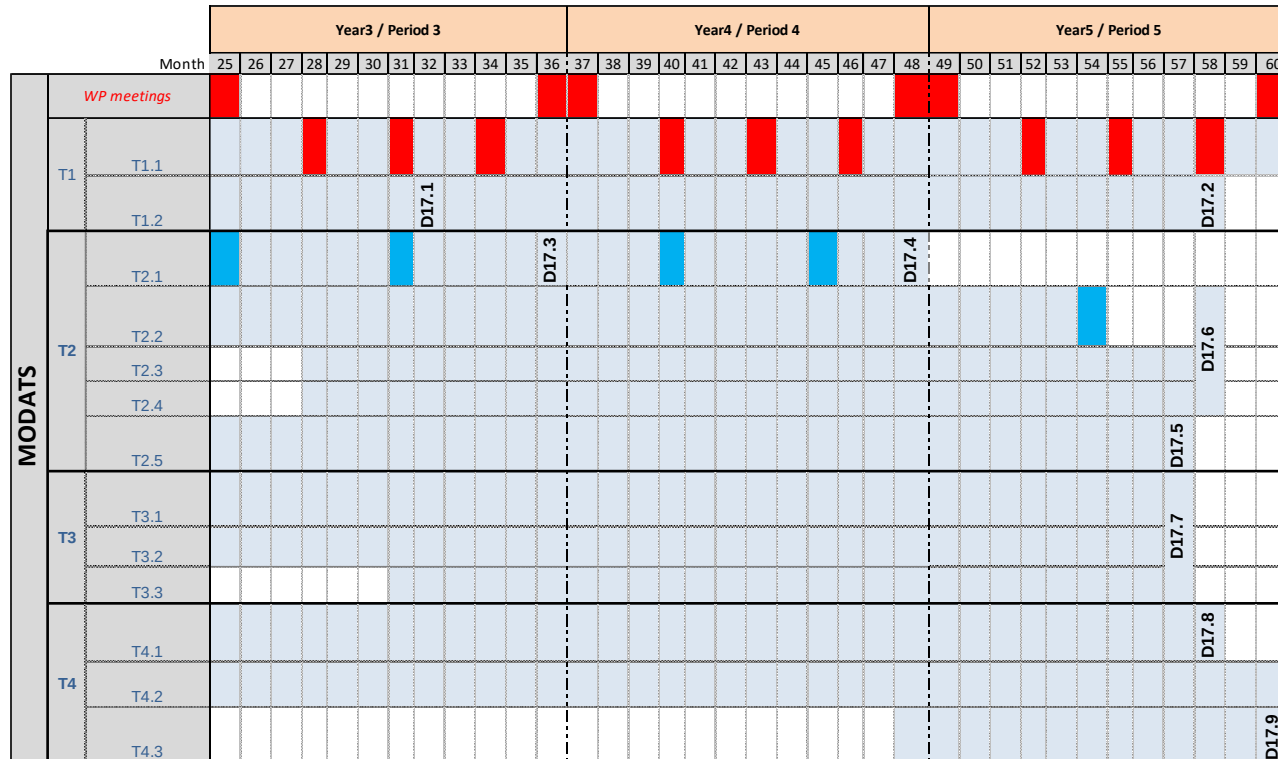


Figure 21 - Timing of WP17 MODATS

3.2. Management structure, milestones and procedures

The overall EURAD-1 organisation can be seen in the Figure below.

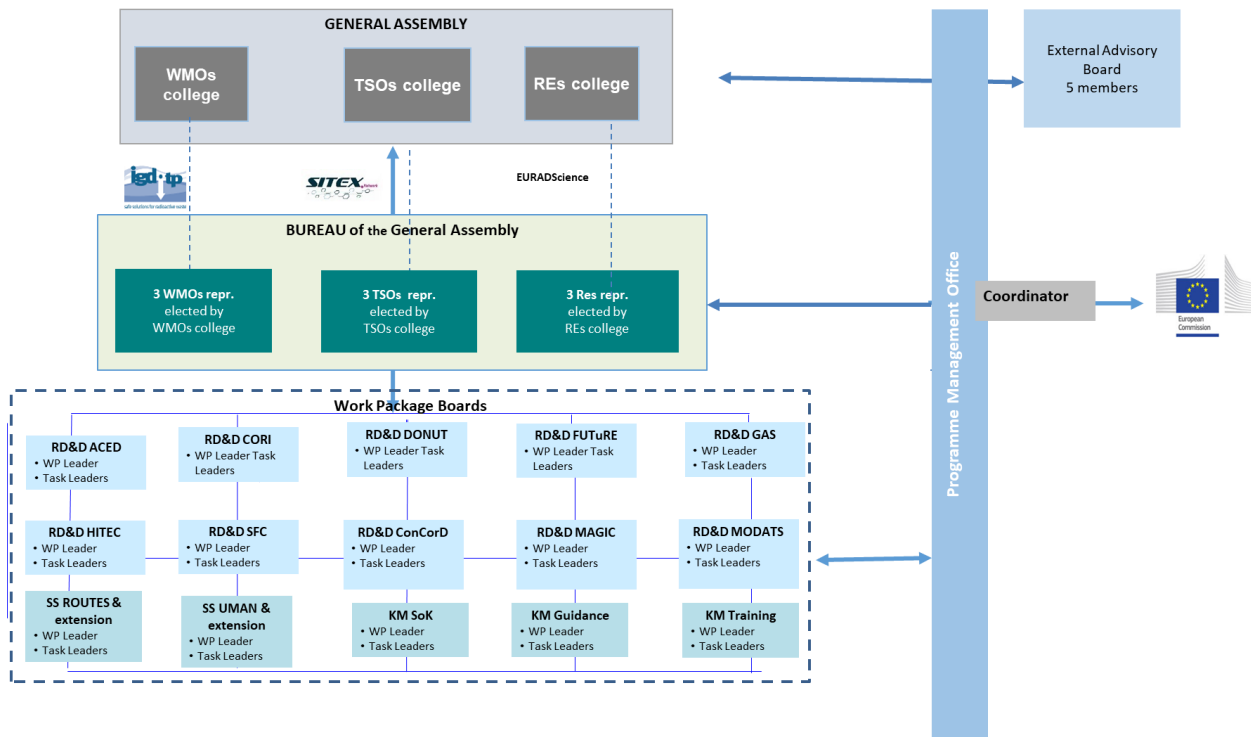


Figure 22 -Governance of the EURAD-1

The **General Assembly** is the ultimate decision-making body of the EURAD consortium. It is responsible for agreeing the strategy of EURAD in line with the content of the Vision, SRA/Roadmap and the Euratom Work Programme. It is composed of one representative of each Beneficiary (Mandated organisations). Beneficiaries fall into one of the three following colleges: Waste Management Organisations (WMOs), Technical Support Organisations (TSOs) and Research Entities (REs). Each category has its own **college** within the General Assembly: WMOs college, TSOs college and REs college⁴.

The General Assembly shall be free to act on its own initiative to formulate proposals and take decisions, following preview with the Bureau and/or Programme Management Office. In addition, proposals made by the Bureau and by the Programme Management Office shall be considered and decided upon by the General Assembly.

The General Assembly shall meet regularly (at least twice a year). The members of the Bureau and the PMO shall also participate in the General Assembly meetings. It is anticipated that the WP Leaders and the CS representative shall be invited as observers, however the General Assembly reserves the right to call closed meetings, if required.

The General Assembly shall establish a **Bureau**. The Bureau is accountable to the General Assembly. It proposes documents and decisions to be taken by the General Assembly. It acts on behalf of the General Assembly in close interactions with the Programme Management Office during the elaboration of proposals, for subsequent decision by the General Assembly. The Bureau shall be composed of a total of nine representatives; 3 elected by each General Assembly.

⁴ The establishment of the colleges is meant to be compatible with the boundary conditions of independence (Maintenance of Independence principle) between the “expertise function” (fulfilled by TSOs and by some Research Entities) and the “implementer function” (fulfilled by WMOs). It shall allow verification that the positions/decisions of the GA are inclusive in terms of actors (Inclusiveness principle).

- The WMOs College appoints its three Bureau representatives (including one representative from a country with early stage/ small RWM programme).
- The TSOs College appoints its three Bureau representatives (including one representative from a country with early stage/small RWM programme).
- The REs College appoints its three Bureau representatives (including one representative from a country with early stage/small RWM programme).

The Bureau members shall represent the interest of their respective community and not the interest of their own organisation or country. The composition of the Bureau shall be regularly reviewed/re-elected for suitability of roles, responsibilities and membership (at least by mid-term of the first 5-year implementation). This shall be done through consultation with each of the Colleges and any changes approved by the General Assembly.

Participation of a CS Expert (facilitator) in Bureau meetings as Observer

A representative from an organisation acting as CS Expert (LTP) may be invited by the bureau in a number of bureau meetings to express CS views on the activities to develop by the EJP. He/she will be designated by the CSO group.

The aim is to enable CSOs through one of their CS Expert to express their views during the update of the Strategic Research Agenda/Roadmap and the definition of future waves of activities. The ambition of the EURAD Consortium is to establish effective dialogue with Civil Society in order to enhance mutual on the RD&D needed to develop safe solutions in the processing and disposal of radioactive waste.

If the Chairperson of the Bureau deems it necessary, or on request of a Bureau member, the Bureau may, regarding either all or part of the agenda, be convened as a closed session where participation may be limited to the Bureau members.

The **Programme Management Office (PMO)** is in charge of scientific and technical coordination of the implementation of the programme, as well as the day-to-day management and communication activities. It is responsible to the General Assembly for the overall top-level planning, coordination and implementation of the EURAD Work Plan in line with the strategy agreed by the General Assembly. It interacts with the EC and key stakeholders: national programmes, international organisations/ programmes, Civil Society Organisations, science/policy interface.

The PMO is housed in the premises of the Coordinator [**Andra**] which is the legal entity acting as the intermediary between the Parties and the European Commission. For the first 2,5 years (except for [**JRC**] who will be involved in the PMO over the 5 years), staff from [**CNRS**], [**RWM**], [**IRSN**] and [**JRC**] will participate in the PMO. The PMO shall organise regular meetings gathering all the WP Leaders to ensure interactions between the projects and ensuring joint programming of activities. A dedicated Work Package is established for the activities of the PMO **Erreur ! Source du renvoi introuvable.** In addition, the PMO shall be reinforced with a Chief Scientific Officer that shall act as a EURAD high-level spokesperson with a recognized broad and high-level strategic overview, able to contextualize EURAD progress and results vis-a-vis the Roadmap, i.e. linking EURAD scientific/technical/strategic outcomes to milestones typical of different phases of a RWM programme. Such a role shall be given on a rolling basis, e.g. every two years.

For each technical Work Package a **Work Package (WP) Board** is set-up. It is composed of the Work Package Leader and the task leaders. The WP Board ensures that the WP is progressing according to the agreed specifications, milestones and planning. The WP Board is also responsible for reporting the work progress, any WP deliverables and eventual modifications of the WP work plan to the Programme Management Office.

External advisory board (EAB) advises the General Assembly on strategic and implementation issues related to the EURAD and its coherence with respect to the Strategic Research Agenda and Vision. The EAB is composed of scientific and technical experts at international level, Civil Society Expert (external to EURAD, e.g. a social scientist or CS expert outside Europe), IAEA representative, NUGENIA and other potential international organisations, nuclear safety authorities' representatives (through WENRA and ENSREG networks). The constitution of the EAB shall be approved during the first General Assembly meeting.

The EAB shall be invited to the annual meeting and shall provide external advice and recommendations for the implementation of EURAD.

Conditions for Participation

The beneficiaries of the Joint Programme have received a mandate by their National Programme owner to participate in the JP implementation phase (the mandate shall confirm that organisations are responsible for managing/implementing a RWM programme and/or managing/ implementing a RD&D programme needed for implementation). The Joint Programme assumes no responsibilities for maintenance or impact of the National Programme. The Joint Programme is complementary to Member-States National Programme, and the interactions between the two are managed via the national mandate. This includes the preservation of the independence and role of Beneficiaries in the national-decision making process.

According to Article 6 of the 2011/70/EURATOM directive, Member-States shall ensure that the competent regulatory authority is functionally separated from any other body or organisation concerned with the management of spent fuel and radioactive waste, in order to ensure effective independence from undue influence on its regulatory function. This requirement has several implications for the expertise function which is aimed at providing the technical and scientific basis for supporting the decision made by the regulatory function. Arrangements must therefore be made by the Member-States National Programme to maintain the independence role of potentially different Joint Programme participants. Regarding the Joint Programme, the use and interpretation of results, (produced by the Joint Programme) in the context of the national geological disposal programme is the respective responsibility of the WMOs and TSOs.

3.3. Consortium as a whole

EURAD participants are those organisations with scientific and technical responsibilities and a national mandate for research in radioactive waste management, including disposal. This includes the implementer, the regulatory expertise function, and those with scientific and technical responsibilities and a national mandate for research and development in radioactive waste management in their respective countries.

As of today, 51 organisations and 23 countries (20 EU Member-States and 3 Associated Countries) have received a mandate by their National Programme owner to participate as “Mandated Actors” (i.e. Participants) in EURAD (See List of EURAD Mandated Actors under Appendix Founding Document). This includes:

- **Waste Management Organisations (WMOs)** – have ultimate responsibility for the implementation of geological disposal (which includes the management of a supporting RD&D programme), and for some the wider remit of RWM (including waste characterisation, treatment and packaging). WMOs from across Europe form a core part of the Joint Programme and provide a driving force for what is needed for successful and practical implementation from an industrial perspective. WMOs have established a network and coordination framework for RD&D needs of the implementers of geological disposal at the European level via the Implementing Geological Disposal Technology Platform (see, [IGD-TP](#));
- **Technical Support Organisations (TSOs)** – carrying out activities aimed at providing the technical and scientific basis for supporting the decisions made by a national regulatory body⁵. As safety cases for waste processing, storage and geological disposal develop, so too does the safety case review and independent scrutiny responsibility by regulatory organisations in the framework of the decision-making process. This requires specific skills from the regulatory expertise function undertaken by safety authorities, regulators, and their technical support organisations (TSOs). Several TSOs, together with other organisations fulfilling a regulatory expertise function and CSOs have established the [SITEX](#) network to support independent technical expertise in the field of safety of geological disposal of radioactive waste; and
- **Research Entities (REs)** – working to different degrees on the challenges of RWM including disposal (and sometime in direct support to implementers or WMOs or TSOs), under the responsibility of Member-States.

⁵ It is noted that the distinction between TSOs and REs in several Member States is a somewhat grey area as several Research Entities also fulfil (at least partially) an expertise function in their country and therefore also meet the conditions associated with the terms of a “TSO”.

This includes national research centres, some research organisations and some universities that could also be funded by other sources. RE's provide scientific excellence and leading-edge research on basic components and generic processes in relation to the management of radioactive waste, and therefore represent a large proportion of the contributions to the Joint Programme.

National RWM programmes involved in EURAD cover a broad spectrum of stages of development and level of advancement, particularly with respect to their plans and national policy towards implementing geological disposal ('Advanced Stage Programme', 'Early Stage Programme'). Programmes differ significantly depending on the national waste inventory, with some Member-States only responsible for relatively small volumes of medical and research reactor-derived wastes ('Small Inventory Programme'), compared to others that have comparatively large and /or complex waste inventories derived from large nuclear power (and fuel reprocessing) and defence programmes. Programmes also differ significantly in the way in which they are managed, particularly with respect to the national policy and socio-political landscape with respect to long-term storage solutions and geological disposal.

Regardless of size and stage of implementation, all Member-States are responsible for the safe management of radioactive waste and are required to report periodically on the status of their National Programme (See, [Waste Directive](#)).

3.4.Resources to be committed

As explained in introduction of Section 3 Implementation, and according to the EURATOM WP2018 call, the Joint Programme shall remain flexible to include new activities in order to be as needs-driven as possible and to allow later inclusion of new organisations that would be mandated during the course of an implementation phase.

Under the EURAD first implementation phase (EURAD-1), we propose to ensure this by allocating about 70% of the available RD&D/Strategic Studies budget to RD&D/Strategic Studies WPs/tasks that shall start at Month 1. The not allocated budget will be allocated to existing or new WPs/tasks that will be approved by the General Assembly during the course of EURAD-1 and integrated in the Annual Work Plan 3.

For KM WPs 46% of the budget has been allocated. The remaining 54% of the budget will be allocated on an annual basis.

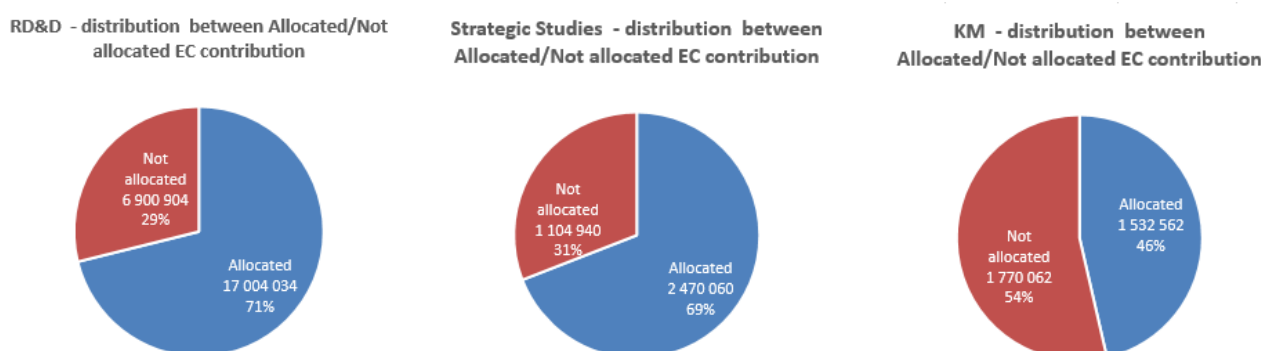


Figure 23 – Distribution of EC contribution between Allocated and Not Allocated budget for RD&D, SS an KM

The Bureau and PMO decided that it was wise to retain a modest reserve and develop a flexibility allocation mechanism for the small reserve part of the second wave budget.

The reserve will be used for any new priority challenges such as requests from the EC or activities agreed by the General Assembly. It will also be subjected to annual reassessment of the situation, to ensure that this reserve is utilised before the end of EURAD in the most appropriate manner.

To ensure the retention of this small reserve, it was required that all of the second wave work packages were slightly reduced and that reduction contributed to this flexibility allocation mechanism. The reductions were achieved by each 2nd wave work package (exception made for ROUTES extension) defining an option that would not start at the beginning of the work package and would, if not implemented, not affect delivery of the other tasks or activities within the WP. Those options represent 2 % of each work package total budget.

The formal decision if and how to implement the options will be taken by General Assembly at meeting n°6 in 2022 as part of the above mentioned periodic reassessment and will consider the possible issues and challenges that could appear and hinder reaching the key objectives of the Joint Programme.

The mechanism to take such a decision will be developed and adopted at the GA n°5 in September 2021.

3.4.1. Overview of total eligible costs/EC requested contribution

Table 2 – overview of total eligible costs/EC requested contribution (allocated and not allocated budget) per categories of WP and per categories of activity before the second wave

Allocated budget – « first wave »												
	KM activities		RDD activities		SS activities		Administration		ICS activities		Total	
	Total	EC requested contribution	Total	EC requested contribution	Total	EC requested contribution	Total	EC requested contribution	Total	EC requested contribution	Total	EC requested contribution
RDD WPs	497 125	248 563	34 208 357	16 821 630							34 705 482	17 070 193
SS WPs					3 259 570	2 281 474			227 369	193 429	3 486 939	2 474 903
KM WPs	1 820 515	1 177 708	0						0		1 820 515	1 177 708
PMO WP	182 405	182 405	182 405	182 405	182 405	182 405	1 780 515	1 532 562	264 749	264 749	2 592 478	2 344 524
total	2 500 045	1 608 676	34 390 761	17 004 034	3 441 974	2 463 878	1 780 515	1 532 562	492 117	458 178	42 605 414	23 067 328
Not Allocated budget - (secured under Coordinator budget)												
	KM activities		RDD activities		SS activities		Administration		ICS activities		Total	
	Total	EC requested contribution	Total	EC requested contribution	Total	EC requested contribution	Total	EC requested contribution	Total	EC requested contribution	Total	EC requested contribution
RDD WPs			13 801 808	6 900 904							13 801 808	6 900 904
SS WPs					1 587 317	1 111 122			274 031	191 822	1 861 348	1 302 944
KM WPs	1 416 178	991 324									1 416 178	991 324
PMO WP							237 500	237 500			237 500	237 500
total	1 416 178	991 324	13 801 808	6 900 904	1 587 317	1 111 122	237 500	237 500	274 031	191 822,00	17 316 834	9 432 672
Total budget												
	KM activities		RDD activities		SS activities		Administration		ICS activities		Total	
	Total	EC requested contribution	Total	EC requested contribution	Total	EC requested contribution	Total	EC requested contribution	Total	EC requested contribution	Total	EC requested contribution
RDD WPs	497 125	248 563	48 010 165	23 722 534	0	0	0	0	0	0	48 507 290	23 971 097
SS WPs	0	0	0	0	4 846 886	3 392 596	0	0	501 400	385 251	5 348 287	3 777 847
KM WPs	3 236 693	2 169 033	0	0	0	0	0	0	0	0	3 236 693	2 169 033
PMO WP	182 405	182 405	182 405	182 405	182 405	182 405	2 018 015	1 770 062	264 749	264 749	2 829 978	2 582 024
total	3 916 223	2 600 000	48 192 570	23 904 939	5 029 291	3 575 000	2 018 015	1 770 062	766 149	650 000	59 922 248	32 500 000

3.4.2. Indicative Distribution of EC between the different types of activities

The Figure below shows the initial distribution of EC contribution between the different types of activities, as detailed in Table 2. The distribution of EC contribution between the different types of activities shall not be capped. It can be subject to modification after approval by the General Assembly

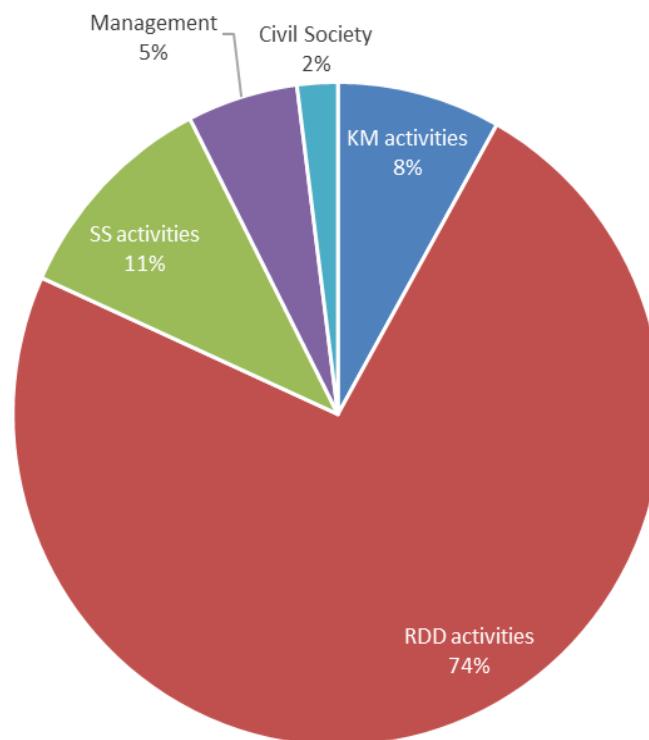


Figure 24 - Distribution of EC contribution between the different types of EURAD Deployment Activities (allocated and not allocated) before the second wave
Distribution allocated budget between the different types of eligible costs

Figure 25 below shows the distribution of the total allocated budget between the different categories of eligible costs.

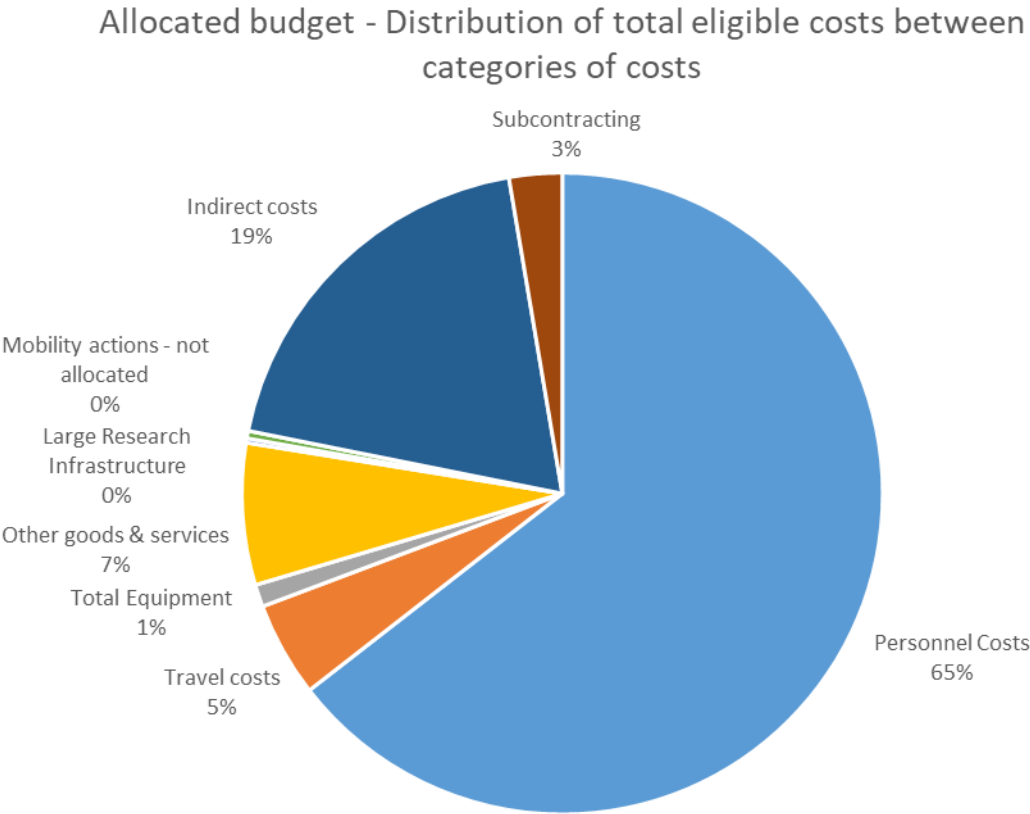


Figure 25 - Allocated budget - distribution of total eligible costs between categories of costs

3.4.3. 'Other direct cost' items (travel, equipment, other goods and services, large research infrastructure)

1/ANDRA	Cost (€)	Justification
Travel	229 400	Travel costs are needed to properly implement the actions that are planned in each relevant WP (WPs annual meetings/Tasks meetings, workshops, seminars); to participate in EURAD General Assemblies and EURAD Annual Meetings , WP workshops; and to participate in scientific conferences/workshops to present EURAD/WPs results and outcomes.
Equipment	103 500	Equipment costs are planned under the following RD&D WPs: - HITEC: 18 000€ - CORI: 10 000€ - ConCorD: 10 500 € corrosion cells and autoclaves Teflon jacketed (EMSE) - MAGIC: 15 000 € Experimental setup to maintain crack opening in RC ties subjected to saturation and desaturation with water similar to the Cigeo underground environment ones. (LMDC) - MODATS : 50 000 € 40 000€ for Manufacturing optical fiber cable (coating selection) 10 000€ for acquisition of high performance optical time-domain reflectometer (OTDR) is an optoelectronic instrument to characterize an optical fibre cable during experiment under neutron
Other goods and services	705 500	Costs for Other goods and services are planned under the following RD&D WPs: - PMO: 380 000€ (organisation of meetings, Website + Extranet Envelop for invitation for external experts) - ACED: 3 000€ - DONUT:4 000€ - HITEC:15 000€ - FUTURE:44 000€ - CORI: 88 500€: Task 2: Underground Research Laboratory testing, translation Task 3: electro-diffusion measurements of organic molecules. - ConCorD : 75 500 € (EMSE) Consumables and supplies for corrosion and stress corrosion cracking tests Supply of cold spray samples, including the purchase of powder and gas and the provision of the technological platform Consumables for sample preparation and their characterisation, Consumables for microwave processing (refractories), Rehabilitation of 3 autoclave lines and the consumables associated to their use during the leaching tests - MAGIC : 15 000€ (LMDC) Adaptation of existent experimental setups and buy of consumables (gas and chemical products) to maintain chemical environment during tests and measure the residual strength at the end of the tests. - MODATS : 79 500 € 39 000€ for the organisation of 5 MODATS WP annual meetings (task1) 5 000€ for the face-to-face meeting organisation of the executive board (remote meeting will done mainly using TEAMS) 3 000€ audit cost (WP1) 20 000€ for the Workshops organisation (6 WS)

		5 000€ participation to Waste Management conference in Phoenix (task 4) 2500€ participation to Optical Fiber Sensors conference in 2022 5 000€ for printing Costs for Other goods and services are planned under the following Strategic Studies WPs: - ROUTES: 1 000€.
Total	1 038 400	

2/ARAO	Cost (€)	Justification
Travel	5 000	Travel costs are needed to properly implement the actions that are planned in each relevant WP (WPs annual meetings/Tasks meetings, workshops, seminars) ; to participate in EURAD General Assemblies and EURAD Annual Meetings , WP workshops; and to participate in scientific conferences/workshops to present EURAD/WPs results and outcomes.
Equipment	-	-
Other goods and services	-	-
Total	5 000	

3/BEL V	Cost (€)	Justification
Travel	32 125	Travel costs are needed to properly implement the actions that are planned in each relevant WP (WPs annual meetings/Tasks meetings, workshops, seminars) ; to participate in EURAD General Assemblies and EURAD Annual Meetings , WP workshops; and to participate in scientific conferences/workshops to present EURAD/WPs results and outcomes.
Equipment	-	-
Other goods and services	59 172	Costs for Other goods and services are planned under the following RD&D WPs: - ACED: 17 000€. Consumables and raw materials for the implementation of the new in-situ experiment NE2-2/1 of Task 2. Costs for Other goods and services are planned under the following Strategic Studies WPs: - UMAN: 40 172€. Organization of seminars and workshops of the WP (budget will be transferred to the organizations hosting these workshops/seminars when identified). - UMAN extension : 2 000 € Costs associated with WP meeting #4
Total	91 297	

4/BGE

The sum of the costs for 'travel', 'equipment', and 'goods and services' does not exceed 15% of the personnel costs for BGE.

5/CEA	Cost (€)	Justification
Travel	78 500	Travel costs are needed to properly implement the actions that are planned in each relevant WP (WPs annual meetings/Tasks meetings, workshops, seminars) ; to participate in EURAD General Assemblies and EURAD Annual Meetings , WP workshops; and to participate in scientific conferences/workshops to present EURAD/WPs results and outcomes.
Equipment	-	-
Other goods and services	307 818	Costs for Other goods and services are planned under the following RD&D WPs:: - ACED: 116 000€ : it corresponds to consumables for solution and solid analyses (ICPM-MS analysis ; SEM, TEM, Raman, ToF-SIMS) of the various experiments (glass/steel/clay and glass/steel/cement buffer/clay) - DONUT: 2 200€ : Consumables for computer - HITEC: 5 894€ : this cost corresponds to consumables for the several mechanical tests performed on clay host rock - FUTuRE: 37 000€ : it corresponds to consumables necessary for the diffusion experiments (for example radioactive and non-radioactive tracers), and for post-mortem analysis of solid samples (m-XAS, m-XRF, m-LIBs) - CORI: 69 724€ : it corresponds to consumables that are necessary for the migration experiments planned with C-14 radiolabeled organics - MAGIC: 15 000 € : Task 3: Maintenance of devices used for additional experiments / Task 4: Maintenance of computational facilities + Acquisition of a new cluster node for parallel computing - MODATS : 61 000 € Consumables for organic synthesis and chemical characterization (chemical products, solvents, chromatography, NMR, ...) Material and consumables for electrografting of the dyes: potentiostat, solvents, dyes, metallization of glass plates, chemical characterization of the grafting: FTIR, XPS, AFM, Raman, profilometry. Optical components: light source, spectrometer, optical fibers, mirrors, optical calculations... Maintenance of the laboratory equipments needed for chemical analysis. Complete experimental set up for the real test at the Andra URL Costs for <i>Other goods and services</i> are planned under the following Strategic Studies WPs: - ROUTES: 1 000€. organisation of a meeting
Total	386 318	

6/ CIEMAT	Cost (€)	Justification
Travel	140 900	Travel costs are needed to properly implement the actions that are planned in each relevant WP (WPs annual meetings/Tasks meetings, workshops, seminars) ; to participate in EURAD General Assemblies and EURAD Annual Meetings , WP workshops; and to participate in scientific conferences/workshops to present EURAD/WPs results and outcomes.
Equipment	105 557,60	Costs for Equipment are planned under the following RD&D WPs :

		HITEC : 17 000 € FUTURE: 15 000 € SFC: 39 557,60 € CORI : 22 000 € ConCorD : 12 000 €
Other goods and services	242 451	Costs for Other goods and services are planned under the following RD&D WPs : ACED : 44 000 € GAS : 16 051 € HITEC : 23 900 € FUTURE : 30 000 € CORI : 35 000 € ConCorD : 87 000 € MAGIC: 6 500 €
Total	488 908,60	

7/ChRDI	Cost (€)	Justification
Travel	20 000	Travel costs are needed to properly implement the actions that are planned in each relevant WP (WPs annual meetings/Tasks meetings, workshops, seminars) ; to participate in EURAD General Assemblies and EURAD Annual Meetings , WP workshops; and to participate in scientific conferences/workshops to present EURAD/WPs results and outcomes.
Equipment	-	-
Other goods and services	7 000	Costs for Other goods and services are planned under the following RD&D WPs: - HITEC: 1 000€. Costs for organizing of seminars/meetings, rental of equipment for presentations - ConCorD : 6 000 € Raw materials for SiC based composites, chemicals, materials for PVD method cathodes, small labware and tools, consumables for work implementation
Total	27 000	

8/CNRS	Cost (€)	Justification
Travel	190 500	Travel costs are needed to properly implement the actions that are planned in each relevant WP (WPs annual meetings/Tasks meetings, workshops, seminars) ; to participate in EURAD General Assemblies and EURAD Annual Meetings , WP workshops; and to participate in scientific conferences/workshops to present EURAD/WPs results and outcomes.
Equipment	124 922	Equipment costs are planned under the following RD&D WPs: - GAS: 20 000€ - Characterization of the nano-porous structure properties and its effect on H2 sorption, Raman Spectroscopy, X-ray diffraction, QUENS, CT, TEM... - CORI: 10 000€ - HITEC: 30 000€ - Triaxial cell transparent to X-ray under high Temperature and confining pressure - SFC: 49 922€ - Experiment approach for study of degradation process of spent nuclear fuel: Cutting-edge synchrotron methods at the Rossendorf beamline (i.e. high resolution diffraction, x-ray absorption spectroscopy and x-ray emission spectroscopies)

		- MAGIC: 15 000€ Fabrication of a new testing set for creep tests with micro-tomography monitoring
Other goods and services	441 738	Costs for Other goods and services are planned under the following RD&D WPs: - ACED: 33 500€ - Consumables and samples for in situ experiment for mineralogical, chemical and transport properties evolution, chemical and mineralogical analyses of solid phases (X-ray tomography, XRD, SEM EDS, Raman spectrometry and TEM) - DONUT: 24 560€. CPU for Diffusion Poisson Coupled Model and new numerical methods. Workshops/meetings. - GAS: 132 700€. Characterization the nano porous structure properties, gas sorption desorption and propagation process in a large range of pressure, Raman Spectroscopy, X-ray diffraction, QUENS, CT, TEM + meetings and workshop organizations - HITEC: 54 550€. Consumables and samples of Boom Clay, Opalinus Clay, Callovo Oxfordian clay for X-ray measurement under high Temperature and confining pressure - FUTuRE: 100 428€. Preparation of clay samples, consumable sorption and redox experiment in a specifically designed chemical reactor - CORI: 51 000€. Consumable and supplies for alpha and gamma radiolytic degradation pf PCE - ConCorD : 30 000 € Consumables for the fabrication of materials (powders, precursors, additives, solvents, gas, etc.) and associated characterizations (access to the CARMALIM -Characterization of Materials of Limoges) platform). Chemicals, consumables, irradiation facility, samples characterisation - MAGIC : 15 000 € Cost for the use of micro-tomography platform, samples fabrication and small consumables (jackets, strain gages etc.)
Total	757 160	

9/COVRA	Cost (€)	Justification
Travel	53 900	Travel costs are needed to properly implement the actions that are planned in each relevant WP (WPs annual meetings/Tasks meetings, workshops, seminars) ; to participate in EURAD General Assemblies and EURAD Annual Meetings , WP workshops; and to participate in scientific conferences/workshops to present EURAD/WPs results and outcomes.
Equipment	-	-
Other goods and services	27 900	Costs for Other goods and services are planned under the following RD&D WPs: - ACED: 12 800€. Certified concrete samples have been exposed to geological representative clay media for several years at start of ACED. To support chemical evolution models, these samples are experimentally investigated by Jülich, ZAG and COVRA. Each organisation performs different chemical analysis to obtain a coherent image. COVRA's in-house laboratory equipment will also be used. The costs are for the sample preparation and measurement of chemical elements using ICP.

		- DONUT: 300€. DONUT is WP on the development and improvement of numerical methods and tools for modelling of coupled processes. COVRA will prepare benchmarks for the evaluation of the methods and numerical tools described considering their relevance in the scope of multi-physical assessment from the point of view of the implementer. Specifically COVRA plans to develop a benchmark for numerical models with steep chemical gradients across solid interfaces. This contribution can be of help with the evaluation of the efficiency and computational cost of different numerical models/solvers for models with a steep chemical gradient across interfaces between solid materials. - MAGIC : 12 800 € Certified concrete samples as well as porous mortars with a sufficient pore size for microbial activity have been exposed to geological representative clay media since 2016. To support chemo-mechanical evolution models and to understand the impact of the microbial activity on this evolution, these samples are experimentally investigated by FZJ, SCK-CEN and COVRA. Each organisation performs different analysis to obtain a coherent image. COVRA's in-house laboratory equipment will also be used for determination of the compressive strength. The costs are for the sample preparation and measurement of chemical elements using ICP-OES and sample preparation. Costs for Other goods and services are planned under the following Strategic Studies WPs: - ROUTES: 2 000€. The WP will describe and compare the different approaches to characterization, treatment and conditioning and to long-term waste management routes, and identify opportunities for collaboration between MS (Member-States). It will identify safety-relevant issues and their R&D needs associated with the waste management routes (cradle to grave), including the management routes of legacy and historical waste, taking into account that programmes are at different stages of development, have with different amounts and types of radioactive waste to manage and considering interdependencies between the routes. COVRA will coordinates the task to evaluate the potential for developing and using shared technologies and facilities.
Total	81 800	

10/FTMC	Cost (€)	Justification
Travel	24 000	Travel costs are needed to properly implement the actions that are planned in each relevant WP (WPs annual meetings/Tasks meetings, workshops, seminars) ; to participate in EURAD General Assemblies and EURAD Annual Meetings , WP workshops; and to participate in scientific conferences/workshops to present EURAD/WPs results and outcomes.
Equipment	-	-
Other goods and services	9 000	Costs for <i>Other goods and services</i> are planned under the following RD&D WPs: - CORI: 9 000€ In Task 2, FTMC will perform hydrolytic degradation of PVC/Cellulose and identification of degradation products. For this task the material (PVC,

		cellulose) as an object of research, chemicals and goods for hydrolytic degradation are needed. Ion exchange/gas chromatography sorbents, pipette tips, centrifuge tubes, pH electrode will also be needed for detection of degradation products. In Task 4, for study of the competitive effect of Fe(II)/Fe(III) onto radionuclides (Am-243 and Pu-242) sorption in the presence of organics (low molecular weight organic acids / phthalate / adipate) in contact with CEM I/ CEM V cement-based materials (pH 12.5) FTMC must purchase organics and radionuclide solutions (Am-243 and Pu-242). Laboratory glass, goods for filtration (filters) and centrifugation (centrifuge tubes) will be needed. For the examination of chemical and phase composition of the cement the service at X-ray spectroscopy and XRD will be need during experiments.
Total	33 000	

11/CV REZ	Cost (€)	Justification
Travel	18 000	Travel costs are needed to properly implement the actions that are planned in each relevant WP (WPs annual meetings/Tasks meetings, workshops, seminars) ; to participate in EURAD General Assemblies and EURAD Annual Meetings , WP workshops; and to participate in scientific conferences/workshops to present EURAD/WPs results and outcomes.
Equipment	20 000	Equipment costs are planned under the following RD&D WPs: - CORI: 20 000€ Task 2 and 3: gamma radiation source Cobalt-60 with the half-life 5 years. Total price of the source is approximately 80 000 €. Whole CORI contribution (20 000€) will be used for the project issues.
Other goods and services	14 000	Costs for <i>Other goods and services</i> are planned under the following RD&D WPs: - CORI: 13 000€ This money will be used for the material, necessary for irradiation and testing of the superplasticizers (Task 1) and cement samples (task 2), e.g. ducts for gasses, gauges, glass, cables or so on. - MAGIC : 1 000 € Calibration talon for Ultrasound measurement
Total	52 000	

12/DEKOM	Cost (€)	Justification
Travel	9 900	Travel costs are needed to properly implement the actions that are planned in each relevant WP (WPs annual meetings/Tasks meetings, workshops, seminars) ; to participate in EURAD General Assemblies and EURAD Annual Meetings , WP workshops; and to participate in scientific conferences/workshops to present EURAD/WPs results and outcomes.
Equipment	-	-
Other goods and services	-	-
Total	9 900	

13/EEAE	Cost (€)	Justification
Travel	9 400	Travel costs are needed to properly implement the actions that are planned in each relevant WP (WPs annual meetings/Tasks meetings, workshops, seminars) ; to participate in EURAD General Assemblies and EURAD Annual Meetings , WP workshops; and to participate in scientific conferences/workshops to present EURAD/WPs results and outcomes.
Equipment	-	-
Other goods and services	-	-
Total	9 400	

14/ENRESA	Cost (€)	Justification
Travel	42 500	Travel costs are needed to properly implement the actions that are planned in each relevant WP (WPs annual meetings/Tasks meetings, workshops, seminars) ; to participate in EURAD General Assemblies and EURAD Annual Meetings , WP workshops; and to participate in scientific conferences/workshops to present EURAD/WPs results and outcomes.
Equipment	-	-
Other goods and services	-	-
Total	42 500	

15/JUELICH

The sum of the costs for 'travel', 'equipment', and 'goods and services' does not exceed 15% of the personnel costs for JUELICH.

16/GRS

The sum of the costs for 'travel', 'equipment', and 'goods and services' does not exceed 15% of the personnel costs for GRS.

17/IAE	Cost (€)	Justification
Travel	5 500	Travel costs are needed to properly implement the actions that are planned in each relevant WP (WPs annual meetings/Tasks meetings, workshops, seminars); to participate in EURAD General Assemblies and EURAD Annual Meetings , WP workshops; and to participate in scientific conferences/workshops to present EURAD/WPs results and outcomes.
Equipment	-	-
Other goods and services	-	-
Total	5 500	

18/INCT	Cost (€)	Justification
Travel	8 400	Travel costs are needed to properly implement the actions that are planned in each relevant WP (WPs annual meetings/Tasks meetings, workshops, seminars) ; to participate in EURAD General Assemblies and EURAD Annual Meetings , WP workshops; and to participate in scientific conferences/workshops to present EURAD/WPs results and outcomes.
Equipment	-	-
Other goods and services	1 000	Costs for <i>Other goods and services</i> are planned under the following Strategic Studies WPs: - ROUTES: 1 000€. Cost of organization of internal meetings, small consumables, dissemination of information between Polish stakeholders (webpage, posters, leaflet).
Total	9 400	

19/IRSN	Cost (€)	Justification
Travel	179 800	Travel costs are needed to properly implement the actions that are planned in each relevant WP (WPs annual meetings/Tasks meetings, workshops, seminars) ; to participate in EURAD General Assemblies and EURAD Annual Meetings , WP workshops; and to participate in scientific conferences/workshops to present EURAD/WPs results and outcomes.
Equipment	10 000	Equipment costs are planned under the following RD&D WPs: - GAS: 10 000€. Development of a special set-up consisting on a transparent PMMA (Polymethyl methacrylate) cell will be used to perform a microstructural analysis of the mixture at initial state and during gas /water injections by X-ray micro-tomography and laboratory consumables for the mock-up test of gas injection into highly heterogeneous bentonite pellet-powder sample.
Other goods and services	193 000	Costs for <i>Other goods and services</i> are planned under the following WP: - PMO: 80 000€. Costs for <i>Other goods and services</i> are planned under the following RD&D WPs: - ACED: 64 500€. Laboratories materials and consumables. - DONUT: 1 500€. Laboratories materials and consumables. - MAGIC : 10 000 € Consumables for laboratory work associated to 1 PhD student activities (18 months), sample recovering in the in situ experiments, characterisation tools maintenance - MODATS : 20 000 € 15 000 € Meeting organisation (IRSN) 5 000 € Meeting organisation (MUTADIS) Costs for <i>Other goods and services</i> are planned under the following Strategic Studies WPs: - ROUTES: 15 000€. Organisation of workshops and meetings. - UMAN extension : 2 000 € UMAN Seminar n°5 (MUTADIS)
Total	382 800	

20/IST-LPSR	Cost (€)	Justification
Travel	8 400	Travel costs are needed to properly implement the actions that are planned in each relevant WP (WPs annual meetings/Tasks meetings, workshops, seminars) ; to participate in EURAD General Assemblies and EURAD Annual Meetings , WP workshops; and to participate in scientific conferences/workshops to present EURAD/WPs results and outcomes.
Equipment	-	-
Other goods and services	-	-
Total	8 400	
21/IST-ID	Cost (€)	Justification
Travel	8 400	Travel costs are needed to properly implement the actions that are planned in each relevant WP (WPs annual meetings/Tasks meetings, workshops, seminars) ; to participate in EURAD General Assemblies and EURAD Annual Meetings , WP workshops; and to participate in scientific conferences/workshops to present EURAD/WPs results and outcomes.
Equipment		
Other goods and services	5 660	Costs for <i>Other goods and services</i> are planned under the following RD&D WPs: - ROUTES: 4 000€. Organisation of meetings. - ROUTES extension : 1 660 € Workshop organisation
Total	14 060	

22/JSI	Cost (€)	Justification
Travel	75 300	Travel costs are needed to properly implement the actions that are planned in each relevant WP (WPs annual meetings/Tasks meetings, workshops, seminars) ; to participate in EURAD General Assemblies and EURAD Annual Meetings , WP workshops; and to participate in scientific conferences/workshops to present EURAD/WPs results and outcomes.
Equipment	-	-
Other goods and services	103 400	Costs for <i>Other goods and services</i> are planned under the following WP: - PMO: 28 400€. Organisation of meetings. Costs for <i>Other goods and services</i> are planned under the following RD&D WPs: - ACED: 8 000€. Chemicals, gases for instruments, standards, laboratory consumables. - CORI: 62 000€. Chemicals, gases for instruments, standards, laboratory consumables. - SFC: 4 000€. Chemicals, gases for instruments, standards, laboratory consumables. - MODATS : 5 000 € Involvement in sub-task 2.5.
Total	178 700	

23/JRC	Cost (€)	Justification
Travel	70 000	Travel costs are needed to properly implement the actions that are planned in each relevant WP (WPs annual meetings/Tasks meetings, workshops, seminars) ; to participate in EURAD General Assemblies and EURAD Annual Meetings , WP workshops; and to participate in scientific conferences/workshops to present EURAD/WPs results and outcomes.
Equipment	-	-
Other goods and services	208 631	Costs for Other goods and services are planned under the following WP: - PMO: 2 000€. Organisation of meetings. Costs for Other goods and services are planned under the following RD&D WPs: - SFC: 206 631€. Waste and consumables for implementation in SFC WP
Total	278 631	

24/KIT

The sum of the costs for 'travel', 'equipment', and 'goods and services' does not exceed 15% of the personnel costs for KIT.

25/LEI	Cost (€)	Justification
Travel	41 525	Travel costs are needed to properly implement the actions that are planned in each relevant WP (WPs annual meetings/Tasks meetings, workshops, seminars) ; to participate in EURAD General Assemblies and EURAD Annual Meetings , WP workshops; and to participate in scientific conferences/workshops to present EURAD/WPs results and outcomes.
Equipment	-	-
Other goods and services	4 000	Costs for <i>Other goods and services</i> are planned under the following RD&D WPs: - DONUT: 2 000€. Consumables and supplies, dissemination and conference fee, open acces publication fee - MAGIC : 2 000 € Updating of the annual licence for the computer code COMSOL
Total	45 525	

26/MTA EK	Cost (€)	Justification
Travel	24 900	Travel costs are needed to properly implement the actions that are planned in each relevant WP (WPs annual meetings/Tasks meetings, workshops, seminars) ; to participate in EURAD General Assemblies and EURAD Annual Meetings , WP workshops; and to participate in scientific conferences/workshops to present EURAD/WPs results and outcomes.
Equipment	18 500	Equipment costs are planned under the following RD&D WPs: - ACED: 6 500€. Encapsulation machine, boxes for the in-situ experiments (with temperature, humidity pH control), access to study the surface of the containers (exp. wet catalytic oxidation, corrosion and other redox processes on steel container surfaces). - DONUT: 8 000€ - SFC: 4 000€. Rental of Ar, N2, H2 gas cylinders, in-situ cells, for irradiation test, special capsules.

Other goods and services	26 600	Costs for Other goods and services are planned under the following RD&D WPs: - ACED: 4 000€. Consumables: radioisotopes, chemicals, laboratory material for supporting experimental work, steel containers for several experiments. Dissemination cost (workshops, meetings); to present the results. - DONUT: 6 000€ - SFC: 9 000 EUR. Consumables like: thermocouples, sealing rings etc... - FUTuRE: 7 600€. Consumables: radioisotopes in solution form, chemicals, laboratory material for supporting experimental work
Total	70 000	

27/NAGRA	Cost (€)	Justification
Travel	110 375	Travel costs are needed to properly implement the actions that are planned in each relevant WP (WPs annual meetings/Tasks meetings, workshops, seminars); to participate in EURAD General Assemblies and EURAD Annual Meetings , WP workshops; and to participate in scientific conferences/workshops to present EURAD/WPs results and outcomes.
Equipment	57 500	Costs for Equipment are planned under the following RD&D WPs : ACED: 17 500 € (UBern)Construction of special diffusion cell devices made of Titanium, purchase of swelling pressure sensors. GAS: 40 000 € (CIMNE / EPFL / ZHAW) Water/gas injection tests on rock/bentonite samples are performed by CIMNE and EPFL in the context of TP3.1 ("Barrier Integrity"). Test execution requires adaptations/modifications of the existing permeameter devices to cope with high pressures and very low water/gas flow rates (further details are described in the upcoming MS124). ZHAWs equipment costs are related to the development and testing of imaging methods (micro-CT, FIB etc.) for microstructural characterisation of bentonite and Opalinus Clay.
Other goods and services	348 798	Costs for Other goods and services are planned under the following RD&D WPs : - ACED: 2 200 € UBern Purchase of various chemical products and isotopically-labelled tracer for Fe(II) migration experiment. - GAS : 5 000 € : CIMNE / EPFL CIMNE /EPFL perform basic geotechnical characterisations of 2 host rock formations (Boom Clay, Opalinus Clay) and for granular bentonite. Shipment of test material, imaging of cores, sample preparation, etc are covered by this budget postion - HITEC: 3 300 € : NAGRA Consumables - ConCorD : 323 298 € : NAGRA / EPFL / JACOBS Nagra: Publication costs for a open access special issue of a peer-reviewed journal for CoCorD papers. EPFL: genetic sequencing costs. Jacobs: operational costs of the irradiation facility - MODATS : 15 000 € : ETH 5 000 € publication costs We plan to disseminate our results in leading geophysical journals. Based on our experience, typical costs per paper are approximately 2000 to 3000 Euros. We expect publishing at least 3 papers from the project results. Costs exceeding 5000 Euros will be covered over own ETH funds. 10000 € HPC costs

		The Exploration and Environmental Geophysics Group (EEG) at ETH Zurich, in which MODATS will be hosted, is shareholder of the large-scale computer cluster EULER operated by ETH Zurich. For accessing an adequate number of CPUs on EULER, the EEG Group has to make substantial annual contributions. The overall computing time on EULER, required for MODATS, is expected to amount to approx. 10'000 Euro. These costs are part of the ETH in kind contributions.
Total	516 673	

28/NCSRD	Cost (€)	Justification
Travel	21 800	Travel costs are needed to properly implement the actions that are planned in each relevant WP (WPs annual meetings/Tasks meetings, workshops, seminars) ; to participate in EURAD General Assemblies and EURAD Annual Meetings , WP workshops; and to participate in scientific conferences/workshops to present EURAD/WPs results and outcomes.
Equipment	-	-
Other goods and services	1 000	Costs for <i>Other goods and services</i> are planned under the following Strategic Studies WPs: - ROUTES: 1 000€. Costs for organising a meeting
Total	22 800	

29/NES	Cost (€)	Justification
Travel	8 400	Travel costs are needed to properly implement the actions that are planned in each relevant WP (WPs annual meetings/Tasks meetings, workshops, seminars) ; to participate in EURAD General Assemblies and EURAD Annual Meetings , WP workshops; and to participate in scientific conferences/workshops to present EURAD/WPs results and outcomes.
Equipment		-
Other goods and services	2 660	Costs for <i>Other goods and services</i> are planned under the following Strategic Studies WPs: - ROUTES: 1 000€. Costs for organising a meeting - ROUTES extension : 1 660 € Workshop organisation
Total	11 060	

30/NJF	Cost (€)	Justification
Travel	6 400	Travel costs are needed to properly implement the actions that are planned in each relevant WP (WPs annual meetings/Tasks meetings, workshops, seminars) ; to participate in EURAD General Assemblies and EURAD Annual Meetings , WP workshops; and to participate in scientific conferences/workshops to present EURAD/WPs results and outcomes.
Equipment	-	-
Other goods and services	-	-
Total	6 400	

31/NRG	Cost (€)	Justification
Travel	15 500	Travel costs are needed to properly implement the actions that are planned in each relevant WP (WPs annual meetings/Tasks meetings, workshops, seminars) ; to participate in EURAD General Assemblies and EURAD Annual Meetings , WP workshops; and to participate in scientific conferences/workshops to present EURAD/WPs results and outcomes.
Equipment	-	-
Other goods and services	1 000	Costs for Other goods and services are planned under the following RD&D WPs: - DONUT: 1 000€.-
Total	16 500	

32/ONDRAF/NIRAS

The sum of the costs for 'travel', 'equipment', and 'goods and services' does not exceed 15% of the personnel costs for ONDRAF/NIRAS.

33/Posiva	Cost (€)	Justification
Travel	25 000	Travel costs are needed to properly implement the actions that are planned in each relevant WP (WPs annual meetings/Tasks meetings, workshops, seminars) ; to participate in EURAD General Assemblies and EURAD Annual Meetings , WP workshops; and to participate in scientific conferences/workshops to present EURAD/WPs results and outcomes.
Equipment		
Other goods and services	4 000	Costs for Other goods and services are planned under the following RD&D WPs: - MODATS : 4 000 € Arranging a workshop in Task 3.2
Total	29 000	

34/PSI

The sum of the costs for 'travel', 'equipment', and 'goods and services' does not exceed 15% of the personnel costs for PSI.

34/PURAM

The sum of the costs for 'travel', 'equipment', and 'goods and services' does not exceed 15% of the personnel costs for PURAM.

36/RATEN	Cost (€)	Justification
Travel	32 400	Travel costs are needed to properly implement the actions that are planned in each relevant WP (WPs annual meetings/Tasks meetings, workshops, seminars) ; to participate in EURAD General Assemblies and EURAD Annual Meetings , WP workshops; and to participate in scientific conferences/workshops to present EURAD/WPs results and outcomes.
Equipment	-	-
Other goods and services	29 500	Costs for Other goods and services are planned under the following RD&D WPs: - FUTURE: 13 900€ - purchasing 99Tc standard solution, pure clay minerals, and other lab ware. - CORI: 14 600€ - purchasing 59Ni and organic 14C radioactive solutions, and other lab ware

		Costs for Other goods and services are planned under the following Strategic Studies WPs: - ROUTES: 1 000€ (cost for hosting one meeting)
Total	61 900	

37/RWM	Cost (€)	Justification
Travel	57 500	Travel costs are needed to properly implement the actions that are planned in each relevant WP (WPs annual meetings/Tasks meetings, workshops, seminars) ; to participate in EURAD General Assemblies and EURAD Annual Meetings , WP workshops; and to participate in scientific conferences/workshops to present EURAD/WPs results and outcomes.
Equipment	-	-
Other goods and services	45 595	<i>Costs for Other goods and services are planned under the following RD&D WPs:</i> - MAGIC: 45 595€: Costs associated with PhD studentship including consumables (microbial, chemicals and reagents, glassware, speciality gases, molecular ecology tools, DNA sequencing) and analytical charges.
Total	103 095	

38/SCK•CEN	Cost (€)	Justification
Travel	114 000	Travel costs are needed to properly implement the actions that are planned in each relevant WP (WPs annual meetings/Tasks meetings, workshops, seminars) ; to participate in EURAD General Assemblies and EURAD Annual Meetings , WP workshops; and to participate in scientific conferences/workshops to present EURAD/WPs results and outcomes.
Equipment	43 000	Equipment costs are planned under the following RD&D WPs: - GAS: 8 000€. Equipment costs: pressure sensors, diffusion cells, Swagelok material, magnetic coupled gear pumps, pump heads - ConCorD : 35 000 € Equipment to build additional test cells to enable investigation of more replicates simultaneously
Other goods and services	294 845	Costs for Other goods and services are planned under the following RD&D WPs: - ACED: 49 700 € o Organisation of ACED WP meetings o Computer and software licences, open access publications - DONUT: 3 445€ o Computer and software licences, open access publications - FUTuRE: 17 000€ o Lab consumables, analysis costs, radioactive spike solutions, diffusion cells - CORI: 143 700€ o ISA and carbohydrate measurements o 24 stainless steel irradiation containers with Swagelok material o 24 teflon containers (2L) for chemical degradation studies o Purchase of pure alpha and beta ISA - ConCorD : 41 000 € : Consumables for microbiology and corrosion work, including material for DNA extraction, ATP kits, enzymes, stainings, primers, sequencing, preparation of media, preparation for SEM/EDX, IC, GC, open acces costs for publication

		- MAGIC : 40 000 € Laboratory consumables to conduct mechanical, chemical and microbial analysis. Open access costs for publications
Mobility actions not allocated	220 258	KM Training: Cost for mobility actions not allocated: 220 258€
Total	672 103	

39/SKB	Cost (€)	Justification
Travel	51 250	Travel costs are needed to properly implement the actions that are planned in each relevant WP (WPs annual meetings/Tasks meetings, workshops, seminars) ; to participate in EURAD General Assemblies and EURAD Annual Meetings , WP workshops; and to participate in scientific conferences/workshops to present EURAD/WPs results and outcomes. Those travel costs include 21 250 Euros for UU In-Kind Contribution against payment, not used on the Beneficiary's premises under SFC WP.
Equipment	-	-
Other goods and services	25 000	Those other goods and services are related UU In-Kind Contribution against payment, not used on the Beneficiary's premises to arrange workshops and meetings planned for SFC WP
Total	76 250	

40/SSTC NRS	Cost (€)	Justification
Travel	60 025	Travel costs are needed to properly implement the actions that are planned in each relevant WP (WPs annual meetings/Tasks meetings, workshops, seminars) ; to participate in EURAD General Assemblies and EURAD Annual Meetings , WP workshops; and to participate in scientific conferences/workshops to present EURAD/WPs results and outcomes.
Equipment	-	-
Other goods and services	-	-
Total	60 025	

41/STUBA	Cost (€)	Justification
Travel	14 525	Travel costs are needed to properly implement the actions that are planned in each relevant WP (WPs annual meetings/Tasks meetings, workshops, seminars) ; to participate in EURAD General Assemblies and EURAD Annual Meetings , WP workshops; and to participate in scientific conferences/workshops to present EURAD/WPs results and outcomes.
Equipment	-	-
Other goods and services	-	-
Total	14 525	

42/SÚRAO	Cost (€)	Justification
Travel	231 500	Travel costs are needed to properly implement the actions that are planned in each relevant WP (WPs annual meetings/Tasks meetings, workshops, seminars) ; to participate in EURAD General Assemblies and EURAD Annual Meetings , WP workshops; and to participate in scientific conferences/workshops to present EURAD/WPs results and outcomes.
Equipment	58 000	Equipment costs are planned under the following RD&D WPs: - ACED: 8 000€ (UJV). Modification of existing experimental apparatus for evaluation of specific issues, computing technology - GAS: 8 500€ (UJV). Migration cells, GDS pumps, possible modification of existing experimental apparatus. - HITEC: 16 500€ (CU, UJV). Modification of existing experimental apparatus, sensors (5000€ for UJV) - FUTuRE: 15 000€ (UJV). Migration cells; GDS Pumps; Shielding; equipment for tracer tests - CORI: 10 000€ (UJV). Experimental apparatus and cells, pressure pumps, depreciation costs of analytical device
Other goods and services	305 198	Costs for Other goods and services are planned under the following RD&D WPs: - ACED: 8000€. (UJV). External analyses, software licences, publication costs - DONUT: 12 780€ (SÚRAO, CTNU, CU, TUL, UJV). Translation costs, software licences (?) - GAS: 27 500€ (CTU, UJV) Laboratory materials and consumables, maintenance of migration apparatus. - HITEC: 38 875€ (CTU, CU, UJV). Laboratory chemicals and consumables, external analyses (8500€ for UJV) - FUTuRE: 15 100€ (UJV). Radionuclide source purchase; Laboratory chemicals; Maintenance of migration apparatus; External analyses (XRD) - CORI: 50 300€ (CTU, UJV). Radiochemicals, external analyses, laboratory tools and consumables - ConCorD : 119 542 € UJV (81 542 €): Task 3: equipment for construction of cells for irradiation; equipment and maintenance of irradiation equipment; external analyses; laboratory tools and consumables; radiation safety equipment Task 4: laboratory tools and consumables Task 5: Laboratory chemicals and consumables, external analyses; material for construction of experimental cells; maintenance of anaerobic box for the experiment TUL (38 000 €): TUL Task 4: laboratory goods and consumables necessary for performing proposed microbiological analyses of experimental samples. The molecular-genetic approach requires purchasing of special laboratory kits, chemistry and plastics as well as regular service of laboratory equipment (sequenator, laminar flow-box, light cyler). Maintenance of anaerobic box for the spore-regeneration experiments. - MAGIC : 33 101 € NGS and qPCR molecular analysis, epi-fluorescence microscopy. Purchase of DNA isolation kits, DNA purification kits, real-time PCR SybrGreen master mix, barcoded primers, NGS library preparation kits, chips, Live/dead stain, testing cells, displacement/ force sensors/ gauges, minor laboratory tools, electronics and material, minor services as calibration, regular inspection, reparation.
Total	594 698	

43/SURO	Cost (€)	Justification
Travel	34 400	Travel costs are needed to properly implement the actions that are planned in each relevant WP (WPs annual meetings/Tasks meetings, workshops, seminars) ; to participate in EURAD General Assemblies and EURAD Annual Meetings , WP workshops; and to participate in scientific conferences/workshops to present EURAD/WPs results and outcomes.
Equipment	-	-
Other goods and services	6 000	Costs for <i>Other goods and services</i> are planned under the following Strategic Studies WPs: - UMAN : 5 000 € Costs associated with the workshop of Subtask 4.3 - ROUTES: 1 000€. Workshop/meetings organisation within T5
Total	40 400	

44/TNO	Cost (€)	Justification
Travel	5 000	Travel costs are needed to properly implement the actions that are planned in each relevant WP (WPs annual meetings/Tasks meetings, workshops, seminars) ; to participate in EURAD General Assemblies and EURAD Annual Meetings , WP workshops; and to participate in scientific conferences/workshops to present EURAD/WPs results and outcomes.
Equipment	5 000	Equipment costs are planned under the following RD&D WPs: - FUTuRE: 5000€. TNO shares its geochemical lab with Utrecht University and Deltares. We need to rent equipment from UU for the experiments foreseen. This will be arranged under the partnership agreement that exists among these three organisations. Additionally, depreciations costs for expensive apparatus and analyses must be booked.
Other goods and services	12 800	Costs for Other goods and services are planned under the following RD&D WPs: - FUTuRE: 12 800€. Chemicals as well as commercially available minerals must be bought for the experimental activities. Besides, small laboratory equipment may be bought.
Total	22 800	

45/TS ENERCON	Cost (€)	Justification
Travel	12 000	Travel costs are needed to properly implement the actions that are planned in each relevant WP (WPs annual meetings/Tasks meetings, workshops, seminars) ; to participate in EURAD General Assemblies and EURAD Annual Meetings , WP workshops; and to participate in scientific conferences/workshops to present EURAD/WPs results and outcomes.
Equipment	-	-
Other goods and services	750	Costs for Other goods and services are planned under the following RD&D WPs: - DONUT: 750 €. Cost for organisation of a meeting
Total	12 750	

46/TUS	Cost (€)	Justification
Travel	30 625	Travel costs are needed to properly implement the actions that are planned in each relevant WP (WPs annual meetings/Tasks meetings, workshops, seminars) ; to participate in EURAD General Assemblies and EURAD Annual Meetings , WP workshops; and to participate in scientific conferences/workshops to present EURAD/WPs results and outcomes.
Equipment	-	-
Other goods and services	8 483	Costs for Other goods and services are planned under the following RD&D WPs: - SFC: 683€ - Consumables, supplies, post costs, communication costs, organisation of meetings with experts from other Bulgarian organisations. - DONUT: 7 800€ - Consumables, supplies, organisation of annual workshops and periodical meetings with experts, post and communication costs.
Total	39 108	

47/UCY	Cost (€)	Justification
Travel	11 900	Travel costs are needed to properly implement the actions that are planned in each relevant WP (WPs annual meetings/Tasks meetings, workshops, seminars) ; to participate in EURAD General Assemblies and EURAD Annual Meetings , WP workshops; and to participate in scientific conferences/workshops to present EURAD/WPs results and outcomes.
Equipment	-	-
Other goods and services	-	-
Total	11 900	

48/UHelsinki	Cost (€)	Justification
Travel	33 000	Travel costs are needed to properly implement the actions that are planned in each relevant WP (WPs annual meetings/Tasks meetings, workshops, seminars) ; to participate in EURAD General Assemblies and EURAD Annual Meetings , WP workshops; and to participate in scientific conferences/workshops to present EURAD/WPs results and outcomes.
Equipment	-	-
Other goods and services	69 100	Costs for <i>Other goods and services</i> are planned under the following RD&D WPs: - DONUT: 3 000€. Supplies / Computational services - HITEC: 57 600€. (JYFL) Temperature and water flow controlling units. Sample holders and instrumentation for X-ray tomographic experiments / Laboratory instruments and supplies for X-ray tomographic experiments / (GTK) XCT using time (UHelsinki) Laboratory supplies - FUTURE: 4 000 €. Laboratory supplies and irradiation services - MAGIC : 4 500 € C-14 labelled methyl methacrylate; radioactive tracer for porosity determination of concrete samples; Irradiation treatment
Total	102 100	

49/UKRI-BGS	Cost (€)	Justification
Travel	22 000	Travel costs are needed to properly implement the actions that are planned in each relevant WP (WPs annual meetings/Tasks meetings, workshops, seminars) ; to participate in EURAD General Assemblies and EURAD Annual Meetings , WP workshops; and to participate in scientific conferences/workshops to present EURAD/WPs results and outcomes.
Equipment	-	-
Other goods and services	238 884	Costs for Other goods and services are planned under the following RD&D WPs: - GAS: 102 430€ - HITEC: 136 454€ This budget covers: ▪ Dedicated cells (isostatic, triaxial, uniaxial) ▪ Flow meters ▪ Consumables for gas injection ▪ Tubing and pressure fittings ▪ Displacement and pressure transducers ▪ Data acquisition ▪ Construction and comissioning of apparatus, ▪ Numerical modelling ▪ Regular lab analyses ▪ Imaging and data processing ▪ Sample Preparation ▪ Petrophysical characterisation
Total	260 884	

50/VTT	Cost (€)	Justification
Travel	90 900	Travel costs are needed to properly implement the actions that are planned in each relevant WP (WPs annual meetings/Tasks meetings, workshops, seminars) ; to participate in EURAD General Assemblies and EURAD Annual Meetings , WP workshops; and to participate in scientific conferences/workshops to present EURAD/WPs results and outcomes.
Equipment	2 000	Small server for data storage and management of the monitoring data received from partners
Other goods and services	72 364	Costs for Other goods and services are planned under the following RD&D WPs: - ACED: 8 000€. Consumables, publications - HITEC: 9000€. 2 000 € for publication, 2 000 € for meeting organisation costs and 5 000 € for material & consumables - ConCorD : 45 364 € Chemicals, Materials, Consumables, Analyse costs, Open access costs, Audit costs, - MODATS : 10 000 € 6 000 € for open access fees 4 000 € for certificate on financial statement (auditing cost)
Large research infrastructure	132 844	- SFC: 7 900€ - ACED: 55 458€ - HITEC: 58 584€ - MODATS : 10 902 € LRI cost of VTT Research Facility. The LRI costs are calculated based on working hours of the project and according to VTT's ex-ante assessment of the

		methodology on Direct Costing for Large Research Infrastructures (LRI), approved by the Commission on 24th February 2015. The Materials, Production & Performance Research Facilities covers wide variety of material R&D laboratories in VTT locations. The laboratories are divided in to subgroups; autoclaves simulating process facilities, electron microscopy laboratory e.g. with high resolution requirement, trailer laboratory for dangerous liquid environments, tribology laboratory including the nanoindentation device, accredited non-destructive testing (NDT) laboratory, hotlab for elevated temperatures, creep laboratory for long-term loading, metallographic laboratory, destructive materials testing laboratory, fatigue laboratory and additive manufacturing laboratory with 3D printing devices for metallic materials. The laboratories concentrating on powder technologies and are divided in to two groups; powder manufacturing laboratory and consolidation laboratory e.g. hot isostatic pressing (HIP). The Research Facility provides also equipment for testing and experimental research in the area of vibration and durability in the area of Robotics multi-technology research, development and testing facilities. Centre for Nuclear Safety (CNS) will include class A, B and C facilities for experimental research and handling of radioactive materials. Research facility consists of hot cells and equipment used in CNS. Hot cells that protect employees from radiation are situated in class A laboratory in two separate floors. Equipment that are used to examine the properties of radioactive material samples are located inside the hot cells. Samples are handled behind lead glass utilizing manipulators and cameras. Opening of transport capsules of radioactive materials, storing of radioactive samples and specimens as well as handling of radioactive waste will also occur in class A laboratory. A Comprehensive set of microscopes will be linked to the class A laboratory. VTT's methodology on LRI complies with the clauses of the H2020 Grant Agreement (Capitalised and operating costs of large research infrastructure Article 6.2.D.4, the extent verified during the audit) and therefore, the LRI costs should be considered as direct costs of the project.
Total	298 108	

51/VUJE	Cost (€)	Justification
Travel	5 000	Travel costs are needed to properly implement the actions that are planned in each relevant WP (WPs annual meetings/Tasks meetings, workshops, seminars) ; to participate in EURAD General Assemblies and EURAD Annual Meetings , WP workshops; and to participate in scientific conferences/workshops to present EURAD/WPs results and outcomes.
Equipment	-	-
Other goods and services	-	-
Total	5 000	

3.4.4. Detailed allocated budget per WP and per Participant

WP	Category of cost	TOTAL		Andra		ARAO		BEL V		BGE		CEA		CHRED		CIEMAT		CNRS		COVRA	
		Cost	pm	Cost	pm	Cost	pm	Cost	pm	Cost	pm	Cost	pm	Cost	pm	Cost	pm	Cost	pm	Cost	pm
PMO	Personnel costs - task 1 - admin, legal & financial coordination	426,0	60,0	426,0	60,0																
	Personnel costs - task 2 - overall S/T coordination/integration	448,0	43,8	21,3	3,0													168,0	12,0		
	Personnel costs - task 3 - Extension/update of the Roadmap/SRA	125,5	15,3	71,0	10,0													14,0	1,0		
	Personnel costs - task 4 - Identification of Experts	56,3	8,0	21,3	3,0			35,0	5,0												
	Personnel costs - task 5 - Internal communication/meetings	92,2	13,0	85,2	12,0			7,0	1,0												
	Personnel costs - task 6 - Dissemination	114,6	14,2	71,0	10,0													14,0	1,0		
	Personnel costs - task 7 - International collaboration	14,2	2,0	14,2	2,0																
	Personnel costs - task 8 - Coordination of ICS activities	185,7	20,1																		
	Total Personnel Costs	1 462,5	176,3	710,0	100,0			42,0	6,0									196,0	14,0		
	Total Travel Costs	174,5		55,0														20,0			
	Other goods & services - organisation of meetings	150,4		120,0																	
	Other goods & services - Website + Extranet	90,0		90,0																	
	Envelop for invitation for external experts	170,0		170,0																	
	Envelop for CS group	80,0																			
	Total Other goods & services	490,4		380,0																	
	Total other Direct costs	664,9		435,0														20,0			
	Total Direct costs	2 127,4		1 145,0				42,0										216,0			
	Total Indirect Costs	531,9		286,3				10,5										54,0			
	Subcontracting -	768,4		768,4																	
	TOTAL Costs	3 427,7		2 199,6				52,5										270,0			
	EC requested contribution	3 267,7		2 199,6				52,5										270,0			
ACED	Personnel costs - Task 1	301,5	32,6	24,8	2,8											6,7	1,5			70,4	5,5
	Personnel costs - Task 2	1 262,8	239,0					53,5	5,0							167,9	49,0	85,9	13,0		
	Personnel costs - Task 3	1 231,7	178,6	215,0	25,6							346,1	62,5					103,6	19,0	38,4	3,0
	Personnel costs - Task 4	509,4	65,5	26,5	3,0															25,6	2,0
	Total Personnel Costs	3 305,2	515,7	266,3	31,4			53,5	5,0			346,1	62,5			174,6	50,5	189,5	32,0	134,4	10,5
	Total travel costs	201,5		13,5				5,0				10,0				10,0		22,0		13,5	
	Total Equipment	33,0																			
	Total Other goods & services	378,7		3,0				17,0				116,0				44,0		33,5		12,8	
	Large Research Infrastructure (LRI)	55,5																			
	Total direct costs	3 973,9		282,8				75,5				472,1				228,6		245,0		160,7	
	Total Indirect Costs	993,5		70,7				18,9				118,0				57,1		61,3		40,2	
	Total subcontracting	140,5																			
	TOTAL BUDGET	5 107,8		353,4				94,4				590,1				285,7		306,3		200,9	
	EC requested contribution	2 553,9		176,7				47,2				295,1				142,9		153,1		100,4	
DONUT	Personnel costs - Task 1	49,0	8,5	19,6	2,5													9,0	1,5		
	Personnel costs - Task 2	1 163,7	262,0	87,8	11,0							144,8	9,5					432,4	74,5		
	Personnel costs - Task 3	515,0	73,0	87,8	11,0																
	Personnel costs - Task 4	714,4	140,3	79,8	10,0																
	Personnel costs - Task 5	176,8	33,9	25,0	2,5															7,5	0,6
	Total Personnel Costs	2 619,0	517,7	300,1	37,0							144,8	9,5					441,4	76,0	7,5	0,6
	Total Travel costs	178,5		17,0								5,0						25,0		5,0	
	Total Equipment	8,0																			
	Total Other goods & services	90,7		4,0								2,2						24,6		0,3	
	Total direct costs	2 896,2		321,1								152,0						491,0		12,8	
	Total Indirect Costs	724,0		80,3								38,0						122,8		3,2	
	Total subcontracting	96,2																			
	TOTAL BUDGET	3 716,5		401,4								190,0						613,8		16,0	
	EC requested contribution	1 858,2		200,7								95,0						306,9		8,0	

WP	Category of cost	CVREZ		Dekom		EEAE		ENRESA		CPST		JUELICH		GRS		IAE		INCT		IRSN		IST-ID	
		Cost	pm	Cost	pm	Cost	pm	Cost	pm	Cost	pm	Cost	pm	Cost	pm	Cost	pm	Cost	pm	Cost	pm	Cost	pm
PMO	Personnel costs - task 1 - admin, legal & financial coordination																						
	Personnel costs - task 2 - overall S/T coordination/integration																			47,5	4,8		
	Personnel costs - task 3 - Extension/update of the Roadmap/SRA																			12,5	1,3		
	Personnel costs - task 4 - Identificaton of Experts																						
	Personnel costs - task 5 - Internal communication/meetings																						
	Personnel costs - task 6 - Dissemination																			12,0	1,2		
	Personnel costs - task 7 - International collaboration																						
	Personnel costs - task 8 - Coordination of ICS activities																			174,1	17,9		
	Total Personnel Costs																			246,1	25,1		
	Total Travel Costs																			34,5			
	Other goods & services - organisation of meetings																						
	Other goods & services - Website + Extranet																						
	Envelop for invitation for external experts																						
	Envelop for CS group																			80,0			
	Total Other goods & services																			80,0			
	Total other Direct costs																			114,5			
	Total Direct costs																			360,6			
	Total Indirect Costs																			90,1			
	Subcontracting -																						
	TOTAL Costs																			450,7			
	EC requested contribution																			450,7			
ACED	Personnel costs - Task 1							8,2	1,0			51,3	6,8										
	Personnel costs - Task 2																			277,2	42,0		
	Personnel costs - Task 3											85,1	13,0										
	Personnel costs - Task 4											124,0	20,0							73,0	10,0		
	Total Personnel Costs							8,2	1,0			260,4	39,8							350,2	52,0		
	Total travel costs							8,5				10,0								18,5			
	Total Equipment											1,0											
	Total Other goods & services											4,0								64,5			
	Large Research Infrastructure (LRI)																						
	Total direct costs							16,7				275,4								433,2			
	Total Indirect Costs							4,2				68,9								108,3			
	Total subcontracting							140,5															
	TOTAL BUDGET							161,4				344,3								541,5			
	EC requested contribution							80,7				172,1								270,8			
DONUT	Personnel costs - Task 1											9,9	1,5										
	Personnel costs - Task 2																			73,5	24,0		
	Personnel costs - Task 3											283,0	43,0										
	Personnel costs - Task 4											111,7	14,5										
	Personnel costs - Task 5							39,9	4,8					152,0	16,7								
	Total Personnel Costs							39,9	4,8			404,6	59,0	171,5	18,7					73,5	24,0		
	Total Travel costs							13,5				15,0		10,0						5,0			
	Total Equipment																						
	Total Other goods & services											18,4		3,0						1,5			
	Total direct costs							53,4				437,9		184,5						80,0			
	Total Indirect Costs							13,3				109,5		46,1						20,0			
	Total subcontracting							89,4															
	TOTAL BUDGET							156,1				547,4		230,6						100,0			
	EC requested contribution							78,0				273,7		115,3						50,0			

WP	Category of cost	IST-LPSR		JRC		JSI		KIT		LEI		MTA EK		NAGRA		NCSRD		NES	
		Cost	pm	Cost	pm	Cost	pm	Cost	pm	Cost	pm	Cost	pm	Cost	pm	Cost	pm	Cost	pm
PMO	Personnel costs - task 1 - admin, legal & financial coordination																		
	Personnel costs - task 2 - overall S/T coordination/integration			125,1	12,0														
	Personnel costs - task 3 - Extension/update of the Roadmap/SRA			20,8	2,0														
	Personnel costs - task 4 - Identificaton of Experts																		
	Personnel costs - task 5 - Internal communication/meetings																		
	Personnel costs - task 6 - Dissemination			10,4	1,0														
	Personnel costs - task 7 - International collaboration																		
	Personnel costs - task 8 - Coordination of ICS activities					11,7	2,2												
	Total Personnel Costs			156,4	15,0	11,7	2,2												
	Total Travel Costs			40,0		5,0													
	Other goods & services - organisation of meetings			2,0		28,4													
	Other goods & services - Website + Extranet																		
	Envelop for invitation for external experts																		
	Envelop for CS group																		
	Total Other goods & services			2,0		28,4													
	Total other Direct costs			42,0		33,4													
	Total Direct costs			198,4		45,1													
	Total Indirect Costs			49,6		11,3													
	Subcontracting -																		
	TOTAL Costs			248,0		56,3													
	EC requested contribution			87,9		56,3													
ACED	Personnel costs - Task 1									5,0	1,0								
	Personnel costs - Task 2					80,0	19,0					20,0	5,0	299,6	54,0				
	Personnel costs - Task 3					80,0	19,0					24,0	6,0						
	Personnel costs - Task 4									50,0	10,0								
	Total Personnel Costs					160,0	38,0			55,0	11,0	44,0	11,0	299,6	54,0				
	Total travel costs					8,5				5,0		8,5		5,0					
	Total Equipment											6,5		17,5					
	Total Other goods & services					8,0						4,0		2,2					
	Large Research Infrastructure (LRI)																		
	Total direct costs					176,5				60,0		63,0		324,3					
	Total Indirect Costs					44,1				15,0		15,8		81,1					
	Total subcontracting																		
	TOTAL BUDGET					220,6				75,0		78,8		405,4					
	EC requested contribution					110,3				37,5		39,4		202,7					
DONUT	Personnel costs - Task 1																		
	Personnel costs - Task 2											24,0	12,0						
	Personnel costs - Task 3																		
	Personnel costs - Task 4																		
	Personnel costs - Task 5									25,0	5,0								
	Total Personnel Costs									25,0	5,0	24,0	12,0						
	Total Travel costs									5,0		5,0							
	Total Equipment											8,0							
	Total Other goods & services									2,0		6,0							
	Total direct costs									32,0		43,0							
	Total Indirect Costs									8,0		10,8							
	Total subcontracting																		
	TOTAL BUDGET									40,0		53,8							
	EC requested contribution									20,0		26,9							

WP	Category of cost	NRG		NJF		ONDRAF/NIRAS		Posiva		PSI		PURAM		RATEN/ICN		RAWRA/SÚRAO		RWM/NDA	
		Cost	pm	Cost	pm	Cost	pm	Cost	pm	Cost	pm	Cost	pm	Cost	pm	Cost	pm	Cost	pm
PMO	Personnel costs - task 1 - admin, legal & financial coordination																		
	Personnel costs - task 2 - overall S/T coordination/integration																	86,1	12,0
	Personnel costs - task 3 - Extension/update of the Roadmap/SRA																	7,2	1,0
	Personnel costs - task 4 - Identificaton of Experts																		
	Personnel costs - task 5 - Internal communication/meetings																		
	Personnel costs - task 6 - Dissemination																	7,2	1,0
	Personnel costs - task 7 - International collaboration																		
	Personnel costs - task 8 - Coordination of ICS activities																		
	Total Personnel Costs																	100,5	14,0
	Total Travel Costs																	20,0	
	Other goods & services - organisation of meetings																		
	Other goods & services - Website + Extranet																		
	Envelop for invitation for external experts																		
	Envelop for CS group																		
	Total Other goods & services																		
	Total other Direct costs																	20,0	
	Total Direct costs																	120,5	
	Total Indirect Costs																	30,1	
	Subcontracting -																		
	TOTAL Costs																	150,6	
	EC requested contribution																	150,6	
ACED	Personnel costs - Task 1															6,0	1,5		
	Personnel costs - Task 2									134,7	12,0					49,2	29,0		
	Personnel costs - Task 3									87,0	6,0								
	Personnel costs - Task 4																		
	Total Personnel Costs									221,7	18,0					55,2	30,5		
	Total travel costs									13,5						13,5			
	Total Equipment															8,0			
	Total Other goods & services									4,0						8,0			
	Large Research Infrastructure (LRI)																		
	Total direct costs									239,2						84,7			
	Total Indirect Costs									59,8						21,2			
	Total subcontracting																		
	TOTAL BUDGET									299,0						105,8			
	EC requested contribution									149,5						52,9			
DONUT	Personnel costs - Task 1															4,8	1,5		
	Personnel costs - Task 2	54,5	5,0							123,0	9,0					223,6	117,0		
	Personnel costs - Task 3									119,5	9,0					24,7	10,0		
	Personnel costs - Task 4															74,6	36,0		
	Personnel costs - Task 5															40,7	15,0		
	Total Personnel Costs	54,5	5,0							242,5	18,0					368,5	179,5		
	Total Travel costs	5,0								8,5						39,5			
	Total Equipment																		
	Total Other goods & services	1,0														12,8			
	Total direct costs	60,5								251,0						420,7			
	Total Indirect Costs	15,1								62,8						105,2			
	Total subcontracting																		
	TOTAL BUDGET	75,6								313,8						525,9			
	EC requested contribution	37,8								156,9						263,0			

WP	Category of cost	SCK-CEN		SKB		SSTC NRS		STUBA		SURO		TNO		TS ENERCON		TUS		UCY	
		Cost	pm	Cost	pm	Cost	pm	Cost	pm	Cost	pm	Cost	pm	Cost	pm	Cost	pm	Cost	pm
PMO	Personnel costs - task 1 - admin, legal & financial coordination																		
	Personnel costs - task 2 - overall S/T coordination/integration																		
	Personnel costs - task 3 - Extension/update of the Roadmap/SRA																		
	Personnel costs - task 4 - Identificaton of Experts																		
	Personnel costs - task 5 - Internal communication/meetings																		
	Personnel costs - task 6 - Dissemination																		
	Personnel costs - task 7 - International collaboration																		
	Personnel costs - task 8 - Coordination of ICS activities																		
	Total Personnel Costs																		
	Total Travel Costs																		
	Other goods & services - organisation of meetings																		
	Other goods & services - Website + Extranet																		
	Envelop for invitation for external experts																		
	Envelop for CS group																		
	Total Other goods & services																		
	Total other Direct costs																		
	Total Direct costs																		
	Total Indirect Costs																		
	Subcontracting -																		
	TOTAL Costs																		
	EC requested contribution																		
ACED	Personnel costs - Task 1	99,2	8,5																
	Personnel costs - Task 2	34,8	3,0																
	Personnel costs - Task 3	192,5	16,5																
	Personnel costs - Task 4	157,8	13,5																
	Total Personnel Costs	484,2	41,5																
	Total travel costs	20,5																	
	Total Equipment																		
	Total Other goods & services	49,7																	
	Large Research Infrastructure (LRI)																		
	Total direct costs	554,4																	
	Total Indirect Costs	138,6																	
	Total subcontracting																		
	TOTAL BUDGET	692,9																	
	EC requested contribution	346,5																	
DONUT	Personnel costs - Task 1													5,7	1,5				
	Personnel costs - Task 2																		
	Personnel costs - Task 3																		
	Personnel costs - Task 4	115,6	26,0											64,8	17,1				
	Personnel costs - Task 5															19,2	4,0		
	Total Personnel Costs	115,6	26,0											70,5	18,6	19,2	4,0		
	Total Travel costs	5,0												5,0		5,0			
	Total Equipment																		
	Total Other goods & services	3,4												0,8		7,8			
	Total direct costs	124,0												76,2		32,0			
	Total Indirect Costs	31,0												19,1		8,0			
	Total subcontracting													6,9					
	TOTAL BUDGET	155,0												102,1		40,0			
	EC requested contribution	77,5												51,1		20,0			

WP	Category of cost	UHELSINKI		UKRI-BGS		VTT		VUJE	
		Cost	pm	Cost	pm	Cost	pm	Cost	pm
PMO	Personnel costs - task 1 - admin, legal & financial coordination								
	Personnel costs - task 2 - overall S/T coordination/integration								
	Personnel costs - task 3 - Extension/update of the Roadmap/SRA								
	Personnel costs - task 4 - Identificaton of Experts								
	Personnel costs - task 5 - Internal communication/meetings								
	Personnel costs - task 6 - Dissemination								
	Personnel costs - task 7 - International collaboration								
	Personnel costs - task 8 - Coordination of ICS activities								
	Total Personnel Costs								
	Total Travel Costs								
	Other goods & services - organisation of meetings								
	Other goods & services - Website + Extranet								
	Envelop for invitation for external experts								
	Envelop for CS group								
	Total Other goods & services								
	Total other Direct costs								
	Total Direct costs								
	Total Indirect Costs								
	Subcontracting -								
	TOTAL Costs								
	EC requested contribution								
ACED	Personnel costs - Task 1					30,0	4,0		
	Personnel costs - Task 2					60,0	8,0		
	Personnel costs - Task 3					60,0	8,0		
	Personnel costs - Task 4					52,5	7,0		
	Total Personnel Costs					202,5	27,0		
	Total travel costs					16,0			
	Total Equipment								
	Total Other goods & services					8,0			
	Large Research Infrastructure (LRI)					55,5			
	Total direct costs					282,0			
	Total Indirect Costs					70,5			
	Total subcontracting								
	TOTAL BUDGET					352,4			
	EC requested contribution					176,2			
DONUT	Personnel costs - Task 1								
	Personnel costs - Task 2								
	Personnel costs - Task 3								
	Personnel costs - Task 4	116,0	20,0						
	Personnel costs - Task 5								
	Total Personnel Costs	116,0	20,0						
	Total Travel costs	5,0							
	Total Equipment								
	Total Other goods & services	3,0							
	Total direct costs	124,0							
	Total Indirect Costs	31,0							
	Total subcontracting								
	TOTAL BUDGET	155,0							
	EC requested contribution	77,5							

WP	Category of cost	TOTAL		Andra		ARAO		BEL V		BGE		CEA		CHRD		CIEMAT		CNRS		COVRA	
		Cost	pm	Cost	pm	Cost	pm	Cost	pm	Cost	pm	Cost	pm	Cost	pm	Cost	pm	Cost	pm	Cost	pm
GAS	Personnel costs - task 1	114,2	10,0																		
	Personnel costs - task 2	1 672,1	350,3							10,8	0,8					149,9	32,0	385,2	104,1	36,7	4,5
	Personnel costs - task 3	1 424,8	236,8	60,0	6,0					34,8	2,7	61,2	5,0			69,3	13,0	175,8	36,8	47,9	6,0
	Personnel costs - task 4	602,3	70,5	81,0	9,0							56,2	4,5							94,7	9,8
	Total Personnel Costs	3 813,4	667,6	141,0	15,0					45,5	3,6	117,4	9,5			219,2	45,0	561,0	140,9	179,4	20,3
	Total travel costs	251,0		13,5						8,5		8,5				13,5		24,5		16,0	
	Total Equipment	91,5																20,0			
	Total Other goods & services	291,7														16,1		132,7			
	Total direct costs	4 447,6		154,5						54,0		125,9				248,8		738,2		195,4	
	Total Indirect Costs	1 111,9		38,6						13,5		31,5				62,2		184,6		48,9	
	Total subcontracting	76,3																			
	TOTAL BUDGET	5 635,8		193,1						67,5		157,4				311,0		922,8		244,3	
	EC requested contribution	2 638,3		96,5						33,8		78,0				155,5		436,7		111,2	
HITEC	Personnel costs - task 1	178,7	25,4	10,0	1,0					9,5	0,8					22,3	5,5				
	Personnel costs - task 2	1 600,1	255,6	117,0	11,7					155,0	12,2	240,2	25,5			117,3	22,0	398,2	83,0		
	Personnel costs - task 3	1 453,7	392,2	135,3	16,7									61,0	69,0	285,7	64,0				
	Personnel costs - task 4	188,3	20,2	10,0	1,0					9,5	0,8										
	Total Personnel Costs	3 420,8	693,2	272,3	30,4					173,9	13,7	240,2	25,5	61,0	69,0	425,3	91,5	398,2	83,0		
	Total travel costs	218,0		18,5						8,5		10,0		10,0		18,5		15,0			
	Total Equipment	81,5		18,0												17,0		30,0			
	Total Other goods & services	367,4		15,0								5,9		1,0		23,9		54,6			
	Large Research Infrastructure (LRI)	58,6																			
	Total direct costs	4 146,2		323,8						182,4		256,1		72,0		484,7		497,8			
	Total Indirect Costs	1 036,6		80,9						45,6		64,0		18,0		121,2		124,4			
	Total subcontracting	38,2																			
	TOTAL BUDGET	5 220,9		404,7						228,0		320,1		90,0		605,8		622,2			
	EC requested contribution	2 507,5		202,4						114,0		160,1		45,0		302,9		311,1			
FUTURE	Personnel costs - task 1	81,8	8,3	10,0	1,0							8,5	1,0								
	Personnel costs - task 2	1 813,1	349,7	131,8	16,3							12,7	1,5			146,5	33,0	355,7	93,0		
	Personnel costs - task 3	1 158,6	237,2	121,2	15,2							149,9	20,5			88,8	20,0	151,9	31,0		
	Total Personnel Costs	3 053,5	595,1	263,0	32,5							171,0	23,0			235,3	53,0	507,6	124,0		
	Total travel costs	149,4		18,5								8,5				8,5		20,0			
	Total Equipment	73,0														15,0					
	Total Other goods & services	379,7		44,0								37,0				30,0		100,4			
	Total direct costs	3 655,7		325,5								216,5				288,8		628,0			
	Total Indirect Costs	913,9		81,4								54,1				72,2		157,0			
	Total subcontracting																				
	TOTAL BUDGET	4 569,6		406,9								270,7				361,0		785,0			
	EC requested contribution	2 284,8		203,4								135,3				180,5		392,5			
CORI	Personnel costs - task 1	77,1	9,9	24,0	2,4							11,3	1,4			6,2	1,4	12,0	1,4		
	Personnel costs - Task 2	916,0	155,1	125,6	16,4											224,9	38,6				
	Personnel costs - Task 3	794,1	163,5	30,0	3,0							112,6	17,0			202,2	51,0				
	Personnel costs - Task 4	1 063,5	205,7	20,0	2,0							97,2	17,0			97,7	22,0	134,3	20,0		
	Total Personnel Costs	2 850,7	534,2	199,6	23,8							221,0	35,4			306,0	74,4	371,2	60,0		
	Total travel costs	214,5		16,0								13,5				13,5		18,5			
	Total Equipment	72,0		10,0												22,0		10,0			
	Total Other goods & services	616,9		88,5								69,7				35,0		51,0			
	Total direct costs	3 754,2		314,1								304,3				376,5		450,7			
	Total Indirect Costs	938,5		78,5								76,1				94,1		112,7			
	Total subcontracting																				
	TOTAL BUDGET	4 692,7		392,6								380,3				470,7		563,4			
	EC requested contribution	2 346,3		196,3								190,2				235,3		281,7			

WP	Category of cost	CVREZ		Dekom		EEAE		ENRESA		CPST		JUELICH		GRS		IAE		INCT		IRSN		IST-ID	
		Cost	pm	Cost	pm	Cost	pm	Cost	pm	Cost	pm	Cost	pm	Cost	pm	Cost	pm	Cost	pm	Cost	pm	Cost	pm
GAS	Personnel costs - task 1																			6,0	1,0		
	Personnel costs - task 2																			156,0	26,0		
	Personnel costs - task 3											74,0	12,0	102,5	11,0					6,0	1,0		
	Personnel costs - task 4																			78,0	12,0		
	Total Personnel Costs											74,0	12,0	102,5	11,0					246,0	40,0		
	Total travel costs											10,0		5,0						16,0			
	Total Equipment													5,0						10,0			
	Total Other goods & services											6,0											
	Total direct costs											90,0		112,5						272,0			
	Total Indirect Costs											22,5		28,1						68,0			
	Total subcontracting																						
	TOTAL BUDGET											112,5		140,7						340,0			
	EC requested contribution											56,3		70,3						168,0			
HITEC	Personnel costs - task 1							9,2	1,1														
	Personnel costs - task 2																						
	Personnel costs - task 3																						
	Personnel costs - task 4							8,2	1,0														
	Total Personnel Costs							17,4	2,1														
	Total travel costs							5,0															
	Total Equipment																						
	Total Other goods & services																						
	Large Research Infrastructure (LRI)																						
	Total direct costs							22,4															
	Total Indirect Costs							5,6															
	Total subcontracting																						
	TOTAL BUDGET							28,0															
	EC requested contribution							14,0															
FUTURE	Personnel costs - task 1											29,6	3,0										
	Personnel costs - task 2											296,8	40,0	83,2	10,4								
	Personnel costs - task 3											160,0	36,0										
	Total Personnel Costs											486,4	79,0	83,2	10,4								
	Total travel costs											25,5		5,0									
	Total Equipment																						
	Total Other goods & services											52,3											
	Total direct costs											564,2		88,2									
	Total Indirect Costs											141,1		22,1									
	Total subcontracting																						
	TOTAL BUDGET											705,3		110,3									
	EC requested contribution											352,7		55,1									
CORI	Personnel costs - task 1																						
	Personnel costs - Task 2	15,0	5,0							29,0	10,0	73,3	10,0										
	Personnel costs - Task 3	21,0	7,0																				
	Personnel costs - Task 4									23,0	10,0	129,0	17,0										
	Total Personnel Costs	36,0	12,0							52,0	20,0	202,3	27,0										
	Total travel costs	8,5								8,5		13,5											
	Total Equipment	20,0																					
	Total Other goods & services	13,0								9,0		7,8											
	Total direct costs	77,5								69,5		223,6											
	Total Indirect Costs	19,4								17,4		55,9											
	Total subcontracting																						
	TOTAL BUDGET	96,9								86,9		279,5											
	EC requested contribution	48,4								43,4		139,7											

WP	Category of cost	IST-LPSR		JRC		JSI		KIT		LEI		MTA EK		NAGRA		NCSRD		NES	
		Cost	pm	Cost	pm	Cost	pm	Cost	pm	Cost	pm	Cost	pm	Cost	pm	Cost	pm	Cost	pm
GAS	Personnel costs - task 1													16,0	1,0				
	Personnel costs - task 2							32,2	5,0										
	Personnel costs - task 3							32,2	5,0					512,0	83,0				
	Personnel costs - task 4							19,3	3,0	32,5	6,5			48,0	3,0				
	Total Personnel Costs							83,6	13,0	32,5	6,5			576,0	87,0				
	Total travel costs							11,0		5,0				28,5					
	Total Equipment													40,0					
	Total Other goods & services							2,0						5,0					
	Total direct costs							96,6		37,5				649,5					
	Total Indirect Costs							24,1		9,4				162,4					
	Total subcontracting																		
	TOTAL BUDGET							120,7		46,9				811,9					
	EC requested contribution							59,9		23,4				387,2					
HITEC	Personnel costs - task 1													16,0	1,0				
	Personnel costs - task 2									50,0	10,0			22,4	1,4				
	Personnel costs - task 3							45,0	9,0										
	Personnel costs - task 4													16,0	1,0				
	Total Personnel Costs							45,0	9,0	50,0	10,0			54,4	3,4				
	Total travel costs							5,0		5,0				8,5					
	Total Equipment																		
	Total Other goods & services							0,5						3,3					
	Large Research Infrastructure (LRI)																		
	Total direct costs							50,5		55,0				66,2					
	Total Indirect Costs							12,6		13,8				16,6					
	Total subcontracting																		
	TOTAL BUDGET							63,1		68,8				82,8					
	EC requested contribution							31,6		34,4				41,4					
FUTURE	Personnel costs - task 1																		
	Personnel costs - task 2							153,6	28,0			62,0	21,0						
	Personnel costs - task 3							189,2	44,0										
	Total Personnel Costs							342,8	72,0			62,0	21,0						
	Total travel costs							13,5				6,4							
	Total Equipment							8,0											
	Total Other goods & services							30,0				7,6							
	Total direct costs							394,3				76,0							
	Total Indirect Costs							98,6				19,0							
	Total subcontracting																		
	TOTAL BUDGET							492,9				95,0							
	EC requested contribution							246,4				47,5							
CORI	Personnel costs - task 1							23,6	3,3										
	Personnel costs - Task 2					101,5	14,0	22,5	5,0										
	Personnel costs - Task 3					87,0	12,4	94,5	17,0										
	Personnel costs - Task 4							419,6	80,0										
	Total Personnel Costs					188,5	26,4	560,2	105,3										
	Total travel costs					8,5		46,5											
	Total Equipment																		
	Total Other goods & services					62,0		44,0											
	Total direct costs					259,0		650,7											
	Total Indirect Costs					64,8		162,7											
	Total subcontracting																		
	TOTAL BUDGET					323,8		813,4											
	EC requested contribution					161,9		406,7											

WP	Category of cost	NRG		NJF		ONDRAF/NIRAS		Posiva		PSI		PURAM		RATEN/ICN		RAWRA/SÚRAO		RWM/NDÁ	
		Cost	pm	Cost	pm	Cost	pm	Cost	pm	Cost	pm	Cost	pm	Cost	pm	Cost	pm	Cost	pm
GAS	Personnel costs - task 1					59,2	4,5												
	Personnel costs - task 2					162,0	30,4			120,0	24,0					79,7	30,0		
	Personnel costs - task 3					50,0	9,6									83,4	23,0		
	Personnel costs - task 4					70,2	7,8											26,5	3,5
	Total Personnel Costs					341,5	52,3			120,0	24,0					163,1	53,0	26,5	3,5
	Total travel costs					28,0				5,0						18,5		5,0	
	Total Equipment															8,5			
	Total Other goods & services															27,5			
	Total direct costs					369,5				125,0						217,6		31,5	
	Total Indirect Costs					92,4				31,3						54,4		7,9	
	Total subcontracting																		
	TOTAL BUDGET					461,8				156,3						272,0		39,4	
	EC requested contribution					230,9				78,1						136,0		22,8	
HITEC	Personnel costs - task 1					31,3	4,9	3,0	0,5							13,8	4,0	11,2	1,6
	Personnel costs - task 2					232,3	39,7											31,5	4,5
	Personnel costs - task 3							6,0	1,0							316,4	113,0	22,4	3,2
	Personnel costs - task 4					9,3	0,8	6,0	1,0							8,1	3,0	11,2	1,6
	Total Personnel Costs					272,9	45,4	15,0	2,5							338,3	120,0	76,3	10,9
	Total travel costs					13,5		8,5								28,5		11,0	
	Total Equipment															16,5			
	Total Other goods & services					21,3										38,9			
	Large Research Infrastructure (LRI)																		
	Total direct costs					307,7		23,5								422,2		87,3	
	Total Indirect Costs					76,9		5,9								105,5		21,8	
	TOTAL BUDGET					384,6		29,4								527,7		109,1	
	EC requested contribution					192,3		14,7								263,9		54,6	
FUTURE	Personnel costs - task 1									12,2	1,0								
	Personnel costs - task 2									287,5	45,5					66,6	32,0		
	Personnel costs - task 3									166,0	35,5			48,4	22,0				
	Total Personnel Costs									465,7	82,0			48,4	22,0	66,6	32,0		
	Total travel costs									13,5				5,0		10,0			
	Total Equipment									30,0						15,0			
	Total Other goods & services									15,6				13,9		15,1			
	Total direct costs									524,8				67,3		106,7			
	Total Indirect Costs									131,2				16,8		26,7			
	Total subcontracting																		
	TOTAL BUDGET									655,9				84,1		133,3			
	EC requested contribution									328,0				42,1		66,7			
CORI	Personnel costs - task 1									128,7	13,0					102,8	33,4		
	Personnel costs - Task 2									99,0	11,0			26,4	12,0	82,5	29,6		
	Personnel costs - Task 3													11,0	5,0	62,3	23,6		
	Personnel costs - Task 4																		
	Total Personnel Costs									227,7	24,0			37,4	17,0	247,6	86,6		
	Total travel costs									10,0				8,5		33,0			
	Total Equipment															10,0			
	Total Other goods & services									28,3				14,6		50,3			
	Total direct costs									266,0				60,5		340,9			
	Total Indirect Costs									66,5				15,1		85,2			
	TOTAL BUDGET									332,4				75,6		426,1			
	EC requested contribution									166,2				37,8		213,1			

WP	Category of cost	SCK-CEN		SKB		SSTC NRS		STUBA		SURO		TNO		TS ENERCON		TUS		UCY	
		Cost	pm	Cost	pm	Cost	pm	Cost	pm	Cost	pm	Cost	pm	Cost	pm	Cost	pm	Cost	pm
GAS	Personnel costs - task 1	23,3	2,0																
	Personnel costs - task 2	106,2	24,0																
	Personnel costs - task 3																		
	Personnel costs - task 4	63,0	5,4																
	Total Personnel Costs	192,6	31,4																
	Total travel costs	16,0																	
	Total Equipment	8,0																	
	Total Other goods & services																		
	Total direct costs	216,6																	
	Total Indirect Costs	54,1																	
	Total subcontracting																		
	TOTAL BUDGET	270,7																	
	EC requested contribution	135,4																	
HITEC	Personnel costs - task 1			15,0	2,0														
	Personnel costs - task 2																		
	Personnel costs - task 3			30,0	4,0														
	Personnel costs - task 4			22,5	3,0														
	Total Personnel Costs			67,5	9,0														
	Total travel costs			8,5															
	Total Equipment																		
	Total Other goods & services																		
	Large Research Infrastructure (LRI)																		
	Total direct costs			76,0															
	Total Indirect Costs			19,0															
	TOTAL BUDGET			95,0															
	EC requested contribution			47,5															
FUTURE	Personnel costs - task 1	15,2	1,3									6,4	1,0						
	Personnel costs - task 2	108,8	11,0																
	Personnel costs - task 3											83,2	13,0						
	Total Personnel Costs	124,0	12,3									89,6	14,0						
	Total travel costs	5,0										5,0							
	Total Equipment											5,0							
	Total Other goods & services	17,0										12,8							
	Total direct costs	146,0										112,4							
	Total Indirect Costs	36,5										28,1							
	Total subcontracting																		
	TOTAL BUDGET	182,5										140,5							
	EC requested contribution	91,3										70,3							
CORI	Personnel costs - task 1																		
	Personnel costs - Task 2	92,8	9,7																
	Personnel costs - Task 3	39,0	3,5																
	Personnel costs - Task 4	55,9	5,1															13,6	4,0
	Total Personnel Costs	187,7	18,3															13,6	4,0
	Total travel costs	11,0																5,0	
	Total Equipment																		
	Total Other goods & services	143,7																	
	Total direct costs	342,4																18,6	
	Total Indirect Costs	85,6																4,7	
	TOTAL BUDGET	428,0																23,3	
	EC requested contribution	214,0																11,6	

WP	Category of cost	UHELSINKI		UKRI-BGS		VTT		VUJE	
		Cost	pm	Cost	pm	Cost	pm	Cost	pm
GAS	Personnel costs - task 1			9,6	1,5				
	Personnel costs - task 2			433,4	69,5				
	Personnel costs - task 3			115,7	22,7				
	Personnel costs - task 4	32,9	6,0						
	Total Personnel Costs	32,9	6,0	558,7	93,7				
	Total travel costs	5,0		13,5					
	Total Equipment								
	Total Other goods & services			102,4					
	Total direct costs	37,9		674,6					
	Total Indirect Costs	9,5		168,7					
	Total subcontracting			76,3					
	TOTAL BUDGET	47,3		919,6					
	EC requested contribution	23,6		334,7					
HITEC	Personnel costs - task 1					37,5	3,0		
	Personnel costs - task 2			236,1	45,6				
	Personnel costs - task 3	261,7	62,0	173,9	31,8	116,4	18,5		
	Personnel costs - task 4					87,5	7,0		
	Total Personnel Costs	261,7	62,0	410,0	77,3	241,4	28,5		
	Total travel costs	15,0		8,5		20,5			
	Total Equipment								
	Total Other goods & services	57,6		136,5		9,0			
	Large Research Infrastructure (LRI)					58,6			
	Total direct costs	334,3		555,0		329,5			
	Total Indirect Costs	83,6		138,7		82,4			
	Total subcontracting			38,2					
	TOTAL BUDGET	417,9		731,9		411,9			
	EC requested contribution	208,9		263,0		205,9			
FUTURE	Personnel costs - task 1								
	Personnel costs - task 2	108,0	18,0						
	Personnel costs - task 3								
	Total Personnel Costs	108,0	18,0						
	Total travel costs	5,0							
	Total Equipment								
	Total Other goods & services	4,0							
	Total direct costs	117,0							
	Total Indirect Costs	29,3							
	Total subcontracting								
	TOTAL BUDGET	146,3							
	EC requested contribution	73,1							
CORI	Personnel costs - task 1								
	Personnel costs - Task 2								
	Personnel costs - Task 3								
	Personnel costs - Task 4								
	Total Personnel Costs								
	Total travel costs								
	Total Equipment								
	Total Other goods & services								
	Total direct costs								
	Total Indirect Costs								
	Total subcontracting								
	TOTAL BUDGET								
	EC requested contribution								

WP	Category of cost	TOTAL		Andra		ARAO		BEL V		BGE		CEA		CHRD		CIEMAT		CNRS		COVRA	
		Cost	pm	Cost	pm	Cost	pm	Cost	pm	Cost	pm	Cost	pm	Cost	pm	Cost	pm	Cost	pm	Cost	pm
SFC	Personnel costs - Task 1	94,9	12,3													8,9	2,0				
	Personnel costs - Task 2	1 111,6	159,8													131,7	29,7				
	Personnel costs - Task 3	2 320,3	406,5													632,1	146,6	409,3	79,1		
	Personnel costs - Task 4	430,9	74,1									75,6	10,9	9,0	4,5	223,2	44,2				
	Total Personnel Costs	3 957,8	652,6									75,6	10,9	9,0	4,5	995,9	222,5	409,3	79,1		
	Total Travel costs	199,8										5,0		5,0		26,0		15,0			
	Total Equipment	113,4														39,6		49,9			
	Total Other goods & services	241,3																			
	Large Research Infrastructure (LRI)	7,9																			
	Total direct costs	4 520,2										80,6		14,0		1 061,5		474,2			
	Total Indirect Costs	1 033,2										20,2		3,5		265,4		118,6			
	Total subcontracting	208,8																			
	<i>Total In-kind contribution against payment</i>	<i>387,3</i>																			
	TOTAL BUDGET	5 762,1										100,8		17,5		1 326,8		592,8			
	EC requested contribution	2 744,1										50,4		8,8		663,4		296,4			
UMAN	Personnel costs - task 1	137,9	14,7					74,9	7,0	22,2	1,8										
	Personnel costs - task 2	218,6	25,8					10,7	1,0							4,4	1,0	4,6	0,5	6,4	0,5
	Personnel costs - task 3	337,4	46,0	3,2	0,4			17,1	1,6	1,3	0,1					11,1	2,5	23,0	2,5	12,8	1,0
	Personnel costs - task 4	307,5	32,6	23,4	2,6			27,8	2,6	58,4	4,6							4,6	0,5		
	Personnel costs - task 5	335,6	38,5	25,5	2,8			7,5	0,7												
	Personnel costs - task 6	335,6	38,5	31,5	3,5																
	Total Personnel Costs	1 337,0	157,6	83,5	9,3			138,0	12,9	81,9	6,5					15,5	3,5	32,2	3,5	19,2	1,5
	Total Travel Costs	293,6		11,5				23,6		13,9						5,5		7,0		5,5	
	Total Equipment																				
	Total Other goods & services	49,2						42,2													
	Total direct costs	1 679,8						203,8		95,8						21,0		39,2		24,7	
	Total Indirect Costs	419,9		95,0				51,0		23,9						5,3		9,8		6,2	
	Total subcontracting			23,8																	
	TOTAL BUDGET	2 099,7		118,8				254,8		119,7						26,3		49,0		30,9	
	EC requested contribution	1 489,9		83,1				178,3		83,8						18,4		34,3		21,6	
ROUTES	Personnel costs - task 1	86,6	9,3	2,5	0,3															3,2	0,3
	Personnel costs - task 2	114,8	16,7	35,0	3,5			3,1	0,3			4,1	0,3			1,3	0,3				
	Personnel costs - task 3	150,9	25,9									21,0	1,5			15,5	3,5				
	Personnel costs - task 4	278,5	37,1	16,5	1,7							23,1	1,7			7,3	1,7				
	Personnel costs - task 5	175,3	25,3																		
	Personnel costs - task 6	243,7	29,6			5,1	1,2					40,6	2,9			5,3	1,2			47,4	3,7
	Personnel costs - task 7	59,6	7,6																		
	Personnel costs - task 8	142,5	21,1	10,0	1,0											1,8	0,4			5,1	0,4
	Total Personnel Costs	1 252,1	172,4	64,0	6,4	5,1	1,2	3,1	0,3			88,8	6,3			31,2	7,0			55,7	4,4
	Total Travel Costs	317,5		11,9		5,0		3,5				8,0				8,4				9,9	
	Total Equipment																				
	Total Other goods & services	35,3		1,0								1,0								2,0	
	Total direct costs	1 604,9		76,9		10,1		6,6				97,8				39,6				67,6	
	Total Indirect Costs	401,2		19,2		2,5		1,7				24,4				9,9				16,9	
	Total subcontracting	3,6																			
	TOTAL BUDGET	2 009,8		96,1		12,6		8,3				122,2				49,5				84,5	
	EC requested contribution	1 432,0		67,3		8,8		5,8				85,5				34,7				59,1	

WP	Category of cost	CVREZ		Dekom		EEAE		ENRESA		CPST		JUELICH		GRS		IAE		INCT		IRSN		IST-ID	
		Cost	pm	Cost	pm	Cost	pm	Cost	pm	Cost	pm	Cost	pm	Cost	pm	Cost	pm	Cost	pm	Cost	pm	Cost	pm
SFC	Personnel costs - Task 1																						
	Personnel costs - Task 2							11,4	1,4	11,5	3,8												
	Personnel costs - Task 3											150,0	36,0										
	Personnel costs - Task 4																						
	Total Personnel Costs							11,4	1,4	11,5	3,8	150,0	36,0										
	Total Travel costs							10,0		5,0		5,0											
	Total Equipment											5,0											
	Total Other goods & services																						
	Large Research Infrastructure (LRI)																						
	Total direct costs							21,4		16,5		160,0											
	Total Indirect Costs							5,4		4,1		40,0											
	Total subcontracting							208,8															
	<i>Total In-kind contribution against payment</i>																						
	TOTAL BUDGET							235,5		20,6		200,0											
	EC requested contribution							117,8		10,3		100,0											
UMAN	Personnel costs - task 1													11,5	1,3					23,3	1,8		
	Personnel costs - task 2											25,0	3,3	13,8	1,5					5,3	0,6		
	Personnel costs - task 3							12,4	1,5	7,6	2,0			0,9	0,1					26,6	3,2		
	Personnel costs - task 4							8,3	1,0					18,3	2,0					3,5	0,3		
	Personnel costs - task 5													13,8	1,5					208,2	18,9		
	Total Personnel Costs							20,7	2,5	7,6	2,0	25,0	3,3	58,2	6,4					266,8	24,8		
	Total Travel Costs							5,5		3,5		5,5		15,5						39,0			
	Total Equipment																						
	Total Other goods & services																			2,0			
	Total direct costs							26,2		11,1		30,5		73,7						307,8			
	Total Indirect Costs							6,6		2,8		7,6		18,4						77,0			
	Total subcontracting																						
	TOTAL BUDGET							32,8		13,9		38,2		92,2						384,8			
	EC requested contribution							22,9		9,7		26,7		64,5						289,5			
ROUTES	Personnel costs - task 1											1,8	0,3							54,9	5,5		
	Personnel costs - task 2					2,8	0,7			1,1	0,3	2,1	0,3	2,9	0,3	0,7	0,2	2,1	0,7	2,9	0,3	0,8	0,2
	Personnel costs - task 3					1,0	0,3					29,3	4,0							10,0	1,0	6,8	1,3
	Personnel costs - task 4					0,8	0,2			6,3	1,7	1,8	0,3	4,4	0,5	4,2	1,0	11,9	4,0	16,5	1,7		
	Personnel costs - task 5					3,0	0,8							12,3	1,3			3,0	1,0			11,0	2,0
	Personnel costs - task 6			17,4	2,0	4,8	1,2			4,6	1,2	8,8	1,2							12,0	1,2	5,5	1,0
	Personnel costs - task 7																			50,6	5,9		
	Personnel costs - task 8			3,5	0,4	1,6	0,4							7,7	1,1			1,2	0,4			2,2	0,4
	Total Personnel Costs			20,9	2,4	14,0	3,5			11,9	3,1	43,9	6,0	27,3	3,1	4,8	1,1	18,1	6,0	146,9	15,5	26,2	4,8
	Total Travel Costs			9,9		9,4				7,0		13,0		8,4		5,5		8,4		33,8		8,4	
	Total Equipment																						
	Total Other goods & services											4,0						1,0		15,0		5,7	
	Total direct costs			30,8		23,4				18,9		60,9		35,7		10,3		27,5		195,7		40,3	
	Total Indirect Costs			7,7		5,8				4,7		15,2		8,9		2,6		6,9		48,9		10,1	
	Total subcontracting																						
	TOTAL BUDGET			38,5		29,2				23,7		76,1		44,7		12,9		34,4		244,6		50,4	
	EC requested contribution			26,9		20,4				16,6		53,3		31,3		9,0		24,1		196,4		35,3	

WP	Category of cost	IST-LPSR		JRC		JSI		KIT		LEI		MTA EK		NAGRA		NCSRD		NES	
		Cost	pm	Cost	pm	Cost	pm	Cost	pm	Cost	pm	Cost	pm	Cost	pm	Cost	pm	Cost	pm
SFC	Personnel costs - Task 1			16,0	2,0			11,5	2,0					32,0	2,0				
	Personnel costs - Task 2			75,0	9,4	78,4	10,8	74,0	9,4	35,0	7,0			4,3	0,3				
	Personnel costs - Task 3			441,2	52,1			238,4	40,0			88,0	22,0	28,8	1,8				
	Personnel costs - Task 4													76,3	4,8				
	Total Personnel Costs			532,2	63,5	78,4	10,8	323,9	51,4	35,0	7,0	88,0	22,0	141,5	8,8				
	Total Travel costs			15,0		5,0		18,5		5,0		5,0		11,0					
	Total Equipment							4,5				4,0							
	Total Other goods & services			206,6								9,0							
	Large Research Infrastructure (LRI)																		
	Total direct costs			753,8		83,4		346,9		40,0		106,0		152,5					
	Total Indirect Costs			188,5		20,8		86,7		10,0		26,5		38,1					
	Total subcontracting																		
	<i>Total In-kind contribution against payment</i>																		
	TOTAL BUDGET			942,3		104,2		433,6		50,0		132,5		190,6					
	EC requested contribution			334,2		52,1		216,8		25,0		66,3		95,3					
UMAN	Personnel costs - task 1																		
	Personnel costs - task 2					5,3	1,0	12,0	2,0	5,0	1,0			16,0	1,0				
	Personnel costs - task 3					21,5	3,5	12,8	1,6	0,5	0,1			1,6	0,1				
	Personnel costs - task 4							8,8	1,1	13,0	2,6			49,6	3,1				
	Personnel costs - task 5					11,9	2,3	21,0	3,5										
	Total Personnel Costs					38,7	6,8	54,6	8,2	18,5	3,7			67,2	4,2				
	Total Travel Costs					10,5		11,6		7,6				9,9					
	Total Equipment																		
	Total Other goods & services																		
	Total direct costs					49,2		66,2		26,1				77,1					
	Total Indirect Costs					12,3		16,6		6,5				19,3					
	Total subcontracting																		
	TOTAL BUDGET					61,5		82,8		32,7				96,3					
	EC requested contribution					43,1		57,9		22,9				67,4					
ROUTES	Personnel costs - task 1															14,6	1,4		
	Personnel costs - task 2	2,0	0,3			2,1	0,3			1,5	0,3					10,4	1,4	7,3	0,7
	Personnel costs - task 3					10,6	2,0									6,4	0,8		
	Personnel costs - task 4	4,8	0,7			8,7	1,7			8,3	1,7					0,9	0,2		
	Personnel costs - task 5	15,5	2,3			9,1	1,3									69,4	8,8	31,6	3,0
	Personnel costs - task 6	8,3	1,2			8,0	1,5									12,6	1,2	12,6	1,2
	Personnel costs - task 7					9,0	1,7												
	Personnel costs - task 8	2,8	0,4			13,1	2,2			2,0	0,4					39,6	5,1	11,3	1,1
	Total Personnel Costs	33,4	4,8			60,5	10,6			11,7	2,3					153,8	18,7	62,7	6,0
	Total Travel Costs	8,4				22,3				6,9						21,8		8,4	
	Total Equipment																		
	Total Other goods & services															1,0		2,7	
	Total direct costs	41,8				82,8				18,6						176,6		73,8	
	Total Indirect Costs	10,4				20,7				4,7						44,2		18,4	
	Total subcontracting															3,6			
	TOTAL BUDGET	52,2				103,6				23,3						224,4		92,2	
	EC requested contribution	36,6				72,5				16,3						157,1		64,6	

WP	Category of cost	NRG		NJF		ONDRAF/NIRAS		Posiva		PSI		PURAM		RATEN/ICN		RAWRA/SÚRAO		RWM/NDÁ	
		Cost	pm	Cost	pm	Cost	pm	Cost	pm	Cost	pm	Cost	pm	Cost	pm	Cost	pm	Cost	pm
SFC	Personnel costs - Task 1																		
	Personnel costs - Task 2									152,0	10,7					1,4	0,4		
	Personnel costs - Task 3									275,6	19,4								
	Personnel costs - Task 4																		
	Total Personnel Costs									427,6	30,1					1,4	0,4		
	Total Travel costs									8,5						5,0			
	Total Equipment									10,5									
	Total Other goods & services																		
	Large Research Infrastructure (LRI)																		
	Total direct costs									446,6						6,4			
	Total Indirect Costs									111,7						1,6			
	Total subcontracting																		
	<i>Total In-kind contribution against payment</i>																		
	TOTAL BUDGET									558,3						8,0			
	EC requested contribution									279,1						4,0			
UMAN	Personnel costs - task 1													6,1	2,8				
	Personnel costs - task 2	10,9	1,0			15,4	1,0									5,9	2,0	9,1	1,0
	Personnel costs - task 3					17,0	1,1	7,9	1,5	50,5	4,0			12,1	5,5	8,9	3,0		
	Personnel costs - task 4	30,0	2,8			5,4	0,4			16,8	1,3			0,2	0,1	0,3	0,1		
	Personnel costs - task 5							7,9	1,5									18,1	2,0
	Total Personnel Costs	40,9	3,8			37,8	2,5	15,9	3,0	67,3	5,3			18,4	8,4	15,0	5,1	27,2	3,0
	Total Travel Costs	7,0				7,6		5,5		9,0				14,0		10,5		8,0	
	Total Equipment																		
	Total Other goods & services																		
	Total direct costs	47,9				45,4		21,4		76,3				32,4		25,5		35,2	
	Total Indirect Costs	12,0				11,3		5,3		19,1				8,1		6,4		8,8	
	Total subcontracting																		
	TOTAL BUDGET	59,9				56,7		26,7		95,3				40,5		31,9		44,0	
	EC requested contribution	41,9				39,7		18,7		66,7				28,3		22,4		30,8	
ROUTES	Personnel costs - task 1					3,9	0,3												
	Personnel costs - task 2	3,4	0,3			4,5	0,3							0,6	0,3	1,2	0,3		
	Personnel costs - task 3																		
	Personnel costs - task 4					77,1	5,0							5,9	2,7	6,6	1,7		
	Personnel costs - task 5																		
	Personnel costs - task 6			3,2	1,5														
	Personnel costs - task 7																		
	Personnel costs - task 8			0,9	0,4	6,2	0,4							2,2	1,0				
	Total Personnel Costs	3,4	0,3	4,1	1,9	91,5	5,9							8,8	4,0	7,8	1,9		
	Total Travel Costs	3,5		6,4		11,9								4,9		5,5			
	Total Equipment																		
	Total Other goods & services													1,0					
	Total direct costs	6,9		10,5		103,4								14,7		13,3			
	Total Indirect Costs	1,7		2,6		25,9								3,7		3,3			
	Total subcontracting																		
	TOTAL BUDGET	8,6		13,1		129,3								18,3		16,6			
	EC requested contribution	6,0		9,2		90,5								12,8		11,6			

WP	Category of cost	SCK-CEN		SKB		SSTC NRS		STUBA		SURO		TNO		TS ENERCON		TUS		UCY	
		Cost	pm	Cost	pm	Cost	pm	Cost	pm	Cost	pm	Cost	pm	Cost	pm	Cost	pm	Cost	pm
SFC	Personnel costs - Task 1			26,5	4,3														
	Personnel costs - Task 2	167,4	15,5	314,5	50,5	6,6	3,1									13,1	2,7		
	Personnel costs - Task 3															21,6	4,5		
	Personnel costs - Task 4															46,7	9,7		
	Total Personnel Costs	167,4	15,5	341,0	54,7	6,6	3,1									81,5	17,0		
	Total Travel costs	5,0		26,3		5,0										11,0			
	Total Equipment																		
	Total Other goods & services			25,0												0,7			
	Large Research Infrastructure (LRI)																		
	Total direct costs	172,4		392,3		11,6										93,2			
	Total Indirect Costs	43,1		1,3		2,9										23,3			
	Total subcontracting																		
	<i>Total In-kind contribution against payment</i>			387,3															
	TOTAL BUDGET	215,5		393,5		14,4										116,4			
	EC requested contribution	107,8		196,8		7,2										58,2			
UMAN	Personnel costs - task 1																		
	Personnel costs - task 2	17,5	1,5			2,1	1,0	3,7	1,0							4,9	1,0		
	Personnel costs - task 3	44,3	3,8			3,4	1,6	0,4	0,1	0,4	0,1			6,0	1,2	0,5	0,1		
	Personnel costs - task 4	1,2	0,1			0,2	0,1	2,2	0,6	14,4	3,5					7,8	1,6		
	Personnel costs - task 5					4,7	2,3									10,9	2,3		
	Total Personnel Costs	63,0	5,4			10,4	5,0	6,3	1,7	14,8	3,6			6,0	1,2	24,0	5,0		
	Total Travel Costs	10,5				7,6		6,1		10,5				3,5		7,6			
	Total Equipment																		
	Total Other goods & services									5,0									
	Total direct costs	73,5				18,0		12,4		30,3				9,5		31,6			
	Total Indirect Costs	18,4				4,5		3,1		7,6				2,4		7,9			
	Total subcontracting																		
	TOTAL BUDGET	91,8				22,5		15,5		37,8				11,9		39,5			
	EC requested contribution	64,3				15,8		10,9		26,5				8,3		27,7			
ROUTES	Personnel costs - task 1									5,7	1,4								
	Personnel costs - task 2	3,4	0,3	2,2	0,3	7,4	3,5	1,1	0,3	1,2	0,3			1,5	0,3	1,4	0,3	1,8	0,3
	Personnel costs - task 3	11,7	1,0			6,3	3,0	7,4	2,0							14,4	3,0	3,8	0,6
	Personnel costs - task 4			1,9	0,3	3,5	1,7	3,5	1,0	0,8	0,2					7,9	1,7		
	Personnel costs - task 5									20,5	5,0								
	Personnel costs - task 6			9,0	1,2	2,5	1,2			4,9	1,2								
	Personnel costs - task 7																		
	Personnel costs - task 8					3,2	1,1	1,5	0,4	10,7	2,6							2,5	0,4
	Total Personnel Costs	15,0	1,3	13,1	1,7	22,8	10,5	13,5	3,6	43,8	10,7			1,5	0,3	23,7	4,9	8,1	1,3
	Total Travel Costs	5,5		5,5		8,4		8,4		8,4				3,5		7,0		6,9	
	Total Equipment																		
	Total Other goods & services									1,0									
	Total direct costs	20,5		18,6		31,2		21,9		53,2				5,0		30,7		15,0	
	Total Indirect Costs	5,1		4,6		7,8		5,5		13,3				1,2		7,7		3,8	
	Total subcontracting																		
	TOTAL BUDGET	25,7		23,2		39,0		27,3		66,5				6,2		38,4		18,8	
	EC requested contribution	18,0		16,2		27,3		19,1		46,6				4,3		26,9		13,1	

WP	Category of cost	UHELSINKI		UKRI-BGS		VTT		VUJE	
		Cost	pm	Cost	pm	Cost	pm	Cost	pm
SFC	Personnel costs - Task 1								
	Personnel costs - Task 2					35,3	5,0		
	Personnel costs - Task 3					35,3	5,0		
	Personnel costs - Task 4								
	Total Personnel Costs					70,5	10,0		
	Total Travel costs					8,5			
	Total Equipment								
	Total Other goods & services								
	Large Research Infrastructure (LRI)					7,9			
	Total direct costs					86,9			
	Total Indirect Costs					21,7			
	Total subcontracting								
	<i>Total In-kind contribution against payment</i>								
	TOTAL BUDGET					108,6			
	EC requested contribution					54,3			
UMAN	Personnel costs - task 1								
	Personnel costs - task 2					37,5	2,5		
	Personnel costs - task 3					13,6	1,6		
	Personnel costs - task 4					11,3	1,3		
	Personnel costs - task 5								
	Total Personnel Costs					62,4	5,4		
	Total Travel Costs					10,5			
	Total Equipment								
	Total Other goods & services								
	Total direct costs					72,9			
	Total Indirect Costs					18,2			
	Total subcontracting								
	TOTAL BUDGET					91,1			
	EC requested contribution					63,8			
ROUTES	Personnel costs - task 1								
	Personnel costs - task 2					3,5	0,3		
	Personnel costs - task 3							6,7	2,0
	Personnel costs - task 4					55,8	4,7		
	Personnel costs - task 5								
	Personnel costs - task 6					31,2	2,6		
	Personnel costs - task 7								
	Personnel costs - task 8					13,8	1,1		
	Total Personnel Costs					104,2	8,6	6,7	2,0
	Total Travel Costs					8,4		5,0	
	Total Equipment								
	Total Other goods & services								
	Total direct costs					112,6		11,7	
	Total Indirect Costs					28,2		2,9	
	Total subcontracting								
	TOTAL BUDGET					140,8		14,6	
	EC requested contribution					98,6		10,2	

WP	Category of cost	TOTAL		Andra		ARAO		BEL V		BGE		CEA		CHRD		CIEMAT		CNRS		COVRA	
		Cost	pm	Cost	pm	Cost	pm	Cost	pm	Cost	pm	Cost	pm	Cost	pm	Cost	pm	Cost	pm	Cost	pm
KM SoK	Personnel costs - task 1	175,3	24,5	7,0	0,7			28,0	4,0	50,8	5,0					3,1	0,7				
	Personnel costs - task 2	404,1	46,6	5,0	0,5					302,8	29,8					1,1	0,3				
	Personnel costs - task 3	189,1	25,0							101,6	10,0										
	Personnel costs - task 4	128,6	27,5	22,0	2,2					30,5	3,0					0,9	0,2				
	Personnel costs - task 5	30,5	3,0							30,5	3,0										
	Total Personnel Costs	927,6	126,6	34,0	3,4			28,0	4,0	516,1	50,8					5,1	1,2				
	Travel Costs	61,0		8,0						20,0						7,0					
	Other goods & services																				
	Total Direct costs	988,6		42,0				28,0		536,1						12,1					
	Total Indirect Costs	247,2		10,5				7,0		134,0						3,0					
	Total Costs	1 235,8		52,5				35,0		670,2						15,1					
	EC requested contribution	864,1		36,8				24,5		469,1						10,6					
KM Guidance	Personnel costs - task 1	106,6	18,0					28,0	4,0												
	Personnel costs - task 2	48,7	8,3																		
	Personnel costs - task 3	345,7	74,0																		
	Total Personnel Costs	501,0	100,3					28,0	4,0												
	Travel Costs	59,0																			
	Other goods & services																				
	Total Direct costs	560,0						28,0													
	Total Indirect Costs	140,0						7,0													
	Total Costs	700,0						35,0													
	EC requested contribution	471,4						24,5													
KM Training	Personnel costs - task 1	16,7	2,0													1,1	0,3				
	Personnel costs - task 2	30,5	3,5													3,3	0,8				
	Personnel costs - task 3	20,4	2,6	2,5	0,3											1,1	0,3				
	Personnel costs - task 4	395,3	48,7	42,5	4,3			28,0	4,0							20,2	4,6				
	Personnel costs - task 5	217,1	38,9	41,4	4,1											17,8	4,0				
	Total Personnel Costs	679,9	95,7	86,4	8,6			28,0	4,0							43,5	9,8				
	Travel Costs	70,0		7,0												8,0					
	Other goods & services																				
	Mobility actions - not allocated	220,3																			
	Total Direct costs	970,2		93,4				28,0								51,5					
	Total Indirect Costs	242,5		23,4				7,0								12,9					
	Total Costs	1 212,7		116,8				35,0								64,4					
	EC requested contribution	808,8		81,7				24,5								45,1					
WP15 CONCORD	Personnel costs - task 1	294,0	31,2	30,1	3,3									71,2	71,0	2,7	0,6	26,0	3,3		
	Personnel costs - task 2	548,1	159,0	250,5	50,0													107,5	22,0		
	Personnel costs - task 3	520,2	120,0													31,1	7,0	110,4	36,0		
	Personnel costs - task 4	704,3	126,0													129,8	27,0				
	Personnel costs - task 5	342,1	58,4													48,8	11,0				
	Personnel costs - task 6	544,5	80,0	30,0	3,0																
	Total Personnel Costs	2 953,3	574,5	310,5	56,3									71,2	71,0	212,4	45,6	243,9	61,3		
	Total Travel Costs	142,5		13,5										5,0		16,0		13,5			
	Total Equipment	57,5		10,5												12,0					
	Total Other goods & services	750,7		75,5										6,0		87,0		30,0			
	Total direct costs	3 904,0		410,0										82,2		327,4		287,4			
	Total Indirect Costs	976,0		102,5										20,6		81,8		71,8			
	Total subcontracting																				
	Total In-kind contribution against payment																				
	TOTAL BUDGET	4 880,0		512,5										102,8		409,2		359,2			
	EC requested contribution	2 440,0		256,3										51,4		204,6		179,6			

WP	Category of cost	CVREZ		Dekom		EEAE		ENRESA		CPST		JUELICH		GRS		IAE		INCT		IRSN		IST-ID	
		Cost	pm	Cost	pm	Cost	pm	Cost	pm	Cost	pm	Cost	pm	Cost	pm	Cost	pm	Cost	pm	Cost	pm	Cost	pm
KM SoK	Personnel costs - task 1											77,0	10,0										
	Personnel costs - task 2											84,7	11,0										
	Personnel costs - task 3											77,0	10,0										
	Personnel costs - task 4											38,5	5,0										
	Personnel costs - task 5																						
	Total Personnel Costs											277,2	36,0										
	Travel Costs											13,0											
	Other goods & services																						
	Total Direct costs											290,2											
	Total Indirect Costs											72,6											
	Total Costs											362,8											
	EC requested contribution											253,9											
KM Guidance	Personnel costs - task 1																						
	Personnel costs - task 2																						
	Personnel costs - task 3																						
	Total Personnel Costs																						
	Travel Costs																						
	Other goods & services																						
	Total Direct costs																						
	Total Indirect Costs																						
	Total Costs																						
	EC requested contribution																						
KM Training	Personnel costs - task 1																						
	Personnel costs - task 2																						
	Personnel costs - task 3																						
	Personnel costs - task 4																						
	Personnel costs - task 5																						
	Total Personnel Costs																						
	Travel Costs																						
	Other goods & services																						
	Total Direct costs																						
	Total Indirect Costs																						
	Total Costs																						
	EC requested contribution																						
WP15 CONCORD	Personnel costs - task 1											8,8	1,6	31,3	4,3								
	Personnel costs - task 2																						
	Personnel costs - task 3																						
	Personnel costs - task 4											160,8	24,0										
	Personnel costs - task 5													80,3	11,0								
	Personnel costs - task 6											204,0	30,0										
	Total Personnel Costs											373,6	55,6	111,6	15,3								
	Total Travel Costs											10,0		8,5									
	Total Equipment																						
	Total Other goods & services											7,0		10,0									
	Total direct costs											390,6		130,1									
	Total Indirect Costs											97,7		32,5									
	Total subcontracting																						
	<i>Total In-kind contribution against payment</i>																						
	TOTAL BUDGET											488,3		162,6									
	EC requested contribution											244,1		81,3									

WP	Category of cost	IST-LPSR		JRC		JSI		KIT		LEI		MTA EK		NAGRA		NCSRD		NES	
		Cost	pm	Cost	pm	Cost	pm	Cost	pm	Cost	pm	Cost	pm	Cost	pm	Cost	pm	Cost	pm
KM SoK	Personnel costs - task 1			1,0	0,1														
	Personnel costs - task 2																		
	Personnel costs - task 3																		
	Personnel costs - task 4			1,0	0,1														
	Personnel costs - task 5																		
	Total Personnel Costs			2,1	0,2														
	Travel Costs																		
	Other goods & services																		
	Total Direct costs			2,1															
	Total Indirect Costs			0,5															
	Total Costs			2,6															
	EC requested contribution			0,9															
KM Guidance	Personnel costs - task 1			10,3	1,0	8,0	1,5												
	Personnel costs - task 2			5,2	0,5	2,7	0,5												
	Personnel costs - task 3			20,6	2,0	106,0	20,0												
	Total Personnel Costs			36,1	3,5	116,6	22,0												
	Travel Costs			7,0		7,0													
	Other goods & services																		
	Total Direct costs			43,1		123,6													
	Total Indirect Costs			10,8		30,9													
	Total Costs			53,9		154,5													
	EC requested contribution			19,1		108,2													
KM Training	Personnel costs - task 1			2,6	0,3														
	Personnel costs - task 2			2,6	0,3														
	Personnel costs - task 3			2,6	0,3														
	Personnel costs - task 4			38,6	3,7														
	Personnel costs - task 5			38,6	3,7	39,5	7,5												
	Total Personnel Costs			84,9	8,2	39,5	7,5												
	Travel Costs			8,0		3,5													
	Other goods & services																		
	Mobility actions - not allocated																		
	Total Direct costs			92,9		43,0													
	Total Indirect Costs			23,2		10,8													
	Total Costs			116,2		53,8													
	EC requested contribution			41,2		37,7													
WP15 CONCORD	Personnel costs - task 1							2,1	0,3					132,4	9,3				
	Personnel costs - task 2													209,0	28,4				
	Personnel costs - task 3													175,7	36,0				
	Personnel costs - task 4																		
	Personnel costs - task 5							167,7	23,7										
	Personnel costs - task 6							192,0	32,0					118,5	15,0				
	Total Personnel Costs							361,8	56,0					635,6	88,7				
	Total Travel Costs							10,0						31,5					
	Total Equipment																		
	Total Other goods & services							6,0						323,3					
	Total direct costs							377,8						990,4					
	Total Indirect Costs							94,5						247,6					
	Total subcontracting																		
	Total In-kind contribution against payment																		
	TOTAL BUDGET							472,3						1 238,0					
	EC requested contribution							236,1						619,0					

WP	Category of cost	NRG		NJF		ONDRAF/NIRAS		Posiva		PSI		PURAM		RATEN/ICN		RAWRA/SÚRAO		RWM/NDA	
		Cost	pm	Cost	pm	Cost	pm	Cost	pm	Cost	pm	Cost	pm	Cost	pm	Cost	pm	Cost	pm
KM SoK	Personnel costs - task 1																		
	Personnel costs - task 2																		
	Personnel costs - task 3																		
	Personnel costs - task 4																		
	Personnel costs - task 5																		
	Total Personnel Costs																		
	Travel Costs																		
	Other goods & services																		
	Total Direct costs																		
	Total Indirect Costs																		
	Total Costs																		
	EC requested contribution																		
KM Guidance	Personnel costs - task 1											12,0	2,0			39,0	6,5		
	Personnel costs - task 2											19,8	3,3			18,0	3,0		
	Personnel costs - task 3											60,0	10,0			66,0	11,0		
	Total Personnel Costs											91,8	15,3			123,0	20,5		
	Travel Costs											12,0				19,0			
	Other goods & services																		
	Total Direct costs											103,8				142,0			
	Total Indirect Costs											26,0				35,5			
	Total Costs											129,8				177,5			
	EC requested contribution											90,8				124,3			
KM Training	Personnel costs - task 1															0,8	0,3		
	Personnel costs - task 2															0,8	0,3		
	Personnel costs - task 3															0,8	0,3		
	Personnel costs - task 4															13,0	4,1		
	Personnel costs - task 5															13,0	4,1		
	Total Personnel Costs															28,5	9,0		
	Travel Costs															8,0			
	Other goods & services																		
	Total Direct costs															36,5			
	Total Indirect Costs															9,1			
	Total Costs															45,6			
	EC requested contribution															31,9			
WP15 CONCORD	Personnel costs - task 1															13,1	3,7		
	Personnel costs - task 2																		
	Personnel costs - task 3															169,7	48,6		
	Personnel costs - task 4															63,0	22,0		
	Personnel costs - task 5															45,3	12,7		
	Personnel costs - task 6																		
	Total Personnel Costs															291,1	87,0		
	Total Travel Costs															21,0			
	Total Equipment																		
	Total Other goods & services															119,5			
	Total direct costs															431,6			
	Total Indirect Costs															107,9			
	Total subcontracting																		
	<i>Total In-kind contribution against payment</i>																		
	TOTAL BUDGET															539,5			
	EC requested contribution															269,7			

WP	Category of cost	SCK-CEN		SKB		SSTC NRS		STUBA		SURO		TNO		TS ENERCON		TUS		UCY	
		Cost	pm	Cost	pm	Cost	pm	Cost	pm	Cost	pm	Cost	pm	Cost	pm	Cost	pm	Cost	pm
KM SoK	Personnel costs - task 1					8,4	4,0												
	Personnel costs - task 2					10,5	5,0												
	Personnel costs - task 3					10,5	5,0												
	Personnel costs - task 4					35,7	17,0												
	Personnel costs - task 5																		
	Total Personnel Costs					65,1	31,0												
	Travel Costs					13,0													
	Other goods & services																		
	Total Direct costs					78,1													
	Total Indirect Costs					19,5													
	Total Costs					97,6													
	EC requested contribution					68,3													
KM Guidance	Personnel costs - task 1					3,2	1,5			6,2	1,5								
	Personnel costs - task 2					1,1	0,5			2,1	0,5								
	Personnel costs - task 3					35,7	17,0			57,4	14,0								
	Total Personnel Costs					39,9	19,0			65,6	16,0								
	Travel Costs					7,0				7,0									
	Other goods & services																		
	Total Direct costs					46,9				72,6									
	Total Indirect Costs					11,7				18,2									
	Total Costs					58,6				90,8									
	EC requested contribution					41,0				63,5									
KM Training	Personnel costs - task 1	11,7	1,0			0,5	0,3												
	Personnel costs - task 2	23,3	2,0			0,5	0,3												
	Personnel costs - task 3	11,7	1,0			0,5	0,3			1,2	0,3								
	Personnel costs - task 4	224,4	19,3			8,0	3,8			20,5	5,0								
	Personnel costs - task 5	17,5	1,5			8,2	3,9			41,0	10,0								
	Total Personnel Costs	288,6	24,8			17,7	8,5			62,8	15,3								
	Travel Costs	19,0				8,0				8,5									
	Other goods & services																		
	Total Direct costs	527,8				25,7				71,3									
	Total Indirect Costs	132,0				6,4				17,8									
	Total Costs	659,8				32,2				89,1									
	EC requested contribution	461,8				22,5				62,4									
WP15 CONCORD	Personnel costs - task 1	46,0	4,6																
	Personnel costs - task 2																		
	Personnel costs - task 3																		
	Personnel costs - task 4	175,0	17,0																
	Personnel costs - task 5																		
	Personnel costs - task 6																		
	Total Personnel Costs	221,0	21,6																
	Total Travel Costs	8,5																	
	Total Equipment	35,0																	
	Total Other goods & services	41,0																	
	Total direct costs	305,5																	
	Total Indirect Costs	76,4																	
	Total subcontracting																		
	<i>Total In-kind contribution against payment</i>																		
	TOTAL BUDGET	381,9																	
	EC requested contribution	190,9																	

WP	Category of cost	UHELSINKI		UKRI-BGS		VTT		VUJE	
		Cost	pm	Cost	pm	Cost	pm	Cost	pm
KM SoK	Personnel costs - task 1								
	Personnel costs - task 2								
	Personnel costs - task 3								
	Personnel costs - task 4								
	Personnel costs - task 5								
	Total Personnel Costs								
	Travel Costs								
	Other goods & services								
	Total Direct costs								
	Total Indirect Costs								
	Total Costs								
	EC requested contribution								
KM Guidance	Personnel costs - task 1								
	Personnel costs - task 2								
	Personnel costs - task 3								
	Total Personnel Costs								
	Travel Costs								
	Other goods & services								
	Total Direct costs								
	Total Indirect Costs								
	Total Costs								
	EC requested contribution								
KM Training	Personnel costs - task 1								
	Personnel costs - task 2								
	Personnel costs - task 3								
	Personnel costs - task 4								
	Personnel costs - task 5								
	Total Personnel Costs								
	Travel Costs								
	Other goods & services								
	Mobility actions - not allocated								
	Total Direct costs								
	Total Indirect Costs								
	Total Costs								
	EC requested contribution								
WP15 CONCORD	Personnel costs - task 1					1,7	0,3		
	Personnel costs - task 2					119,0	16,0		
	Personnel costs - task 3								
	Personnel costs - task 4								
	Personnel costs - task 5								
	Personnel costs - task 6								
	Total Personnel Costs					120,6	16,3		
	Total Travel Costs					5,0			
	Total Equipment								
	Total Other goods & services					45,4			
	Total direct costs					171,0			
	Total Indirect Costs					42,8			
	Total subcontracting								
	Total In-kind contribution against payment								
	TOTAL BUDGET					213,8			
	EC requested contribution					106,9			

WP	Category of cost	TOTAL		Andra		ARAO		BEL V		BGE		CEA		CHRD		CIEMAT		CNRS		COVRA	
		Cost	pm	Cost	pm	Cost	pm	Cost	pm	Cost	pm	Cost	pm	Cost	pm	Cost	pm	Cost	pm	Cost	pm
WP16 MAGIC	Personnel costs - task 1	149,2	18,5	10,0	1,0															12,2	1,0
	Personnel costs - task 2	791,7	133,4	161,3	23,0													130,0	25,0	39,6	3,3
	Personnel costs - task 3	1 144,1	189,3	15,0	2,0							52,0	8,0			21,5	4,3	126,0	22,5		
	Personnel costs - task 4	793,2	170,2	180,1	50,3							89,5	11,3			174,4	50,9	41,5	8,3		
	Total Personnel Costs	2 878,3	511,3	366,5	76,3							141,5	19,3			195,9	55,2	297,5	55,8	51,8	4,3
	Total Travel Costs	121,5		13,5								5,0				6,0		5,0		4,0	
	Total Equipment	30,0		15,0														15,0			
	Total Other goods & services	282,0		15,0								15,0				6,5		15,0		12,8	
	Total direct costs	3 311,8		410,0								161,5				208,4		332,5		68,6	
	Total Indirect Costs	827,9		102,5								40,4				52,1		83,1		17,1	
	Total subcontracting	60,0		60,0																	
	TOTAL BUDGET	4 199,7		572,4								201,8				260,5		415,6		85,7	
	EC requested contribution	2 099,8		286,2								100,9				130,2		207,8		42,9	
WP17 MODATS	Personnel costs - Task 1	189,3	18,5	81,0	9,0																
	Personnel costs - Task 2	1 453,9	164,7	58,5	6,5																
	Personnel costs - Task 3	1 091,7	191,0	88,5	38,0							155,0	27,0					65,9	7,0		
	Personnel costs - Task 4	154,1	43,5	22,5	2,5																
	Total Personnel Costs	2 889,0	417,7	250,5	56,0							155,0	27,0					65,9	7,0		
	Total Travel costs	160,5		12,0								5,0						5,0			
	Total Equipment	54,0		50,0																	
	Total Other goods & services	215,5		79,5								61,0									
	Large Research Infrastructure (LRI)	10,9																			
	Total direct costs	3 329,9		392,0								221,0						70,9			
	Total Indirect Costs	832,5		98,0								55,2						17,7			
	Total subcontracting	226,4																			
	TOTAL BUDGET	4 388,8		489,9								276,2						88,7			
	EC requested contribution	2 194,4		245,0								138,1						44,3			
TOTAL	Total Personnel Costs	37 901,2	6508,4	3 347,5	486,4	5,1	1,2	320,6	36,2	817,4	74,6	1 701,5	228,9	141,2	144,5	2 859,9	659,1	3 713,8	736,6	448,0	41,5
	Total travel costs	2 812,8		229,4		5,0		32,1		50,9		78,5		20,0		140,9		190,5		53,9	
	Total Equipment	613,9		103,5												105,6		124,9			
	Total Other goods & services	4 189,5		705,5				59,2				307,8		7,0		242,5		441,7		27,9	
	Total Large Research Infrastructure (LRI)	132,8																			
	Mobility actions - not allocated	220,3																			
	TOTAL OTHER DIRECT COSTS	7 969,3		1 038,4		5,0		91,3		50,9		386,3		27,0		488,9		757,2		81,8	
	TOTAL DIRECT COSTS	45 870,5		4 385,9		10,1		411,9		868,3		2 087,8		168,2		3 348,8		4 470,9		529,8	
	Total Indirect Costs	11 370,8		1 096,5		2,5		103,0		217,1		521,9		42,1		837,2		1 117,7		132,4	
	Total subcontracting	1 618,4		828,4																	
	<i>Total in-kind contribution against payment</i>	<i>387,3</i>																			
	TOTAL BUDGET	58 859,7		6 310,7		12,6		514,9		1 085,4		2 609,7		210,3		4 186,0		5 588,7		662,2	
	TOTAL EC CONTRIBUTION using internal funding rate	32 001,5		4 332,0		8,8		357,3		700,7		1 328,6		105,1		2 124,1		2 914,5		343,2	
	EC contrib. calculated with EC single rate 55% (ECportal)	32 106,7		3 470,9		6,9		283,2		597,0		1 435,3		115,6		2 302,3		3 073,8		364,2	

WP		Category of cost	CVREZ		Dekom		EEAE		ENRESA		CPST		JUELICH		GRS		IAE		INCT		IRSN		IST-ID	
			Cost	pm	Cost	pm	Cost	pm	Cost	pm	Cost	pm	Cost	pm	Cost	pm	Cost	pm	Cost	pm	Cost	pm	Cost	pm
WP16 MAGIC	Personnel costs - task 1	1,6	0,5									23,4	3,0							56,2	7,0			
	Personnel costs - task 2	32,0	10,0									66,7	8,0	109,3	17,9									
	Personnel costs - task 3	7,4	2,3									194,5	30,8							202,7	37,1			
	Personnel costs - task 4											229,8	33,8							24,2	6,3			
	Total Personnel Costs	41,0	12,8									514,4	75,6	109,3	17,9					283,1	50,4			
	Total Travel Costs	4,5										14,0		3,0						17,0				
	Total Equipment																							
	Total Other goods & services	1,0										16,5								10,0				
	Total direct costs	46,5										544,9		112,3						310,1				
	Total Indirect Costs	11,6										136,2		28,1						77,5				
	Total subcontracting																							
	TOTAL BUDGET	58,1										681,1		140,3						387,6				
EC requested contribution	29,0										340,6		70,2						193,8					
WP17 MODATS	Personnel costs - Task 1											248,5	35,5							159,8	16,2			
	Personnel costs - Task 2											177,7	27,0							40,2	5,0			
	Personnel costs - Task 3	98,9	31,0																					
	Personnel costs - Task 4																							
	Total Personnel Costs	98,9	31,0									426,2	62,5							200,0	21,2			
	Total Travel costs	5,0										13,5								16,0				
	Total Equipment											2,0												
	Total Other goods & services											6,0								20,0				
	Large Research Infrastructure (LRI)																							
	Total direct costs	103,9										447,7								236,0				
	Total Indirect Costs	26,0										111,9								59,0				
	Total subcontracting																							
TOTAL BUDGET	129,9										559,6								295,0					
EC requested contribution	64,9										279,8								147,5					
TOTAL	Total Personnel Costs	175,9	55,8	20,9	2,4	14,0	3,5	97,6	11,8	83,0	28,9	3 238,0	491,8	663,7	82,8	4,8	1,1	18,1	6,0	1 812,6	253,0	26,2	4,8	
	Total travel costs	18,0		9,9		9,4		42,5		24,0		148,0		55,4		5,5		8,4		179,8		8,4		
	Total Equipment	20,0										8,0		5,0						10,0				
	Total Other goods & services	14,0								9,0		122,0		13,0				1,0		193,0		5,7		
	Total Large Research Infrastructure (LRI)																							
	Mobility actions - not allocated																							
	TOTAL OTHER DIRECT COSTS	52,0		9,9		9,4		42,5		33,0		278,0		73,4		5,5		9,4		382,8		14,1		
	TOTAL DIRECT COSTS	227,9		30,8		23,4		140,1		116,0		3 516,0		737,1		10,3		27,5		2 195,4		40,3		
	Total Indirect Costs	57,0		7,7		5,8		35,0		29,0		879,0		184,3		2,6		6,9		548,8		10,1		
	Total subcontracting							438,6																
	Total In-kind contribution against payment																							
	TOTAL BUDGET	284,8		38,5		29,2		613,8		145,0		4 395,0		921,3		12,9		34,4		2 744,2		50,4		
	TOTAL EC CONTRIBUTION using internal funding rate	142,4		26,9		20,4		313,4		80,0		2 292,9		488,0		9,0		24,1		1 766,6		35,3		
	EC contrib. calculated with EC single rate 55% (ECportal)	156,6		21,2		16,1		337,6		79,8		2 417,3		506,7		7,1		18,9		1 509,3		27,7		

WP	Category of cost	IST-LPSR		JRC		JSI		KIT		LEI		MTA EK		NAGRA		NCSRD		NES	
		Cost	pm	Cost	pm	Cost	pm	Cost	pm	Cost	pm	Cost	pm	Cost	pm	Cost	pm	Cost	pm
WP16 MAGIC	Personnel costs - task 1																		
	Personnel costs - task 2																		
	Personnel costs - task 3																		
	Personnel costs - task 4									40,2	7,3								
	Total Personnel Costs									40,2	7,3								
	Total Travel Costs									2,0									
	Total Equipment																		
	Total Other goods & services									2,0									
	Total direct costs									44,2									
	Total Indirect Costs									11,0									
	Total subcontracting																		
	TOTAL BUDGET									55,2									
	EC requested contribution									27,6									
WP17 MODATS	Personnel costs - Task 1													6,2	0,5				
	Personnel costs - Task 2					42,4	8,0							112,6	9,0				
	Personnel costs - Task 3													335,6	33,0				
	Personnel costs - Task 4													6,3	0,5				
	Total Personnel Costs					42,4	8,0							460,6	43,0				
	Total Travel costs					5,0								16,0					
	Total Equipment																		
	Total Other goods & services					5,0								15,0					
	Large Research Infrastructure (LRI)																		
	Total direct costs					52,4								491,6					
	Total Indirect Costs					13,1								122,9					
	Total subcontracting													105,0					
	TOTAL BUDGET					65,5								719,5					
	EC requested contribution					32,8								359,8					
TOTAL	Total Personnel Costs	33,4	4,8	811,7	90,4	736,3	132,3	1 771,9	314,9	267,9	52,8	218,0	66,0	2 234,9	289,1	153,8	18,7	62,7	6,0
	Total travel costs	8,4		70,0		75,3		116,1		41,5		24,9		110,4		21,8		8,4	
	Total Equipment							12,5				18,5		57,5					
	Total Other goods & services			208,6		103,4		82,5		4,0		26,6		348,8		1,0		2,7	
	Total Large Research Infrastructure (LRI)																		
	Mobility actions - not allocated																		
	TOTAL OTHER DIRECT COSTS	8,4		278,6		178,7		211,1		45,5		70,0		516,7		22,8		11,1	
	TOTAL DIRECT COSTS	41,8		1 090,3		915,0		1 983,0		313,4		288,0		2 751,6		176,6		73,8	
	Total Indirect Costs	10,4		272,6		228,8		495,8		78,3		72,0		687,9		44,2		18,4	
	Total subcontracting													105,0		3,6			
	<i>Total in-kind contribution against payment</i>																		
	TOTAL BUDGET	52,2		1 362,9		1 143,8		2 478,8		391,7		360,0		3 544,5		224,4		92,2	
	TOTAL EC CONTRIBUTION using internal funding rate	36,6		483,4		674,7		1 255,4		207,0		180,0		1 772,8		157,1		64,6	
	EC contrib. calculated with EC single rate 55% (ECportal)	28,7		483,4		629,1		1 363,3		215,4		198,0		1 949,5		123,4		50,7	

WP	Category of cost	NRG		NJF		ONDRAF/NIRAS		Posiva		PSI		PURAM		RATEN/ICN		RAWRA/SÚRAO		RWM/NDA	
		Cost	pm	Cost	pm	Cost	pm	Cost	pm	Cost	pm	Cost	pm	Cost	pm	Cost	pm	Cost	pm
WP16 MAGIC	Personnel costs - task 1									30,0	3,0					5,8	2,0		
	Personnel costs - task 2									60,1	6,0					102,9	31,3		
	Personnel costs - task 3									195,6	25,6					23,8	7,6	149,7	33,1
	Personnel costs - task 4									13,5	2,0								
	Total Personnel Costs									299,1	36,6					132,4	40,9	149,7	33,1
	Total Travel Costs									12,0						19,5		5,0	
	Total Equipment																		
	Total Other goods & services									65,0						33,1		45,6	
	Total direct costs									376,1						185,0		200,3	
	Total Indirect Costs									94,0						46,3		50,1	
	Total subcontracting																		
	TOTAL BUDGET									470,2						231,3		250,4	
	EC requested contribution									235,1						115,6		125,2	
WP17 MODATS	Personnel costs - Task 1							3,0	0,5										
	Personnel costs - Task 2					118,8	9,5	18,0	3,0	260,9	28,5							28,2	3,0
	Personnel costs - Task 3							60,0	10,0									28,2	3,0
	Personnel costs - Task 4							6,0	1,0										
	Total Personnel Costs					118,8	9,5	87,0	14,5	260,9	28,5							56,3	6,0
	Total Travel costs					11,0		11,0		8,5								8,5	
	Total Equipment																		
	Total Other goods & services							4,0		15,0									
	Large Research Infrastructure (LRI)																		
	Total direct costs					129,8		102,0		284,4								64,8	
	Total Indirect Costs					32,4		25,5		71,1								16,2	
	Total subcontracting							50,0											
	TOTAL BUDGET					162,2		177,5		355,5								81,1	
	EC requested contribution					81,1		88,8		177,7								40,5	
TOTAL	Total Personnel Costs	98,8	9,1	4,1	1,9	862,4	115,6	117,9	20,0	2 332,4	266,5	91,8	15,3	112,9	51,4	1 838,3	666,4	436,5	70,5
	Total travel costs	15,5		6,4		72,0		25,0		88,5		12,0		32,4		231,5		57,5	
	Total Equipment									40,5						58,0			
	Total Other goods & services	1,0				21,3		4,0		127,9				29,5		305,2		45,6	
	Total Large Research Infrastructure (LRI)																		
	Mobility actions - not allocated																		
	TOTAL OTHER DIRECT COSTS	16,5		6,4		93,3		29,0		256,9		12,0		61,9		594,7		103,1	
	TOTAL DIRECT COSTS	115,3		10,5		955,7		146,9		2 589,3		103,8		174,8		2 433,0		539,6	
	Total Indirect Costs	28,8		2,6		238,9		36,7		647,3		26,0		43,7		608,2		134,9	
	Total subcontracting							50,0											
	<i>Total in-kind contribution against payment</i>																		
	TOTAL BUDGET	144,1		13,1		1 194,7		233,6		3 236,7		129,8		218,6		3 041,2		674,5	
	TOTAL EC CONTRIBUTION using internal funding rate	85,8		9,2		634,5		122,2		1 637,4		90,8		121,0		1 574,9		424,4	
	EC contrib. calculated with EC single rate 55% (ECportal)	79,3		7,2		657,1		128,5		1 780,2		71,4		120,2		1 672,7		371,0	

WP	Category of cost	SCK-CEN		SKB		SSTC NRS		STUBA		SURO		TNO		TS ENERCON		TUS		UCY	
		Cost	pm	Cost	pm	Cost	pm	Cost	pm	Cost	pm	Cost	pm	Cost	pm	Cost	pm	Cost	pm
WP16 MAGIC	Personnel costs - task 1	10,0	1,0																
	Personnel costs - task 2	90,0	9,0																
	Personnel costs - task 3	134,9	11,3																
	Personnel costs - task 4																		
	Total Personnel Costs	234,9	21,3																
	Total Travel Costs	8,0																	
	Total Equipment																		
	Total Other goods & services	40,0																	
	Total direct costs	282,9																	
	Total Indirect Costs	70,7																	
	Total subcontracting																		
	TOTAL BUDGET	353,6																	
	EC requested contribution	176,8																	
WP17 MODATS	Personnel costs - Task 1			6,3	0,5	1,1	0,5												
	Personnel costs - Task 2			119,2	9,5														
	Personnel costs - Task 3					16,8	8,0												
	Personnel costs - Task 4			6,3	0,5	75,6	36,0												
	Total Personnel Costs			131,8	10,5	94,5	45,0												
	Total Travel costs			11,0		11,0													
	Total Equipment																		
	Total Other goods & services																		
	Large Research Infrastructure (LRI)																		
	Total direct costs			142,8		105,5													
	Total Indirect Costs			35,7		26,4													
	Total subcontracting			71,4															
	TOTAL BUDGET			249,9		131,9													
	EC requested contribution			125,0		65,9													
TOTAL	Total Personnel Costs	2 093,8	219,3	553,4	75,9	257,0	122,1	19,8	5,3	187,0	45,6	89,6	14,0	77,9	20,1	148,4	30,9	21,7	5,3
	Total travel costs	114,0		51,3		60,0		14,5		34,4		5,0		12,0		30,6		11,9	
	Total Equipment	43,0										5,0							
	Total Other goods & services	294,8		25,0						6,0		12,8		0,8		8,5			
	Total Large Research Infrastructure (LRI)																		
	Mobility actions - not allocated	220,3																	
	TOTAL OTHER DIRECT COSTS	672,1		76,3		60,0		14,5		40,4		22,8		12,8		39,1		11,9	
	TOTAL DIRECT COSTS	2 765,9		629,6		317,0		34,3		227,4		112,4		90,7		187,5		33,6	
	Total Indirect Costs	691,5		60,6		79,3		8,6		56,8		28,1		22,7		46,9		8,4	
	Total subcontracting			71,4										6,9					
	Total in-kind contribution against payment			387,3															
	TOTAL BUDGET	3 457,4		761,6		396,3		42,9		284,2		140,5		120,2		234,4		42,0	
	TOTAL EC CONTRIBUTION using internal funding rate	1 884,2		385,5		248,1		30,0		198,9		70,3		63,7		132,8		24,8	
	EC contrib. calculated with EC single rate 55% (ECportal)	1 901,6		418,9		217,9		23,6		156,3		77,3		66,1		128,9		23,1	

WP	Category of cost	UHELSINKI		UKRI-BGS		VTT		VUJE	
		Cost	pm	Cost	pm	Cost	pm	Cost	pm
WP16 MAGIC	Personnel costs - task 1								
	Personnel costs - task 2								
	Personnel costs - task 3	21,2	4,7						
	Personnel costs - task 4								
	Total Personnel Costs	21,2	4,7						
	Total Travel Costs	3,0							
	Total Equipment								
	Total Other goods & services	4,5							
	Total direct costs	28,7							
	Total Indirect Costs	7,2							
	Total subcontracting								
	TOTAL BUDGET	35,8							
	EC requested contribution	17,9							

WP17 MODATS	Personnel costs - Task 1					91,8	7,5		
	Personnel costs - Task 2					286,0	35,5		
	Personnel costs - Task 3					25,0	2,0		
	Personnel costs - Task 4					37,5	3,0		
	Total Personnel Costs					440,3	48,0		
	Total Travel costs					22,0			
	Total Equipment					2,0			
	Total Other goods & services					10,0			
	Large Research Infrastructure (LRI)					10,9			
	Total direct costs					485,2			
	Total Indirect Costs					121,3			
	Total subcontracting								
	TOTAL BUDGET					606,5			
	EC requested contribution					303,2			

TOTAL	Total Personnel Costs	539,7	110,7	968,7	171,0	1 242,0	143,8	6,7	2,0
	Total travel costs	33,0		22,0		90,9		5,0	
	Total Equipment					2,0			
	Total Other goods & services	69,1		238,9		72,4			
	Total Large Research Infrastructure (LRI)					132,8			
	Mobility actions - not allocated								
	TOTAL OTHER DIRECT COSTS	102,1		260,9		298,1		5,0	
	TOTAL DIRECT COSTS	641,8		1 229,6		1 540,1		11,7	
	Total Indirect Costs	160,5		307,4		385,0		2,9	
	Total subcontracting			114,5					
	<i>Total in-kind contribution against payment</i>								
	TOTAL BUDGET	802,3		1 651,5		1 925,1		14,6	
	TOTAL EC CONTRIBUTION using internal funding rate	401,1		597,7		1 008,9		10,2	
	EC contrib. calculated with EC single rate 55% (ECportal)	441,2		908,3		1 058,8		8,0	

3.4.5. Not allocated budget (secured under Coordinator budget)

RDD	ConCorD option Direct cost	92 000,00
	MAGIC option Direct cost	68 457,00
	MODATS option Direct cost	311 156,00
	Not allocated RDD Direct cost	200 761,02
	indirect costs	168 093,50
	Not allocated EC contrib. RDD	420 233,76
SS	UMAN extension option Direct cost	10 625,00
	Not Allocated SS direct cost	10 127,21
	indirect costs	5 188,05
	Not allocated EC contrib. SS	18 158,18
KM	Not Allocated KM costs	40 453,86
	indirect costs	10 113,47
	Not allocated EC contrib. KM	35 397,13
PMO	Not Allocated PMO Direct cost	19 800,00
	indirect costs	4 950,00
	Not allocated EC contrib. PMO	24 750,00
TOTAL	TOTAL NOT ALLOCATED DIRECT COSTS	753 380,09
	TOTAL NOT ALLOCATED INDIRECT COSTS	188 345,02
	TOTAL EC CONTRIBUTION NOT ALLOCATED	498 539,08

4. Members of the consortium

4.1. Beneficiaries

	No	Name	Acronym
Participant	1	Agence nationale pour la gestion des déchets radioactifs	Andra
Description of the legal entity Andra, The French National Agency for Radioactive Waste Management, is a public industrial and commercial organization created by the Act of 30 December 1991 (Nuclear Act related to Nuclear Waste Management). It comes under the supervision of the French Ministries for Energy, Research and the Environment, and is responsible for the long-term management of radioactive waste produced in France. It is in charge of the research program (concept design and long-term evolution) on a deep geological repository for high and intermediate level long lived radioactive wastes. It has also an industrial responsibility of operating the disposal facilities for short lived, low and intermediate level radioactive waste. For that purpose, Andra engaged its research process as of early 1994 and is currently operating an underground research laboratory in argillaceous rock, located in the Meuse/Haute-Marne region, in the vicinity of Bure. At the same time, Andra is further developing the technical concept of a repository. www.andra.fr			
Description of main tasks in EURAD-1, with an explanation of how its profile matches the tasks Andra is the Coordinator of EURAD and will be deeply involved in the EURAD Programme Management Office (PMO-WP1). Andra will also be actively involved in : - WP2-ACED : In tasks 3 & 4, Andra's participation is aiming to describe the HLW cell evolution thanks to reactive transport modelling. These modelling will integrate experimental results and coupling processes between chemistry and environmental conditions. The reassembly of these different modelling will allow providing a coherent, comprehensive and systematic scheme of a HLW cell chemical evolution. - WP3-CORI: Andra will participate in CORI in the different tasks : - o Task 1 : Experiments in the deep geological laboratory in Bure on in-situ leaching tests to investigate the superplasticizer mobility. - o Task 2 : (co-Leader) Determination of the diffusion coefficient of various organic molecules by electro-diffusion tests and integration of the results. degradation and characterization of organic matter, production of a State of the Art about degradation of polymers and releasing of organic species - o Task 3 : Integration of the results on the basis of a geochemical model. - WP4-DONUT: - o Task 1: "S/T coordination, State-of-the-art and training material" - o Task 5: "Benchmarks of methods and tools and methods for coupled processes"; contribution as defining representative cases with couplings and use of numerical tools. - WP5-FUTuRE: - o Task 1: Andra will provide input data (sorption, redox of RN) and contribute to the state of the art report. - o Task 2 : Andra will provide rock samples, pore water and data on associated physico-chemical properties. - o Task 3 : Andra will provide rock samples, pore water and data on associated physico-chemical properties.			

- **WP6- GAS:** o involved in task 3 about “Barrier Integrity” and leader of sub task 3.2 (Pathway closure and sealing processes). Andra will participate in this task to the state of art document and will provide (i) preserved host rock samples and EBS material and (ii) experimental data sets from previous and from new in-situ experiments in Bure URL. Andra is also involved in task 4 “Repository Performance Aspects” as leader of the task, and will contribute to repository scale numerical simulations. Andra will also contribute as data provider for Task 2 “Transport Mechanisms”
 - **WP7- HITEC** Andra is involved in task 1, 2 and 4 and leads the Subtask 2.3 – THM modelling of effect of temperature in near and far field – Benchmark exercise. Andra will participate in the task to the state of art report (Subtask 1.2) and will provide available data on Callovo Oxfordian claystone. In Subtask2.3, Andra will provided in situ data as a benchmark exercise and will also participate to the benchmark exercises. In subtask 4.1 Andra will participate to evaluate how the progress beyond the state-of-the-art allows reducing the uncertainties and increasing the margin by which the safety functions can be fulfilled.
 - **WP9- ROUTES** Andra leads Task 2 « Identify challenging wastes to be collaboratively tackled within the Joint Programme - Mapping and shared understanding at EU level of the practical issues on waste management routes » and contributes to other tasks. Andra contribution aims to provide up to date information on the French situation on waste management routes including opened questions and to analyze and consolidate data from various situations within Europe. ROUTES Extension aims at deeper collaborative work by SIMS and LIMS (MAP and LAP). As waste management organisation in France in charge of the development and the operation of the disposal, ANDRA will participate to the qualitative analysis and assessments of the disposal options for SIMS (subtask 3) in combination with the related predisposal routes (subtask 2).
- WP10- UMAN:** Andra will contribute and share experience in tasks 2, 4 and 5. Namely, Andra will lead the subtask 3.4 on characterization and significance of uncertainties related to human aspects, and the topic 3 (Uncertainty management options throughout a GD Programme) of the subtask 5.1 devoted at preparing, supporting and reporting on pluralistic analyses. As part of UMAN extension, ANDRA will participate in the workshops organised by Subtasks 3.6 and 4.3 and contribute, as member of the subtask 4.2 expert group, to:
- the compilation and review of available information on uncertainty management options and preferences
 - the development of the material for the workshop organized by Subtask 4.3 and the seminar organized by Task 5
 - the writing of Task 4 deliverable.
- **WP11- KM SoK** – Andra will contribute to the establishment of the EURAD Knowledge platform that will be developed under WP11.
 - **WP13- KM Training/Mobility** – Andra will contribute to the establishment / implementation of the Training/Mobility programme under WP13.
 - **WP15-ConCorD:**
 - o Andra also offers to contribute to Task 6. The aim of the work will be to simplify and apply at the disposal scale the irradiation and microbial models developed in Tasks 3 and 4, in which only the most relevant processes will be described and eventually coupled. To fulfil the goals, Andra has developed an interface between CALIPSO, a corrosion module based on electrochemical equations and CRUNCHTOPE, an open-source reactive transport model. This interface enables complex coupling between the composition of the contact water from one side and the nature and formation rate of the corrosion products on the other side.

As part of the model simplification at the disposal scale, we can presume that the model has been built in previous tasks based on experimental results. If no model is available

from previous tasks, and in order to be able to build a preliminary/minimalist model, the available results must be sufficient, and a trend must emerge.

The state of the art should be able to account for the numerical models that have already been developed. Regarding the formalism available in the numerical tool, these alteration models (under irradiation and micro-bio) could be dependent on the activity of aqueous species (to be defined), the quantity of mineral phases (real or fictitious), and temperature. Other numerical tricks could be considered to account for the models described in tasks 3 and 4.

The model that will finally be used in the Task Integration, will take into account both models from task 2 and 3, (in case the results of each task 2 and 3 would allow to deduce a model at the disposal scale), or one model from task 2 or 3, in case the results of one of these tasks 2-3 would not allow to deduce a model at the disposal scale.

- **WP16-MAGIC :**

Andra is proposing jointly with LMDC (3rd part of Andra) and partners in tasks 2 and 3 to study the mechanical evolution due to the effect of corrosion mechanical stresses due to corrosion products, loss of section and adhesion of steels of the reinforced concrete under loading and chemical degradation. Andra intends to rely on continuous feedback from Cigeo's research program where different types of cementitious structures and different sequences of disturbances can occur, in order to meet the main objective of MAGIC (mechanical multi-scale evolution under chemical degradation).

Different initial boundary conditions and corrosion pathways will be studied: with/without loading, with/without mechanical degradation, with/without carbonation. Through task 2 and 3, data will be acquired to consolidate the upscaling and the structural modelling (task 4).

The study will be displayed in all the tasks, in a way to guarantee a complete interface from the nano to macro scale testing program till the structural modelling scale.

Below the description concerning Andra's action in each task:

- Participation in the End User Group, and the feedback on task 1,
- Particular implication in the mechanical degradation aspects of the SOTA, with the implication of LMDC for the modelling (corrosion modelling, reinforced concrete).
- Andra will participate as contact point on the task 2 on mechanical aspects and later on, on the management of the due actions (Task1).
- Andra will provide specimens taken from Andra's URL, different kind of reinforced specimen can be targeted (and the number will be updated depending on the observed behaviour), in different structures (lining with precast/grouted concrete, shafts...). Specimens will be drilled on the structures, conditioned and send to LMDC. A special adaptation should be done in a way to target specimen with steel reinforcements in particular on the shaft linings.
Sample without reinforcement and with different interface and conditions (host rock, or shotcrete contacts, unsaturated or saturated condition, with or without reinforcement) will be sent to task 2 partners (Lam3) for carbonation analysis.

Andra will participate jointly with LMDC on the analysis of the different tests on the different studied conditions and analysis. As well as the simulation procedure, and interface in a way to achieve the upscaling simulation till the real scale of a reinforced structure (Task 2, 3 & 4).

- **WP17-MODATS**

Andra is the leader of MODATS project and leads management of the project (task 1), lead the task 3 dedicated to "novel and optimised" technology and co-leads the dissemination activities (task 4).

Within task 2, Andra will contribute to all subtasks. Andra will bring its specific approach about data management and data processing. Andra will bring data set to elaborate Data-

driven model in AHA1605 test case. Andra will participate to the discussion on the tools for the monitoring with the CSO.

- Within task 3, Andra will lead the report Technology Development in the MODATS WP of EURAD: Final Report (D3.1) Andra will continue to develop the optical fiber cable in a perspective to finalize the qualification (task 3.2). Andra will participate to the look to the impact on sensors to multi-barrier system.

a curriculum vitae or description of the profile of the persons, including their gender, who will be primarily responsible for carrying out the proposed research and/or innovation activities

Louise THEODON (Female) is a European project manager and has a several years' experience in the set-up, negotiation and management of all kind of projects : B to B with industries, European projects and French national projects. She will be in charge of coordinating EURAD first implementation phase and will be involved in the PMO WP.

Jacqueline OLTRA (Female), began as International assistant at Andra's International Department, where she acquired her experience in international exchanges (IAEA, OECD and international partners). After that, she has been involved for several years as Management Assistant, in the management of the general operating expenses and the personnel costs of Andra. Finally, she has joined the European and national research projects Unit to use her skills to support the coordination mainly in the PMO WP activities. Thanks to her knowledge of Project Management, she has developed management tools to coordinate and facilitate EC projects/programmes periodic reporting, in particular.

Gilles ARMAND (Male), Ph.D in rock mechanics at Joseph Fourier University (Grenoble, France) on Rock joint behavior (experimental and constitutive modeling). After a post-doctoral fellowship at McGill University (Canada) and at IRSN (France), he joined the French Radioactive waste management agency (ANDRA) as research engineer in charge of field experiments in geomechanics at the Meuse/Haute-Marne Underground research laboratory. In 2009, he became manager of the Fluid and Solid Mechanics Department at R&D department of ANDRA. His main research fields are: Excavation damaged zone (EDZ) characterization and modeling, hydro mechanical and creep behavior of claystone, THM behaviour and design of support in tunnelling

Benoît COCHEPIN (Male), Ph.D. in material sciences, pilot different numerical projects dedicated to the chemical evolution of waste disposals. These projects aim at incorporating physical phenomena at the real scale that induce mineral transformations, which in return impact transport and retention properties of the host rock. Key qualifications include experience with various reactive transport simulation tools. Key role concerns conceptualizing and performing reactive transport simulations. Contributions to former European project (PAMINA, CEBAMA) and to the international numerical benchmark project of reactive transport tools (SeSBENCH).

Christelle MARTIN (Female), engineer in chemistry, 41 years old. Worked in different companies involved in nuclear activities for 18 years, and at Andra as R&D engineer and project manager since 2007 in the Research and Development Division, Waste Packages and Material Department. In charge of the studies on the physical and chemical behaviour of vitrified waste in repository conditions. She will take part in ACED Subtask 1.5, especially for the analysis of experiments and models about glass/steel interactions.

Guillaume PEPIN (Male), Senior Scientific Engineer, specialized on "Performance and Safety assessment" and "Numerical Simulation", Head of Performance Assessment Department (20 persons), Research and Development Division, Andra.

- Description/quantification of phenomenological behavior of disposal components scale and geological environment (operating and post-closure period)
 - ✓ Integration of scientific knowledge to {components, physical process, space, time}
 - ✓ Conceptual models and quantification of Thermo-Hydro-Mechanics-Chemical-Radiological behavior
- Performance and safety assessment of disposal system

- ✓ Physical and numerical conceptualization of safety scenarios
- Improvement/development of numerical tools able to represent multi-physics couplings over large time and space scales

Denise RICARD (Female), graduated in chemistry, PhD in physical chemistry of polymers. After her thesis, worked during 3 years in a laboratory of the engineering department of Technical University of Lisbon in the development of polymer membranes. Before joining Andra, in 2008, worked in during one year in the laboratory of Arts et Métiers Paristech specialized in the ageing of polymers. Since 2008, have been working in the R&D department of Andra as engineer and specialist of organic matter. One of my research topics is the degradation of organic materials (polymers and bitumen) in disposal conditions.

Jean-Charles ROBINET (Male), Ph. D in geosciences at University of Poitiers (France). Specialist in the transport and interactions of solutes in clay-rock systems and multi-scale analysis of natural material structure. Have been working at Andra in the R&D division since 2009. Since 2016, in charge of the Transfer Group responsible for radionuclide speciation and transport from the waste cells to the biosphere. Currently, coordinator of the CTEC (Chemistry and Transfer in Complex Environments) Andra R&D program and co-coordinator of the national NEEDS MIPOR (Porous Media) project. Previously involved in several national and European project (FP- FUNMIG, FP7 CatClay...).

Jean TALANDIER (Male) PhD in mechanics from Paris VI University in 1994, with a specialization in numerical methods for fluid mechanic. Involved in R&D program in Andra since 1995, he is in charge of gas issues for radioactive waste disposal, deputy head of fluid and solid mechanics department since 2012. He manages the research program developed by Andra about gas/water transfer and hydro-mechanical behaviour of swelling clays. Participation in the European projects GASNET (A thematic network on gas issues in safety assessment of deep repositories for nuclear waste (2001-2004), FORGE 2009-2013 (Fate Of Repository GasEs) as coordinator for Andra, work package leader in European project BEACON (Bentonite Mechanical Evolution).

Jacques WENDLING (Male), Senior Scientific Engineer, specialized on “Performance and Safety assessment” and “Gas transfer”, Deputy Head Manager of Performance Assessment Department (20 persons) of Research and Development Division.,

- Performance and safety assessment for all types of disposal system (surface subsurface, deep underground). Participation in several international cooperation programs in performance and safety assessment, mainly for Lithuania and South Korea
- Lead of two-phase flow numerical program at Andra
- Participation in European Projects:
 - ✓ CAST WP6 “Performance assessment”
 - ✓ Lead of European project FORGE 2009-2013 (Fate Of Repository GasEs) WP1.2 “Repository-scale numerical simulations of gas migration”
 - ✓ Andra’s Research and Development Division representative in European project DOPAS 2012-2016 (Demonstration Of Plugs And Seals)

Pierre HENOCQ (Male), Ph.D in civil engineering on the physical, chemical and electrokinetical properties of the cement-based materials at Laval University in Quebec City (Canada), worked during 7 years as project manager in the R&D department at SIMCO Technologies inc. which is specialized in the service life assessment of concrete structures. Since 2013, works at Andra in the R&D department on the radionuclide migration in the cementitious materials. Also participating to the European project CEBAMA as Andra’s representant in the End-User group and as co-coordinator in the work package CORI in the framework of EURAD-1.

Jean-Michel HOORELBEKE (Male), Safety, Environment and Waste Management Strategy Deputy Director at Andra, has thirty years of experience in the design and safety approach of waste repositories in France, shallow and underground. He is also experienced in designing interim storage facilities for waste and spent fuel. As geological disposal project manager from 1993 to 2007, he has defined and implemented Andra’s iterative approach between knowledge acquisition, repository design, modelling and safety assessment. His experience in waste management strategy includes the proposal in 2008 of a national scheme for the long term management of disused sealed sources in France, the development of

an overall optimisation methodology for the French HLW and ILW management system, the undergoing development of a graded approach aiming at enhancing the proportionality of French disposal routes to the harmfulness of wastes. His international experience includes contributions to various IAEA consultancy and technical meetings (ILW...) as well as NEA expert groups (reversibility, predisposal). He was Key Expert for the UE Devco program in Ukraine to develop disposal concepts (INSC PROJECT – U4.01/09 B).

Jean-Noël DUMONT (Male), Special Adviser at Andra. He is in charge of societal aspects for the definition of the disposal strategy for the management of radioactive wastes of the various kinds. Namely, he is the coordinator of Andra's Memory Program, which aims at consolidating and extending memory preservation for the existing and future repositories. Based in the headquarters of Andra near Paris, he has 37 years of experience, with more than 20 years in the waste management business. He is a graduated engineer from Mines-ParisTech.

Vincent MAUGIS (Male), Knowledge Management Officer for Andra. M. Eng. in Knowledge Management and Innovation Engineering (2002), he has carried research and development in knowledge management and decision support for sustainable development policy-making at MIT. Before joining Andra, Maugis has designed and implemented the national knowledge management system for supporting the performance of French healthcare and medico-social facilities as well as intergovernmental knowledge management services for supporting social development policy-making. Within the EJP, Maugis provides scientific and methodological support to the Knowledge Management Workpackages.

a list of up to 5 relevant publications, and/or products, services (including widely-used datasets or software), or other achievements relevant to the call content

- [1] **PHILIPP SCHAEDELE, THOMAS KAEMPFER, GUILLAUME PEPIN, JACQUES WENDLING & JUERGEN BROMMUNDT**: Combining high-resolution two-phase with simplified single-phase simulations in order to optimize the performance of PA/SA simulations for a deep geological repository for radioactive waste, in Norris, S., Bruno, J., Van Geet, M. & Verhoef, E. (eds) *Radioactive Waste Confinement: Clays in Natural and Engineered Barriers*. Geological Society, London, Special Publications, 443, <http://doi.org/10.1144/SP443.4>, 2016
- [2] Henocq, P. (2017). A sorption model for alkalis in cement-based materials–Correlations with solubility and electrokinetic properties. *Physics and Chemistry of the Earth, Parts A/B/C*, 99, 184-193.
- [3] Gas transport properties through intact and fractured Callovo-Oxfordian mudstones, April 2017, Geological Society London Special Publications SP454.7, J. F. Harrington, R. Cuss, J. Talandier
- [4] A Thematic Network on Gas Issues in Safety Assessment of Deep Repositories for Radioactive Waste (GASNET)- Final report, 2003 – EUR20620
- [5] M. L. Schlegel, C. Martin, F. Brucker, C. Bataillon, C. Blanc, M. Chorro, P. Jollivet, Alteration of nuclear glass in contact with iron and claystone at 90 °C under anoxic conditions: Characterization of the alteration products after two years of interaction, *Applied Geochemistry*, 70, 27-42 (2016)
- [6] Marty N. C. M., Munier I., Gaucher E. C., Tournassat C., Gaboreau S., Vong C. Q., Giffaut E., Cochepin B. et Claret F. (2014) Simulation of cement/clay interactions: Feedback on the increasing complexity of modelling strategy. *Transport in Porous Media*. Vol. 104, 2, 385-405.
- [7] Marty N. C. M., Bildstein O., Blanc P., Claret F., Cochepin B., Gaucher E. C., Jacques D., Lartigue J. E., Liu S., Mayer K. U., Meeussen J. C. L., Munier I., Pointeau I., Su D. et Steefel C. I. (2014a) Benchmarks for multicomponent reactive transport across a cement/clay interface. *Computational Geosciences*. Vol. 19, 635-653.
- [8] Radiochemical ageing of epoxy coating for nuclear plants, *Radiation Physics and Chemistry*, Volume 79, Issue 3, March 2010, Pages 362-364.
- [9] Robinet J.C., Coelho, D., Altmann S., (2011) « State of the art on cation diffusion in clay mineral systems ». EC Project CatClay - Public report.
- [10] Dumont J.-N., Charton P., Boissier F.: Andra's Strategy and Approach for Long-Term Memory Preservation of a Deep Geological Repository, *Waste Management Symposium*, Phoenix, (2015)

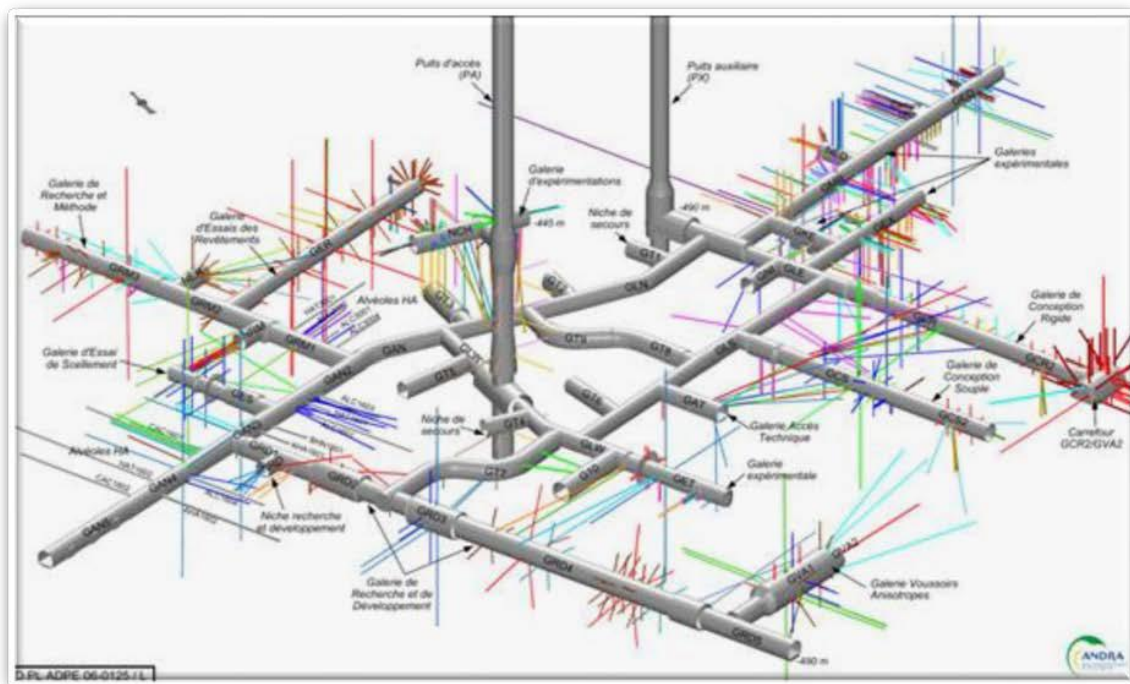
[11] Recent relevant publication: The search for proportionality of radioactive waste management solutions to their harmfulness, in Radioprotection, Volume 53, Number 3, July-September 2018, pp 67 – 173 (www.radioprotection.org)

a list of up to 5 relevant previous projects or activities, connected to the subject of this proposal

- JOPRAD, H2020, EURATOM
- CHANCE, H2020, EURATOM
- THERAMIN, H2020, EURATOM
- Cebama, H2020, EURATOM
- CAST, FP7, EURATOM
- CatClay, FP7, EURATOM
- FUNMIG, FP6, EURATOM

1. CMHM facilities

Andra's major research facility is the Underground Research Laboratory located on the eastern boundary of the Paris Basin (Meuse/Haute Marne region) and aiming at studying the feasibility of the reversible geological disposal of high-level and intermediate-level long-lived radioactive waste (Cigéo project) in the Callovo-Oxfordian clay formation. More than 15 years of research and development works have been



carrying out in this URL to support the main milestones and reports of the Cigéo project.

Figure 7: The current MHM URL network consisting in 1.7 km of drifts and about 850 boreholes (various colour lines)

The MHM URL consists in (Figure 1):

- 2 shafts of 500 m ;
- 1 drift 40 m long at –445m (upper part of Callovo-Oxfordian clay formation, more rich in calcite) from the ground surface;
- A current network of 1.7 km of drifts located at – 490m. The sections of drift vary between 18 and 60 m² according to scientific and technological objectives. About 850 boreholes been drilled in all directions (vertical up and down, horizontal, oblique) up to 100 m long, in a wide range of diameter between 22 mm and 350 mm. The purposes of these boreholes are very large:
 - o R&D objectives: geological survey, hydrogeological, geochemical, microbiological and rock mechanical studies;
 - o Characterisation of anthropic impacts: temperature, excavation and ventilation, alkaline plume etc.;
 - o Technical aims: excavation and support (lining) techniques.

More than 11 000 sensors have been installed in the rock, inside boreholes, in the drifts, in the shafts, allowing a continuous monitoring at distance. The type of sensors tested is very large according to concerned Thermal, Hydraulic, Mechanical, Chemical and Radiological domains: from very classical sensors (ex. pressure/temperature) to the development of innovative optic fibre with distributed measurements and sensors for thermal and mechanical long term monitoring.

2. *Observatoire pérenne de l'environnement (OPE)*

Around the expected site of the Cigéo surface facilities, Andra has designed an ambitious network of monitoring stations including purposed built observatories in forest and agricultural land associated with atmospheric, climatic and water (surface and underground) monitoring stations. Data from these observatories acquired continuously are complemented by grid survey for soil quality and biodiversity. In total an area of 900 km² is surveyed with a focus on a restricted 240 km² in direct proximity of the expected site of the Cigéo surface facilities. An environmental specimen bank is also starting to collect samples during the operating period since a century with the aim to provide samples for retrospective analysis if and when necessary in the future.

This observation network constitutes Andra's long term observatory (called OPE for Observatoire pérenne de l'environnement) which is scheduled to monitor the environment for around 120 years. OPE is also actively interacting with other complementary observatories through national and international environmental programs.

	No	Name	Acronym
Participant	2	Agencija za radioaktivne odpadke	ARAO
Description of the legal entity The ARAO is a public service agency that concludes contracts in connection with its activities with the line ministry competent for the Energy Directorate. The ARAO is the mandatory service of general economic interest provider of management of radioactive waste generated in the territory of Slovenia. Its task is to takeover, transport, and carry out pre-treatment, treatment, conditioning, and storage of radioactive waste generated in industry, research and medicine. The ARAO is authorised to manage and carry out long-term monitoring and maintenance of disposal sites of hydrometallurgical tailings and mine waste tailings and repositories for radioactive waste and spent fuel after their closure. By planning and providing long-term, safe and cost-effective solutions for radioactive waste and spent fuel management, including the construction of the LILW repository, it provides infrastructural and professional support to the use of nuclear and radiation technologies in Slovenia. The radioactive waste management as a mandatory service of general economic interest will, when the infrastructure conditions are met, also provide for the final disposal of the radioactive waste and spent fuel generated during the operation and decommissioning of the nuclear power plant and for the disposal of radioactive waste from all other industrial activities.			
Description of main tasks in EURAD-1, with an explanation of how its profile matches the tasks ARAO as mandated WMO from Republic of Slovenia will be engaged in Task n°6 – Shared solutions in European countries under Strategic Study WP on “Waste management routes in Europe from cradle to grave (ROUTES)”. Task objectives n°6: - Describe and assess knowledge on and approaches to sharing technology and facilities between members states. - Provide an overview of the interest in and experience with sharing technology/facilities in the different steps of waste management. - Identify gaps and define needs for R&D, strategic priorities and opportunities for collaboration between member states, as applied to challenging wastes as defined in task 1 and LAPs. The Krško Nuclear Power Plant (Krško NPP) is one of the main pillars of the Slovenian power system. The plant is operated by the public company Krško NPP d.o.o. and owned by state-owned Slovenian and Croatian electrical power companies (GEN energija d.o.o. and Hrvatska Elektroprivreda d.d., respectively). In accordance with The Bilateral Slovenian-Croatian Agreement on the Krško NPP, both countries share responsibility for RW and SF management. In Resolution on the 2016–2025 National Program for Managing Radioactive Waste and Spent Nuclear Fuel (ReNPRRO16-25) in Republic of Slovenia the conceptual idea of shared facilities and regional cooperation in waste management, including the dual-track approach, was clearly implemented. In Slovenia radioactive waste (RW) and spent fuel (SF) management must be implemented in such a way so as to ensure modern principles of RW and SF management. Especially relevant principles for the task objectives are: - The principles of international cooperation Slovenia is aware of the responsibility and opportunity presented at the regional and global levels to safely and sustainably resolve issues related to radioactive waste and spent fuel management together with other countries. In its actions, account should be taken of the principles adopted in this policy and regional and international agreements. National responsibility for radioactive waste and spent fuel management shall be considered in parallel with active participation in international regional efforts to make progress towards joint regional programmes for disposal. - The principle of seeking a joint solution Slovenia is aware of the responsibility for the management of radioactive waste and spent fuel and its disposal and shall, in accordance with The Bilateral Slovenian-Croatian Agreement on the Krško NPP, strive to ensure an effective joint solution for the decommissioning and disposal of radioactive waste and spent fuel from the Krško NPP with Republic of Croatia. For long-term spent fuel management, a dual-track strategy has been adopted as a reasonable solution in the present situation. The dual-track approach in Slovenian strategy includes both first, the option of			

multinational disposal is kept open, and second, the basic reference conceptual scenario for national geological disposal is included. With regard to disposal and sharing of facilities, the ARAO participates at the EU level in two programmes which address the possibility of building a multinational/regional repository for spent fuel and high-level waste (ERDO-WG and IGD-TP) and is also involved in the work of the International Framework for Nuclear Energy Cooperation (IFNEC). Due to special status of the Krško NPP, ARAO has gained lots of experience in sharing of facilities during sitting and construction permit approval process for possible joint Slovenian and Croatian LILW repository (negotiations in progress) and construction of joint dry storage facility for SF in Křrko NPP. ARAO has gained a lot of experience also in sharing of potential regional/multinational disposal facilities through cooperation with other WMO and stakeholders (IAEA, OECD/NEA, WNA, IFNEC, ERDO-WG, Reginal Seminar, ...).
a curriculum vitae or description of the profile of the persons, including their gender, who will be primarily responsible for carrying out the proposed research and/or innovation activities CV for Leon Kegel, ARAO leon.kegel@arao.si Working in ARAO in Planning and Development Section for 10 years in the area of long-term policy and strategy development for RW&SF management including long-term storage and final disposal facility development with associate costs assessment. Head of project for development of technical expert basis for National Programme for Radioactive Waste and Spent Fuel Management for period 2016-2025 under EC Directive 2011/70. Head of project for preparation of joint Slovenian-Croatian Program of NPP Krřko Decommissioning and Program of SF & RW Disposal.
a list of up to 5 relevant publications, and/or products, services (including widely-used datasets or software), or other achievements relevant to the call content • Kegel L., Źagar T.: Preparation of Decommissioning Program for NPP with Shared Ownership, International conference on Advancing the Global Implementation of Decommissioning and environmental Remediation Programmes; Madrid, Spain, May 2016, • Kegel L., Źagar T.: Preparation of the National Programme for the Spent Fuel and Radioactive Waste Management Taking Into Account Possibility of Potential Multinational/Regional Disposal Facilities Development, International conference on the Safety of Radioactive Waste Management; IAEA, Vienna, Avstria, November 2016 • Kegel L.: Slovenian Approach on Costing LILW Repository (including costs for shared LILW repository), “Technical Meeting on Financing Schemes for Radioactive Waste Disposal Programmes”, Vienna, Austria, May 22 –26, 2017
a list of up to 5 relevant previous projects or activities, connected to the subject of this proposal • Preparation of joint Slovenian-Croatian Program of NPP Krřko Decommissioning and Program of SF & RW Disposal from Krřko NPP • ARAO membership in ERDO-WG from 2009 • ARAO membership in IFNEC RNFSWG dealing with multinational disposal facilities • IAEA INPRO preparation of the Study on Cooperative Approaches to the Back End of the Nuclear Fuel Cycle (NFC): Drivers and Institutional, Economic and Legal Impediments - The Multinational Repository Concept: Opportunities and Benefits for Consideration by Potential Service Providers
a description of any significant infrastructure and/or any major items of technical equipment, relevant to the proposed work; N/A
if operational capacity cannot be demonstrated at the time of submitting the proposal, describe the concrete measures that will be taken to obtain it by the time of the implementation of the task. N/A

	No	Name	Acronym
Participant	3	Bel V	Bel V
Description of the legal entity Bel V is a technical subsidiary of the Federal Agency for Nuclear Control (Belgian Safety Authority). By virtue of its activities and its relations to the FANC, Bel V is the Belgian Technical Safety Organisation. The FANC relies on the technical expertise of Bel V for carrying out inspections in nuclear installations in Belgium. Bel V acts as well as expert for the safety assessments of nuclear projects and participates actively in working groups that are organized in the framework of international organizations. Its financial resources are allocated in part to research and development activities.			
Description of main tasks in EURAD-1, with an explanation of how its profile matches the tasks WP UMAN: Bel V will act as WP leader. As national TSO, the oversight of uncertainty management approaches and activities carried out by proponents or licensees of waste management facilities is part of Bel V's core business activities. As WP leader, Bel V will coordinate Task 1 dedicated to WP coordination, interactions with KM WP & integration. Bel V will contribute to Subtask 2.1 on the generic strategies for managing uncertainties by providing a regulatory perspective on uncertainty management strategies and approaches. In Subtask 3.5, Bel V will collect and synthesize relevant information on uncertainties associated with spent fuel including regarding the experience gained through its activities in the Belgian national programme. In Task 4 on uncertainty management options, Bel V will identify regulatory preferences on the management options and contribute to the analysis of options and the identification of needs for future activities that will be synthesised in Task 1. In Task 5 on the interactions between all categories of actors, Bel V, as coordinator of the WP, will participate in key meetings related to Topics 1 to 4 and the organisation of the seminars and review the deliverables. Bel V will coordinate the UMAN extension (Task 1 and associated subtasks) and participate in the workshops organised by Subtasks 3.6 and 4.3. Bel V, as WP leader, will also contribute to the organisation of the 5 th seminar and to ensuring the consistency and interactions between Task 5 and the other tasks. As national TSO, the oversight of uncertainty management approaches and activities carried out by proponents or licensees of waste management facilities is part of Bel V's core business activities.			
WP ACED: Bel V will participate in Subtask 2.2 of this WP. In this framework, Bel V will contribute to piloting the new experiment focusing on the evolution of grout cement/CEM I and carbon steel interfaces at 80°C. In the framework of its R&D programme, Bel V has developed knowledge and expertise in this topic, notably by being involved in and co-funding the following PhD's: • PhD on the effect of temperature on geochemistry, microstructure and diffusion at cement/clay interfaces (P. Lalan 2013-2015); • PhD on the development of a coupled experimental, numerical and statistical homogenization approach towards an accurate feedback relationship between porosity and diffusive properties of model cementitious materials in the field of reactive transport modelling (N. Seigneur 2012-2016) Bel V involvement in the previous EC-H2020 SITEX projects (where Bel V coordinated the TSO SRA development) has also contributed to develop expertise in this topic.			
WP ROUTES: Bel V will be involved in Task 2 of this WP, devoted to identifying challenging wastes to be collaboratively tackled within the Joint Programme and mapping and share understanding at EU level of practical issues on waste management routes. As a TSO Bel V oversights safety aspects related to radioactive waste management in Belgium and has thus developed knowledge and experience on existing and missing waste management routes. Moreover, Bel V is involved in the management of safety issues on waste management (e.g. drums affected by ASR gel formation, bitumen drums) that would be worth to share in the framework of this WP.			
a curriculum vitae or description of the profile of the persons, including their gender, who will be primarily responsible for carrying out the proposed research and/or innovation activities Mr. Frank Lemy holds a degree in Mining Engineering from the Faculté Polytechnique de Mons (Belgium) and a Ph.D. in Rock Mechanics from the Laval University (Canada). He has worked for 5 years as researcher and lecturer in the fields of geomechanics and engineering geology at the Laval University and ETH Zürich (Switzerland). He has held for more than 5 years a position of expert in radioactive waste			

management at FANC (Belgian Nuclear Safety Authority) and has been involved since 2008 in the Belgian surface and geological disposal projects. He has also participated in several international R&D projects and working groups dealing with the safety of repositories (PAMINA, FORGE, SITEX, IGSC, HIDRA,...). He has participated as a task leader of the TSO working group in the JOPRAD project, that paved the way to the EURAD. He is currently working as a safety analyst at Bel V in the fields of waste management, geology and civil engineering and coordinates the technical review of the post-closure safety assessment of the Belgian surface disposal repository. He is responsible for the development and implementation of a R&D programme for supporting the regulatory review of the safety case for a geological disposal facility. **Mr. Valéry Detilleux** holds a Ph.D. in physical chemistry from the Université catholique de Louvain (Belgium). He works at Bel V as a safety analyst, where he is involved in the review of safety assessments for radioactive waste treatment, conditioning and disposal facilities. He is responsible for the development and implementation of a R&D programme for supporting the regulatory review of the safety case for a geological disposal facility. He was actively involved in the former EC-SITEX and SITEX-II projects. In the framework of SITEX-II, he coordinated the development of the TSO Strategic Research Agenda. Moreover, he participated in international working groups such as IAEA GEOSAF II and IAEA PRISM.

a list of up to 5 relevant publications, and/or products, services (including widely-used datasets or software), or other achievements relevant to the call content

Publications:

- Bernier, F., Lemy, F., De Cannière, P. & Detilleux, V. (2017). Implications of safety requirements for the treatment of THMC processes in geological disposal systems for radioactive waste. *Journal of Rock Mechanics and Geotechnical Engineering*, Volume 9, Issue 3, June 2017, Pages 428-434.
- Lemy F. & Bernier F. (2013). Regulatory Expectations Regarding the Safety Case: Moving from Conceptualization to Implementation. *Euradwaste'13 Conference*, Vilnius, 14-16 October 2013.
- Bernier F. & Lemy F. (2013). Implications of the Regulatory Framework and Activities on R&D Supporting Repository Implementation. *The Safety Case for Deep Geological Disposal of Radioactive Waste: 2013 State of the Art*, 2nd International Safety Case Symposium, 7-9 October 2013, Paris, France.
- Detilleux V., Depuydt J., Noterman N., Van De Velde T., Marloye D., De Smet F. (2017). Gel formation in conditioned waste drums: overview of the issue and lessons learned by the Regulatory Body, *Proceedings of the EUROSAFE Forum 2017*, 247-252
- Lalan P., Dauzères A., De Windt L., Bartier D., Sammaljärvi J., Barnichon J.-D., Techer I., Detilleux V. (2016) Impact of a 70 °C temperature on an ordinary Portland cement paste/claystone interface: An in situ experiment, *Cement and Concrete Research*, 83, 164-178

a list of up to 5 relevant previous projects or activities, connected to the subject of this proposal

Besides its participation in various national and international projects related to radioactive waste management (e.g. IAEA-PRISM, PRISMA, HIDRA I&II, GEOSAF and MODARIA, EC-MICADO and PAMINA), Bel V was actively involved in the following projects that paved the way to the EURAD proposal:

- SITEX I & II (WP leader), JOPRAD (task leader)

Moreover, Bel V is involved in the following group, whose activities are connected to tasks in which Bel V will participate in the framework of EURAD (e.g. WP UMAN):

- NEA IGSC

Finally, as a TSO, Bel V is a.o. involved in the following activities in support to the national regulatory authority

- Review of the license application for the radioactive waste surface disposal facility in Dessel, Belgium
- Review of safety assessment methodologies submitted in the framework of the national geological disposal programme
- Review of license applications and modification requests for facilities where nuclear waste are generated and managed (e.g. NPPs, radioactive waste and spent fuel storage facilities), as well as the regular inspection of these facilities.

a description of any significant infrastructure and/or any major items of technical equipment, relevant to the proposed work

The new experiment in which Bel V will be involved in the framework of WP ACED will take place in the IRSN URL at Tournemire.

if operational capacity cannot be demonstrated at the time of submitting the proposal, describe the concrete measures that will be taken to obtain it by the time of the implementation of the task.

N/A

	No	Name	Acronym
Participant	4	Bundesgesellschaft für Endlagerung	BGE
Description of the legal entity BGE is the federal company for radioactive waste disposal, implementer and German waste management organization. The BGE is entrusted with the task of implementing site selection procedures for a final repository, particularly for heat-generating radioactive waste. Additionally, the BGE is operator of the Asse II shaft mine, the Konrad final repository and the Morsleben final repository.			
Description of main tasks in EURAD-1, with an explanation of how its profile matches the tasks WP HITEC: BGE intends to develop a time dependent anisotropic THM model for argillaceous rock which incorporates strength and stiffness anisotropy, a time-dependent deformation, a dependency of permeability on irreversible strains, a hydro-mechanical coupling for saturated and/or unsaturated conditions and a thermo-mechanical coupling able to predict the thermally induced opening of fractures in claystone. The planned contribution of BGE focuses on the Task 2 related question "How good are the current THM models in representing the stress changes at repository relevant conditions?" by the constitutive modelling of THM behaviour of COX and Opalinus Clay within an open source process level code. The aim is to close existing gaps in regard to the hydro-mechanical coupling with respect to the temperature effects and increase the understanding of the relationships between involved phenomena. WP GAS: BGE envisages in collaboration with UFZ to develop a TH ² M constitutive material model for bentonite which takes into account the two phase flow formulation and the pathway dilation process and incorporate some of the state of the art THM formulation for bentonite actually developed in the scope of the European project BEACON. The results will provide a better understanding of the consequences of gas migration in terms of demonstrating the barrier integrity. WP UMAN: As Task Lead BGE will develop and distribute a questionnaire in order to identify the different actors and collect information about their roles and interests. Also BGE will be in charge of the writing of the deliverable. BGE will contribute to the compilation and review of uncertainty management options, provide an input regarding the options considered in the German programme (considering in particular the construction, operation, and closure of a repository mine). BGE will organize and participate in the workshops, provide an input on the pros and cons from the viewpoint of the German WMO, contribute to the analysis of options, to the identification of needs for future activities and to the writing of the deliverable. In the WP extension, BGE will coordinate Task 4 and participate in the workshops organised by Subtasks 3.6 and 4.3. WP KM – State-of-Knowledge: BGE will provide the WP Lead. Together with the other participants specifications for the development of a knowledge platform will be elaborated and a "prototype" platform will be set up on the basis of these developed specifications. This platform will be hosted by BGE.			
a curriculum vitae or description of the profile of the persons, including their gender, who will be primarily responsible for carrying out the proposed research and/or innovation activities Panja Feuker, Diplom-Geologist (M. Sc.): Geology/Palaeontology, 47, female Key qualifications Project management of international projects in geothermal energy and mining. Panning and designing of international projects. Environmental impact studies in Hydrogeology/Hydrology. Professional Experience: Initialization, implementation and coordination of international projects in mining and geothermal energy. Project Management and evaluation of mining and geothermal projects. Evaluation of environmental impact studies in mining.			

Language skills: German (native), English (fluent), Spanish (fluent)

WP: KM

Astrid Göbel, Diplom-Geologist (M. Sc.): Geology/Geochemistry, Natural Resources, 51, female

Key qualifications Project Management, evaluation and strategic controlling of repository projects, development of standards and processes. Crisis and Contingency Management. Quality Assurance Management.

Professional Experience: Initialization, implementation and coordination of RD&D (planning, JOPRAD, EJP1). Project Management, implementation and evaluation of disposal projects. Key questions on Radioactive Waste Disposal. Committee work (national/international).

Language skills: German (native), English (fluent)

WP: GAS, HITEC, KM, UMAN

Philipp Herold, Dipl.-Ing: Mining Engineer, Project Manager, 33, male

Key qualifications: Underground mining engineering, Mining ventilation planning and simulation. Planning and design of retrieval technologies, design of sealing elements.

Professional Experience: Planning and conception of ventilations systems and underground drifts. Planning of hoisting system for Belgian disposal concept. Underground transport system.

Language skills: German (native), English (fluent)

WP: HITEC

Gunnar Hoefer, Diplom-Geograph (M. Sc.): Physical Geography and Landscape Ecology, Geology, Soil Science, Hydrology, Water Resources Management & Environmental Law, 47, male

Key qualifications Knowledge Management. Project Management. Geodata Management. Geoscientific impact planning of site specific interims storage facilities. Environmental impact planning of site specific interims storage facilities.

Professional Experience: Environmental reporting, environmental impact studies, developement of the project site selection, geoinformatics, geodata management planning, personnel planning, approval management, advanced training planning, knowledge management, data management.

Language skills: German (native), English (fluent)

WP: KM

Christian Müller, PhD: Geoscientist, Research Associate, 40, male

Key qualifications Geomechanical and THM modelling of geological structures (rock salt, clay and granite) as well as geotechnical barriers. Main applications are the performance and safety assessment and the interpretation/ validation against laboratory and in-situ experiments.

Professional Experience: Rock characterisation and rock modelling. Geomechanical modelling. THM modelling.

Language skills: German (native), English (fluent)

WP: GAS

Nina Müller-Hoeppel, PhD: Civil Engineer, Department Head, 60, female

Key qualifications: Conception and development of engineered barrier systems. Project Management, planning and coordination of large scale research projects. Participation in the development of computer programs performance assessment.

Professional Experience: Senior expert for geotechnical stability of the Morsleben repository mine. Participation in several R&D projects related to the backfilling and sealing, including materials development. Senior expert for geotechnical stability systems for the Asse mine.

Language skills: German (native), English (fluent)

WP: UMAN

Eric Kuate Simo, MSc.: Civil Engineer, Research Associate, 29, male

Key qualifications: Geotechnical engineering. Structural engineering. Geomechanical modelling. THM modelling.

Professional Experience: Geomechanical and THM modelling of geological structures (rock salt, clay and granite) as well as geotechnical barriers. Performance and safety assessment and the interpretation, Thermal design of deep geological HLW repositories.

Language skills: French (native), German (fluent), English (fluent)
WP: GAS, HITEC

a list of up to 5 relevant publications, and/or products, services (including widely-used datasets or software), or other achievements relevant to the call content

Jobmann, M., Bebiolka, A., Burlaka, V., Herold, P., Jahn, S., Lommerzheim, A., Maßmann, J., Meleshyn, A., Mrugalla, S., Reinhold, K., Rübel, A., Stark, L. & Ziefle, G. (2017): Safety Assessment Methodology for a German High-level Waste Repository in Clay Formations. Journal of Rock Mechanics and Geotechnical Engineering, Volume 9, Issue 5, Pages 856-876.

Jobmann, M.; Breustedt, M.; Li, S.; Polster, M. & Schirmer, S. Investigations on THM effects in buffer, EDZ and argillaceous host rock DBE TECHNOLOGY GmbH, 2013

Jobmann, M.; Burlaka V. Herold, P.; Kuate Simo, E.; Maßmann, J.; Meleshyn, A.; Rübel, A. & Ziefle, G. Projekt ANSICHT, Systemanalyse für die Endlagerstandortmodelle, Methode und exemplarische Berechnungen zum Sicherheitsnachweis DBE TECHNOLOGY GmbH, BGR, GRS, 2017

Jobmann, M.; Flügge, J.; Gazul, R.; Hammer, J.; Herold, P.; Krone, J.; Kuate Simo, E.; Kühnlenz, T.; Laggiard, E.; Lommerzheim, A.; Meleshyn, A.; Müller, C.; Rübel, A.; Wolf, J. & Zhao, H. Investigation on long-term safety aspects of a radioactive waste repository in a diagenetic clay formation BGR, GRS, DBE TECHNOLOGY, 2017

Jobmann, M. & Meleshyn, A. Evaluation of temperature-induced effects on safety-relevant properties of clay host rocks with regard to HLW/SF disposal Mineralogical Magazine, 2015, 79, 1389-1395

a list of up to 5 relevant previous projects or activities, connected to the subject of this proposal

GENESIS: Safety-based design of a generic repository in claystone, 2007

This project investigated where and under which conditions the disposal of heat-generating waste in different clay formations in Germany is possible and reasonable. The aim was to determine a layout of the underground disposal configuration for all types of waste to be considered with optimal drift spacings without exceeding the temperature limit of the host rock. In addition, investigations of the thermo-mechanical behaviour of the rock were used to evaluate the stability of a corresponding mine in the clay formation under consideration.

ERATO: Reference concept for a repository for radioactive waste in claystone, 2010

In this project, the currently most advantageous disposal options were developed and, based on these, a reference mine planning for a selected clay rock formation in Germany was prepared.

TEMTON: Investigations on the effect of a temperature load on clay formations in Germany in the near and far field, 2013

In this project, a constitutive model which consists on the determination of permeability change of claystone based on the current stress state was developed. This model was used within the framework of the TED heater test in the underground laboratory in Bure, France. In addition, it was quantified how the geotechnical barrier made of bentonite could be modified so that the large amounts of heat of the radioactive waste to be introduced could be dissipated into the clay formation in a suitable manner. This concerns the thermal properties of a bentonite barrier that can actually be achieved.

ISIBEL/ISIBEL-II: Review and evaluation of the instruments for a safety assessment of repositories for high level waste, 2013

Within the scope of this joint project of BGR, GRS and BGE, a safety and demonstration concept for a repository in a salt formation was developed which is based on a repository concept designed according to thermo-mechanical aspects. These design calculations were carried out using process level modelling.

ANSICHT: Safety Assessment Methodology for a German High-level Waste Repository in Clay Formations, 2016

Within the scope of this joint project, BGR, GRS and BGE developed a safety and demonstration concept for a repository in a claystone formation in Germany. Based on the safety philosophy developed in the ANSICHT project, a repository concept and a qualitative backfilling and sealing concept were developed. On the basis of these principles, two location-specific FEP catalogues (North and South Germany) were developed which describe all essential processes taking place in and around the repository. An essential part of the work consisted in the verification of the integrity of the geological barrier and the closure system by means of numerical simulations at process level and engineering verification procedures.

a description of any significant infrastructure and/or any major items of technical equipment, relevant to the proposed work;

- 8 High End Workstations: 2 CPUs, 12 kernels, 56 threads, 128 GB RAM
- Numerical codes: OGS, FLAC3D, PFC3D, 3DEC, TOUGH2

if operational capacity cannot be demonstrated at the time of submitting the proposal, describe the concrete measures that will be taken to obtain it by the time of the implementation of the task

N/A

	No	Name	Acronym
Participant	5	Commissariat à l'Energie Atomique et aux Energies Alternatives	CEA
Description of the legal entity The French Alternative Energies and Atomic Energy Commission (CEA) is a key player in research, development and innovation in four main areas: defence and security, low carbon energies (nuclear and renewable energies), technological research for industry, fundamental research in the physical sciences and life sciences. CEA represents 16,000 permanent staff, spread among 9 research centers in France. Drawing on its widely acknowledged expertise, the CEA actively participates in collaborative projects with a large number of academic and industrial partners. Amongst its missions, CEA (Nuclear Energy Division) is working on the optimization of the current nuclear industry. In this framework, CEA is carrying out research for the management of radioactive wastes and spent fuel.			
Description of main tasks in EURAD-1, with an explanation of how its profile matches the tasks CEA is involved in 5 work packages of the Joint Programme. Regarding Cement-Organics-Radionuclide-Interactions (WP CORI) and Fundamental Understanding of radionuclide mobility (WP Future), CEA will provide dedicated experiments to study the mobility of the radionuclides of interest in cement and compacted clay rocks, benefiting of its skills in this domain. CEA has developed a large experience on the vitrified wastes, and their long-term behaviour under disposal conditions. Hence, CEA will also contribute to the assessment of chemical evolution of High Level Waste disposal cell by characterizing and modelling long-term interactions in a glass/steel/clay system (ACED). Furthermore, CEA has been involved since many years on the characterization of thermo-mechanical behaviour of bentonite, in the framework of European projects and collaboration with Andra. Enriched by this experience, CEA proposes to characterize the thermo-mechanical behaviour of clay host-rocks (WP HITEC). At last, CEA, who has conducted large scope of research on spent nuclear fuel behaviour under dry storage in the framework of 1991 French law, will provide experimental data on the behaviour of spent fuel rod under dry storage in incidental scenario (no tight cladding) (WP Spent fuel). WP16-MAGIC : The LECBA is a CEA laboratory that specializes in the study of cement-based and clayey materials involved in the electro-nuclear industry with a specific interest in nuclear power plants, waste containers and waste disposal. The laboratory maintains a cross-disciplinary culture of engineers and researchers, building on synergies between fundamental and applied research. In the Task 3 , we will mainly share the experimental results of a PhD project that was defended at the end of 2019 (Ekoé KANGNI-FOLI). The main objective was to characterize the consequences of carbonation on two model pastes (C-S-H paste and C-S-H + CH paste) in terms mineralogical, microstructural and length changes. Some remaining samples could be used by the partners for additional tests if need be. In the Task 4 , we will create a sequential numerical approach to describe atmospheric carbonation accounting for the coupling between geochemistry with mechanics. HYTEC (from Mines-ParisTech) will be the relevant geochemical code to generate the mesh and compute the mineralogical evolution and porosity changes. The results will be communicated to Cast3m (the finite-element code from CEA) using a procedure to be defined and Cast3m will compute the change in mechanical properties and the subsequent stress buildup and potential crack development. This study will require a post-doctoral student. WP17-MODATS: Innovative Sensors: development of an optical pH sensor for porewater monitoring The development and characterization of an optical pH sensor for the neutral pH range will be studied. Some tests, in the Underground Research Laboratory of Andra in the argillaceous Callovo-Oxfordian geological formation, are expected.			
a curriculum vitae or description of the profile of the persons, including their gender, who will be primarily responsible for carrying out the proposed research and/or innovation activities Dr. Philippe Dillmann (male) is “Directeur de Recherche” at the French CNRS, doctor and engineer in materials science and “ <i>Habilitation à Diriger des Recherches</i> ”. He is director of the “Laboratoire Archéomatériaux et Prévision de l’Altération” (CNRS and CEA), deputy director of the UMR3685 and UMR5060 of the CNRS. He conducts researches for 20 years on long term alteration of metals and glasses. He funded the Working Party 21 of the European Federation of Corrosion, dedicated to the long term			

corrosion. Philippe Dillmann is involved in the Scientific Committee of several French and International Institutions, among them, the Labex LaScArcBdx, the Fondation des Sciences du Patrimoine, the European Federation of Corrosion, the Centre Européen d'Archéométrie (Belgium).

Dr. Stéphane Gin (male) received a Master degree from Orléans University, France, and a PhD degree from Poitiers University, France in 1994. Since 1995, he works at the French Atomic Energy and Alternatives Energy Commission (CEA) of Marcoule, France, starting his career as scientist on nuclear and commercial glass corrosion problems. In 2001, he took the lead of the “Long term behavior of HLW glass” group within the Department of treatment and conditioning of nuclear waste at CEA. From 2012 to 2013, he was visiting scientist at Pacific Northwest National Laboratory, USA. Dr Gin is also part of advisory boards on high-level waste management in Belgium, the UK, and the USA.

After graduating as chemist engineer in 2001, **Virginie Blin (female)** joined the Laboratory of Radionuclide Migration Measurement and Modeling (L3MR) where, during 10 years, she is in charge of several radionuclides retention and diffusion studies, both in claystone and cementitious materials, and particularly of *in situ* radionuclides diffusion experiments carrying out a in the Andra's Meuse/Haute-Marne Underground Laboratory. End of 2011, she takes the head of the Laboratory. Since end of 2017, she is project manager of a CEA R&D project, which deals with long term behavior of IL-LL waste packages and engineered/natural barriers of deep disposal.

Dr Nathalie Macé (female) has defended in 2006 a PhD thesis on the “effect of temperature onto selenite retention by an altered cement paste and its constitutive cementitious phases” (University of Orsay (Paris XI). From 2007 to 2009, she has a Post-doctoral position on “Micro-scale Investigations of the Speciation and the Mobility of Uranium in Cementitious Materials (MISUC)”. This work has been funded as an EURATOM Marie-Curie fellowship and performed in the Laboratory for Waste Management of the Paul Scherrer Institut, (Villigen, Switzerland). In 2010, she joined the L3MR Laboratory of CEA, where she is in charge of studying the radionuclides retention and diffusion in cementitious matrices (individual cement phases, hydrated cement paste, mortar and concrete).

Dr. Romain V.H. Dagnelie (male) received his PhD degree in 2009 at the University Paris-XI (Orsay, France), where he studied photochemistry and detection of gaseous organic pollutants. In 2010, he joined the Laboratory of Radionuclide Migration Measurement and Modelling. His research interests include the transport of radionuclides in the environment, with a focus on behaviour of organic molecules in the context of radioactive waste disposal. To that aim, he is developing adsorption and diffusion experiments at various scales, including field experiments in deep underground research laboratories.

Dr. Sébastien Savoye (male) is a senior expert at CEA, doctor in geochemistry and “Habilitation à Diriger des Recherches”. He is expert in experiments and modelling of retention/diffusion of radionuclides through various porous media (claystones, compacted clays, cement-based materials, bitumen) under large experimental conditions (partial water saturation, high temperature, high ionic strength, acidic or alkaline fluids and redox perturbation). He was coordinator of the European Project entitled “CatClay” and involved in the EU Recosy project dedicated to the redox issues.

a list of up to 5 relevant publications, and/or products, services (including widely-used datasets or software), or other achievements relevant to the call content

- “Origin and consequences of silicate glass passivation by surface layers”, Gin, Stéphane; Jollivet, Patrick; Fournier, Maxime; et al. NATURE COMMUNICATIONS Volume: 6, Article Number: 6360 Published: FEB 2015
- “Diffusion of organic anions in clay-rich media: effects of anion exclusion on retardation”; Dagnelie R.V.H, Rasamimanana S., Blin V., Radwan J., Thory ., Robinet J-C., Lefèvre G. Chemosphere, submitted.
- “Use of quantitative digital autoradiography technique to investigate the chlorine-36-labelled radiotracer transport in concrete”; N. Macé, P. Fichet, S. Savoye, J. Radwan, C. Lim, S. Lefèvre, J. Page and P. Henocq. Applied Geochemistry, submitted.
- “Adsorption of polar organic molecules on sediments: Case-study on Callovian-Oxfordian claystone”, S. Rasamimanana, G. Lefèvre, R. V. H. Dagnelie, Chemosphere, Volume 181, August 2017, Pages 296-303

- “Effect of water saturation on the diffusion/adsorption of ^{22}Na and cesium onto the Callovo-Oxfordian claystones”, Savoye S., Lefevre S., Fayette A., Robinet J.Ch, 2017, *Geofluids*, 1683979, <https://doi.org/10.1155/2017/1683979>
- “Behavior of a defective nuclear fuel rod in dry storage conditions studied with a new experimental”, L. Desgranges, M.P. Ferroud-Plattet, R. Alloncle, I. Aubrun, J.M. Untrau, P. Lhuillery, *Nuclear Technology*, vol. 163, 2008

a list of up to 5 relevant previous projects or activities, connected to the subject of this proposal

Since 1999, PRECCI project is the national program lead by CEA on the study of spent fuel long-term behaviour, under storage and disposal conditions. This national project is supported by EDF/R&D and Andra. CEA provides research to respond to Andra’s needs regarding the development of a geological disposal of ILW and HLW (national Cigéo Project).

CEA coordinated European Projects connected to EURAD: SFS (“Spent Fuel Stability under Repository Conditions”, 5th FP) and CATCLAY (*processes of CATion migration in CLAYrocks*, 7th FP). CEA contributed to NF-PRO (6th FP) and RECOSY (7th FP) EU projects. CEA participated to various experiments conducted by Andra in the underground Laboratory of Bure, on bentonite used as sealing material.

a description of any significant infrastructure and/or any major items of technical equipment, relevant to the proposed work;

Hot laboratory in CEA Cadarache Centre for the study of spent fuel behaviour (in a closed system, or in air)

Laboratory in CEA Saclay Centre for the study of radionuclide migration in porous media

if operational capacity cannot be demonstrated at the time of submitting the proposal, describe the concrete measures that will be taken to obtain it by the time of the implementation of the task.

N/A

		No	Name:	Acronym
Participant	6		Centro de investigaciones energéticas, medioambientales y tecnológicas	CIEMAT
Description of the legal entity				
Brief participant description:				
The CIEMAT (Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas) is a public research body assigned to the Ministry of Science, Innovation and Universities, focusing on energy and the environment as well as in many vanguard technologies and in various areas of fundamental research. The mission of the CIEMAT is to contribute to the sustainable development of the country and the quality of life of its citizens, through the generation and application of scientific and technological knowledge. During the last decade, CIEMAT develop a strategy into the institutional project Physico-Chemistry of Actinides and Radioactive waste Management, participating in many projects related to the research on radioactive waste repositories, radionuclide transport processes, spent fuel and have been involved in National R&D Programs financed by ENRESA (the Spanish National Agency for Radioactive Waste Management) and the Nuclear Safety Council, as well as in European Union Programs in both R&D and the EURATOM Treaty. Besides CIEMAT has a wide experience in E&T in Nuclear Technology and Radiation Protection such as preparation and development on an annual basis of the Education and Training Program related to nuclear technology, radiation protection and in all the rest of R & D areas. Within the European and international networks dealing with these topics the following projects, among others, in which CIEMAT participated, can be highlighted: CEBAMA, nTOF-ND-ADS, MUSE, PDS-XADS, Red-Impact, SARNET, PHEBEN2, ARTIST, CABRI, ACSEPT, HotLab, SFS, NF-PRO, MIKADO, ACACIAS, EUROPART, ADOPT, ACTAF, FEBEX I, PEBS, CEBAMA, BEACON FEBEX II, NF-PRO, FUNMIG, CROCK, BELBAR, RESEAL II, FORGE, 1st Nuclides, REDUPP, MATISSE, TIARA, ECVET, ENETRAP, DEVCO, ACTINET Thematic Network.				

Description of main tasks in EURAD-1, with an explanation of how its profile matches the tasks

CIEMAT will contribute to RD&D Work Packages:

Mechanistic understanding of gas transport in clay materials (GAS)

WP GAS -Task 2.2 “Advection (displacement vs. dilation)” is dedicated to improving the understanding of advective gas transport regimes in clay materials.

CIEMAT will focus on the identification of the phenomena that govern gas flow behaviour and the determination of the range of actual conditions (gas pressure, stress/deformation, saturation) at which each gas transport regime occurs on EBS buffer material. The group began to carry out this type of tests in 1998 and has continued them improving the control and analysis conditions. Different barrier materials have been tested in the context of different projects. Close relationship with UPC (TLP) modellers will address the initial experimental work, which is expected to provide valuable data sets to validate the models and to define the future experiments.

Influence of temperature on clay-based material behaviour (HITEC)

Task 1.2 State of the art. CIEMAT will be responsible for this task since it has been involved in projects related with the effect of temperature on barriers for more than 20 years. The group recently participated in the related project PEBS.

Task 3.1 Assessment of the impact of high temperatures over long time periods on the clay buffer properties, including materials coming from large-scale in situ tests and from specific laboratory tests. The group has participated as leading organisation in the dismantling and postmortem analysis of in situ tests (FEBEX, EB) and of laboratory TH tests with FEBEX and MX-80 bentonites, two of the materials included in EURAD-1.

Task 3.2 Determination of parameters at temperatures $>100^{\circ}\text{C}$. CIEMAT will determine the water retention curve of two bentonites with a methodology previously tested in the FEBEX-DP project that will be fine-tuned for high temperature.

Task 3.3 Small-scale experiments simulating the conditions of the barrier in a repository. The group has performed this kind of tests since 1992, continuously improving the control and analysis conditions. Different barrier materials have been tested in the context of different projects.

Assessment of Chemical Evolution of ILW and HLW Disposal Cells (ACED)

Subtask T1.5: Analysis of experiments and numerical model studies on interfaces, which is included in Task 1: Establishing the state of the art (SOTA) & integration.

As a part of the main objective of ACED is “to improve methodologies to obtain multi-scale quantitative models for the chemical model at cell disposal scale based on existing and new experimental data and process knowledge”. For that is proposed “compile and integrate the process level knowledge and description of reactivity at the interfaces between materials relevant for ILW and HLW disposal cells”. An important basis to do it is “the state-of-the-art scientific knowledge and experimental evidence on chemical processes acting at the interface of 2 materials”. CIEMAT will contribute to the analysis of existing experimental data on relevant processes occurring at the steel/iron-clay (bentonite) materials in the context of HLW, based in its previous experience in the context of NF-PRO, PEBS and FEBEX-family projects. The analysis will include existing work on natural/archaeological analogues that may provide useful information for long-term processes. The final input would be the conceptual model describing processes at the interface that serves to support modelling (Tasks 3 and 4).

Subtask T2.1: Steel/clay material interface reactivity, which is included in Task 2: Interface scale: Reactivity of steel/material interfaces.

A laboratory experimental program for the study of metal-compacted FEBEX bentonite interaction started in august 2006 in CIEMAT, focused on the characterization of geochemical processes occurring in the bentonite barrier and their influence on corrosion of the carbon steel container as in the transitory stage of a DGR. Six identical experimental cells (named FB1 to 6) containing bentonite blocks in contact with Fe powder in order to enhance corrosion phenomena were designed and mounted at CIEMAT. The upper closing of the cells was made by means of a stainless steel plug. Inside this plug there was a deposit in which water circulated at room temperature (25°C). The bottom part of the cells was a plane stainless steel

heater set at a temperature of 100 °C. Then, a temperature gradient is established. The hydration is made through the upper plug of the cell with water taken from a stainless steel pressurized deposit. The cells were instrumented with capacitive-type sensors placed inside the clay at two different levels, at 18 and 74 mm from the heater. Four cells (FB1 to 4) were dismantled after 0.6, 1, 1.6 and 4.5 years under NF-PRO and PEBS projects. Two of these cells are still in operation, one being hydrated with granite water (FB5) and the other one without hydration (FB6). FB5 and 6 will be dismantled and analysed in the context of ACED work package.

Additionally, in 2008, an experiment involving iron and bentonite was designed and assembled in the CIEMAT laboratories to study the diffusion of corrosion products in the buffer material and analyse structural changes in the bentonite, considering a conservative scenario: saturated bentonite, aerobic conditions and high corrosion rates. For that, a block of FEBEX bentonite compacted to a dry density of 1.65 g/cm³ was used for this experiment. Six holes ($\phi=1$ cm) were drilled in the bentonite and filled with a cylindrical stainless-steel sinter surrounded by iron powder. The experiment was assembled in a square cell (120 x 120 mm and 16 mm-high) made out of methacrylate and stainless steel 316L. Hydration of bentonite with granite-type water (Ca-HCO₃) occurred through the sinters. The aim of this experiment is to evaluate the potential alteration of bentonite and the mobility of iron in the most conservative scenario. The corrosion of the metals will be analysed as well.

The value of the experiments is that they will provide useful information on the spatial (by comparison with in situ experiment, e.g. FEBEX-DP) and temporal (as explained above the experiments are the lasts of a series of identical experiments dismantled sequentially after different times of operation) evolution of the mineral alteration and geochemical impact on the bentonite barrier due to the interaction with iron materials. The experiments are set at different hydration and temperature conditions simulating different stages of the repository operation.

The expected outcome of the analysis of long-term interaction tests involving metal and clay as engineered barrier (bentonite) is the assessment of the impact on primary safety functions of EBSs of the metal corrosion products in tests under THC controlled conditions such as Types of corrosion, Corrosion rates, Corrosion products, Fe sorption and mobility, Chemical fronts/mass transport, secondary phase formation.

The results will serve as a base for modelling studies (e.g. Tasks 3 and 4). UDC modelled previous FB experiments and the dismantling of the FB5 and 6 experiments will help to assess the iron/bentonite interaction previous model.

Spent Fuel characterisation and evolution until disposal (SFC):

CIEMAT is coordinating the WP together with NAGRA and Uppsala University due to that CIEMAT will be involved in main coordination activities in task 1.

In task 2 CIEMAT will contribute to the activities: Task 2.1 Compare and benchmark state-of-the art codes for SNF depletion calculations based on the selected assemblies, by Monte Carlo simulations for PWR and BWR assemblies using the EVOLCODE system (MCNP and ORIGEN/ACAB). Performing sensitivity studies and propagate nuclear data uncertainties to define confidence limits based on the present status of nuclear data libraries and identify nuclear data requiring improvement CIEMAT will contribute by Sensitivity analyses and nuclear data uncertainties propagation and identifying fuel irradiation history parameters that influence the source terms and propagate uncertainties of these parameters to the observables. CIEMAT will perform studies on Impact of fuel irradiation history parameters uncertainties on inventory calculations with sensitivity analyses. CIEMAT will perform deliverables related to these activities. Task 2.2 CIEMAT will develop and test a prototype of a combined neutron and gamma-ray monitor based on the CLYC inorganic scintillator. Task 2.3 CIEMAT will contribute to the activities of 2.3.4 with theoretical calculation of radionuclide inventories and to the activities of 2.3.5 on evaluation of deviations between analytically and numerically determined inventories studied in this subtask. Task 2.4 CIEMAT will contribute to the activities 2.4.2 and 2.4.4. CIEMAT will evaluate “SNF data set package A/B” by using the “sophisticated” code.

In task 3 CIEMAT will estimate key variables in cladding performance like creep, hydrides distribution and hydrides radial reorientation (i.e., embrittlement) with thermo-mechanical FRAPCON code. In addition, simulations will be conducted in a comprehensive frame of uncertainty quantification by using the BEPU (Best Estimate Plus Uncertainties) methodology. Realistic thermal histories will be explored by using the ANSYS-FLUENT package (3D thermo-fluid dynamics code). Furthermore CIEMAT will study the influence of oxygen pressure and temperature in the alteration of the spent nuclear fuel (SNF) and setting. Experiments will be performed with UO₂/doped UO₂, MOX and irradiated fuel in collaboration with NNL. The reaction system to characterize in-situ the fuel will be set under non-active condition and developed to work in the hot-cells. Finally CIEMAT will participate in the subtask 3.3 by modelling of the fuel rod history with FRAPCON-xt from the reactor to the long term dry storage with focus on the stress (causing PCMI that drives PCI) from two major sources: postulated UO₂ swelling due to oxidation in the presence of an oxidizing agent and/or alpha-decay. Additionally, SNF alteration under interim dry storage conditions and degradation effects of the cladding will be investigated experimentally with UO₂/doped UO₂, MOX. Micro indentation measurements, Raman, SEM, micro-XRD will be performed.

In task 4 CIEMAT will lead the activities perform and will contribute by Identification of credible accident scenarios studies and Mechanical analysis. Use of the source terms from Task 2 to evaluate the accidental scenario. Finally Re-criticality modelling for different accident scenarios will be achieved and the identification and quantification of major sources of uncertainties

Cement-Organics-Radionuclide interactions (CORI).

CIEMAT will lead task 4 and it will participate in Task 3 (Organic-Cement Interactions) and Task 4 (Organic-Cement-Radionuclide Interactions). The objective of the work proposed in Task 3 is to provide information on the mobility of organics present in cements, under the conditions of a waste repository. The focus will be brought on the isosaccharinic acid, ISA, as main cellulose degradation product, and superplasticizers (polycarboxylates, PC) and their degradation products. The main materials considered for these studies will be CSH (possibly CASH), CEM I, and CEM V. The possibility of including portlandite and ettringite will be evaluated. The water chemical conditions will be representative for each material and for the cement, two degraded states will be considered.

In Task 4 it will be investigated the role of the presence of organics on radionuclide (RN) retention/migration under cementitious conditions, trying to combine different experimental techniques and thermodynamic sorption modelling. In Task 4, the behavior of ternary systems will be studied by different techniques: batch sorption tests on powdered materials and small consolidated cement blocks, diffusion tests (through-diffusion or in-diffusion) and sorption modelling. The RN of interest for CIEMAT are ⁶³Ni (II); ¹⁵²Eu(III) (as possible homologue of Am(III)) and ²³⁸Pu and ²³³U as redox sensitive elements. Diffusion tests are planned in collaboration with HZDR. The combination of batch sorption and diffusion experiments will be used as a methodology to assess the mobility of RN-organic complexes in cements: therefore, batch data will be used as the basis for design diffusion tests (chemistry, RN concentration, organic concentration). The priority for transport experiments will be for those elements whose retention resulted more affected by the presence of organics.

Fundamental understanding of radionuclide retention (FUTuRE)

CIEMAT will participate in Task 2 (Mobility) and Task 3 (Redox). The main objectives of the work proposed 2 are: 1) to analyse transport mechanisms of RN in compacted/consolidated clays and the dependence of diffusion coefficient as a function of the temperature; 2) to analyse the reversibility of sorption processes in (compacted) clays and to understand which properties of the clay (and RN) may affect mostly the (ir)reversibility of the retention. 3) To point out the differences between batch/compacted systems. A complete geochemical and mineralogical characterization of different clays will be initially carried out by different techniques. Special consideration will be given to the following radionuclides (RN): Ra (or homologues), Ni, Zn, Ac(IV, VI), Tc and Se.

CIEMAT work-plan in Task 3 aims to identify, and to describe theoretically, the surface mechanisms responsible for the retention of redox sensitive radionuclides (RN) as Se, Tc and U, in systems composed by mixtures of clays and other minerals, especially Fe oxides to relate mineral characteristics and RN

reactivity. A bottom-up approach is proposed to describe the retention mechanisms in complex systems, starting from the detailed study of RN sorption in the single systems (batch sorption tests in individual minerals) to more realistic conditions (mixtures, complex materials and compacted samples) to identify new variables and processes as complexity increases. A complete experimental and modelling work is proposed, and experiments will be carried out under controlled redox conditions.

CIEMAT will contribute as well to the two **Strategic Studies Work Packages** such as Waste Management routes in Europe from cradle to grave (ROUTES) and Understanding of uncertainty, risk and safety (UMAN).

Knowledge Management Work Packages

The main tasks of the Knowledge Management and Training Division of CIEMAT in EURAD-1 are related with the Knowledge Management Programme. CIEMAT in collaboration with UPM and supported by ENRESA are yearly delivering a post-graduate course on RWMD since 1989 covering detailed technical questions about the management of both low-and-intermediate-activity wastes and the high-activity level, together with the wastes generated during decommissioning and dismantling of installations, as well as the general and institutional aspects relevant in Spain. CIEMAT has a extensive know-how in E&T in Nuclear Technology and Radiation Protection since the fifties. Particularly, we can result the professionalizing Master programme in Nuclear Engineering and Applications since 1969 and the Radiation Protection Expert course. Also CIEMAT has a wide experience in dissemination of knowledge in RD&D activities of the research centre through both, the social media and the traditional and in crosscutting activities that will provide capacity building, stakeholder engagement, and outreach/communication. International experience on RD&D open platforms developed under UE FP7 projects (Matisse, Tiara, ECVET, ENETRAP...) integrating the capacity building strategy in the R&D projects.

CONTAINER CORROSION under Disposal conditions :

CIEMAT will contribute to Tasks 3 and 4 (Corrosion under irradiation and Microbial effects).

Experiments in **Tasks 3 and 4** are linked. **Task 3** will generate samples from the irradiation of smectite-rich bentonite samples with varying gamma radiation doses (from 1 to 100 KGy) under variable levels of water saturation, dry densities and temperatures. These samples will be interrogated for geochemical and mineralogical changes due to irradiation. The aim is to evaluate radiation induced changes in bentonite (water radiolysis, gas production, ...). To irradiate the samples, CIEMAT Nayade ⁶⁰Co gamma irradiation pool facility will be used. This facility allows radiation rates up to 40 kGy/s, so that relevant doses from 1 to 100 kGy can be attained.

Task 4 will investigate the response of sulfate-reducing bacteria present in the bentonite, to irradiation coupled to variable bentonite dry density, water saturation, and temperature. In these experiments, **the University of Granada (UGR) will be in charge of microbial analyses.**

The second objective of **Task 4** is to experimentally and study sulfide mobility in compacted bentonite, as relevant agents for microbially-induced metal corrosion (MIC). Relevant Cu and Fe- corrosion products will be included, to analyse coupled effects. Using an irradiation dose that inhibits SRB survival, the bentonite will be sterilized prior to compaction to either include or exclude microbial processes from the diffusion study. The results of these tests aim to improve the knowledge on the impact of sulfide on canister performance under different chemical conditions and to support the repository performance assessment. CIEMAT-FAFP collaborates with the Microbiology Department of the **University of Granada (UGR)**. The UGR will carry out microbial studies. In addition, a collaboration will be initiated with AMPHOS 21 and the University of Bern, for the modelling activities of sulfide diffusion experiments. (link to Task 6).

CIEMAT will also contribute to **Task 5 Transients** by experimental and theoretical study of the impact of hydraulic/gas and thermal transients, occurring at the container /bentonite interface in order to relate induced metal corrosion with gas/hydraulic and temperature conditions, representative of near field-transients. Both carbon-steel Cu- canisters are considered.

To analyse both gas/hydraulic and temperature nearfield transients, two well-differentiated activities are proposed:

I. Analysis and characterisation of bentonite samples, as a function of heater contact and Cu-OFP coupons from in-situ real scale tests carried out at Äspo (Sweden) LOT (Long Term Test of Buffer Material:

processes in a water-saturated Wyoming bentonite buffer concerning microbiology, cation transport, and copper heater corrosion at temperatures ranging 90-140°C) and ABM (Alternative Buffer Materials test: 11 different saturated clays selected to examine effects of smectite content, interlayer cations and overall iron redox chemistry, at 130°C of temperature with a carbon steel heater) in-situ experiments. Results will be used to select the boundary conditions and the Fe- or Cu- corrosion products to be included in other studies (link to activities proposed in **Task 3** and **Task 4**). Modelling activities will be carried out in collaboration with [AMPHOS21] within **Task 6**.

II. The laboratory experimental study will focus on analysing, at laboratory scale, the effect of bentonite pore-water chemistry and dissolved gases in metal corrosion processes. Compacted bentonite samples (i.e., FEBEX bentonite, SWy-3) in contact to carbon steel coupons will be prepared at two different bentonite dry densities (1.4 and 1.65 g/cm³). The experiments will be performed at two water saturation conditions (100% and 60%). Experiments will reflect the chemical development of the system (two infiltrating pore waters with different chemistry, oxidising and reducing conditions and thermal effect (ambient temperature) and 80 °C. The presence of sulfate-reducing bacteria (link to **Task 4**), and the comparison between non-irradiated and irradiated samples (link to **Task 3**), will be considered.

Chemo Mechanical AGIng of Cementitious materials :

Only LTPs (UGR and IDAEACSIC) will participate to the activity of the WP. The experience of CIEMAT and LTPs participating in this proposal focuses on the mechanical-physic-chemistry of cement and concrete, the durability of cementitious materials and the identification and modeling of those processes that determine the behavior of the components of a high-level radioactive waste repository at different spatial and temporal scales. The R&D is developed in the framework of national and international research projects, the European Commission framework programs on radioactive wastes and ENRESA's R&D programs. The group has been involved in the study of different aspects of cement-based barriers under relevant disposal conditions in projects as ESDRED, ECOCLAY I and II, NF-PRO, PEBS, FEBEX-DP, CEBAMA, MIND and PREDIS. CIEMAT and LTPs conform an interdisciplinary group owning laboratories prepared to determine chemical, physical, mechanical, mineralogical and microbiological properties of cement-based materials. Furthermore, the IDAEA-CSIC provides its expertise in modeling to link mechanical and chemical processes across scales.

Task 3 : UGR will collaborate with SCK CEN in task 3 to study the impact of microbial processes on the alteration of cement through the analysis of the presence of microbial biofilm on the surface of cement and through the identification of microbial generated alteration productions (sulfur attack, etc.). These studies will be conducted using a combination of microscopic techniques (STEM/HAADF, HRTEM/EDX, FESEM/Raman).

Task 4: IDAEA-CSIC will contribute to Task 4, being sub-task leader of ST4.2 on Upscaling methods from nano to micro to REV. The main tasks will consist in developing a novel multi-scale method, perform predictive modelling of multi-scale hydro-chemo-mechanical behaviour of cementitious materials (concrete) under repository conditions using the developed multi-scale framework (in collaboration with UFZ), and to calibrate and test the developed numerical framework using experimental data described in the literature or provided by partners in Task 2 and Task 3 (in collaboration with UFZ).

ROUTES extension :

CIEMAT will contribute to ROUTES Extension by

- sharing their national experiences,
- evaluating the applicability of the developed solutions to their challenges and by
- reviewing the reports.

a list of up to 5 relevant publications, and/or products, services (including widely-used datasets or software), or other achievements relevant to the call content

1. Becquerelite mineral phase: Crystal structure and thermodynamic and mechanical stability by using periodic DFT. Francisco Colmenero, Ana Maria Fernandez, Vicente Timón and Joaquin Cobos. July 2018. RSC Advances 8(43):24599-24616.
2. Effect of the oxidation front penetration on in-clad hydrogen migration. F. Feria, L.E. Herranz. Journal of Nuclear Materials, 500, 349-360., 2018.

3. Temperature Dependent Gibbs Free Energies of Reaction of Uranyl Containing Materials Based on Density Functional Theory. Francisco Colmenero, Ana Maria Fernandez, Vicente Timón and Joaquin Cobos, February 2018. The Journal of Physical Chemistry C 122(10)
4. Raman study of the oxidation in (U, Pu)O₂ as a function of Pu content. Jone M. Elorrieta, D. Manara, Laura J Bonales, Joaquin Cobos. September 2017. Journal of Nuclear Materials 495.
5. Gens, A., Wieczorek, K., Gaus, I., Garitte, B., Mayor J.C., Schuster, K., Armand, G., García-Siñeriz, J.L., Tricl, T. (2017). Performance of the Opalinus Clay under thermal loading: experimental results from Mont Terri rock laboratory (Switzerland). Swiss Journal of Geosciences, 110: 269–286, doi: 10.1007/s00015-016-0258-8.

a list of up to 5 relevant previous projects or activities, connected to the subject of this proposal

1. Modern Spent Fuel DISolution and Chemistry in Failed COnTainer Conditions (DISCO). Project ID: 755443. H2020-Euratom-1.2. - Contribute to the Development of Solutions for the Management of Radioactive Waste.
2. Bentonite Mechanical evolution (BEACON) Horizon 2020 Framework Programme. Grant Agreement: 745942. European Commission. 2017-2021.
3. Cement-based materials, properties, evolution, barrier functions (CEBAMA). 662147NFRP-062014. (2015–2019).
4. Understanding and Physical and Numerical Modelling of the Key Processes in the Near-Field and their Coupling for Different Host Rocks and Repository Strategies (NF-PRO). FP6-EURATOM-NUWASTE. (FI16W-CT-2003-02389).

ENETRAP European network for education and training in radiation protection - (III, II, I) Project ID: 516529, Project ID: 232620. Funded under: FP6-7-EURATOM.

a description of any significant infrastructure and/or any major items of technical equipment, relevant to the proposed work;

The CIEMAT is an interdisciplinary institution which covers a wide range of topics, from basic research to nuclear technologies. A significant infrastructure and major items of technical equipment, relevant in the field characterization and stability studies on radioactive waste management under pre and disposal conditions.

The nuclear facilities include ordinary laboratories, hot-laboratories (IR-30, IR09 and IR36) where it is possible to perform the hot-experiments. The IR30 has three glove-box, five fume cupboards, an UV-V spectrometer, a potentiometric titrator, oscillating shakers, centrifuges. And IR36 is equipped with two gamma spectrometer (Ge detectors), an alpha spectrometer, ICP-MS, HPLC-DAD and a HPLC-MS/MS. Moreover, CIEMAT dispose of a laboratory equipped to perform a RAMAN spectrometry and IR09 with X-ray diffraction. Additionally, CIEMAT facilities include a gamma irradiation site. The NAYADE IRRADIATION UNIT is a 1.2 m and 4.5 m deep square pool, providing a height of water enough to serve like biological shielding for 100.000 Ci of Cobalt-60. At the present, Náyade Unit has 4.000 Ci distributed in 60 sources in six lots according to its activity. Therefore at CIEMAT we have the possibility to carry out a high kind of irradiation experiments to assess the stability of selected systems, even a simplified simulated irradiation loop.

CIEMAT has laboratories to study gas transport processes in porous media, both under steady and transient conditions and advanced laboratory on unsaturated soil mechanics to perform THM tests on materials often used in radioactive waste disposal such as bentonite and argillaceous rock.

CIEMAT develops an annual E&T Plan open to all player (academia, research institutions and industry), but specially focused on research and industry, that promotes the research as well as encouraging the search of solutions for addressing the main great global challenge in a multidisciplinary approach. In addition, it offers the training of scientific personnel and technologists, as well as support to research groups and companies for their participation in national and international RD&D projects.

CIEMAT participate also in different national and international projects of capacity building, analysing of infrastructures, mobility of students and professionals, establishing links among institutions and promoting specific education in nuclear field. Also CIEMAT has experience in the implementation of e-learning systems (LCMS), developing e-learning content, MOOCS, and delivering e-learning, blended and face-to-face courses in energy areas.

if operational capacity cannot be demonstrated at the time of submitting the proposal, describe the concrete measures that will be taken to obtain it by the time of the implementation of the task.
N/A

	No	Name	Acronym
Participant	7	Chornobyl Research and Development Institute	ChRDI
Description of the legal entity The Chornobyl Research and Development Institute (ChRDI) is a key scientific organization in the following areas: radiation safety, environmental safety, nuclear and renewable energy, handling of radioactive materials of the nuclear fuel cycle, fundamental and technological research in the field of chemical sciences, physical sciences, environmental sciences. ChRDI has extensive experience in the management of radioactive waste and spent nuclear fuel, including emergency and accidental radioactive materials. Permanent staff of the Institute work in stationary conditions in the city of Kyiv and on the territory of the Chornobyl Exclusion Zone, as well as like mobile emergency personals on radioactive and chemical «dangerous» objects. Based on own experience and recognition of other science and technical organizations, ChRDI actively participates in joint projects and programs with foreign and domestic academic and industrial partners. ChRDI (Department of Nuclear Technology and Radiation Safety) is the main task for safe handling of spent nuclear fuel, monitoring of the state of biological protection, including emergency radioactive materials. In this context, ChRDI conducts research for the management of radioactive waste and spent fuel.			
Description of main tasks in EURAD-1, with an explanation of how its profile matches the tasks ChRDI is involved in Spent Fuel Characterization (WP SFC) Subtask 4.2 Consequence Analysis of Postulated Accidents, ChRDI will conduct special studies and provide data for 20 years of research. The results of 20-year studies include: analysis of the status of temporary storage facilities (intermediate storage) in which radioactive waste was contained (dynamics for 20 years) and those where radioactive waste was stored without pre-treatment and conditioning and was placed directly in the reinforced concrete compartments of the near-surface storage (dynamics for 20 years). Analysis of the causes of radiation accidents and their consequences during interim storage of radioactive waste. The ChRDI also has large experience in handling of radioactive materials, their identification, characterization and transport to the places of disposal. Important is the experience of the ChRDI when assessment of engineering structures and places of long-term storage of radioactive materials, degradation of the state of multilayer containers and engineer barriers over time and under the influence of ionizing radiation, other external factors (from the moment of the accident at the Chernobyl Nuclear Power Plant). WP15- ConCorD : All activities are performed by the Linked Third Party KIPT described in 4.2			
a curriculum vitae or description of the profile of the persons, including their gender, who will be primarily responsible for carrying out the proposed research and/or innovation activities Dr. Iryna Poliakova (female) received a degree of Master of physics from Kyiv National Taras Shevchenko University (Department of Nuclear Physics), Ukraine in 2003 and a PhD degree from Academy of Postgraduate Education and Management under the Ministry of Ecology and Natural Resources of Ukraine, Ukraine in 2017. Since 2017 she works at the ChRDI as Head of the Department of Nuclear Technology and Radiation Safety. In 2003, began her career as an engineer at the Radioactive Waste Management Company at State Corporation «Radon». Participates in many scientific studies and state and international projects related to the nuclear-fuel cycle waste, technical decisions on the safe storage of radioactive materials, and environmental protection. Among the projects: -The Radiation Protection in Uranium Industry in Accordance with the IAEA's International Safety Standards and Council Directive 2013/59/EURATOM. (International project IAEA - Ukraine) - 2014-2015; - Segregation of emergency radioactive waste arising from a radiation accident at Fukushima-1 (Japan). - 2012 - 2014 (International project Japan-Ukraine); - Manufacturing and certification of packing transport containers PKTIV-120H, intended for transportation and temporary storage of waste ionizing radiation sources in near-surface storage facilities of radioactive			

waste of Ukraine at special enterprises of the State Corporation «Ukrainian State Association "Radon»-2012 (International project France-Ukraine);

- Manufacturing and certification of mobile modular protective camera for discharging of spent sources of ionizing radiation of types Э1 - Э3, Э1М - Э4М, БГИ-30, БГИ-45, БГИ-60А, БГИ-75А, БГИ-90А, БГИ-45У, БГИ-60У, БГИ-75У, БГИ-90У with the subsequent localization of spent sources of ionizing radiations in the packaging transport container PCTIV-120Н.- (International project France-Ukraine). - 2012-2014.

-Removal of spent sources of ionizing radiation from installations K-100000 and MPX-γ-25M of the Institute of Physics of the National Academy of Sciences of Ukraine - 2008 to 2009 (International project USA - Ukraine).

Author of Patents:

Patent № 113939 «Method of storage of liquid radioactive waste», 27.02.17.

Patent № U2017082019 «Installation for simulating (reconstitution) the environment of the mine and research of devices and elements of aerogas, dust and dosimetric control taking into account the parameters of the environment», 08.08.2017.

Dr. Pavlo Korchagin (male) received a Master degree from Kyiv National Polytechnic Institute, Ukraine, and a PhD degree from Polytechnic Institute, Ukraine in 2003. Since 2016, he works at the ChRDI. He began his career as a scientist in the radiological laboratory of the Institute of Nuclear Research, Ukraine. After the accident at the Chernobyl Nuclear Power Plant in 1986, he was transferred to the Chernobyl Exclusion Zone, eliminating the consequences of the radiation accident. He has considerable theoretical and practical experience in dealing with radioactive waste, spent nuclear fuel, and emergency waste. One of the authors of the Law of Ukraine "On Radioactive Waste Management". Has many scientific and technical solutions in issues related to deep geological disposal. Participates in many international projects.

a list of up to 5 relevant publications, and/or products, services (including widely-used datasets or software), or other achievements relevant to the call content

Poliakova I., Korchagin P. «Creation of the infrastructure for long-term storage and disposal of radioactive waste resulting from the Chornobyl catastrophe», Monograph. Twenty-five years of the Chernobyl disaster. Safety of the Future: National Report of Ukraine /Editorial: V. Baloga (editor in chief), V. Holosha (deputy editor-in-chief), O. Yevdin (Deputy Editor-in-Chief), G. Perepelyatnikov (executive secretary, M. Borisyuk, A. Ishchenko, etc. - K.: KIM, 2011. - p. 259-262. (Ukr.).

Poliakova I. «Evaluation of the protective properties of the container for the storage of spent sources of ionizing radiation», Collection of scientific works of the Institute of Geochemistry of the environment. - Kyiv, 2013. - Issue. 22. - p. 179-187. (Ukr.).

Korchagin P., Poliakova I. «Assessment of long-term safety of radioactive waste disposal sites», Materials of the scientific and technical conference «Problems of Radioactive Waste Management in Ukraine» IX International Forum «Protection Technology». - Kyiv, 2010. - p. 51-54. (Ukr.). “Diffusion of organic anions in clay-rich media: effects of anion exclusion on retardation”; Dagnelie R.V.H, Rasamimanana S., Blin V., Radwan J., Thory ., Robinet J-C., Lefèvre G. Chemosphere, submitted.

Andrievsky V., Poliakova I., Tokarevsky V., Turbaevsky V. «The problems of handling of radioactive technological products in the production of nuclear fuel in Ukraine», Ecological Sciences: Scientific and Practical Journal. - Kyiv, No. 1-2 /2016 (12-13) - p. 109-11. (Ukr.).

Korchagin P., Zamostyan P., Shestopalov V. Monograph «Treatment of radioactive waste in Ukraine: problems, experience, perspectives», Kiev, Ivan Fyodorov Publishing House, 2000, -178 p.

a list of up to 5 relevant previous projects or activities, connected to the subject of this proposal

1. Awareness-raising and informational campaign within the framework of the program of spent isolated ionizing radiation sources handling. Amnesty of ionizing radiation sources. In partnership with Oak Ridge National Laboratory, USA, 2016.
2. Segregation of Emergency Radioactive Waste Arising From a Radiation Accident at Fukushima-1 (Japan). - 2012 - 2014 (International project Japan-Ukraine).

3. Scientific and technological research partnership for sustainable development (Science and Technology Research Partnership for Sustainable Development, SATREPS). In partnership with Fukushima University, 2015. 4. Project of the NATO Trust Fund for the Disposal of Radioactive Waste in Ukraine. Elimination of Vakulenchuk Radioactive Waste Repository. On the order of NATO Support and Procurement Agency (NSPA). In partnership with NT-Engineering company, 2016. 5. The concept of reforming the Chornobyl Exclusion Zone "Reform of the Exclusion Zone". In partnership with the State Agency of Ukraine on Exclusion Zone Management, 2016. 6. Rebranding of the Chornobyl Exclusion Zone "Chernobyl - Territory of Change". In partnership with the Ministry of Ecology and Natural Resources of Ukraine and the State Agency of Ukraine on Exclusion Zone Management, 2015. 7. The research project on the cultivation of energy crops in the exclusion zone has been initiated as a part of the development of the concept for reforming the Chornobyl Exclusion Zone (the Zone) and the use of alternative and renewable energy sources, 2015.
a description of any significant infrastructure and/or any major items of technical equipment, relevant to the proposed work; Radiological Laboratory in the Chornobyl Exclusion Zone.
if operational capacity cannot be demonstrated at the time of submitting the proposal, describe the concrete measures that will be taken to obtain it by the time of the implementation of the task. N/A

	No	Name	Acronym
Participant	8	Centre Nationale de Recherche Scientifique	CNRS
Description of the legal entity The CNRS (National Centre for Scientific Research) is a government-funded research organization under the administrative authority of French Ministry in charge of research. As the largest fundamental research organization in Europe, CNRS is involved in all fields of knowledge. Interdisciplinary programs and actions offer a gateway into new domains of scientific investigation and enable CNRS to address the needs of society and industry. CNRS is organized in 1053 research units spread throughout France. These units are either intramural or in partnership with universities, other research organizations, or industry. CNRS is involved in research on nuclear waste mainly through four of its ten institutes (IN2P3, INC, INSMI, INSU). Additionally, CNRS has an academic research network SCINEE (Nuclear Science for energy and environment) including French universities and leads a national program on nuclear energy NEEDS (Nuclear Energy Environment Waste Society) with national R&D partners (ANDRA, EDF, ORANO, FRAMATOME, IRSN, BRGM, CEA) including material for nuclear waste and nuclear waste geological disposal. CNRS has specific roles in ACED, DONUT, GAS, HITEC, FUTuRE, CORI, SFC and UMAN. The Hubert Curien Pluridisciplinary Institute (IPHC) is a French Research Institute belonging to both the Nuclear and Particle Physics National Institute (IN2P3) of National Scientific Research Center (CNRS) and the University of Strasbourg. With some 400 employees, IPHC is one of the biggest Institute of Strasbourg University. Founded in 2006, IPHC spans a wide range of scientific disciplines and includes four Departments, namely, the Department of Ecology, Physiology and Ethology, the Department of Subatomic Research, the Department of Analytical Sciences, and the Department of Radiobiology, Hadron Therapy and Molecular Imaging. IPHC is a successful example of an ambitious institute that aims to gather diverse scientific expertise and advanced equipment, and to bring out multidisciplinary research projects contributing at the highest scientific and technological levels to development of basic scientific knowledge and to applications addressing key societal challenges in areas such as energy, health and the environment. CNRS/IN2P3/IPHC has specific roles in FUTuRE. CNRS/IN2P3/Subatech The laboratory SUBATECH is a mixed research unit, operated conjointly by the legal entities CNRS, the IMT-A and the University of Nantes. In the EURAD EURAD only personnel of IMT-A (linked third party to CNRS) and of the CNRS contribute. The laboratory is located in Nantes/France on the campus of IMT-A. The laboratory has been ranked “excellent” by the national evaluation commission HCERES. The laboratory produces about 120 papers largely in high impact journals with about 6000 citations per year. About 5 papers per year are on the thematic of EURAD. Principal research orientations are in nuclear physics and in radiochemistry. Nuclear waste management and disposal is a key research subject of this laboratory, supported also by a Chair, financed by industry. The laboratory pilots as well the recent ERASMUS mundus project SARENA, which is the only ERASMUS mundus on nuclear energy in Europe and it offers a strong contribution to teaching in nuclear waste management. CNRS/IN2P3/Subatech has specific roles in ACED, FUTuRE, CORI and UMAN. CNRS/INC/CEMHTI The CEMHTI laboratory (CEMHTI: Conditions extrêmes et Matériaux : Hautes Températures et Irradiations, UPR3079) (Orléans, France) is managed by Catherine Bessada. It has a total of 70 permanent researchers, engineers and technicians. The activities are organized in 4 teams of researches mainly focused on the study of materials and their characterization in extreme conditions of temperature and irradiation. One of these poles called DEFIR (Defects, Impurities Radiotracers: Properties, materials and imaging) is managed by Marie-France Barthe and dedicates its research activities in the field /study of nuclear materials and their behaviour under irradiation. The researchers have good expertise in experimental studies of the irradiation induced damage and the interactions of light elements with defects in different materials (SiC, UO₂, W, Fe based alloys...) by using positron annihilation spectroscopy and ion beam			

analysis techniques available around the different accelerators operated and developed in the “Particle beam Platform” : cyclotron, Pelletron and slow positron beams.
CNRS/INC/CEMHTI has specific roles in SFC.

CNRS/INC/ICSM

The activities of ICSM are mainly devoted to the elaboration and characterization of several kinds of optimized actinide bearing precursors prepared by wet chemistry routes, then to their conversion into the final actinide-based oxides by heating. A particular interest is focused either on the sintering capability of the materials during densification process and also to the evaluation of the chemical durability of the materials when submitted to dissolution/leaching/alteration tests in order to understand their behavior during their reprocessing or in the field of their long-term storage in underground repository site. In particular, two laboratories have developed new ways of in situ and in operando monitoring of evolving solid/liquid interfaces during dissolution or leaching tests by combining microscopy and spectroscopy based techniques.
CNRS/INC/ICSM has specific roles in SFC.

CNRS/INC/IC2MP

The Institute of Chemistry of Poitiers: Materials and Natural Resources (IC2MP) is a multidisciplinary research institute that specializes in the study of materials, the natural environment, and reactions. The Institute particularly focuses on the synthesis, decontamination and exploitation of natural resources. The Institute is composed of a total of ~250 persons including a staff of 100 researchers (75 faculty members from the University of Poitiers and 25 CNRS), 50 Engineers & Technician staff, ~80 PhD students and ~20 postdoctoral researchers.
CNRS/INC/IC2MP has specific roles in FUTuRE and GAS.

CNRS/INSIS/3SR

Laboratoire 3SR - Sols, Solides, Structures, Risques - conducts cutting edge research in solid mechanics, with application to structural, civil and environmental engineering, as well as energy and health. It is a « Unité Mixte de Recherche » meaning that it is under the administrative and scientific tutelage of three institutions: one national research body CNRS-INSIS, as well as two local universities, l'Université Grenoble Alpes and Grenoble-INP. This research lab is divided into three research teams. The research done in Laboratoire 3SR is in the general field of Solid Mechanics. More specifically, the main domains of the research carried out in Laboratoire 3SR concern:

- Technological and Environmental Risks:
- For surface and sub-surface storage
- For gravity and seismic risk
- For underground collapse (structure-climate interaction)
- Safety of sensitive structures
- The Mechanical Behaviour and Maintenance of:
- Structures and geotechnical engineering works
- Complex materials (granular media, porous media, fibrous and woven materials, reinforced, biological and bio-inspired materials, etc.)

In all these domains are approached by experiments and modelling which are done both at the material scale, as well as at the engineering scale. Experimental work is carried out with the objective of understanding, analysing and informing theoretical and analytical models taking into account physical-mechanical coupling over multiple scales. Laboratoire 3SR has numerous original and relevant experimental installations in the fields of mechanics of materials, geomaterials as well as structures, with some installations being totally unique worldwide.

CNRS/INSIS/3SR has specific roles in HITEC.

CNRS/INSMI/LJAD

The LJAD laboratory is structured around 6 teams: Algebra, Topology and Geometry
Geometry, Analysis and Dynamics, EDP and Numerical Analysis, Numerical Modeling and Fluid Dynamics, Probability and Statistics, Interfaces of Mathematics and Complex Systems. Bringing together 135 researchers and teacher-researchers, 16 administrative staff and research assistance engineers and 74 doctoral and post-doctoral students, the laboratory is also a partner of INRIA, of the CEA (CEA) under the LRC Fusion of the Doctoral School (EDSFA) and participates in many ANR projects. This project takes

place in the LJAD team Partial Differential Equations and Numerical Analysis (around 40 permanent researchers and 20 PhD students) which has developed for a few years a group on geosciences applications including 2 permanent researchers, Konstantin Brenner and Roland Masson, and several doctoral and postdoctoral students.

CNRS/INSMI/LJAD has specific roles in DONUT.

CNRS/INSMI/LMAP

The Porous Media Group of LMAP (University of Pau and Pays de l'Adour (UPPA) & CNRS UMR 5142) is involved in the development and the implementation of advanced mathematical and numerical methods for modeling multi-scales reactive multiphase flow in reservoirs including thermo-hydro-mechanical impacts, pore scale modeling and simulation of complex fluid flows, numerical homogenization. We investigate high-performance parallel processing as a tool to develop a new generation reservoir simulator implemented in the environment of the parallel open-source software DuMuX.

CNRS/INSMI/LMAP has specific roles in DONUT

CNRS/IRCER

The University of Limoges (via IRCER) proposed a contribution in the ConCorD workpackage set in subtask 2.1 where ceramics are considered as novel materials for overpacks. It is based on current IRCER knowledge acquired in the fabrication of large silico-aluminate ceramic containers and their sealing with a ceramic-based material as-well. The idea here will be to adapt the ceramic formulations of the sealing material to allow an optimized microwave sintering (i.e., optimized material/microwave coupling), this last point being treated specifically by the team of EMSE-LGF. The mechanical properties and lixiviation tests of the assemblies will allow to estimate the efficiency and durability of these new kinds of materials.

University of Limoges proposes to develop intimate blends of ceramic powders and ideally core-shell ceramic powders containing a glassy phase starting from the sealing formulations based on IRCER's know-how acquired during a previous project a previous project dedicated to the sealing of containers by plasma technology. It is expected from the blends or core-shell structuring at the local scale of the different components of the sealing material a better if even optimized coupling with the microwaves. For instance, the core and the shell will differ by their ability to couple the microwaves. It will then be possible to derive benefit locally (i.e., at the powder grain level) of the best-coupling material to get a localized, efficient, homogeneous and fast heating process. These sealing formulations will be basically silico-aluminates that will be modified, if necessary, following a sol-gel route. The IRCER's work will be conducted in direct collaboration with the team of CNRS – LGF UMR 5146, who will be the End-User of the powders and will perform the microwave experiments.

Description of main tasks in EURAD-1, with an explanation of how its profile matches the tasks

See detailed sheets per CNRS laboratory

a curriculum vitae or description of the profile of the persons, including their gender, who will be primarily responsible for carrying out the proposed research and/or innovation activities

See detailed sheets per CNRS laboratory

a list of up to 5 relevant publications, and/or products, services (including widely-used datasets or software), or other achievements relevant to the call content

See detailed sheets per CNRS laboratory

a list of up to 5 relevant previous projects or activities, connected to the subject of this proposal

See detailed sheets per CNRS laboratory

a description of any significant infrastructure and/or any major items of technical equipment, relevant to the proposed work.

See detailed sheets per CNRS laboratory

8/CNRS	Name	Acronym
	Institut Pluridisciplinaire Hubert Curien UMR 7178 CNRS/IN2P3 – University of Strasbourg	CNRS-IPHC
Description of the legal entity The Hubert Curien Pluridisciplinary Institute (IPHC) is a French Research Institute belonging to both the Nuclear and Particle Physics National Institute (IN2P3) of National Scientific Research Center (CNRS) and the University of Strasbourg. With some 400 employees, IPHC is one of the biggest Institute of Strasbourg University. Founded in 2006, IPHC spans a wide range of scientific disciplines and includes four Departments, namely, the Department of Ecology, Physiology and Ethology, the Department of Subatomic Research, the Department of Analytical Sciences, and the Department of Radiobiology, Hadron Therapy and Molecular Imaging. IPHC is a successful example of an ambitious institute that aims to gather diverse scientific expertise and advanced equipment, and to bring out multidisciplinary research projects contributing at the highest scientific and technological levels to development of basic scientific knowledge and to applications addressing key societal challenges in areas such as energy, health and the environment.		
Description of main tasks in EURAD-1, with an explanation of how its profile matches the tasks Tasks will be handled by the Radiochemistry IPHC team, which has a long experience in actinide / lanthanide chemistry studies and has developed innovative methodologies to elucidate speciation of actinides and heavy metals at mineral / water interface and effect of organic matter. Main IPHC tasks are as follows. (1) Experimental investigations on surface complexes of uranyl formed at the low concentration level in relevant uranyl-solution-compacted clay systems (COX and Opalinous clay), in presence of phosphate ligands, small organic molecules and competing trace metals (Ni and Fe), by means of ATR-FTIR spectroscopy and complementary techniques (CPM and ESI-MS). (2) ATR-FTIR experiments to investigate sorption reversibility of uranyl sorbed in the uranyl-solution-compacted clay systems (COX and Opalinous clay) and uranyl-solution-hematite systems studied. These two main tasks match with the subtasks in the EURAD proposal entitled “Mobility of Radionuclides in the compacted clay” and “Reversibility of sorption”.		
a curriculum vitae or description of the profile of the persons, including their gender, who will be primarily responsible for carrying out the proposed research and/or innovation activities Del Nero Mirella Date of birth: 10 August 1965, Female PhD in Geochemistry CNRS Researcher at the Hubert Curien Pluridisciplinary Institute (IPHC) Department of Subatomic Research, Radiochemistry group, UMR7178 French National Research Center (CNRS) - Strasbourg University, Strasbourg, France. 35 international publications, 93 oral/poster communications Scientific profile description I am a multidisciplinary scientist using (geo)chemistry to understand the migration behavior of actinides (An) and other trace metal elements (TME) in natural systems. My main research interest is exploring the chemical speciation of An / TME in mineral-solution systems relevant to geosphere. I have taken on major scientific challenges related to the field of environmental chemistry of An and TME, i.e., molecular-level identification of species, in situ speciation at (nano)mineral-solution interfaces, effect of natural organic matter, by using experimental set-ups based on advanced surface spectroscopy techniques (e.g., ATR-FTIR) or ultrahigh resolution mass spectrometry technique (ESI-FTMS). Another area of interest is applying mechanistic data on the sorption / speciation of An and TME acquired in laboratory to field data in order to provide new insights into micro-pollutant transfers in the environment.		
a list of up to 5 relevant publications, and/or products, services (including widely-used datasets or software), or other achievements relevant to the call content Fleury G., Del Nero M., Barillon R. 2017. Molecular fractionation of a soil fulvic acid (FA) and competitive sorption of trace metals in hematite-solution systems: effect of the FA-to-mineral ratio. <i>RSC Advances</i> , 7, 43090 – 43103. Fleury G., Del Nero M., Barillon R. 2017. Effect of mineral surface properties on the sorptive fractionation mechanisms of soil fulvic acids: molecular-scale ESI-MS studies. <i>Geochim. Cosmochim. Acta</i> , 196, 1-17. Galindo C., Del Nero M. 2013. Trace Level Uranyl Complexation with Phenylphosphonic Acid in Aqueous Solution: Direct Speciation by High Resolution Mass Spectrometry. <i>Inorganic Chemistry</i> , 52, 4372-4383.		

Del Nero M., Galindo C., Bucher G., Georg S., Mazan V., Barillon R. 2013. Speciation of oxalate at corundum colloid-solution interfaces and its effect on colloid aggregation under conditions relevant to freshwaters. <i>Colloids and Surfaces A: Physicochemical and Engineering Aspects</i>, 418, 165-163. Del Nero M., Galindo C., Barillon R., Madé B. 2011. TRLFS Evidence for Precipitation of Uranyl Phosphate on the Surface of Alumina: Environmental Implications. <i>Environmental Science and Technology</i>, 45(9), 3982–3988.
a list of up to 5 relevant previous projects or activities, connected to the subject of this proposal • INTERREG 2016-2018 EU Program. Participation to the project “URCforSR: Upper Rhine Cluster for Sustainability Research”. Leaders: Universities of Freiburg and Basel. • EC2CO / ECODYN 2017-2018 Program of CNRS / INSU (Earth Sciences Institute). Leader of the project “ECOMU: An interdisciplinary approach for evaluating eco-toxicological impacts of soil metal micro-pollutants of a former uranium mine (Rophin, France)”. • FaiDoRA (weak doses, risks, alerts) 2016 Program of the Interdisciplinary Mission of the CNRS. Leader of the project “BIOECO-MET: A new methodology for evaluating bioavailability and impacts of soil micro-pollutants”. • Master-Project 2018-2017 “Radionuclides in their environment” of CNRS / IN2P3 (Nuclear and Particle Physics National Institute). Co-leader of the project “Ecodynamics of heavy metals in the environment”.
a description of any significant infrastructure and/or any major items of technical equipment, relevant to the proposed work; Relevant Equipments : - Attenuated Total Reflectance Fourier Transform Infrared Spectroscopy (ATR-FTIR) : a surface spectroscopy technique to investigate in-situ chemical species sorbed at trace level at the mineral-solution interface and to obtain their IR spectra - Coherence Probe Microscopy (CPM): a non-destructive microscopy technique to conduct in-situ and depth-resolved investigations on the morphology of surface species / precipitates formed at the mineral-solution interface - Electrospray ionisation Fourier Transform Mass Spectrometry (ESI-FTMS) - A powerful mass spectrometry technique for identifying chemical aqueous species / molecules in complex mixtures and obtaining their rough chemical formula.

	Name	Acronym
8/CNRS	Centre Nationale de Recherche Scientifique Laboratory SUBATECH	CNRS-SUBATECH
Description of the legal entity The laboratory SUBATECH is a mixed research unit, operated conjointly by the legal entities CNRS, the IMT-A and the University of Nantes. In EURAD only personnel of IMT-A (linked third party to CNRS, see section 4.2) and of the CNRS contribute. The laboratory is located in Nantes/France on the campus of IMT-A. The laboratory has been ranked “excellent” by the national evaluation commission HCERES. The laboratory produces about 120 papers largely in high impact journals with about 6000 citations per year. About 5 papers per year are on the thematic of EURAD. Principal research orientations are in nuclear physics and in radiochemistry. Nuclear waste management and disposal is a key research subject of this laboratory, supported also by a Chair, financed by industry. The laboratory pilots as well the recent ERASMUS mundus project SARENA, which is the only ERASMUS mundus on nuclear energy in Europe and it offers a strong contribution to teaching in nuclear waste management.		
Description of main tasks in EURAD-1, with an explanation of how its profile matches the tasks WP 1 PMO: participation in project coordination, B. Grambow WP 3 ACED/Task 2.1, 2.2 and 3.1: contribute to the characterization of the interface experiments (glass/steel; steel/clay, cement/steel) using isotopic tracing techniques WP 4 CORI /task 1.1: coordinator, 1.2 contribution to SOTA, 1.3 preparation of training material, 2.0 study of alpha/ Gamma Radiolytic degradation of Superplasticizers using available irradiation facilities and characterization of degradation products in solution and gas phase and 4.0 characterization of the interactions of organics, radionuclides and cement: The main objective is studying the effect of ISA on the mobility (uptake and transport) of U(VI) in hardened cement pastes: study the diffusion behaviour in HCP samples in presence of ISA for two degradation states, (II and III) WP 5 FUTURE/Task 2: contribute to the identification / quantification of the uptake processes of elements of interest considering both the “real” (and notably the behaviour of the naturally-occurring elements) and model systems. WP 6 GAS/Task 2.1: Subatech will perform computational atomistic modelling to investigate the molecular mechanisms of gas sorption in clay-based materials with further extension to a mesoscale and multiscale modelling and will contribute to characterize the nanoporous structure properties and its effect on H2 sorption (IR/Raman spectroscopy, X-Ray diffraction, QENS, etc.). WP 9 UMAN/Task 3.1: Subatech is subtask leader to provide a high-level integrated picture of the various types of uncertainties that are potentially relevant for safety. WP15- ConCorD: SUBATECH proposes to study the effect of gamma irradiation on the physicochemical evolution of the interface of container material and buffer. Traditional (copper, carbon steel) and novel materials will be used as well as the buffer material (bentonite, bentonite mixes, geopolymers). We have been studying the effect of gamma radiation on a variety of systems and materials under simulated repository-relevant conditions (dose rate, integrated dose, temperature, water saturation, water composition) for the last two decades. Among the materials investigated we distinguish waste matrices (spent nuclear fuel, nuclear glasses, ceramics, graphite), engineered barriers (cement, concrete, containers) and host rock (in particular clays). The interface material/buffer will be irradiated in a Cs-137 gamma irradiator under controlled atmosphere and relative humidity. The radiolysis products will be analysed, and the solid samples will be characterised. The main outcome would be the material corrosion kinetics and secondary phases that will be used for modelling activities.		
a curriculum vitae or description of the profile of the persons, including their gender, who will be primarily responsible for carrying out the proposed research and/or innovation activities Abdesselam Abdelouas (CNRS/IMT-A, male) is Professor of Radiochemistry and Nuclear Materials at IMT, Atlantique, and Head of the Radiochemistry Group at Subatech Laboratory, Nantes. He graduated from the University of Strasbourg, and spent a US DoE-funded Postdoc working on radioactive waste management. He was named an Expert for the European Commission in the field of Education & Training for the nuclear sector. He is also Adjunct Professor at Mody University, India. He is coordinator of the recently accepted ERASMUS mundus project SARENA. He will participate in WPs ACED and GAS Bernd Grambow (CNRS/IMT-A, male) is Professor of Excellence at IMT Atlantique, Nantes, holding a Chair on nuclear waste disposal and former director of Subatech laboratory. He received his PhD from the		

FU Berlin, and held research positions at the Pacific Northwest National Laboratory, Hahn Meitner Institute Berlin, and Forschungszentrum Karlsruhe. He is an expert in radiochemistry, nuclear waste disposal science, geochemical modeling, and radionuclide migration in the environment. He will participate in the PMO and in UMAN.

Catherine Landesman (CNRS/SUBATECH, feminine) is senior research scientist at SUBATECH laboratory. She received her PhD from the University Paris XI, Orsay as radiochemist. She was working at CEA and IRSN before joining the CNRS. She is specialist in radionuclide interaction with cementitious materials and has participated in many EURATOM projects.

Johan Vandenborre (CNRS/SUBATECH, masculine) has received his PhD in radiochemistry in 2005 from the University Paris XI. He worked onto the radiolytic mechanisms from 10 years with 2 Ph.D. leading and about 15 publications onto this research area. He has worked mainly with the ARRONAX cyclotron which can provide He-ion beam irradiations and gamma source facility. He has developed many analytic tools in order to perform measurements onto solid (Raman Spectroscopy), Solution (UV-Vis Spectrophotometry) and Gas (μ -Gas Chromatography) during irradiation. The aim of this research is the determination of the radiolytic degradation of many species (such as carbonate, calcite, uranium dioxide, Tc) either as solid either in solutions.

Gilles Montavon (CNRS/SUBATECH, masculine), B.Sc. in Chemistry (Strasbourg University), PhD in radiochemistry (Paris-Sud University), is a senior scientist at CNRS in the radiochemistry group of the Subatech laboratory. He leads a team interested in the behaviour of radioelements at ultra-trace concentrations for medical and environmental purposes. He is (co-) author of 82 articles published in peer-reviewed journals (h-index 25). Member of the HCERES as an expert in radiochemistry, he participates in various steering committees for research programs (labex IRON, OSUNA/POLLUSOLS, ZATU)

a list of up to 5 relevant publications, and/or products, services (including widely-used datasets or software), or other achievements relevant to the call content

G. Montavon, A. Sabatié-Gogova, C. Bailly, N. Bessaguet, S. Ribet, D. Durce, E. Giffaut, C. Landesman, B. Grambow Retention of iodide by the Callovian-Oxfordian formation; an experimental study. Applied Clay Sciences, 87, 142-149 (2014)

Chen, Z. Guo, X. Wang, S. Razafindratsima, J.C. Robinet, G. Montavon, C. Landesman Approaches to surface complexation modeling of Ni(II) on Callovo-Oxfordian clay stone. Applied Clay Science 101 (2014) 369–380

Z. Chen, G. Montavon, S. Ribet, Z. Guo, J.C. Robinet, K. David, C. Tournassat, B. Grambow, C. Landesman Key factors to understand in-situ behavior of Cs in Callovo–Oxfordian clay-rock (France) Chemical Geology 387 (2014) 47–58

Grambow B, Geological Disposal of Radioactive Waste in Clay, Elements 12(4):239-245 · 2016

Costagliola, A., J. Vandenborre, G. Blain, V. Baty, F. Haddad, and M. Fattahi, Radiolytic Dissolution of Calcite under Gamma and Helium Ion Irradiation, The Journal of Physical Chemistry C, 121 (2017) 24548-24556.

Bernd Grambow , Johan Vandenborre , Tomo Suzuki-Muresan , Violaine Philippini , Abdesselam Abdelouas , Philippe Deniard , Stéphane Jobic, Solubility equilibrium and surface reactivity at solid/liquid interfaces of relevance to disposal of nuclear waste, J. Chem. Thermodynamics 114 (2017) 172–181

Rachid Bouakkaz, Abdesselam Abdelouas, Bernd Grambow, Kinetic study and structural evolution of SON68 nuclear waste glass altered from 35 to 125 °C under unsaturated H₂O and D₂O vapour conditions, Corrosion Science, 134, 1-16 (2018)

a list of up to 5 relevant previous projects or activities, connected to the subject of this proposal

ANR TESAMI (ANR-MAT et PRO-2012)

ANR CISSRAD (ANR-JCJC-2011)

HTRN FP 5 Euratom

NFPRO, FP5 Euratom

Raphael FP 6, Euratom

FUNMIG, FP6-Euratom

Carbowaste FP6 Euratom

MICADO FP6 Euratom (coordinator)

FRIST Nuclides FP7, EURATOM

CEBAMA H2020, EURATOM

JOPRAD H2020, EURATOM

« Groupements de laboratoire » ANDRA (GL Transfert, 2007-2013 ; GL CTEC 2016-2019)

NEEDS, coordinator of project « Dechets nucléaires »

Master project “stockage des déchets” of CNRS/IN2P3

a description of any significant infrastructure and/or any major items of technical equipment, relevant to the proposed work;

Hot laboratory and LA-ICP-MS, IR/Raman spectroscopy, X-Ray diffraction for work with radioactive and non radioactive substances in WPs CORI, ACED, GAS and FUTURE

Irradiation facilities: The Gamma Source (^{137}Cs) Gamma-Service Medical, model GSM D1 ($E = 0.67$ MeV) is an irradiation facility set in the ARRONAX laboratory. Moreover, the ARRONAX cyclotron provides High energetic He-particle beam ($26 < E < 62$ MeV) useful for our radiolytic degradation experiments. On the same place analytical Tools were developed to measure species into solution and gas produced.

	Name	Acronym
8/CNRS	CEMHTI: Conditions extrêmes et Matériaux : Hautes Températures et Irradiations	CNRS-CEMHTI
Description of the legal entity The CNRS (National Centre for Scientific Research) is a government-funded research organization under the administrative authority of French Ministry in charge of research. As the largest fundamental research organization in Europe, CNRS is involved in all fields of knowledge. Interdisciplinary programs and actions offer a gateway into new domains of scientific investigation and enable CNRS to address the needs of society and industry. CNRS is organized in 1053 research units spread throughout France. These units are either intramural or in partnership with universities, other research organizations, or industry.		
CEMHTI – UPR3079 The CEMHTI laboratory (CEMHTI: Conditions extrêmes et Matériaux: Hautes Températures et Irradiations, UPR3079) (Orléans, France) is managed by Catherine Bessada. It has a total of 70 permanent researchers, engineers and technicians. The activities are organized in 4 teams of researches mainly focused on the study of materials and their characterization in extreme conditions of temperature and irradiation. One of these poles called DEFIR (Defects, Impurities Radiotracers: Properties, materials and imaging) is managed by Marie-France Barthe and dedicates its research activities in the field /study of nuclear materials and their behaviour under irradiation. The researchers have good expertise in experimental studies of the irradiation induced damage and the interactions of light elements with defects in different materials (SiC, UO ₂ , W, Fe based alloys...) by using positron annihilation spectroscopy and ion beam analysis techniques available around the different accelerators operated and developed in the “Particle beam Platform”: cyclotron, Pelletron and slow positron beams. Website: http://www.cemhti.cnrs-orleans.fr/		
Description of main tasks in EURAD-1, with an explanation of how its profile matches the tasks Several people from CEMHTI will be involved in the present project including researchers, engineers and technicians in the work packages Spent Fuel Characterization and Evolution Until Disposal for the subtasks 1.2, 1.3, and 3.2. Marie-France Barthe will be in charge of the scientific work performed in the project and Pierre Desgardin will be involved for positron annihilation spectroscopy and with Thierry Sauvage for helium implantations and characterization using CEMHTI accelerators. The aim is to provide new insights in the He behaviour in simulated spent fuel.		
a curriculum vitae or description of the profile of the persons, including their gender, who will be primarily responsible for carrying out the proposed research and/or innovation activities <u>Marie-France Barthe</u> (contact person, CEMHTI) (F) Female, 53 years, Director of researches at CNRS, deputy manager of CEMHTI, <u>Research activities</u> : study of the properties (nature, formation, recombination, ..) of native and irradiation induced point defects by using positron annihilation spectroscopy in semiconductors (Si, SiC, Diamond...) or insulators (SiO ₂) to understand their electrical properties and in nuclear materials (waste management, GENIV, Fusion reactors : UO ₂ , SiC, iron based alloys, W) to understand their microstructure evolution under irradiation, with special interest in the role of defects in the behaviour of light elements like helium and hydrogen in these nuclear materials (UO ₂ , SiC, W). Formation and Teaching activity: - Lecturer in “Material under irradiation”, and “Positron annihilation Spectroscopy”, University of Orléans (2008-present) - Supervisor of numerous undergraduate (12) and PhD (11) students. <u>Research management</u> : Deputy director, and Head of the research team “DEFIR” in CEMHTI, - Co-director of the “Materials” Project in the NEEDS (Nuclear, Energy, Environment, Defects, Society) French programme. - Leader of Work package and CNRS contact in Euratom projects: F-Bridge (Basic Research for Innovative Fuel Design for GEN IV systems; 2008-2012), (INSPIRE (Investigations Supporting MOX Fuel Licensing in ESNII Prototype Reactors; 2017-2021) - Coordinator of project in “Programme Energie” (CNRS): CHETEXT (2007-2009): Tungsten for fusion: Behaviour of Helium and Hydrogen under irradiation in W, experimental and theoretical studies , - Scientific coordinator for CEMHTI activities in FP7 Euratom projects: F-Bridge (2008-2011), GETMAT (2008-2013), PERFORM60 (2009-2013) - Scientific coordinator for CEMHTI activities in ANR projects : NADIA (2008-2010), RAMIRIS (2008-2010) Publications : 128 publications, 150 Communications in conferences or workshops (107 in international conferences with 11 invited talks), See http://www.researcherid.com/rid/C-6751-2008 ,		
a list of up to 5 relevant publications, and/or products, services (including widely-used datasets or software), or other achievements relevant to the call content		

Substrate temperature and ion kinetic energy effects on first steps of He implantation in tungsten: Experiments and simulations, L. Pentecoste, A-L. Thomann, P. Brault, T. Lecas, P. Desgardin, T. Sauvage, M-F. Barthe, Acta Materialia 141 (2017) 47-58 Lattice location and annealing behaviour of helium atoms implanted in uranium dioxide single crystals, T. Belhabib, P. Desgardin, T. Sauvage, et al, J. of Nucl. Mat. 467, 1-8 (2015) Coupled experimental and DFT plus U investigation of positron lifetimes in UO₂, J. Wiktor, MF Barthe, G. Jomard, et al, Phys. Rev. B90 184101 (2014)
a list of up to 5 relevant previous projects or activities, connected to the subject of this proposal The DEFIR team in CEMHTI has been involved or is still involved in FP7 and H2020 projects such as F-BRIDGE, PERFORM60, GETMAT, MATISSE, MYRTE, SOTERIA, EUROFUSION and INSPYRE.
a description of any significant infrastructure and/or any major items of technical equipment, relevant to the proposed work; Particle beams platform in CEMHTI: This platform operates different types of accelerators. Two of them accelerate light ions (H and He) in the energy range from 0.5 to 3 MeV for the Pelletron and from 7 to 45 MeV for the cyclotron. Various irradiation tools are developed on the beamlines of these machines, especially the DIADDEM and DIAMANT setups dedicated to the introduction of He and its characterization (release as a function temperature, depth profiles) using nuclear reaction $^3\text{He}(d, \text{H})\alpha$. This platform develops and performs the maintenance of slow positron beams used for the characterization of defects in materials. This platform is included in the EMIR French infrastructure.

8/CNRS	Name	Acronym
	Institut de Chimie Séparative de Marcoule	CNRS-ICSM
Description of the legal entity The activities of ICSM are mainly devoted to the elaboration and characterization of several kinds of optimized actinide bearing precursors prepared by wet chemistry routes, then to their conversion into the final actinide-based oxides by heating. A particular interest is focused either on the sintering capability of the materials during densification process and also to the evaluation of the chemical durability of the materials when submitted to dissolution/leaching/alteration tests in order to understand their behavior during their reprocessing or in the field of their long-term storage in underground repository site.		
Description of main tasks in EURAD-1, with an explanation of how its profile matches the tasks In particular, two laboratories have developed new ways of in situ and in operando monitoring of evolving solid/liquid interfaces during dissolution or leaching tests by combining microscopy and spectroscopy based techniques.		
a curriculum vitae or description of the profile of the persons, including their gender, who will be primarily responsible for carrying out the proposed research and/or innovation activities Nicolas Clavier, CR1 Education: PhD in Radiochemistry, University Paris Sud 11 (2004). CNRS tenure researcher since 2006 at the Institute for Separation Chemistry, Marcoule (ICSM – UMR 5257). Member of the Evolving Interfaces in Materials group. Research interests and expertise: fabrication and sintering of nuclear ceramics (fuels, waste form, dedicated instrumentation), radiochemistry, in situ HT characterization techniques (ESEM, Raman, XRD), vibrational spectroscopy of An-bearing compounds Adel Mesbah, CR1 Education: graduated in Chemistry from the University of Constantine in Algeria in 2003. Ph.D. in the physics and chemistry of materials from the University of Henri Poincare – Nancy in 2008. CNRS researcher at ICSM in the laboratory of evolving interfaces in materials (UMR 5257, Marcoule). Research interests and expertise: elaboration and structural characterization by diffraction techniques of actinide-based materials, in particular related to the nuclear fuel cycle. Renaud Podor, IR0 Education: PhD in Solid state chemistry, University of Henri Poincare – Nancy, in 1994. CNRS engineer since 2009 at the Institute for Separation Chemistry, Marcoule (ICSM – UMR 5257). Head of the laboratory dedicated to the study of materials under environmental conditions at ICSM (UMR 5257, Marcoule). Research interests and expertise: material science, in situ HT characterization techniques (ESEM) and in situ / in operando monitoring of evolving interfaces.		
a list of up to 5 relevant publications, and/or products, services (including widely-used datasets or software), or other achievements relevant to the call content 1. L. CLAPAREDE, N. CLAVIER, N. DACHEUX, A. MESBAH, J. MARTINEZ, S. SZENKNECT, P. MOISY : “Multiparametric dissolution of thorium-cerium dioxides solid solutions” Inorg. Chem., 50, 11702-11714, 2011 2. D. HORLAIT, N. CLAVIER, S. SZENKNECT, N. DACHEUX, V. DUBOIS : “Dissolution of cerium(IV)-lanthanide(III) oxides : comparative effects of composition, temperature and acidity” Inorg. Chem., 51, 3868-3878, 2012. 3. S. SZENKNECT, A. MESBAH, D. HORLAIT, N. CLAVIER, S. DOURDAIN, J. RAVAU, N. DACHEUX : “Kinetics of structural and microstructural changes at the solid/solution interface during dissolution of cerium(IV)-neodymium(III) oxides” J. Phys. Chem. C, 116, 12027-12037, 2012. 4. D. HORLAIT, F. TOCINO, N. CLAVIER, N. DACHEUX, S. SZENKNECT : “Multiparametric study of Th _{1-x} Ln _x O _{2-x/2} mixed oxides dissolution in nitric acid media” J. Nucl. Mater., 429, 237-244, 2012. 5. D. HORLAIT, L. CLAPAREDE, F. TOCINO, N. CLAVIER, J. RAVAU, S. SZENKNECT, R. PODOR, N. DACHEUX : “Environmental SEM monitoring of Ce _{1-x} Ln _x O _{2-x/2} mixed-oxides microstructural evolution during dissolution” J. Mater. Chem. A, 2, 5193-5203, 2014.		
a list of up to 5 relevant previous projects or activities, connected to the subject of this proposal ANR COMPACT (2008-2011) New actinide based samples: from precursors to model materials PACEN (2010-2013) then NEEDS projects - Resources FP (2013-2018)		

Solubility and thermodynamic study of uranium or thorium bearing minerals and analogues (phosphates, titanates, silicates, oxides and hydroxides)

GENIORS (2017-2021, H2020)

GEN IV Integrated Oxide fuels recycling strategies, in charge of conversion and dissolution of uranium bearing ceramics

a description of any significant infrastructure and/or any major items of technical equipment, relevant to the proposed work;

The equipment available in the ICSM laboratories (laboratory of evolving interface in materials and laboratory of environmental microscopies and diffraction) allow the elaboration, complete characterization by various techniques (XRD, SEM, TEM, spectroscopies) and sintering of lanthanide, uranium or thorium based materials. Several devices are available to perform the static or dynamic dissolution/leaching/alteration experiments on the prepared radioactive materials. Finally, operando or in situ following of the evolving interfaces is also possible combining ESEM, X-ray reflectometry, Grazing XRD, Raman spectroscopy and AFM.

8/CNRS	Name	Acronym
	Institute of Chemistry of Poitiers: Materials and Natural Resources	CNRS-IC2MP
Description of the legal entity The Institute of Chemistry of Poitiers: Materials and Natural Resources (IC2MP) is a multidisciplinary research institute that specializes in the study of materials, the natural environment, and reactions. The Institute particularly focuses on the synthesis, decontamination and exploitation of natural resources. The Institute is composed of a total of ~250 persons including a staff of 100 researchers (75 faculty members from the University of Poitiers and 25 CNRS), 50 Engineers & Technician staff, ~80 PhD students and ~20 postdoctoral researchers.		
Description of main tasks in EURAD-1, with an explanation of how its profile matches the tasks The work envisaged in FUTUR WP, devoted to the experimental analysis of water and anion diffusion in partially saturated clay media, perfectly the fit in the scope of the priorities of the research thematic developed and the IC2MP regarding the understanding of reactivity of natural media in relation with the exploitation of natural resources. The work envisaged in GAS WP is devoted to the experimental study of the micro-structural and mineralogical changes of claystones in relation with self-sealing and gas migration on the one hand, and to the micro-macro upscaling and development and implementation of a numerical HM model accounting for gas migration and self-sealing. It fits in the scope of the priorities of the research thematic developed and the IC2MP regarding the understanding of the microstructure of clays and clayey rocks as well as upscaling of their hydro-mechanical properties.		
a curriculum vitae or description of the profile of the persons, including their gender, who will be primarily responsible for carrying out the proposed research and/or innovation activities Eric Ferrage is 40 years old and obtained his Ph.D. in 2004 from the ISTERRE Institute in Grenoble (France). In 2005, he was awarded a two-year Marie Curie Intra-European fellowship for a postdoc stay at the Natural History Museum of London (UK). Since his CNRS recruitment in 2007 his research activities contribute to the understanding of the interactions of clay minerals with water and solutes using experimental measurements and theoretical calculations. Eric Ferrage has published 59 international peer-reviewed publications and has contributed to ~120 communications including 20 invited presentations in international or national conferences. Richard Giot is 40 years old and obtained his Ph.D. in 2004 from the LaEGO/ENSG (Nancy, France) He is a specialist of rock mechanics, in particular numerical modelling and HM couplings in clayey rocks. In 2005, he was recruited as a professor assistant at ENSG and attached to LaEGO for research activities. He obtained its HDR in 2013 and was recruited as full professor in 2016 at University of Poitiers (ENSI Poitiers) with research activities at the IC2MP. Richard has published 22 international peer-reviewed publications.		
a list of up to 5 relevant publications, and/or products, services (including widely-used datasets or software), or other achievements relevant to the call content -Tertre E., Savoye S., Hubert F., Prêt D., Dabat T. & Ferrage E. (2018) Diffusion of water through the dual porosity swelling clay mineral vermiculite. Environmental Science & Technology, 52, 1899-1907. -Ferrage E. (2016) Investigation of the interlayer organization of water and ions in smectite from the combined use of diffraction experiments and molecular simulations. A review of methodology, applications, and perspectives. Clays and Clay Minerals, 64, 346-371. -Tertre E., Delville A., Prêt D., Hubert F. & Ferrage E. (2015) Cation diffusion in the interlayer space of swelling clay minerals. A combined macroscopic and microscopic study. Geochimica & Cosmochimica Acta, 149, 251-267. -Hubert F., Bihannic I., Prêt D., Tertre E., Nauleau B., Pelletier M., Demé B. & Ferrage E. (2013) Investigating the anisotropic features of particle orientation in synthetic swelling clay porous media. Clays and Clay Minerals, 61, 397-415. -Michot L.J., Ferrage E., Jiménez-Ruiz M., Boehm M. & Delville A. (2012) Anisotropy features of water and ions dynamics in synthetic Na- and Ca-smectite with tetrahedral layer charge. A combined QENS and molecular dynamics simulations study. Journal of Physical Chemistry C, 116, 16619-16633. - Giot R., Auvray C., Talandier J. 2018. Self-sealing of claystone under X-ray nanotomography. The Geological Society Special Publications. Revision submitted.		

- Dazas B., Ferrage E., Delville A. & Lanson B. (2014) Interlayer structure model of tri-hydrated low-charge smectite by X-ray diffraction and Monte Carlo modeling in the Grand Canonical ensemble. <i>American Mineralogist</i>, 99, 1724-1735. - Fauchille, A. L., Hedan, S., Prêt, D., Cosenza, P., Valle, V., & Cabrera, J. (2014). Relationships between desiccation cracking behavior and microstructure of the Tournemire clay-rock by coupling DIC and SEM methods. In Soga, K., Kumar, K., Biscontin, G., & Kuo, M. (Eds.). (2014). <i>International symposium on Geomechanics from Micro to Macro</i>. CRC Press. ISBN 9781138027077, 1-3 September, Cambridge, pp 1421-1424. - Ferrage E. (2016) Investigation of the interlayer organization of water and ions in smectite from the combined use of diffraction experiments and molecular simulations. A review of methodology, applications, and perspectives. <i>Clays and Clay Minerals</i>, 64, 346-371. - Matskova, N., Pret, D., Gaboreau, S., Cosenza, P., Brechon, R., Gener, I., & Gelin, F. (2017). Towards a Balance of Pore Size Distribution of Non-Conventional Hydrocarbon Reservoirs: a Combination of Bulk Techniques Applied to Comparable Sub-Samples Localized by 3D X-ray μ-Tomography. <i>Unconventional Resources Technology Conference (URTEC)</i>.
a list of up to 5 relevant previous projects or activities, connected to the subject of this proposal -CNRS Interdisciplinary programme NEEDS “porous media” (2016-2018) “Multiscale diffusion of water and solutes in clays”. -CNRS National ECCO programme (2014-2016) “Diffusion and adsorption in clay matrices”. -CNRS Interdisciplinary programme NEEDS “porous media” (2014-2015) “Simulation of virtual porous media for clay minerals”. -French National Funding Agency (ANR) (2009-2012) “Structure and dynamics of interlayer water and ions in smectites”. -CNRS National FORPRO programme (2011-2013) “Influence of water adsorption on pore network modification in clays”. -CNRS National FORPRO programme (2011-2013) “Hydro-Mechanics of clay systems”. -CNRS Interdisciplinary programme NEEDS “porous media” (2016-2018) “Multiscale diffusion of water and solutes in clays”. -French National Funding Agency (ANR) (2009-2012) “Structure and dynamics of interlayer water and ions in smectites”. -CNRS National FORPRO programme (2011-2013) “Influence of water adsorption on pore network modification in clays”.
a description of any significant infrastructure and/or any major items of technical equipment, relevant to the proposed work; All the facilities for the characterization of clay samples and for diffusion experiments are already available at the IC2MP.

8/CNRS	Name	Acronym
	Laboratoire Sols, Solides, Structures et Risques	CNRS-3SR
Description of the legal entity Laboratoire 3SR - Sols, Solides, Structures, Risques - conducts cutting edge research in solid mechanics, with application to structural, civil and environmental engineering, as well as energy and health. It is a « Unité Mixte de Recherche » meaning that it is under the administrative and scientific tutelage of three institutions: one national research body CNRS-INSIS, as well as two local universities, l'Université Grenoble Alpes and Grenoble-INP. This research lab is divided into three research teams. The research done in Laboratoire 3SR is in the general field of Solid Mechanics. More specifically, the main domains of the research carried out in Laboratoire 3SR concern: • Technological and Environmental Risks: • For surface and sub-surface storage • For gravity and seismic risk • For underground collapse (structure-climate interaction) • Safety of sensitive structures • The Mechanical Behaviour and Maintenance of: • Structures and geotechnical engineering works • Complex materials (granular media, porous media, fibrous and woven materials, reinforced, biological and bio-inspired materials, etc.) In all these domains are approached by experiments and modelling which are done both at the material scale, as well as at the engineering scale. Experimental work is carried out with the objective of understanding, analysing and informing theoretical and analytical models taking into account physical-mechanical coupling over multiple scales. Laboratoire 3SR has numerous original and relevant experimental installations in the fields of mechanics of materials, geomaterials as well as structures, with some installations being totally unique worldwide.		
Description of main tasks in EURAD-1, with an explanation of how its profile matches the tasks Laboratoire 3SR has been working for many years on the theme of deep repository of radioactive wastes, both on the characterization of host rocks (several sites in Europe) and on modelling the mechanical behaviour and couplings. Taking into account multiple couplings is one of its research axes. It incorporates imaging skills (X-ray tomography, neutron CT, image correlation DIC) to describe and quantify physical processes. It develops its own modelling tools, notably using multi-scale approaches, to move from behaviour on the scale of the microstructure of the material to behaviour on the macroscopic scale and then that of the engineer, taking into account the phenomena of failure.		
a curriculum vitae or description of the profile of the persons, including their gender, who will be primarily responsible for carrying out the proposed research and/or innovation activities Pierre Bésuelle studies the behaviour of geomaterials and more particularly of rocks, with particular emphasis on the phenomena of failure by strain localization and hydro-mechanical couplings. He has developed original experimental tools for characterizing mechanical behaviour by combining field measurements. It also develops double scale constitutive laws by numerical homogenization of type FEM², the whole in an enriched medium formalism in order to model the failure in an objective way. He has been responsible for one of the teams in the laboratoire 3SR and is currently deputy director of the laboratoire 3SR.		
a list of up to 5 relevant publications, and/or products, services (including widely-used datasets or software), or other achievements relevant to the call content • Bésuelle P., Viggiani G., Desrues J., Coll C., Charrier P., 2013, A laboratory experimental study of the hydromechanical behavior of Boom Clay, Rock Mechanics and Rock Engineering, DOI 10.1007/s00603-013-0421-8. • Di Donna, A. and Laloui, L., Response of soils subjected to thermal cyclic loading: experimental and constitutive study, Engineering Geology, Elsevier B.V., pp. 12, Vol. 190, ISSN: 0013-7952, DOI: 10.1016/j.enggeo.2015.03.003, 2015. • van den Eijnden A.P., Bésuelle P., Collin F., Chambon R., Desrues J., 2016, Modeling the strain localization around an underground gallery with a hydro-mechanical double scale model; effect of anisotropy, Computers and Geotechnics, Volume 85, pp. 384-400.		

Stavropoulou E., Andò E., Tengattini A., Briffaut M., Dufour F., Atkins D., Armand G., 2018, Liquid water uptake in unconfined Callovo Oxfordian clay-rock studied with neutron and X-ray imaging. Acta Geotechnica. 10.1007/s11440-018-0639-4.
a list of up to 5 relevant previous projects or activities, connected to the subject of this proposal projet Needs “Varape” 2016-2018: taking into account the material variability of a natural clay rock within the framework of a double scale modelling
a description of any significant infrastructure and/or any major items of technical equipment, relevant to the proposed work; Laboratoire 3SR is equipped with a multi-scale X-ray CT apparatus where tests can be conducted to image the processes in progress. He has experience working at the ILL in Grenoble to conduct <i>in situ</i> neutron CT.

8/CNRS	Name	Acronym
	Laboratory J.A. Dieudonné of Mathematics	CNRS-LJAD
Description of the legal entity The Laboratory J.A. Dieudonné of Mathematics (LJAD) - UMR 7351 CNRS - includes 6 research teams, around 120 researchers and 40 PhD students. This project takes place in the LJAD team Partial Differential Equations and Numerical Analysis (around 40 permanent researchers and 20 PhD students) which has developed for a few years a group on geosciences applications including 2 permanent researchers, Konstantin Brenner and Roland Masson, and several doctoral and postdoctoral students.		
a curriculum vitae or description of the profile of the persons, including their gender, who will be primarily responsible for carrying out the proposed research and/or innovation activities Roland Masson (male) is full professor at the department of Mathematics J.A. Dieudonné of the University Nice Sophia Antipolis, and leader of the Numerical Analysis and PDEs team. He got his Ph.D at the University Paris VI in 1999 and his Habilitation at the University Paris East in 2006. He has been leader of the applied mathematics department of IFP New Energy from 2000 to 2011. His main research topics deal with discretization methods and solution algorithms for Partial Differential Equations with applications to geosciences. He coordinated and participated to several national projects and industrial collaborations, and has published more than 80 papers.		
a list of up to 5 relevant publications, and/or products, services (including widely-used datasets or software), or other achievements relevant to the call content N. Birgle, R. Masson, L. Trenty, A domain decomposition method to couple nonisothermal compositional gas liquid Darcy and free gas flows, Journal of Computational Physics, 368,1 pp. 210-235, 2018.		
a list of up to 5 relevant previous projects or activities, connected to the subject of this proposal ANR CHARMS « Quantitative Reservoir Models for Complex Hydrothermal Systems » in the challenge Clean, Safe and Efficient Energy (Energie Propre Sûre et Efficace), ongoing project dealing with the simulation of geothermal systems 2016-2020 Erreur ! Référence de lien hypertexte non valide..		
a description of any significant infrastructure and/or any major items of technical equipment, relevant to the proposed work; None		

8/CNRS	Name: Laboratory of Mathematics and its applications UMPR 5142	Acronym: CNRS-LMAP
Description of the legal entity The Porous Media Group of LMAP (University of Pau and Pays de l'Adour (UPPA) & CNRS UMR 5142) is involved in the development and the implementation of advanced mathematical and numerical methods for modeling multi-scales reactive multiphase flow in reservoirs including thermo-hydro-mechanical impacts, pore scale modeling and simulation of complex fluid flows, numerical homogenization. We investigate high-performance parallel processing as a tool to develop a new generation reservoir simulator implemented in the environment of the parallel open-source software DuMu ^X .		
Description of main tasks in EURAD-1, with an explanation of how its profile matches the tasks Since several years, our research interests encompass computational models for porous media flow, transport and deformation phenomena, model coupling and decoupling as well as advanced discretization and solution techniques. Moreover, we are involved in several third-party funded research projects. The group has the experience of numerical simulation of gas migration in the framework of nuclear waste disposal. Indeed, the group was a member from 2002 to 2015 of the French research group MoMaS (Mathematical Modeling and Numerical Simulation for Nuclear Waste Management Problems) and is also part of the French research group MaNu (Mathematics for Nuclear energy). Moreover, from 2009 to 2013, we were involved in the FORGE (Fate Of Repository GasEs) European project (http://www.bgs.ac.uk/forge/home.html). A homemade C++ upscaling code and a finite-volume method implemented in the DuMu^X framework were coupled to study gas migration through engineered and geological barriers for a deep repository of radioactive waste. Since 2012, we have been interested in the coupling between multiphase flow and geochemistry. In the context of the environment DuMu^X, we have developed and implemented a sequential coupling approach solving firstly a fully implicit two-phase flow problem and then a reactive transport problem. Several strategies including sequential iterative approach (SIA) and direct substitution approach (DSA) have been implemented in a high performance computing framework and tested for the resolution of the reactive transport problem. The accuracy and effectiveness of these approaches have been undertaken through numerical investigation for two and three dimensional spaces tests. However, sequential approaches introduce operator splitting errors and some questions about the coupling between all the physical processes have also to be studied to corroborate if some very coupled phenomena can be solved sequentially or if they need to be treated implicitly. Consequently, in view of our above-mentioned competencies, we propose to focus on the two following subtasks: • Development and implementation of a parallel fully-coupled, fully implicit method to solve a non-isothermal reactive multiphase multicomponent flow to achieve improved stability. In comparison with sequential strategies, it will allow the use of larger time steps and secondly, the errors of mass conservation due to the operator splitting will be erased. • Development and implementation of an efficient sequential numerical algorithm for coupling multiphase multicomponent flow and reservoir geomechanics.		
a curriculum vitae or description of the profile of the persons, including their gender, who will be primarily responsible for carrying out the proposed research and/or innovation activities Two permanent people will be involved in the project: • Etienne Ahusborde (CNRS Associate Scientist, LMAP) obtained a Graduate Diploma in Engineering in Mathematics and Mechanical modelling at MATMECA, University of Bordeaux in 2004. After graduation, he performed his PhD in Mechanics at the University of Bordeaux. Since 2010, he is associate scientist for the CNRS. His research activities are mainly dedicated to the numerical simulation of multiphase reactive flows in porous media. His scientific production consists of 19 research papers in peer reviewed journals and approximately 35 oral presentations at national and international conferences and workshops, 3 of which as invited lectures. • Brahim Amaziane (Associate Professor, LMAP) received a PhD of applied mathematics in 1988 from the University of Lyon (France). His research was carried out at INSA Lyon and partly at INRIA Paris and partly at the University of Wyoming, Laramie, USA. His thesis focused on numerical homogenization of two-phase flow in porous media. Since 1988, he works at the University of Pau and Pays de l'Adour as an assistant professor and since 2005 as an associate professor. His scientific production consists of 60 articles in international peer-reviewed journal, about 40 papers in proceedings of international conferences, co-editor of 9 books of international conference		

proceedings, co-editor of 4 special issues of the journal Mathematics and Computers in Simulation (MATCOM) and 2 special issues of the journal Applicable Analysis (AA).
a list of up to 5 relevant publications, and/or products, services (including widely-used datasets or software), or other achievements relevant to the call content 1. Ahusborde E., Amaziane B., El Ossmani M., Improvement of numerical approximation of coupled two-phase multicomponent flow with reactive geochemical transport in porous media, Accepted for publication in Oil and Gas Science and Technology, 2018. 2. Ahusborde E., Amaziane B., El Ossmani M., Finite volume scheme for coupling two-phase flow with reactive transport in porous media, Springer Proceedings in Mathematics and Statistics, Vol 200, 407-415, 2017. 3. Ahusborde E., El Ossmani M., A sequential approach for numerical simulation of two-phase multicomponent flow with reactive transport in porous media, Mathematics and Computers in Simulation, Vol 137, 71-89, 2017. 4. Ahusborde E., Amaziane B., Jurak M. Three-dimensional numerical simulation by upscaling of gas migration through engineered and geological barriers for a deep repository for radioactive waste, Geological Society Special Publication, Vol 415, 123-141, 2015. 5. Amaziane B., El Ossmani M., Jurak M., Numerical simulation of gas migration through engineered and geological barriers for a deep repository for radioactive waste, Comput. Vis. Sci., Vol 15, 3-20, 2012.
a list of up to 5 relevant previous projects or activities, connected to the subject of this proposal 1. 2014-2016: Associate researcher position of Mustapha El Ossmani untitled “Development of a code for numerical simulation of multiphase flows with reactive transport in porous media” (100 K€ funded by ISIFoR: Carnot Institute, Sustainable Engineering of georesources and the Agglomeration Community of Pau-Pyrénées (Territorial Council)). 2. 2017-2020: PhD thesis of Ivana Radišić untitled “Mathematical modeling and numerical simulation of multiphase multicomponent flow with reactive transport in porous media” (funded by the University of Zagreb and the University of Pau and Pays de l'Adour). 3. 2016-2019: PhD thesis of Mohamed Id Moulay untitled “Three-dimensionnal modeling and numerical simulation of multiphase reactive flows in porous media” (funded by ISIFoR and the University of Pau and Pays de l'Adour). 4. 2011-2014: PhD thesis of Viatcheslav Vostrikov untitled “Numerical simulation of two-phase multi-component flow with reactive transport in porous media” (funded by CEA and the University of Pau and Pays de l'Adour). 5. 2009-2013: FORGE project (Fate Of Repository Gases http://www.bgs.ac.uk/forge/). This project funded by the European Union's Seventh Framework Euratom Programme under grant agreement no 230357 studied key gas migration issues in repository performance assessment (200 K€).
a description of any significant infrastructure and/or any major items of technical equipment, relevant to the proposed work; Our group has access to several computing infrastructures: 1. At local level, we have access to the cluster “Pyrene” of the University of Pau and Pays de l'Adour composed of about 1000 cores. 2. At regional level, we have access to the cluster “Avakas” of the MCIA (Aquitaine Mesocenter for Intensive Computing) composed of about 3500 cores. 3. At national level, we have access to the HPC resources of CINES (National Computing Center for Higher Education) composed of about 85000 cores.

	No	Name	Acronym
Participant	9	Centrale Organisatie Voor Radioactief Afval N.V.	COVRA
Description of the legal entity COVRA is a national radioactive waste management organisation of the Netherlands. COVRA is a state-owned enterprise of which the stocks are held by the Ministry of Finance. It is the only company in the Netherlands that is qualified to collect, treat and store radioactive waste and prepare and implement the final disposal. Its legal form is a 'Naamloze Vennootschap' (public limited company). As COVRA is responsible for carrying out all steps in the radioactive waste chain, from collection to the eventual disposal, it has hands on experience with and infrastructure for characterization, treatment and conditioning, storage. It is the smallest certified concrete supplier in the Netherlands, has treatment and storage buildings for all types of radioactive waste. It has two laboratories to perform mechanical experiments, chemical and microbiological analysis and two COMSOL licenses to perform modelling work			
Description of main tasks in EURAD-1, with an explanation of how its profile matches the tasks - DONUT is WP on the development and improvement of numerical methods and tools for modelling of coupled processes. COVRA has just finished its safety case in 2017, in which the safety assessment uses numerical methods and tools for modelling of coupled processes to describe a disposal facility in Boom Clay. COVRA will prepare benchmarks for the evaluation of the methods and numerical tools described considering their relevance in the scope of multi-physical assessment from the point of view of the implementer. Specifically COVRA plans to develop a benchmark for numerical models with steep chemical gradients across solid interfaces. This contribution can be of help with the evaluation of the efficiency and computational cost of different numerical models/solvers for models with a steep chemical gradient across interfaces between solid materials. - Assessment of Chemical Evolution of ILW and HLW Disposal Cells (ACED) is the WP to improve methodologies to obtain multi-scale quantitative models for the chemical model at cell disposal scale based on existing and new experimental data and process knowledge and to improve the description of the most relevant processes driving the chemical evolution into robust mathematical frameworks. COVRA is a co-task leader in this WP and made the first assessment of information from existing or currently running experiments from the first questionnaire that was sent around to interested organizations during the pre-project phase and is responsible for the State of the Art regarding relevant processes that influence the long-term chemical evolution in disposal cells for vitrified HLW and for cemented ILW. Both types of processed waste are owned by COVRA which facilitates access to essential details for parameters that can be used for the models. COVRA contributes to relevant sample material, new experimental data to improve the description of relevant processes, writes the conceptual and mathematical models, and executes calculations at waste package scale and disposal cell scale. - Mechanistic understanding of gas transport in clay materials (GAS) is the WP to improve the mechanistic understanding of gas transport processes in natural and engineered clay materials and to evaluate the gas transport regimes that can be active at the scale of a geological disposal system and their potential impact on barrier integrity and repository performance. COVRA acts as an end-user for this WP and contributes to the conceptualization of gas transport currently treated in COVRA's assessment in natural clay in order to contribute to inform the experimentalists / process-level modellers about the configurations and ranges of conditions that are relevant for disposal systems. - If only because of the long times scales involves, radioactive waste management involves. uncertainty management. Dealing with uncertainties and communicating about them, therefore, forms an integral part of the work COVRA does. The goal of the UMAN work package is to develop a common understanding among the different categories of actors (WMOs, TSOs, REs & Civil Society) on uncertainty management and how it relates to risk & safety. In cases where a common understanding is beyond reach, the objective is to achieve mutual understanding on why views on uncertainties and their management are different for different actors. COVRA will look at the methodological approaches to uncertainty and sensitivity			

analysis. It will participate in technical meetings, share its experience with uncertainty and sensitivity analysis methods and review the deliverable on this topic .

- The WP WM routes in Europe will describe and compare the different approaches to characterization, treatment and conditioning and to long-term waste management routes, and identify opportunities for collaboration between MS (member states). It will identify safety-relevant issues and their R&D needs associated with the waste management routes (cradle to grave), including the management routes of legacy and historical waste, taking into account that programmes are at different stages of development, have with different amounts and types of radioactive waste to manage and considering interdependencies between the routes. COVRA will coordinates the task to evaluate the potential for developing and using shared technologies and facilities. COVRA was involved EC project SAPIERR and has coordinated SAPIERR II, both projects concerning sharing facilities. COVRA chairs the ERDO working group that investigates and promotes sharing R&D, technology and facilities.

COVRA will contribute to ROUTES Extension by

- sharing their national experiences,
- evaluating the applicability of the developed solutions to their challenges and by
- reviewing the reports.
- WP16-MAGIC :
For MAGIC, COVRA's participation in ACED is relevant. COVRA has a lead in the responsibility of the state of the art at the start and the end of this WP, chemical evolution of concrete samples with a focus on the silica aggregates in these samples and conceptualisation and modelling activities at waste package and disposal cell scale. COVRA measures the compressive strength of the concrete samples, the pH profiles and oxygen penetration front profiles after the strength measurement and performs ICP-OES analysis of the exposing solutions and concrete to contribute to the first objective of MAGIC. A major characterisation effort of the concrete samples that is relevant for MAGIC has already been performed e.g. the compressive strength as a function of the saturation degree of these samples. COVRA jointly works with FZK and SCKCEN to study the impact of microbial activity to contribute to the first and third objective of MAGIC.
Task 1: COVRA participates in the End user Group in Task 1 and will contribute to the definition of the base case.
Task 2: The joint Belgian, Dutch and German work investigates the anaerobic and aerobic in microbial influence on the chemo-mechanical behavior of concrete and self-sealing of concrete. Two types of concrete have been made: one type with a required minimum in mechanical strength for safe stacking of waste packages and one type with a lower required minimum in mechanical strength. The samples with a lower required strength for disposal have sufficient large pores for microbial activity. The samples made with OPC are envisaged to have an aerobic environment for this activity and samples made with OPC blended with BFS an anaerobic environment as explained in the proposal. Modelling of the chemical evolution by exposure to a clay pore solution (multi-ionic attack) since 2016 is being performed but will not be charged to MAGIC.

a curriculum vitae or description of the profile of the persons, including their gender, who will be primarily responsible for carrying out the proposed research and/or innovation activities

- Dr. Jeroen Bartol (1984). Researcher at COVRA. Jeroen studied at Utrecht University and Free University Amsterdam where he received a bachelor degree in Earth Science (2007), a master's degree in Geophysics (2008). In 2017, he completed his PhD at Utrecht University. Subject of his PhD was the vertical motions and plate boundary evolution in the Anatolia-Black Sea region. Areas of expertise are geology, sedimentology, numerical (finite element/difference) modelling, rheology and the interaction between surface (e.g. surface uplift/erosion) and subsurface processes (e.g. diapiric process) and he has multiple years of experience as a software developer. He is a member of the NEA Salt Club
- Dr. Erika A.C. Neeft (1974) .Researcher at COVRA. Erika was the technical coordinator for the Dutch national programme on geological disposal. Currently, she describes the safety and design requirements

for the engineered barrier system and calculates the processes of disposed waste in a concrete supported disposal facility in poorly indurated clay. She is a member of the NEA Clay Club and the management board of the NEA Thermodynamic Database and is assigned by the Dutch government to participate in the IAEA International Project on Demonstration of the Operational and Long-Term Safety of Geological Disposal Facilities for Radioactive Waste (GEOSAF Part III). She holds a MSc degree in Earth Sciences from Utrecht University and a PhD in reactor physics (transmutation of nuclear waste) from Delft University of Technology.

- Dr. Ir. Ewoud V. Verhoef (1973). Deputy director of COVRA. Ewoud has lead the Dutch national programme on geological disposal, is the acting chair of the ERDO working group on developing multinational waste management organisation in Europe, and is a member of the executive group of the European technology platform on the disposal of radioactive waste (IGD-TP). He is member of the board of Royal Netherlands Society of Engineers, section Nuclear technology, and the Netherlands Nuclear Society. Ewoud studied chemical technology at Delft University of Technology, where he also received his PhD on research on the influence of policy and legislation on waste management processes.

a list of up to 5 relevant publications, and/or products, services (including widely-used datasets or software), or other achievements relevant to the call content

- Ewoud Verhoef, Erika Neeft, Neil Chapman, Charles McCombie, OPERA Safety case (2017). COVRA report that presents overview of the results and conclusions of the safety case for a geological disposal facility in the Boom Clay in the Netherlands.
- Special issue on Geological disposal of Netherlands Journal of geosciences to geological disposal of radioactive waste Volume 95, Issue 3, September 2016.
- E.A.C. Neeft, Final overview of CAST, CAST report 7.23 (2018) Overview to summarize the results and achievements of CAST and their implications for building confidence in the safety of geological disposal
- R.B. Polder, W.H.A. Peelen, B.Th.J. Stoop, E.A.C. Neeft - Early stage beneficial effects of cathodic protection in concrete structures, Materials and Corrosion 62[2] (2011) 105-110.
E.A.C. Neeft, J.K.H. Visser, W.H.A. Peelen, A.J. van Vliet, J.A. Larbi, Measurements and simulations of the distribution of moisture in concrete, TNO-034-DTM-2009-02726 (2009) 1-81

a list of up to 5 relevant previous projects or activities, connected to the subject of this proposal

- OPERA 2011-2017. Coordination of the national research programme on Geological disposal in the Netherlands. www.covra.nl/downloads/opera
- Cast 2013-2018. WP Leader in EC funded project on C-14 source term www.projectcast.eu
- ERDO-wg. 2009 – present. Chairing and participation in the workgroup. www.erdo-wg.eu
- IGD-tp. Technology platform for the implementation of geological disposal. Member of the executive group. www.igdt.eu
- OECD-NEA. Member of the RWMC, management Board of NEA thermodynamic database, the salt club and the clay club. www.oecd-nea.org/rwm/

a description of any significant infrastructure and/or any major items of technical equipment, relevant to the proposed work;

As COVRA is responsible for carrying out all steps in the radioactive waste chain, from collection to the eventual disposal, it has hands on experience with and infrastructure for characterization, treatment and conditioning, storage. It has treatment and storage buildings for all types of radioactive waste. It has two laboratories to perform experiments and two COMSOL licences to perform the modelling work.

if operational capacity cannot be demonstrated at the time of submitting the proposal, describe the concrete measures that will be taken to obtain it by the time of the implementation of the task

N/A

	No	Name	Acronym
Participant	10	Centre for Physical Sciences and Technology	FTMC
Description of the legal entity			
State research institute acting as TSO in EURAD			
Description of main tasks in EURAD-1, with an explanation of how its profile matches the tasks			
Department of Nuclear Research of FTMC (Engl. FTMC) implements the technological possibilities important for public and NPP needs, performs training and expertise in the fields of nuclear physics, nuclear and mass spectroscopy. The activities are mostly concentrated on numerical analysis (MCNP6, MCNPX, SCALE 6.2, GEANT4, OSCAR LIETDOS, THYROID), criticality, radiation shielding safety, nuclide composition analysis of spent nuclear fuel and radioactive waste and experimental measurements of generation of radionuclides (AMS, IRMS, ICP-MS, nuclear spectrometry equipment: HPGe Detectors, Alpha Particle Spectrometer, X-ray spectrometer, FHT 770 T 6 α, β counter, LSC). Further the mechanism of radionuclide transportation through engineering barriers for the surface repository or geological disposal case, evaluation of safety and reliability of radioactive waste management technology is performed in the department. One of the aims - optimization of nuclear facility radioactive waste RW management based on scientifically approved and environmentally – friendly technology, applying grouping and separation of RW by using modeling and experimental research of nuclide content of radioactive waste from NPPs as well as improvement and application of scaling factor (nuclide vector) methods. In this proposal FTMC (Engl. FTMC) will contribute to: 1. Spent Fuel properties Characterization until disposal (SFC): FTMC will define and verify procedures to determine the source terms of SNF assemblies with realistic confidence limits and will work on comparing the performance of “sophisticated” and “best-practice industry” codes (SCALE6.2 and MCNP6) based on SKB-50 data. The aim of the task to define, verify and recommend state-of-the-art procedures to determine the source terms of SNF assemblies with realistic uncertainties, further (in the second wave of EURAD) the procedures will be applied for other type reactors (RBMK and VVER) to calculate source terms. 2. Cement-Organics-Radionuclides-Interactions (CORI) work package: will perform overview about the organics degradation and release of soluble organic species (PVC and Cellulose), will perform hydrolytic degradation of PVC/Cellulose and identification of degradation products, will study the competitive effect of Fe(II)/Fe(III) onto radionuclides (Am-243 and Pu-242) sorption in the presence of organics (low molecular weight organic acids / phthalate / adipate) in contact with CEM I/ CEM V cement-based materials (pH 12.5); 3. UMAN - EU cooperation activities explaining the uncertainty, risk and safety of different factors. Work will include assessment of uncertainties related to radiological characterisation of radioactive waste generated during NPP operation and decommissioning activities at the different stages of management programme (impact of predisposal steps). Different reactor waste inventory case is specific because of different experience of decommissioning – such analysis of uncertainties relevant to the safety analysis and the safety case will be performed for the first time. The processes cannot be modelled with sufficient precision, or their partial input to the final waste activity cannot be known with adequate accuracy. Therefore general approach is to use the modelling and measurement techniques, complementing each other and therefore reducing the uncertainty and increasing the confidence of activity determination. 4. ROUTES – FTMC will be engage in an activity involving a waste management network in Europe from cradle to grave by touching historical / non-documented waste. FTMC will provide input of Lithuanian situation identify challenging waste streams; describing/comparing waste characterisation approaches; identify WAC's used; disseminating technological waste management solutions for other member states. 5. FTMC will participate in KNOWLEDGE MANAGEMENT activities ensuring access to existing Knowledge (State-of-Knowledge), guiding the development of capability in line with core competencies (Guidance and Training), and improving access to quality tools, resources and communities of practice to share and learn from each other (Dissemination). This project is in compliance with the EU Council Directive 2011/70 on the safe management of all radioactive waste and spent fuel. In 2015 the Government of the Republic of Lithuania has prepared a			

National Program for the Development of Radioactive Waste Management. EURAD will help to implement strategic goals of the program.

a curriculum vitae or description of the profile of the persons, including their gender, who will be primarily responsible for carrying out the proposed research and/or innovation activities:

1. Dr. **R. Plukienė** (female) has 16 years' experience in modeling of the nuclide composition in nuclear systems (SCALE 6.2 MCNPX, MCNP6, Monteburns, ORIGEN, HELIOS codes) and nuclear spectroscopy. She is senior researcher in the mass spectrometry laboratory of FTMC. She was actively participating in nuclear power plant decommissioning projects: responsible for modeling of KNPP constructions and radiological inventory calculation in the project „Evaluation of the Material Backlog and Radiological Inventory of KNPP Units 1 to 4“; responsible for RBMK scaling factor determination in the project: "Assistance to INPP by Technical Support Organisations in the Field of Radiological Characterisation for Block A1 (Reactor and auxiliary systems). Currently she is involved in European Commission „Horizon 2020“ project „Baltic Region Initiative for Long Lasting InnovAtive Nuclear Technologies (BRILLIANT)“ and performing investigation on open/partly closed and closed fuel cycle options in the Baltic region. She was leader of the international programme COST P9 „Radiation Damage in Biomolecular Systems project in our institution (2004-2007). She will be responsible for development of SFC WP activities in EURAD-1 from FTMC. Spent nuclear fuel simulations will be performed by using SCALE6.2 and MCNP6 codes. Estimated volume of works is 3.8 pm (0.36% of SF WP EURAD funds).
2. Dr. **R. Druteikienė** (female) has 20 years' experience in the field of investigation of the peculiarities of radionuclide migration and accumulation abilities in the environmental systems. Currently she is head of mass spectrometry laboratory, chief researcher at FTMC. During the last year her scientific activities are related to investigation of thermodynamically and kinetically controlled processes, surface reactions and microbial processes in the radioactive waste storage barriers. She is actively participating in national and international projects on radioactive waste characterization. She will be responsible for CORI WP activities in EURAD-1 from FTMC. Investigations of cemented radioactive waste are foreseen to ensure the durability of radioactive waste storage. An estimated volume of works is 10 pm (2% of the CORI WP EURAD).
3. Dr. **A. Plukis** (male) has 20 years' experience in nuclear systems modeling, the radiation safety assessment (SCALE 6.2 MCNPX), nuclear spectroscopy and the ion beams use. Currently he is deputy head of department of nuclear research, head of experimental nuclear physics laboratory, chief researcher at FTMC. His main scientific research area is in applied nuclear physics and nuclear power plant decommissioning, modeling of the target for RIB production, neutron cross-section measurement in nToF (CERN), research of kinetics in organic compounds with high quantum luminescence efficiency stimulated by high linear energy transfer particles (neutrons or protons) and photons and development of new systems for low background particle detection. He was leader of several international and national projects: “Characterization of Waste after Decommissioning of Reactor“ (2005 – 2006, project of bilateral French – Lithuanian cooperation programme “Gilibert”); ECONET: Measurements of Yields of the Delayed Neutrons from Nuclear Fission - Splitting Reactions (project of tripartite scientific cooperation (France-Russia-Lithuania); European Commission FP6 project „EURISOL-DS“ (2005 - 2009) for our institution. He is actively participating in national and international projects on radioactive waste characterization. He will be responsible for UMAN WP in EURAD-1 from FTMC. FTMC will collect and synthesize relevant information on inventory uncertainty of various radioactive waste (LLW, ILW, SF/HLW) will contribute to safety analysis of waste package concepts. Volume of work 2 pm (0.9% of UNCERTAINTY WP of EURAD funds).
4. Dr. **L. Juodis** (male) has 18 years research experience in nuclear spectroscopy, heuristic optimization algorithms, radioactive waste management, radiation protection, nuclear fuel thermo-mechanical properties and investigations of the fission product release from the fuel matrix, assessment of internal contamination of reactor primary circuits. He is senior researcher in the experimental nuclear physics laboratory of FTMC. 2010 – 2016, L. Juodis was a coordinator of FTMC work group for assessment the report of environmental impact of Belorussian NPP and participated in governmental commission for solving the nuclear safety and environment protection problems related with nuclear facilities planned to build in the neighborhood of Lithuania, leader of Ignalina program project "Assistance to INPP by Technical Support Organisations in the Field of Radiological

Characterisation for Block A1 (Reactor and auxiliary systems) and leader one of project workpackages of „Horizon 2020“ project „Baltic Region Initiative for Long Lasting Innovative Nuclear Technologies (BRILLIANT)“ at FTMC. He will be responsible for EU cooperation activities ROUTES WP for our institution. Covering the waste management network in Europe from cradle to grave (conditioning, treatment, storage, disposal): priority topic: historical / non-documented waste. The planned volume of work is 2.69 pm (1.32% of ROUTES WP EURAD funds).

5. Dr. **G. Duškesas** (male) has 17 years' experience in the radioactive waste management, radiation protection and expertise of decommissioning of commercial reactors, he was leader of the CARBOWASTE project in our institution, was a contributor to IAEA technical document "Determination and use of scaling factors for waste characterization in nuclear power plants", and is a leader of work package on irradiated graphite characterization at IAEA project GRAPA now. He is research associate in the experimental nuclear physics laboratory of FTMC. He is actively participating in national and international projects on radioactive waste characterization. He is responsible for FTMC activities in Knowledge management program.

a list of up to 5 relevant publications, and/or products, services (including widely-used datasets or software), or other achievements relevant to the call content

1. Remeikis, Vidmantas; Plukis, Artūras; Juodis, Laurynas; Gudelis, Arūnas; Lukauskas, D.; Druteikienė, Rūta; Lujanienė, Galina; Lukšienė, Benedikta; Plukienė, Rita; Duškesas, Grigorijus. (2009) Study of the nuclide inventory of operational radioactive waste for the RBMK-1500 reactor, Nuclear engineering and design, Vol. 239(4), p. 813-818.
2. Barkauskas, Vytenis;. (2016) Actinide-only and full burn-up credit in criticality assessment of RBMK-1500 spent nuclear fuel storage cask using axial burn-up profile, Nuclear Engineering and Design, Vol. 307, p. 197-204.
3. Garankin, Jevgenij; Plukis, Artūras; Plukienė, Rita; Lagzdina, Elena; Remeikis, Vidmantas. (2018) Identification of Particles of Ionizing Radiation by the Analysis of Fluorescence Pulse Form of Thin Pen Film Scintillator, IEEE Transactions on Nuclear Science Vol. 65(2), p. 739 - 743, DOI: 10.1109/TNS.2017.2785683, <http://ieeexplore.ieee.org/document/8231166>
4. Remeikis, Vidmantas ; Lagzdina, Elena; Garbaras, Andrius; Gudelis, Arūnas; Garankin, Jevgenij; , Plukienė, Rita; Juodis, Laurynas; Duškesas, Grigorijus; Lingis, Danielius; Abdulajev, Vladimir; Plukis, Artūras. (2018) Rapid Analysis Method for the Determination of ¹⁴C Specific Activity in Irradiated Graphite, PLOS ONE, p. 1-16, <https://doi.org/10.1371/journal.pone.0191677>
5. Druteikienė, Rūta; Lukšienė, Benedikta; Pečiulytė, Dalė; Mažeika, Kęstutis; Gudelis, Arūnas; Baltrūnas, Dalis Antanas. (2014) Behaviour of ⁹⁹Tc in aqueous solutions in the presence of iron oxides and microorganisms. Applied radiation and isotopes Vol. 89, p. 85-94. ISSN 0969-8043

a list of up to 5 relevant previous projects or activities, connected to the subject of this proposal

2008 – 2013, European Commission FP7 project „Treatment and Disposal of Irradiated Graphite and Other Carbonaceous Waste“ (CARBOWASTE).

2017-2019, Ignalina program project "Assistance to INPP by Technical Support Organisations in the Field of Radiological Characterisation for Block A1 (Reactor and auxiliary systems).

2016-2017, 2200-U12 JOPRAD – EC project (Contract Number: 653951), devoted to the solution of the problems of geological disposal of the spent nuclear fuel.

2007– 2013, European Commission FP7 Collaborative Project REDOX PHENOMENA CONTROLLING SYSTEMS (RECOSY) under grant agreement No.212287.

2013-2015, project No MIP-066/2013 funded by Research Council of Lithuania Radionuclides Migration Parameters Fluctuations in Radioactive Waste Storage Barrier (RADPAR).

a description of any significant infrastructure and/or any major items of technical equipment, relevant to the proposed work;

Applied nuclear physics modeling software: MCNP6, MCNPX, SCALE 6.2, GEANT4 program packages used for different applications solving tasks of particle interaction with material and particularly for determination of nuclide activity in radioactive waste by scaling factor (nuclide vector) method; Computer codes for the evaluation of the contamination levels of various radionuclides in the nuclear power plant equipment, buildings, waste and environment: OSCAR - assessment of radioactive contamination of reactor primary circuit, LIETDOS - simulation of radionuclides migration in the environment, exposure doses for humans and biota; THYROID - assessment of the inhabitants' thyroid exposure doses after the accidents in the nuclear power plants). The modeling software is used for nuclear and radiation safety analysis; generation of radionuclides and mechanism of their transportation through engineering barriers, evaluation of safety and reliability of radioactive waste management technology application, assessment of radionuclide accumulation and migration in the environment.

Mass spectrometry laboratory (AMS, IRMS, ICP-MS) conducts the long-term research and experimental development in physics and technology, achieve the international level competence; to apply mass spectrometry methods to the environmental research, nuclear safety, radioecology fields; to participate in international research programs; to cooperate with domestic and foreign institutions of higher education in preparing highly qualified specialists. The various methods of spectrometry (UV/Vis, IR, Fourier and Raman spectroscopy) and chromatography (gas chromatography equipped with flame ionization detector GC (FID), gas chromatography with mass spectrometer detector, high performance liquid chromatography coupled with spectrophotometric and mass detectors (HPLC-DAD-TOF) are used for quantitative and qualitative analysis of organic compounds.

if operational capacity cannot be demonstrated at the time of submitting the proposal, describe the concrete measures that will be taken to obtain it by the time of the implementation of the task.

N/A

	No	Name	Acronym
Participant	11	Centrum vyzkumu Rez	CV REZ
Description of the legal entity The research organisation Centrum vyzkumu Rez (CV REZ) was founded on 9th October 2002 as 100% subsidiary company of UJV Rez, a.s. (NRI – <i>Nuclear Research Institute</i>). The main aim of the research organisation is research, development and innovations in the field of power generation (especially nuclear). CV REZ owns unique research infrastructure such as experimental research reactors LVR-15 and LR-0 and technological experimental circuits. Significant modernization of the infrastructure is being realized within years 2012-2017 due to realization of the SUSEN project (realized in the framework of the Operational Programme Research and Development for Innovations of the European Regional Development Fund). As of January 1st, 2016 the company CV REZ had a total of 330 employees. The core activities of CV REZ involve fundamental and applied research on experimental research reactors LVR-15 and LR-0. Another activities are arising from the participation of CV REZ in the international Jules Horowitz Reactor project. No less important are national and international projects (especially H2020 projects). CV REZ is a member of the European Energy Research Alliance (EERA) and since 2010 represents the Czech Republic in the EERA managing body – Executive Committee, thereby participating in the realization of the Strategic Energy Technology Plan (SET-Plan). CV REZ is also a member (and co-founder) of the Technology Platform ‘Sustainable Energy CR’.			
Description of main tasks in EURAD-1, with an explanation of how its profile matches the tasks Research Centre Rez (CV REZ) will be providing the gamma irradiator Little Cobalt where the superplasticizers or cement paste samples will be irradiated. Moreover the temperature and the emission of the released gasses will be monitored and regularly analysed. Cement pastes will be tested non-destructively before and after the irradiation. Brushed and/or polished fragments of tested samples will be analysed by SEM, LOM or XRD microscopic analyses. All measured data and work proceeding will be discussed with the other partners in the work team, e.g. with UJV, CTU or SÚRAO. WP16: MAGIC : The work will contribute to Task 1, 2 and 3 - it will focus on the evolution of mechanical behaviour of a low-pH cementitious material under repository-like conditions during an operational phase (10-30°C, saturated and partially saturated; aerobic conditions). The work will be solved by a multidisciplinary team covering all needed types of analyses (mechanical, microstructure, chemical, microbial). The CVREZ will be contribute for characterization of mechanical properties of samples by nondestructive ultrasonic testing and structure analysis, using XRD and SEM for the planned experiment in cooperation with SÚRAO (WMO) and its cooperating research institutions/universities (LTP – TUL, CTU, UJV). WP17-MODATS : The work will contribute to Task 3.2 – Optimised monitoring systems. It will focus on the Qualification of temperature and strain optical fibre sensors (OFS) cables in order to achieve the development of the sensing cable used for the preliminary development phase of the Cigeo project and in order to integrate new technologies to develop systems capable of monitoring the multi-barrier system remotely as well as reliably by distributed temperature sensing. Optical fibre sensors (OFS) are found to be exceptional tools, as they enable distributed measurements, thus providing data over the entire structure. Monitoring with a single fibre can provide information all along the structure behavior, and thus overcome limitations of traditional sensors, whose information is restricted to local effects. Moreover, optical fibre’s small size enables one to reduce invasiveness. Remote sensing would enable the maintenance of the optoelectronic devices during the facility lifetime; only the optical fibre, that is known to be more resistant than electronics, can be exposed to the harsh conditions during the operating period. This explains why, since 2006, Andra has deployed a large qualification process on distributed optical fibre sensing systems in collaboration with several companies and research laboratories. Important development has been performed in the past to get suitable radiation tolerant optical fiber (especially glass matrix) and design			

sensitive external coating to measure strain and temperature in the near field of the high-level disposal cell. Based on the progress, the elaboration of dedicated cables has been realized. The qualification of the sensing optical fiber cable is one of the last steps to get a product ready to use.

The ambition in this project is to qualify the final OFS sensing cable by building a Design of Experiments (DoE) used to characterize the resistance of the cable under Neutron and Gamma Radiation. The DoE results will be analysed through a multivariate analysis (MVA) to permit the best understanding of the physics involved in the fiber degradation and coating degradation through RIA, nonlinear measurement (Raman, Brillouin, Rayleigh) and mechanical analysis.

The work will be solved in cooperation with ANDRA (WMO) and CVREZ (RE). CVREZ will be in charge of the Sub-task – OFS Temp and Strain Qualification and will be responsible for realisation of the experiments with the use of Cf-252 isotopic neutron source.

a curriculum vitae or description of the profile of the persons, including their gender, who will be primarily responsible for carrying out the proposed research and/or innovation activities

Dr. Zbynek Hlavac (male) – main contact of the participant, responsible for the concrete testing activities, graduated at Faculty of Civil Engineering, Brno University of Technology, with Ph.D. degree as a specialist for concrete non-destructive testing. He has experiences in building materials and structures testing and assessment, he prepared more than 30 scientific articles in conference proceedings and technical journals. Since 2013 he works as a researcher in Diagnostics & Qualification department of Centrum vyzkumu Rez s.r.o. (Research Centre Rez Ltd.)

Jaroslava Koťátková (female) graduated at the Faculty of Civil Engineering, Czech Technical University in the field of Material Engineering. She works for Research Centre Rez as a researcher whilst continuing in her Ph.D. studies. Her work is focused on the research relating concrete for nuclear power plants and disposal repositories with focus on material development, material ageing and non-destructive testing. She has vast experience in publishing scientific articles, including articles in impact journals, peer reviewed journals or conference proceedings.

Vít Rosnecký (male) is a technician who takes care about the gamma irradiation facility Little Cobalt in Research Centre Rez Ltd. since 2015. Is responsible for the dosimetry control and radiation protection at his work place in Rez. Has 6-years experience with the work with radionuclides and radioactive sources (Eckert & Ziegler Cesio Ltd.).

Jitka Mikšová (female) has large experience in the field of radioactive waste repositories. She works in the Research Centre Rez Ltd. since 2014. Her publication activity contains more than 17 papers related to the radioactive waste management. She participates in the European meetings related to the radioactive waste disposal since the year 2014.

a list of up to 5 relevant publications, and/or products, services (including widely-used datasets or software), or other achievements relevant to the call content

Koťátková J., Hlaváč Z., Rosnecký V., Mohyla R., Jansa J. The Effect of Superplasticizers on the Properties of Gamma Irradiated Cement Pastes. *Ceramics-Silikáty* 62 (3), 306-310 (2018)

J. Koťátková, J. Zatloukal, P. Reiterman, J. Patera, Z. Hlaváč, P. Brabec, The Effect of Elevated Temperatures and Nuclear Radiation on the Properties of Biological Shielding Concrete, *Key Engineering Materials* 677(2016) 8-16.

Hlaváč, Z.; Rosnecký, V.; Bublíková, P.; Koťátková, J.; Janura, R.; Gregor, K.; Zahrádka, P. STUDY OF RADIATION AND LOCA IMPACT ON CONCRETE PROPERTIES, 2017. Nuclear Technologies for the 21st Century Web site. <http://www.cvrez.cz> (accessed Sep 11, 2018).

Besnus, F.; Metcalf, P.; Mikšová, J.; Wasselin-Trupin, V.; Pflingsten, W.; Smidts, O.; Tokaresvski, O. The ETSON study on treatment processes for the sustainable management of radioactive waste, 2016. International Conference on the Safety of Radioactive Waste Management Web site. https://gnssn.iaea.org/meetings/wasteconference2016/Shared%20Documents/Session%20a%20-%20WPr/Oral/Papers/02a-06-206_Besnus_PAPER.pdf (accessed Sep 11, 2018).

Pellegrini, D.; Bernier, F.; Detilleux, V.; Hériard Dubreuil, G.; Narkuniene, A.; Miksova, J.; Rocher, M. SITEX, the European network of technical expertise organisations for geological disposal, 2016. International Conference on the Safety of Radioactive Waste Management Web site. https://gnssn.iaea.org/meetings/wasteconference2016/Shared%20Documents/Session%203d%20-%20HLW/Oral/Papers/03d-07-184_Pellegrini_PAPER.pdf (accessed Sep 11, 2018).

a list of up to 5 relevant previous projects or activities, connected to the subject of this proposal

SUSEN project. By joining the European Union, the Czech Republic became one of the member states benefiting from targeted support within European regional policy. For the period 2007–2013, all regions of the Czech Republic (except the capital city of Prague) are included in the Convergence target. In compliance with the objectives of European regional policy, one of the priorities of the Czech Republic is to improve the competitiveness of the state and its orientation to a knowledge economy. The operational program Research and Development for Innovations (henceforth “OP R&DI”) is one of the important operational programs contributing to meeting the foregoing objectives. The global objective of OP R&DI is to strengthen the research, development and innovative potential of the Czech Republic which will contribute to growth of competitiveness and create highly-qualified jobs to make the regions of the Czech Republic become important points of concentration of such activities in Europe. The Sustainable Energy Project (SUSustainable ENergy, SUSEN) is implemented as a regional R&D centre in Priority Axis 2 and its objective is to act as a relevant research partner for cooperation within the sphere of application including the establishment of partnerships and cooperation with important European research centres.

The project is built on four foundation piers represented by the following research programs further divided into research activities:

1. Technological Experimental Circuits (TEO)
2. Structural and System Diagnostics (SSD)
3. Nuclear Fuel Cycle (NFC)
4. Material Research (MAT)

Current project will be using the large infrastructure built by the SUSEN project.

Non-destructive control of biological shielding concrete, supported by a grant of the Ministry of Interior of Czech Republic for Inhabitants Safety. Non-destructive testing methods suitable for reactor pressure vessel (PVR) cavity testing are investigated. A robotic system will be developed for ionization channel (in PVR cavity) inspection. 2015-2018.

Irradiation In-pile and out-of-pile stop signal reaction time (SSRT) studies (for EPRI)

Pre-irradiated tensile specimens, 10 dpa, PWR environment, hydraulic loading, deformation rate $10^{-6}/10^{-7} \text{ s}^{-1}$,

Tests of the surveillance specimens of the materials RPVs of the Czech and Slovak NPPs (on going)

Integrated surveillance program for RPVs of the Ukrainian NPPs (on going)

According to the description above, it is clear that the project, which is presented under the EURATOM program, completely relating to activities undertaken in the CV REZ. Material research (resp. cross -cutting fusion research) has an important role in the CV REZ activities. This also follows from the focus of research which is realized within the project SUSEN.

a description of any significant infrastructure and/or any major items of technical equipment, relevant to the proposed work;

Infrastructures of CV REZ

The project will be using the large infrastructure of the European project **Sustainable Energetic SUSEN**. The **gamma irradiator Little Cobalt** (GOMK) is situated in Husinec Rez near Prague. It is targeted for the research of the space issues in the conditions of the very low air pressure and temperature. The cobalt source Co 60 of the gamma rays is a quasi-point type of the source with nominal activity 200 TBq.

if operational capacity cannot be demonstrated at the time of submitting the proposal, describe the concrete measures that will be taken to obtain it by the time of the implementation of the task.

N/A

	No	Name	Acronym
Participant	12	Danish Decommissioning	Dekom
Description of the legal entity Danish Decommissioning (DD) is a state-owned company under the Ministry of Higher Education and Science. DD was established in 2003 and has the responsibility of decommissioning the Danish nuclear research facilities, managing waste from other Danish users of radioactive materials, and participating in the process leading to a longterm solution for the Danish RW. DD has the responsibility for safe handling and storage of all Danish RW, except from NORM. Since 2003 it has been part of the official Danish policy to investigate the possibility to find an international solution for 233 kg of spent research fuel; this has been mentioned again in a recent Parliamentary resolution on long term waste management (B 90, May 2018.) B 90 also stresses the importance of DD participating in international research and development projects on RW management (storage and repository). DD has for several years been a member of the ERDO-WG, focusing on both shared predisposal and disposal solutions. See more information on www.dekom.dk			
Description of main tasks in EURAD-1, with an explanation of how its profile matches the tasks Participant in Waste Management Routes Task 6. Since 2003 it has been part of the official Danish policy to investigate the possibility to find an international solution for 233 kg of spent research fuel; this has been mentioned again in a recent Parliamentary resolution on long term waste management (B 90, May 2018.) B 90 also stresses the importance of DD participating in international research and development projects on RW management (storage and repository). WP9-ROUTES extension : Dekom finds the work performed in the Routes Extension task very relevant and important for SIMS, and for knowledge transfer from LIMS to SIMS. SIMS deal to a great extend with similar problems in their RWM activities, and the Routes project can give valuable input to that process. Dekom can both benefit directly from the activities in our present efforts to develop a national Waste Management Plan, and can hopefully contribute with valuable knowledge from that process. Dekom can furthermore help ensuring the necessary coordination with activities in the ERDO framework, where Dekom is directly involved. DD has for several years been a member of the ERDO-WG, focusing on both shared predisposal and disposal solutions. See more information on www.dekom.dk			
a curriculum vitae or description of the profile of the persons, including their gender, who will be primarily responsible for carrying out the proposed research and/or innovation activities Mr. Ole Kastbjerg Nielsen is managing director in Danish Decommissioning, and has 15 years of experience with decommissioning and waste management. 2003-2008 he was employed as Head of Administration and Safety, and since 2008 he has taken the position of Managing Director. He is actively involved in the ERDO-WG, and with long term waste management in more general, a.o. shared solutions. Before DD, Ole Kastbjerg Nielsen was employed for 11 years in the Danish EPA, the first years in the chemical-toxicological division, and for the last six years as Programme Coordinator for environmental projects in the Russian Federation, supported by a Danish government programme. Educational background: Social Science. Mrs. Heidi Sjølin Thomsen has been employed in Danish Decommissioning for 10 years, with waste management as her primary responsibility. She is a RW expert with very deep knowledge about all aspects of the Danish RW, pre-disposal and disposal related subjects. She is project leader for the process towards a long term solution for the Danish RW. Educational Background: Geology Ole Kastbjerg Nielsen and Heidi Sjølin Thomsen have both been actively involved in the pre-feasibility study for a Danish repository (see below) and investigations in relation to a possible long term storage.			
a list of up to 5 relevant publications, and/or products, services (including widely-used datasets or software), or other achievements relevant to the call content			

Beslutningsgrundlag for et dansk slutdepot for lav- og mellemaktivt affald, udarbejdet af en arbejdsgruppe under Ministeriet for Sundhed og Forebyggelse, november 2008. Danish Decommissioning: Pre-feasibility study for final disposal of radioactive waste. Disposal concepts. Main Report, COWI May 2011. Dansk Dekommissionering og GEUS: Beslutningsgrundlag for et dansk mellemlager for lav- og mellemaktivt affald, februar 2015. Dansk Dekommissionering: Sikkerhed, økonomi og drift for en dansk mellemlagerløsning for radioaktivt affald, COWI august 2016.
a list of up to 5 relevant previous projects or activities, connected to the subject of this proposal Pre-feasibility study for final disposal of radioactive waste, see above publications. Pre-feasibility study for long term storage of Danish RW, see above publications.
a description of any significant infrastructure and/or any major items of technical equipment, relevant to the proposed work; No relevant infrastructure or technical equipment identified, as this is a strategic study.
if operational capacity cannot be demonstrated at the time of submitting the proposal, describe the concrete measures that will be taken to obtain it by the time of the implementation of the task. Not relevant.

	No	Name	Acronym
Participant	13	GREEK ATOMIC ENERGY COMMISSION	EEAE
Description of the legal entity Greek Atomic Energy Commission (EEAE) is the competent regulatory authority for the control, regulation and supervision in the fields of nuclear energy, nuclear technology, radiological and nuclear safety and radiation protection. EEAE is operating as a public entity and enjoying full administrative and financial independence in relation to its duties. It operates under and is supervised by the Minister of Education, Research and Religious Affairs. EEAE was initially established by an Act in 1954. The organization has been re-established with a different scheme in 1987. In 2014, with the Law 4310 (Government Gazette Folio No. 258/A/08.12.2014), a separate chapter, chapter E, titled "Nuclear Energy, Technology and Radiation Protection - Greek Atomic Energy Commission" is included. The obsolete framework is replaced by a new operation framework of EEAE. The new framework brings important improvements, regarding, inter alia, EEAE independence, enforcement means, inspectors role and inspection procedures, licensing authority and transparency enhancement. The new EEAE operation regime is in line with the international and European requirements for radiation protection and nuclear safety regulatory authorities, enhances the independent and effective regulation of this field and addresses some of the IRRS mission findings. EEAE organizational structure was published in the form of a Presidential Decree in 1993. At present, a new Presidential Decree on the internal organization of EEAE has been approved by the government and is in the final stage of issuance. Following IAEA IRRS, in 2012, mission findings, the new internal organization of EEAE provides for the operational separation between its regulatory functions and scientific and technical services. EEAE is governed by a seven-member Board. EEAE employs a sufficient number of about 75 qualified and competent staff to carry out its tasks. Most of EEAE personnel holds a degree of high level education and dispose specialized scientific expertise (M.Sc. and/or Ph.D.). Their continuous training, the participation in EEAE E&T activities and the participation in scientific networks and international fora and activities is encouraged in order to gain the knowledge and experience required for the fulfillment of their tasks. EEAE financial resources come from the public budget and from licensing fees and radiation protection services. The accounts and fiscal reports of the EEAE are subject to the control of the Audit Council. These data and fiscal reports are published on the EEAE website and submitted to the President of the Hellenic Parliament and the relevant Minister alongside the yearly report and the budget for the coming year. EEAE implements an integrated management system; in 2013 it was certified in accordance with the requirements of ISO 9001:2008 standard, which incorporates all functions and accreditations of EEAE. In December 2016, the IMS was updated, fulfilling the requirements of the revised ISO 9001:2015. Specific aspects were further identified to be embedded in the integrated management system to respond to the IRRS findings, in line with IAEA safety requirements. An IAEA IRRS mission was conducted in 2012 and follow-up mission in November 2017, where the majority of the recommendations and suggestions identified in 2012 were successfully considered and implemented by EEAE. EEAE succeeded in participating actively in EC-funded research projects, mainly through FP6 and FP7 (CONRAD, ORAMED, COCAE) Regarding radioactive waste (RW) management EEAE • is responsible for the enforcement and implementation of the "national framework" and recommends actions on improvement. • participates in the formulation and establishment of the "national policy" and ensures compliance and implementation • implements and maintains the system of authorization, inspections and enforcement for the spent fuel (SF) & RW management practices and facilities; it issues the inspection reports and grants the relevant license; • participates in the National Committee on Radioactive Waste Management (EEDRA) • cooperates with EEDRA for the review and updating of the "national program"; it has prepared the 1st "national program"; ensures its proper implementation of the national program.			

- maintains the National database for SF & RW, radioactive sources, radioactive materials or nuclear fuels and conducts annually the national inventory of SF & RW management and assess those that may occur in the future.
- approves proposed SF & RW management streams and technical solutions and SF & RW management practices.
- provides education and training in radiation protection to staff involved in the management of SF & RW.
- prepares and submit to the EC the national reports for SF & RW management

Description of main tasks in EURAD-1, with an explanation of how its profile matches the tasks

EEAE will contribute to ROUTES workpackage :

Task 2: EEAE's main interest on task 2 is to be informed about the best practices in Europe for waste characterization/classification. EEAE has already a limited experience on the subject due to its participation in the characterization of wastes produced by NORM industries during their operation phase, and during their decommissioning. It is also participate to the radiological characterization of wastes produced at a scrap metal recycling industry after the accidental melting of a radioactive source. EEAE also performs the determination of the specific clearance levels to assist these activities.

Task 3: EEAE's main interest on task 3 is to be informed about the best available radio-analytical techniques used for waste characterization and to contribute with its experience on these technique.

Task 5: EEAE will contribute to the analysis of national programmes of other countries with small inventories, in order to identify common aspects and points of interest of the existing and potential disposal options and RW streams. EEAE will contribute to the organization and participation to workshops.

Task 6: Following task 5, EEAE will contribute to the investigation on the common needs, views and attitudes of the EU countries regarding shared solutions of RW management. EEAE will contribute to the organization and participation to workshops.

WP9-ROUTES extension :

EEAE will contribute to Subtask 2 with regard to the analysis and assessment of existing predisposal routes for SIMS, especially concerning the options for radioactive materials which recycling procedure is investigated but is difficult to be done (e.g. lightning rods, smoke detectors, consumer products). EEAE will contribute to Subtask 3 with regard to the analysis and assessment of existing disposal options for SIMS, especially concerning the options for radioactive materials which recycling procedure is investigated but is difficult to be done (e.g. lightning rods, smoke detectors, consumer products) and which are possible to end up as LLW or ILW.

a curriculum vitae or description of the profile of the persons, including their gender, who will be primarily responsible for carrying out the proposed research and/or innovation activities

Dr. Costas J. HOURDAKIS

Current position: Head of the Licensing and Inspection Department (LID/EEAE), Licensing and Inspection Division, Greek Atomic Energy Commission, EEAE. (16 persons). Acted as Head of the Ionizing Radiation Calibration Laboratory (SSDL) until 01.01.2016.

He studied Physics at the University of Athens, Greece (B.Sc. 1985). He awarded postgraduate M.Sc. in medical physics at the University of Surrey, UK (M.Sc. 1987); Ph.D. at the University of Athens, Greece (1995).

Since 2004 he has been an IAEA expert, participating in several IAEA expert missions He has coordinated and/or participated in several international scientific research and development projects regarding the ionizing radiation practices, radiation protection, clinical patient dosimetry and metrology of ionizing radiation, radiological preparedness and response. He is the Greek delegate in the Euratom Treaty Article 37 Group of Experts, in the Commission of Radiation Protection and Public Health (CRPPH) of the NEA/OCDE, in the European Metrology Committee (EURAMET), as well as the Greek (national) coordinator and national focal point at several EU and IAEA committees and working groups.

He is a lecturer in two Greek Medical Physics Post Graduate courses and an invited speaker in many seminars and courses organized by the Greek Atomic Energy Commission and other scientific organizations and committees

Main activities:

Coordinate the work of the LID/EEAE. Issue certificates of compliance with Ionizing Radiation Protection Regulations (IRPR) and operation licenses, transport licences and of radiation sources possession and use licenses.

Performing inspections of radioactive waste (RW) management facilities, as well as medical, research and industrial laboratories using ionizing sources

Organize and perform quality and dosimetry audits in radiotherapy, brachytherapy and diagnostic radiology.

Evaluation of hazard reports, perform of risk assessments and evaluation of doses to public, and radiation workers from ionizing radiation practices, including RW.

Coordinate and assess the management of radioactive waste and disused radioactive sources.

Participates in the committees and working groups for drafting of legislation and guidance on SF and RW management, radiation protection, medical application.

Participate to EEAE's emergency team for radiological accidents and events.

Dr. Konstantinos POTIRIADIS,

Current position: Head of the Department of Environmental Radioactivity at the Greek Atomic Energy Commission. His main activities are:

- Environmental Radioactivity Monitoring: measurements of radioactivity in air, soil, water, foodstuff etc and compilation of data.
- Individual monitoring of exposed workers in the country: internal exposures
- NORMs: Inspection and licensing in facilities and workplaces with NORM activities
- Decommissioning of places with increased levels of naturally occurring radioactive materials.
- Emergency preparedness and response.
- Determination of clearance levels for different practices.
- Management of radioactive materials determined in scrap metal loads.
- Assessment of the environmental impact of NORM wastes to the environment.

He participates and coordinates several Research and Development Projects, as main researcher and he is (co)author of 40 publications in international scientific journals

a list of up to 5 relevant publications, and/or products, services (including widely-used datasets or software), or other achievements relevant to the call content

[1] "Determining minimum alarm activities of orphan sources in scrap loads; Monte Carlo simulations, validated with measurements". Takoudis G, Xanthos S, Clouvas A, Potiriadis C

Nuclear Instruments and Methods in Physics Research, Section A: Accelerators, Spectrometers, Detectors and Associated Equipment 614 (1): 57-67 FEB 21 2010

[2] "Decommissioning a phosphoric acid production plant: a radiological protection case study", Stamatis V, Seferlis S, Kamenopoulou V, Potiriadis C, Koukouliou V, Kehagia K, Dagli C, Georgiadis S, Camarinopoulos L, Journal of Environmental Radioactivity 101 (12): 1013-1023 DEC 2010

[3] "Assessment of the occupational exposure at a fertilizer industry in the northern part of Greece". Potiriadis C, Koukouliou V, Seferlis S, Kehagia K Radiation Protection Dosimetry 144 (1-4): 668-671 MAR 2011

[4] Greek "red mud" residue: A study of microwave reductive roasting followed by magnetic separation for a metallic iron recovery process, Samouhos, M; Taxiarchou, M; Tsakiridis, PE; Potiriadis, K, Journal of hazardous materials, Volume: 254, p. 193-205, JUN 15 2013.

[5] "The COCAE Detector: An Instrument for Localization-Identification of Radioactive Sources".Lambropoulos CP, Aoki T, Crocco J, Dieguez E, Disch C, Fauler A, Fiederle M, Hatzistratis D, Gnatyuk VA, Karafasoulis K, Kosyachenko LA, Levytskyi SN, Loukas D, Maslyanchuk OL, Medvids A, Orphanoudakis T, Papadakis I, Papadimitriou A, Papakonstantinou K, Potiriadis C, Schulman T, Sklyarchuk VV, Spartiotis K, Theodoratos G, Vlasenko OI, Zachariadou K, Zervakis E, IEEE Transactions on Nuclear Science 58 (5): 2363-2370 Part 2, Oct 2011.

a list of up to 5 relevant previous projects or activities, connected to the subject of this proposal [1] “Identification, management and export for recycling of disused and orphan radioactive sources and materials” EEAE and Ministry of Development under EMII 20/6.12.2000 project of the Ministry of Environment; Budget: 1,367,000 Euros. [2] “Detection of radioactive scrap metal in the entrance of steel factories”. (DG XI, European Commission) [3] “Cooperation across Europe for Cd(Zn)Te based Security Instruments” (FP7-SEC-2007-1). [4] “Decommissioning an abandoned phosphoric acid production plant” [5] “Strengthening the Capacity of the Radiation Protection and Nuclear Safety Regulatory Authority of Cyprus, Department of Labour Inspection of Cyprus. EC funding (Budget : 240,000 Euros) a description of any significant infrastructure and/or any major items of technical equipment, relevant to the proposed work; EEAE is equipped with the following infrastructure which can be used in the framework of this proposal and especially in tasks 2 and 3: 1. Low background gamma spectrometry EEAE is equipped with two low background gamma ray spectroscopic systems based on High Purity Germanium detectors (HPGe). The one is a p-type HPGe detector of relative efficiency 70% and the other a broad energy HPGe detector of relative efficiency 50%. The measurements performed by EEAE with γ- spectrometry are accredited according to the requirements of the ELOT EN ISO/IEC 17025 standard. 2. Alpha spectrometry Actinides (thorium, uranium, plutonium, americium and curium), as well as Polonium-210 and Radium-226, are isolated and measured by means of alpha spectrometry. The measuring equipment used in EEAE’s laboratory is a fully automated and integrated alpha spectroscopic system (Alpha Analyst, Canberra), consisting of 12 Passivated Implanted Planar Silicon (PIPS) detectors with 600 mm² active area. EEAE with α- spectrometry in liquid samples are accredited according to the requirements of the ELOT EN ISO/IEC 17025 standard. 3. Liquid scintillation and gas flow detector to measure total α/β radiation The total α/β measurements are performed by a gas flow proportional counter in anticoincidence guard G-M detection. Low energy beta radionuclide emitters can be measured by a liquid scintillation counter of Quantulus type available in EEAE’s laboratory. This instrumentation could be used in the WP2 and WP3 of this proposal in complementarily with the previous ones. 4. In-situ measurements In-situ measurements are usually included in the environmental radioactivity monitoring programme. In situ measurements are performed for the qualitative and the quantitative determination of a potential radiological contamination, the radiological inspection of scrap metals, the in-situ characterization of the materials and the characterization of places during decommissioning activities. EEAE is equipped with four portable γ-ray spectroscopic systems based on germanium detectors of relative efficiency 10%, 20%, 35% and 35% and 5 NaI portable spectroscopic systems. 5. Secondary Standard Dosimetry laboratory (SSDL) Maintaining the dosimetry standard for γ and X radiation and performing calibration of dosimetry equipment in the fields of radiation protection, radiotherapy and diagnostic radiology. Among others, the infrastructure includes Ge spectrometer for field measurements, characterization of radioactive material and material analysis.

6. In addition to the above methods, a pixelated CdTe detector is under development in the framework of a research project. This detector can provide information on the spatial distribution of the radioactive contamination.

if operational capacity cannot be demonstrated at the time of submitting the proposal, describe the concrete measures that will be taken to obtain it by the time of the implementation of the task.

N/A

	No	Name	Acronym
Participant	14	Empresa Nacional de Residuos Radiactivos S.A., S.M.E., M.P.	ENRESA
Description of the legal entity ENRESA is the Spanish radioactive waste management agency, with considerable experience in research and technological activities related to radioactive waste disposal and management of large industrial facilities and research programmes. ENRESA is a public company founded in 1985 by the Spanish Government for the management of radioactive wastes, including: • Design, construction and operation of facilities for the disposal of low-level waste (LLW), interim storage and final disposal of spent fuel, vitrified high-level waste and intermediate-level waste (SF/HLW/ILW). • Decommissioning of nuclear facilities, including nuclear power plants (NPP). • Drafting the R&D plans to cover the needs of the concepts and technical solutions for managing the radioactive wastes and SF in Spain. • Managing the Fund to cover the previous activities.			
Description of main tasks in EURAD-1, with an explanation of how its profile matches the tasks WP DONUT: ENRESA, together with others WMO and one TSO, will prepare benchmarks from the point of view of the implementers and evaluators (task 5). These organisations and their partners participate in most of other work-packages, and the work will be carried out in close cooperation with the linked WPs and the RE involved in this task. The prepared benchmarks will help to quantify how numerical methods developed in DONUT are relevant regarding current used methods, and to compare tools in which these methods are implemented. In order to make the benchmarks relevant for a large community they will address coupled processes representative in different kind host rocks (e.g. clay, crystalline rocks, salt). WP Spent Fuel Evolution: ENRESA will participate in the definition and verification of procedures to determine the source terms of SNF assemblies with realistic confident limits (task 2.4) and in particular in subtask 2.4.2. that considers the use of “state-of-the-art” codes. ENRESA, through ENUSA will also participate in subtask 2.2.2 “Nuclide inventory by radiochemical analysis of a set of BWR SNF samples”. WP HITEC. ENRESA will participate in Tasks 1 (subtask 1.2. State-of-the-art) and 4 (Subtask 4.1 – Guidance for safety case development and repository optimization) of this WP. WP UMAN: ENRESA will participate in Subtask 3.2 “Uncertainties on waste inventory and on the impact of predisposal steps”, Subtask 4.3. “Preferences of the different actors on uncertainty management options”. Experience in developing design and performing safety assessment to obtain site, construction and operation licenses of near surface disposal facility currently in operation in Spain that include uncertainty management will contribute to the WP. KM WPs. ENRESA is not directly involved in these WPs, nevertheless ENRESA may contribute to their development.			
a curriculum vitae or description of the profile of the persons, including their gender, who will be primarily responsible for carrying out the proposed research and/or innovation activities Mrs. Elena Vico (female) studied Physics of Materials (Universidad Complutense of Madrid) and a Master on Environmental Engineering and Management (Escuela de Organización Industrial (EOI), Madrid). She has over 20 years’ experience in radioactive waste management activities within ENRESA, working in several positions. She is currently responsible of the Safety and Licensing department, being in charge of the coordination and supervision of the licensing of the ENRESA’s radioactive waste management facilities and decommissioning projects. At the international level, she has been a member of different committees and working groups at the EC, the OECD/NEA and the IAEA. She also participated in the CASSIOPEE Consortium and in the Club of			

Agencies, composed by different European WMO. She is member of the WG2 of ENSREG (European Nuclear Regulatory Group). At EURATOM R&D Programmes, she was involved in CARBOWASTE project.

Mrs Elena Vico will be responsible for ENRESA participation in the DONUT WP.

Mr. Enrique García-García (male) is an Industrial Engineer (Universidad de Oviedo –UNIOVI) and is in process of getting the PhD (Universidad Nacional de Educación a Distancia -UNED-, Spain). He joined ENRESA in 2015 and is currently working at the Safety and Licensing dept., representing the department in the working group on the activities concerning the deep geological disposal project. He will participate in DONUT WP.

Mr. Francisco Javier Fernández-López, (male) is M.Sc. Industrial Engineering (Focused on Energy Techniques) at Polytechnical University (UPM) - Madrid (Spain) & M.Sc. Civil Engineering (Focused on Physics) at Free University - Brussels (Belgium) (Double Degree Program). At present is Head HLW Eng. and R&D Dpt. at ENRESA. Previous roles at ATC Eng. Dpt. as Responsible for the Electrical and Mechanical Discipline within the ATC Project and at HLW Eng. Dpt. at ENRESA as Responsible for SNF storage and transportation R&D Projects. Previous jobs at Belgonucleaire and ABB. Mr. Fernández López will be responsible for ENRESA participation in the WP Spent Fuel Evolution.

Mr. José María Gómez (male) earned his degree in Industrial Engineering with a M.Sc. in Nuclear Engineering by the Polytechnical University of Madrid (UPM) in Spain and a Research Master (former Diploma) in Fluid Dynamics by the von Karman Institute for Fluid Dynamics in Belgium. He was part of the Spanish bid to host the European Spallation Source acting as a neutronic analyst. Later, he worked in nuclear fuel thermal-hydraulics at ENUSA. Currently, he is working for ENRESA in the HLW Eng. and R&D Dpt., collaborating in several spent nuclear fuel characterization and storage projects. Mr. Gómez will be involved in WP Spent Fuel Evolution.

Mrs. Ana Muñoz (female) studied Industrial Engineering (specialized in Metallurgy) at the Polytechnical University of Madrid (UPM) in Spain, with extensive additional training related to the nuclear sector (as HRP School and WNU Summer Institute). She has over 15 years' experience in nuclear fuel working at ENUSA in the design and manufacturing areas as well as in R&D programs related to the fuel behavior, specially devoted in the last years to the spent fuel performance during storage and transportation. At the international level, she has participated in the SCIP projects of OECD/NEA focused on the damage mechanisms in the cladding. She is currently working for ENRESA in the HLW Eng. and R&D Dpt., collaborating in several spent nuclear fuel performance and storage projects. Mrs. Muñoz will be involved in WP Spent Fuel Evolution.

Mr. Juan Carlos Mayor (male) is Mining Engineer (School of Mines of the Polytechnic University of Madrid) and holds a M. Sc. degree in Civil Engineering (Stanford University). He has over 25 years working experience in the field of radioactive waste management. He is presently Senior Project Manager in charge of the R&D programme of the Site Engineering Dept. of the Spanish Radioactive Waste Management Company (ENRESA) in the fields of Rock Mechanics and Hydrogeology. Previously, he has been staff project engineer at CGS and GYA, two private Spanish consultancy companies in mining, geotechnical engineering and hydrogeology.

At the international level Mr. Mayor has maintained strong cooperation with many of the WMOs, particularly through the EURATOM programme, by participating and coordinating different R&D projects in various URLs (Mont Terri, Grimsel, Hades, Asse mine), including the just finished projects PEBS and MODERN. He is a member of the Steering Committees of the IGD/Technology Platform, Mont Terri Project and Grimsel Test Site (Switzerland) and represents ENRESA at the NEA-IGSC working group on the Characterisation, the Understanding and the Performance of Argillaceous Rocks as Repository Host Formations. Mr. Mayor was member of the International Review Team involved in the NEA peer review of the post-closure radiological safety case produced by SKB (Sweden). He participated as well in various phases of the international DECOVALEX and INTRAVAL projects. Mr. Mayor will be responsible for ENRESA participation in the WP HITEC.

Mrs. Inmaculada López (female) is M. Sc. Chemistry (Chemistry –Physics) (Autónoma University of Madrid) and holds Nuclear Engineering Master (Nuclear Energy Institute-CIEMAT). She has over 25 years working experience in the field of radioactive waste management. She is presently Head of LILW Engineered department of the Spanish Radioactive Waste Management Company (ENRESA). Formerly she was senior engineer in charge of the safety and licensing projects relating LILW and VLLW. Previously, she has been staff project engineer at Westinghouse, private Spanish engineering company. At the international level Mrs. Lopez has been a member of different IAEA Coordinated Research Projects and working groups at the IAEA. She also participates in the DISPONET IAEA Network, composed by different European WMO. She was a member of the ENRESA's expert group for the EC Twinning project “Radioactive waste management and reactor decommissioning”.

Mrs. López will be responsible for ENRESA participation in the WP UMAN.

Mrs. Sylvia De Gregorio (female) is M. Sc. Civil Engineer (Polytechnic University of Madrid). She has over sixteen years working experience in radioactive waste management. Now she is senior engineer at LILW engineering department at the Spanish Radioactive Waste company (ENRESA) being civil works responsible in the department since 2011 and Cabril's dam director since 2007 and working on the design, authorization and licensing of VLLW cells. In last years, she has worked on the design of the Centralised Interim Storage (ATC) installation for High Activity Radioactive waste. Previously she worked in two privates engineering companies INIMA and INGEOTEC as engineer and as project coordinated or project manager.

On an International level, she has worked on several radioactive waste installations design projects and collaborated with the IAEA in consultancies. She has also participated in international congresses organized by ENRESA.

Mr. Joaquín Farias Seifert, (male) is M.Sc. Mining Engineer (School of Mines of the Polytechnic University of Madrid). He has been working for SMM Peñarroya –España (1985-1989), Prephor & Cedesa (1989-1994), Geocontrol SA (1989, 1994-2005), AITEMIN (2005-2011) and ENRESA (2011-). He has been involved in ENRESA's R&D activities since 1994, being a member of the FEBEX (I & II) technical secretariat, and since 2004 he is involved in ENRESA's &D coordination, including the participation in EURATOM FW Programmes. He has been involved in several projects co-funded by the EC FEBEX I and II, NF PRO IP, ESDRED IP, PETRUS II, PETRUS III, etc. Mr. Farias has been the ENRESA's representative in the NEA initiative RK&M. Mr. Farias is responsible of R&D coordination in ENRESA. Mr. Farias will be involved in the WPs in which ENRESA is present, mainly in KM issues.

a list of up to 5 relevant publications, and/or products, services (including widely-used datasets or software), or other achievements relevant to the call content

- SKI 2005. DECOVALEX III Project: Modelling of the FEBEX In-Situ Test. Task 1 Final report. SKI report 2005:20, 197 pp. ISSN 1104-1374.
- ENRESA 2006. FEBEX Project Updated Final report 1994-2004. Publicación Técnica ENRESA 05-0/2006. ENRESA, Madrid. 590 pp. ISSN 1134-380X.
- Mayor, J. C., García-Siñeriz, J. L., Alonso, E., Alheid, H.-J., Blümling, P. (2007a). Engineered barrier emplacement experiment in Opalinus Clay for the disposal of radioactive waste in underground repositories. – In: Bossart, P. & Nussbaum, C. (Eds.): Mont Terri Project – Heater Experiment, Engineered Barrier Experiment and Ventilation Experiment (p.115-179). – Rep. Swiss. Geol. Surv. 1.
- Mayor, J.C. and Velasco, M. (2014). EB dismantling synthesis report. Deliverable D2.1-8 of the PEBS Project.
- Zwicky, H.U. et al. (2010): Nuclide analysis in high burnup fuel samples irradiated in Vandellós 2. Journal of Nuclear Materials 402 (2010) 60-73.
- Lloret, M. et al. (2008): Results of thermal creep tests on highly irradiated Zirlo. Seoul 2008 Water Reactor Fuel Performance Meeting.
- Lloret, M. et al. (2012): Results of thermal creep tests on irradiated Zry2. Manchester 2012 TOP FUEL Meeting.

a list of up to 5 relevant previous projects or activities, connected to the subject of this proposal

• FEBEX I and II, which were projects with the aims of demonstrating the feasibility of manufacturing and assembling an engineered barrier system based on the Spanish SF disposal concept for a crystalline host rock and developing methodologies and models for assessment of the thermo-hydro-mechanical (THM) and thermo-hydro-geochemical (THG) behaviour of the engineered barrier system (near field). • NF-PRO (Understanding and Physical and Numerical Modelling of the Key Processes in the Near Field and their Coupling for Different Host Rocks and Repository Strategies, 6th FP), Components 1 to 5. • PAMINA (Performance Assessment Methodologies IN Application to Guide the Development of the Safety Case, 6th FP). The objective was to improve and harmonise methodologies and tools for demonstrating the safety of deep geological disposal of long-lived radioactive waste for different waste types, repository designs and geological environments. • MICADO (Model uncertainty for the mechanism of dissolution of spent fuel in a nuclear waste repository, 6th FP) focussed on assessing the uncertainties in models describing the dissolution mechanism of spent nuclear fuel in a repository for geological time periods. • The PEBS project (7th FP) aimed at evaluating the sealing and barrier performance of clay-based EBS over time, through development of a comprehensive approach involving experiments, model development and consideration of the potential impacts on long-term safety functions. • The CAST project (CArbon-14 Source Term) (7th FP): Their objective was to develop understanding of the generation and release of 14C from radioactive waste materials under conditions relevant to waste packaging and disposal to underground geological disposal facilities. The project will focus on releases from irradiated metals (steels, Zircalloys) and from ion-exchange materials as dissolved and gaseous species.
a description of any significant infrastructure and/or any major items of technical equipment, relevant to the proposed work;
if operational capacity cannot be demonstrated at the time of submitting the proposal, describe the concrete measures that will be taken to obtain it by the time of the implementation of the task N/A

	No	Name	Acronym
Participant	15	Forschungszentrum Jülich	JUELICH
Description of the legal entity Forschungszentrum Jülich (JUELICH) makes a vital contribution to solving major challenges facing society in the fields of information, energy, and bioeconomy. It focuses on the future of information technologies and information processing, complex processes in the human brain, the transformation of the energy system, and a sustainable bioeconomy. Forschungszentrum Jülich develops simulation and data sciences as a key research method and makes use of large, often unique, scientific infrastructures. Its work spans a range of topics and disciplines and it exploits synergies between the research areas. With some 5,600 employees, Jülich – a member of the Helmholtz Association – is one of Europe's large research centres. The work program within EURAD will be performed in the Institute for Energy and Climate Research – Nuclear Waste Management and Reactor Safety (IEK-6), making use of the knowledge acquired during the last 50 years on safety issues regarding nuclear waste management and reactor safety. Institute for Energy and Climate Research – Nuclear Waste Management (IEK-6) contributes to the Helmholtz program NUSAFE and focuses on topics related to the safe management of nuclear waste and international safeguards as well as reactor safety. The safe management of radioactive waste and its final disposal in a deep geological repository is one of the grand challenges of our times and an integral part of the German “Energiewende”. The related research is multidisciplinary – while IEK-6 research mainly considers nuclear aspects, it addresses the behavior of radionuclides and the relevant waste form materials by combining radio-, geo- and materials chemistry aspects and by integrating experiment and simulation. Research covers the complete chain from waste generation to waste disposal including in particular: (1) Research in support of the long-term safety for deep geological disposal with a focus on repository near-field incl. waste forms, barrier materials and in particular secondary alteration phases (source term), (2) Research on unresolved issues prior to waste disposal e.g. pre-disposal: waste treatment, conditioning, decontamination/hydrometallurgical separation chemistry, with a strong emphasis on special radioactive wastes for which up to now no management solutions have been developed and (3) Research on international safeguards, incl. scientific coordination of the German IAEA Safeguards Support Program and qualification for IAEA Network of Analytical Laboratories. IEK-6 operates radiochemistry laboratories and is strongly linked to the Ernst Ruska-Centre, ER-C, to the Helmholtz Nanofacility with atom probe tomography, to the Jülich Supercomputer Centre, JSC, and the Central Institute for Engineering, Electronics and Analytics, ZEA. Future research will focus on reactive mass transport phenomena at chemically perturbed interfaces within a repository, the further development of solutions for radioactive special wastes and of analytical methods for nuclear safeguards and security applications.			
Description of main tasks in EURAD-1, with an explanation of how its profile matches the tasks JUELICH (IEK-6) will contribute to EURAD on several levels. Within WP FUTURE, JUELICH-IEK-6 will serve as the WP Coordinator and also contribute to the technical RD&D. In WP ACED, JUELICH-IEK-6 will serve as co-task leader and perform RD&D. In WPs CORI and DONUT, JUELICH-IEK-6 will contribute to the RD&D program. Additional activities are related to the Strategic Study ROUTES. Given the high level of technical expertise at JUELICH-IEK-6 in all the fields relevant for the proposed work in EURAD, and the broad experience in coordinating national and international RD&D, JUELICH-IEK-6 is fully able to carry out the work proposed within EURAD. WP15- ConCorD : tasks performed by Linked Third Parties described below WP16-MAGIC : The respective FZJ research unit focuses on topics related to the safe management of nuclear waste and addresses the behaviour of radionuclides and the relevant waste form materials by combining radio-, geo- and materials chemistry aspects and by integrating experiments and simulations. Research covers the in			

particular the long-term safety for deep geological disposal with a focus on the repository near-field (incl. waste forms, barrier materials and the RN source term) and reactive mass transport phenomena within a repository. FZJ operates radiochemistry laboratories and will contribute to the RD&D program of WP MAGIC by applying technical expertise and experience gained, inter alia, in prior EU projects dealing with cementitious materials (CEBAMA, EURAD WP CORI and ACED). FZJ will be involved in Task 2 in a research activity on the chemo-mechanical behaviour of cementitious materials on the meso/macro scale, performed in close collaboration with COVRA and SCK CEN to address the question of the anaerobic and aerobic microbial influence on the chemo-mechanical behaviour and the self-sealing of concretes that have a mechanical support function in a repository. For this purpose, COVRA performed and performs experiments exposing different types of cementitious materials to synthetic clay pore solutions and will perform measurements on the mechanical properties of the cementitious materials. The focus of the work of FZJ will be on the characterisation of the chemical, mineralogical and microstructural properties of the altered cementitious materials using e.g. SEM-EDS (incl. elemental mapping), XRD (combined with Rietveld analyses), XRF, and Raman tomography, while microbial presence/activity and biofilms will be analysed by SCK CEN
a curriculum vitae or description of the profile of the persons, including their gender, who will be primarily responsible for carrying out the proposed research and/or innovation activities Prof. Dr. Dirk Bosbach (male) is an expert in radiochemistry and nuclear materials., with almost 20 years practical experience of R&D in the field. Prof. Bosbach joined JUELICH in 2009 and is director of the Institute of Energy and Climate Research, responsible for JUELICH'S R&D program on nuclear waste management. He has been involved in various national and international collaborative projects related to nuclear waste management and served as WP leader in the EC funded projects FUNMIG, SKIN and DISCO. Dr. Guido Deissmann (male) is an expert in geochemistry/mineralogy with more than 20 years experience related to various aspects of radioactive waste management, such as waste form performance, radionuclide migration and reactive transport modelling, and safety assessments for nuclear waste disposal. Dr. Deissmann joined JUELICH in 2013 as senior scientist after 17 years of scientific consulting. He has been and is involved in various national and international collaborative R&D projects related to nuclear waste management and geological disposal such as the EC funded projects CEBAMA, DISCO and THERAMIN.
a list of up to 5 relevant publications, and/or products, services (including widely-used datasets or software), or other achievements relevant to the call content • Vinograd, V. L., Brandt, F., Rozov, K., Klinkenberg, M., Refson, K., Winkler, B., Bosbach, D. 2013. Solid–aqueous equilibrium in the BaSO₄–RaSO₄–H₂O system: First-principles calculations and a thermodynamic assessment. <i>Geochimica et Cosmochimica Acta</i> 122, 398-417. • Guo, X., Szenknect, S., Mesbah, A., Labs, S., Clavier, N., Poinssot, C., Ushakov, S.V., Curtius, H., Bosbach, D., Ewing, R.C., Burns, P.C., Dacheux, N., Navrotsky, A. 2015. Thermodynamics of formation of coffinite, USiO₄. <i>Proceedings of the National Academy of Sciences of the United States of America</i> 112, 6551-6555. • Poonosamy, J., Kosakowski, Van Loon, L.R., Mäder, U. 2015. Dissolution– precipitation processes in tank experiments for testing numerical models for reactive transport calculations: Experiments and modelling. <i>Journal of Contaminant Hydrology</i> 177/178, 1-17. • Weber, J., Barthel, J., Brandt, F., Klinkenberg, M., Breuer, U., Kruth, M., Bosbach, D. 2016. Nano-structural features of barite crystals observed by electron microscopy and atom probe tomography. <i>Chemical Geology</i> 424, 51-59. • Lange, S., Kowalski, P., Pšenička, M., Klinkenberg, M., Rohmen, S., Bosbach, D., Deissmann, G. 2018. Uptake of ²²⁶Ra in cementitious systems: A complementary solution chemistry and atomistic simulation study. <i>Applied Geochemistry</i> 96, 204-216.
a list of up to 5 relevant previous projects or activities, connected to the subject of this proposal EC projects:

SKIN (FP7): Collaborative project on “Slow Processes in Close-to-Equilibrium Conditions for Radionuclides in Water/Solid Systems of Relevance to Nuclear Waste Management”. January 2011 – December 2013 (WP leader).

FIRST NUCLIDES (FP7): Collaborative project on “Fast / Instant Release of Safety Relevant Radionuclides from Spent Nuclear Fuel”. January 2012 – December 2015.

CEBAMA (Horizon 2020): Collaborative project on “Cement-based materials, properties, evolution, barrier functions”. June 2015 – May 2019.

DISCO (Horizon 2020): Collaborative project on “Modern Spent Fuel Dissolution and Chemistry in Failed Container Conditions”. June 2017 – May 2021(WP leader).

National (German) projects:

VESPA I & II (BMW): Collaborative project on “Behaviour of Long-Lived Fission and Activation Products in the Near-field of a Nuclear Waste Repository and the Possibilities of their Retention”. July 2010 – June 2013 & September 2017 – August 2020.

a description of any significant infrastructure and/or any major items of technical equipment, relevant to the proposed work;

IEK-6 radiochemistry laboratories are fully licensed to handle radioactive materials and equipped with all necessary infrastructures to perform the proposed experimental work. This includes alpha glove boxes, inert gas alpha glove boxes and radionuclide laboratories. State-of-the-art analytical instruments and methods and advanced spectroscopic/diffraction tools exist for the sensitive detection and analysis of radionuclides and related materials. Trace element and isotope analysis is made by instrumental analytical techniques such as ICP-mass spectrometry. Nuclear chemical analyses via alpha-spectrometry, liquid scintillation and gamma-spectroscopy are available. Methods for characterisation of (radioactive) materials such as X-ray diffraction (XRD – powder and single crystal) and Raman-microscopy are installed. A modern environmental scanning electron microscope (ESEM) as well as a state-of-the-art FIB instrument for the preparation of radioactive sample for subsequent TEM and ATP analysis are available in the radiochemistry laboratories. JUELICH operates the Ernst Ruska Centre for Microscopy and Spectroscopy with Electrons, the Helmholtz Nanofacility, and the Central Laboratories for Engineering and Analytics providing dedicated cutting-edge analytical facilities in JUELICH. IEK-6 has established for many years a close collaboration within this framework. IEK-6 also uses different codes for multiphysics, geochemical and reactive transport modelling like iCP COMSOL-PHREEQC, openGeoSys/GEMS and PFLOTRAN amongst others, using the High Performance Computing facilities in JUELICH at the Jülich Supercomputing Centre. Furthermore, at IEK-6 atomistic simulation complements the experimental activities mainly using the DFT codes QUANTUM ESPRESSO and CASTEP, among others.

if operational capacity cannot be demonstrated at the time of submitting the proposal, describe the concrete measures that will be taken to obtain it by the time of the implementation of the task

All required operational capacity to carry out the work proposed by JUELICH within EURAD is fully available.

	No	Name	Acronym
Participant	16	Gesellschaft für Anlagen- und Reaktorsicherheit (GRS) gGmbH	GRS
Description of the legal entity The Gesellschaft für Anlagen- und Reaktorsicherheit (GRS gGmbH) is a non-profit organization which deals with technical-scientific research and provides expertise. The company administers interdisciplinary knowledge, progressive methods and qualified data. GRS was established as a business in January 1977. The headquarters are in Cologne, other locations include: Berlin, Braunschweig and Garching nearby Munich. Currently, there are approximately 450 employees at GRS, 350 of whom work in the technical-scientific sector. GRS is financed by contracts and the present annual volume of contracts is worth 53 million €. In the working field “Waste Management”, GRS is the only institution in Germany with comprehensive interdisciplinary expertise in this wide range of tasks. GRS has the relevant knowledge and experience in the field of disposal of radioactive and chemotoxic waste as well as in the assessment of safety-related questions. The instruments and methods necessary for a safety-analytical assessment have been developed and qualified within the framework of research activities over many years. The participation in committees and co-operation activities, as well as the presentation of the work in international scientific forums ensures the required state of the art in science and technology about expertise and development of procedures. In the Cologne division of GRS, the department of Waste Management Safety supports the authorities and ministry with expertise as Technical Support Organization (TSO). In the Braunschweig division of GRS, the Repository Safety Research department carries out research and develops methods that are essential to the verification of the long-term safety disposal of radioactive and toxic chemical wastes in geological formations. The division is divided into two departments: the Long-Term Safety Analysis department and the Process Analysis department, working in conjunction with an on premises geo-scientific lab. The competence fields “Waste Disposal”, “Assessment of Long-term Safety”, “Geochemical Research”, “Research in Underground Laboratories” and “Geochemical and Geotechnical Laboratory” are mainly oriented towards safety analyses and geosciences as a Research Entity (RE). Priority is given to the development of methods and instruments for the performance of safety analyses and experimental research on the examination of waste disposal concepts and the provision of data and models that are relevant regarding safety in the long term.			

Description of main tasks in EURAD-1, with an explanation of how its profile matches the tasks

GRS is participating in the work packages DONUT and ROUTES as TSO. GRS is also participating in the work packages DONUT, FUTURE, GAS and UMAN as RE. The general competencies of GRS are given in the description of the organisation.

WP15- ConCorD :

GRS will perform its experiments in close cooperation with KIT, namely in **Task 5 Transients**.

This work aims to determine the temporal evolution of rate and propagation of the degradation of spheroidal graphite cast iron GGG40 and copper alloy C71500 in contact with bentonite saturated with pore water in near field temperatures and chemical environments generated after the sealing process in deep geological repositories. The influence of the transient environment parameters temperature, pressure, trapped oxygen and the appearance of radiolysis products on the growth and long-term chemical and mechanical stability of the protective oxide films will be emphasized. Accelerated electrochemical and coupons experiments will be carried out in a complementary way to get an extension of the available knowledge of the corrosion dynamic triggered by chemo-mechanical (stress generated by pressure) transients in the near-field environment of the container as requested in the description.

In this contribution, GRS will perform accelerated electrochemical experiments with specially designed cells working in conditions close to those under deep geological disposal in granite and clay. These techniques allow monitoring the corrosion rate, the corrosion potential and transport process in the protective oxide under transient alterations of chemo-mechanical conditions at the metal-bentonite interface. The degradation kinetics will be elucidated with complementary microscopical surface chemical and morphological investigations of the attack.

The work is a part of a broader joint effort with other proposals within **Task 5**, SURAO(UJV) and **Task 6** by AMPHOS21, where irradiation experiments and advanced numerical modelling of the geochemistry and corrosion of the system, respectively, are targeted.

In addition, GRS will act as Leader of **Subtask 1.2**, where organisation and contribution to SOTA is envisaged.

WP16-MAGIC :

- GRS has experiences in the field of concrete degradation caused by chemical and mechanical attacks since about 20 years. New methods for the investigation of the THM- and THC-coupled processes on sealing materials and sealing systems regarding the concrete degradation were developed in former (LAVA FKZ: 02E11122, LAVA-2 FKZ: 02E11324, LASA FKZ: 02E11132, LASA-EDZ FKZ: 02E11243) projects. Ongoing developments occur in the present project (THyMeCZ FKZ: 02E11689). The GRS lab has both several experimental set-ups for investigation of THM- and THC coupled processes and for determination of mechanical deformation behavior available so as a geochemical lab for analyzation of chemical compositions of solutions and solids. The visualization of the intrusion of solution in a sealing was proven related to the former LAVA-2 project. Geo-PET and CT are available at HZDR.
- GRS will participate to the Task 2 through two experimental approaches:
 - Investigation of the flow along the contact seam between sealing and EDZ (40°C). The effect of percolation to corrosion will be investigated by permeability measurements, solution and solid phase analysis (GRS). The flow of solution into the sealing is visualized using the GeoPET method at HZDR. Additional, progress of corrosion is visualized by CT (HZDR).
 - Determination of material strength dependent on status of degradation at 40°C: The samples will be percolated with solution at 40°C. Progress of corrosion is estimated by permeability measurement and analysis of outflowing solution while percolation. Afterwards the samples will be removed from percolation after 1, 3, 12, and 24 months and will be investigated by triaxial compression short-term strength test (plus original state).

WP9-ROUTES extension :

GRS will make a major contribution to the qualitative assessment of the disposal options (Subtask 3) particularly in subtask 3.1 for the analysis and assessment of existing disposal routes for SIMS and subtask 3.2 for the evaluation of waste routes resulting from subtask 3.1 on disposal option for SIMS.

Based on the existing knowledge with regard to disposal options, GRS will make the central contribution to the consolidation of the findings from the qualitative assessment of disposal options using borehole drilling

technology and concepts. The elaboration of the mutual influence of predisposal routes on this disposal option is also part of the GRS work. This also includes a contribution to guidelines, which the member states can use when selecting suitable predisposal routes and disposal options.

WP10-UMAN extension :

The Repository Research Centre of GRS in Braunschweig has been working for a long time in many fields of repository research, including the identification and handling of relevant uncertainties. GRS contributed essentially to the EC PAMINA project as well as to other international projects aimed at repository performance assessment.

GRS would participate in the workshops organised by Subtasks 3.6 and 4.3 and contribute, as member of the Subtask 4.2 expert group, to:

- the compilation and review of available information on uncertainty management options and preferences
- the development of the material for the workshop organized by Subtask 4.3 and the seminar organized by Task 5.

GRS would also be in charge of the writing of:

- the minutes of the workshop organised by Subtask 4.3
- Task 4 deliverable based on the input provided by other Subtask 4.2 members and the minutes of the workshop.

a curriculum vitae or description of the profile of the persons, including their gender, who will be primarily responsible for carrying out the proposed research and/or innovation activities

BECKER, Dirk-Alexander (male)

Studies: Physics

Diploma and PhD in Physics

Senior Expert and project leader at the Repository Safety Department of GRS gGmbH since 1995.

Main topics of work: modelling of long term safety of repositories, uncertainty management and sensitivity analysis.

BRACKE, Guido (male)

Studies: Chemistry, Geochemistry, Mineralogy

Diploma in Chemistry, PhD in Geochemistry and Mineralogy

Senior Expert and project leader at the Department for Waste Management Safety of GRS gGmbH since 2007.

Main topics of work: Radioactive waste management, Long term safety of repositories, Waste management regulatory framework.

KAUFHOLZ, Peter (male)

Studies: Chemistry, Nuclear Applications, Actinide partitioning

Bachelor's in chemistry, Master in Nuclear Applications, PhD in nuclear fuel chemistry

6 years of experience in the field of radioactive waste management and separation technology.

Main topics of work: Radioactive waste processing and chemistry, Spent fuel behavior in dry storage.

NOSECK , Ulrich (male)

Studies: Chemistry

Diploma in Chemistry, PhD in Physical Chemistry

Senior Expert and project leader at the Department for Site Selection of GRS gGmbH since 1995.

Main topics of work: Safety Case and long term safety assessment for repositories, Geochemical and transport modelling.

RÜBEL, André (male)

Diploma and PhD in Physics

Senior Expert and project leader at the Repository Safety Department of GRS gGmbH since 2001.

Main topics of work: Long term safety of repositories, transport modelling.

BRITZ, Susan (female)

Studies: Geoecology,

Diploma and PhD in Geoecology Scientist at the Department for Site Selection of GRS gGmbH since 2012 Main topics of work: Experimental and numerical studies of geochemical and transport processes, long term safety assessments for repositories. ZHANG, Chun-Liang (male) Studies: Mining engineering (diploma). PhD in geotechnical engineering Senior expert and project leader at the Repository Research Department of GRS gGmbH since 1995. Main topics of work: experimental and numerical analysis of thermo-hydraulic-mechanical coupling processes in different host rocks, buffer and backfill material
a list of up to 5 relevant publications, and/or products, services (including widely-used datasets or software), or other achievements relevant to the call content • Bracke, G., Charlier, F., Liebscher, A., Schilling, F., Röckel, T.: Does Deep Borehole Disposal of HLRW has a Chance in Germany?, atw - Internationale Zeitschrift für Kernenergie, Bd. 62, Nr. 1, S. 46–53, 2017. • Guido BRACKE, Fischer-Appelt K. (2015) Methodological Approach to a Safety Analysis of Radioactive Waste Disposal in Rock Salt: An Example, Progress in Nuclear Energy, 84, 79-88. • DOPAS: Demonstration of Plugs and Seals EC-GA#323273 including four collaborative projects with BMWi /PTKA i. e. LAVA, LASA, THM and PASS, 1.9.2012 – 31.08.2016 • MOSEL: Investigation of Modern Methods of Probabilistic Sensitivity Analysis of Final Repository Performance Assessment Models (collaborative project, BMWi/PTKA, 01.05.2011-31.12.2016) • WEIMAR: Further Development of the Smart-Kd-Concept for Long Term Safety analyses (collaborative project, BMWi/PTKA, 01.06.2017-28.02.2018) •
a list of up to 5 relevant previous projects or activities, connected to the subject of this proposal • EU project MICADO : SUBATECH (Grambow B.), AMPHOS (Bruno J., Duro L., Merino J., Tamayo A.), ANDRA (Martin C., Pepin G., Schumacher S.), BELV (Smidt O.), CEA (Ferry C., Jegou C.), CIEMAT (Quinones J., Iglesias E., Rodriguez Villagra N., Nieto J. M.), ENRESA (Martínez-Esparza A.), FZK•INE (Loida A., Metz V., Kienzler B.), GRS (BRACKE G.), IRSN (Pellegrini D., Mathieu G.), JRC-ITU (Wegen D.), KTH (Jonsson M.), NAGRA (Johnson L.), SKK.CEN (Lemmens K.), SSM (Liu J.), STUDSVIK (Ekeröth E.), UPC (Casas I., de Pablo J.), Quintessa (Hodgkinson D.) (2010) FINAL Project Report: MICADO - Model uncertainty for the mechanism of dissolution of spent fuel in nuclear waste repository, European Commission, Sixth Framework Programme Priority No. Nuwaste-2005/6-3.2.1.1-2. • EU project RECOSEY: https://cordis.europa.eu/result/rcn/140458_en.html • VSG: Preliminary Safety Analysis of the Gorleben site (https://www.grs.de/vorlaeufige-sicherheitsanalyse-gorleben-vsg) • DOPAS: Demonstration of Plugs and Seals EC-GA#323273 including four collaborative projects with BMWi /PTKA i. e. LAVA, LASA, THM and PASS, 1.9.2012 – 31.08.2016 • MOSEL: Investigation of Modern Methods of Probabilistic Sensitivity Analysis of Final Repository Performance Assessment Models (collaborative project, BMWi/PTKA, 01.05.2011-31.12.2016) • WEIMAR: Further Development of the Smart-Kd-Concept for Long Term Safety analyses (collaborative project, BMWi/PTKA, 01.06.2017-28.02.2018)
a description of any significant infrastructure and/or any major items of technical equipment, relevant to the proposed work; geotechnical and geochemical laboratory
if operational capacity cannot be demonstrated at the time of submitting the proposal, describe the concrete measures that will be taken to obtain it by the time of the implementation of the task. N/A

		Name	Acronym
Participant	17	Ignalinos Atomine Elektrine	IAE
Description of the legal entity The state enterprise Ignalina Nuclear Power Plant - <i>Ignalinos Atomine Elektrine</i> (IAE) is carrying out the decommissioning of NPP, construction and operation of storage facilities and repositories for VLLW, LILW, SF (including DGR construction). It includes the operation of key systems that ensure nuclear, radiation and fire protection, as well as physical safety at the INPP, the unloading of spent nuclear fuel from power units and its transportation to the Interim Spent Fuel Storage Facility, equipment and building decontamination and dismantling, and radioactive waste treatment and storage. The INPP decommissioning is set to be completed by 2038.			
Description of main tasks in EURAD-1, with an explanation of how its profile matches the tasks IAE is mainly involved in WP10-ROUTES and more specifically Task 2.1 and Task 4.1.			
a curriculum vitae or description of the profile of the persons, including their gender, who will be primarily responsible for carrying out the proposed research and/or innovation activities Mr. Viktor Ognerubov NSR project manager. 13 year experience in the research activities related to Nuclear engineering safety at Kaunas university of technology, and Lithuanian Energy Institute on thermal-hydraulics and transient accidents, severe accident analysis. 5 years experience and Ignalina NPP as RAW management strategy development and project management of NSR and involvements of national RAW development program preparation, member of supervisory group of DGR project implementation. Experience in approval of NSR project by state institution, licensing process etc.			
a list of up to 5 relevant publications, and/or products, services (including widely-used datasets or software), or other achievements relevant to the call content Implemented and projects under implementation at Ignalina NPP. See list of : completed projects: https://www.iae.lt/en/activity/decommissioning-projects/completed-projects/ current projects: https://www.iae.lt/en/en/activity/decommissioning-projects/current-projects/			
a list of up to 5 relevant previous projects or activities, connected to the subject of this proposal Dismantling of equipment in various buildings of INPP. Implementation of project related to SF and RAW storage facilities See list of : completed projects: https://www.iae.lt/en/activity/decommissioning-projects/completed-projects/ current projects: https://www.iae.lt/en/en/activity/decommissioning-projects/current-projects/			
a description of any significant infrastructure and/or any major items of technical equipment, relevant to the proposed work; See list of Ignalina NPP projects: completed projects: https://www.iae.lt/en/activity/decommissioning-projects/completed-projects/ current projects: https://www.iae.lt/en/en/activity/decommissioning-projects/current-projects/			
if operational capacity cannot be demonstrated at the time of submitting the proposal, describe the concrete measures that will be taken to obtain it by the time of the implementation of the task. See list of : completed projects: https://www.iae.lt/en/activity/decommissioning-projects/completed-projects/ current projects: https://www.iae.lt/en/en/activity/decommissioning-projects/current-projects/			

	No	Name	Acronym
Participant	18	Instytut Chemii i Techniki Jadrowej	INCT (ICHTJ)
Description of the legal entity The Institute of Nuclear Chemistry and Technology is the most recognised institution in Poland in the fields of nuclear chemistry, radiochemistry, radiation chemistry, nuclear chemical engineering and technology. The other fields of the INCT's expertise include application of nuclear methods in material engineering and process engineering, radioanalytical techniques, design and production of measurement instruments based on nuclear techniques, environmental research, radiobiology and radioprotection. The results of research performed at the INCT have already been implemented in various branches of the national economy, particularly in industry, medicine, environmental protection and agriculture. With nine electron accelerators in operation and with a staff experienced in the field of electron beam application, the INCT is one of the most advanced centres of science and technology in this domain. The Institute has four pilot plants equipped with six electron accelerators: for radiation sterilization of medical devices and tissue grafts; for radiation modification of polymers; for removal of SO₂ and NO_x from flue gases and for food hygienisation. The Institute trains international atomic energy agency's fellows and plays a leading role in agency regional projects. Because of its achievements, the INCT has been nominated "the IAEA's collaborating centre in radiation technology and industrial dosimetry". Its expertise and infrastructure was the basis for participation in several EURATOM, FP7 and Horizon2020 grants. The organization is preparing to play a role of TSO in the Polish nuclear energy programme, offering the expertise in: – Radioprotection and biological dosimetry; – Radioactive waste treatment and disposal; – Coolant and fuel chemistry; – Novel nuclear fuel cycles (including GENIV reactors) – front and back end; – Materials for present and novel reactor systems; – Environmental monitoring of nuclear facilities; – Measurement and control devices for NPPs and nuclear laboratories; – Education and training of the staff; – Public information; – Collaborative projects with stakeholders offering interaction between "the technical and the social" approaches. The INCT works in a consortium of Polish institutions developing the project of the selection of a site for a new near-surface repository for low and intermediate radioactive waste and on the scenario of closing up present repository in Rozan.			
Description of main tasks in EURAD-1, with an explanation of how its profile matches the tasks As an organization with the mandate of the Ministry of Energy, the Institute of Nuclear Chemistry and Technology represents the Ministry and Polish stakeholders in the tasks of this proposal. The INCT will mainly work in Strategic Study WP "Waste management routes in Europe from cradle to grave (ROUTES)" providing all necessary information in the national context of radioactive waste management. The INCT will contribute to elaboration of this strategy collecting the existing state-of-the arts methods for characterization, treatment and disposal, especially for problematic waste and identifying future requirements of implemented technologies. As a mandated actor the INCT will disseminate the project results among stakeholders in Poland; evaluate the possibilities of implementation of the studied methods in the program of development of new RW repositories in Poland. By participating in the program provided for in the ROUTES Extension, INCT will collect information useful in two planned and important programs for Poland: the construction of a new repository for low-level radioactive waste and the closure of the existing repository in Rozan. The first topic will involve the need to develop a WAC for a new site, the second is to ensure long-term safety for a closed repository. The development of new technologies for problematic waste is also of interest for the coming years. Therefore, INCT will participate in Subtasks 2 and 3 outlined in this application.			
a curriculum vitae or description of the profile of the persons, including their gender, who will be primarily responsible for carrying out the proposed research and/or innovation activities			

Grazyna Zakrzewska-Koltuniewicz, (F), DSc, PhD, Professor at the Institute of Nuclear Chemistry and Technology, a specialist in radiochemistry and nuclear chemistry. She supervised many national and international research projects concerning radioactive waste treatment, fuel cycle and separation of isotopes. Prof. Zakrzewska was a coordinator of Marie Curie ToK project in FP6 „Advanced Methods of Environment Research and Control” (AMERAC). She represented INCT as a partner, in several EURATOM projects, like IPPA, NEWLANCER, EAGLE, and CHANCE. She worked as an expert in projects related to siting the new repository for low and intermediate level radioactive waste and to the plan of closing up the old Rozan repository. She wrote over 139 scientific papers and was granted 10 patents. Prof. Zakrzewska is a representative of Poland in Radioactive Waste Management Committee of NEA and in Article 37 of EURATOM expert group. She also acts as elected President of Polish Nuclear Society.

Agnieszka Miskiewicz (F), PhD, chemist specialising in radioactive waste processing and separation methods for nuclear and environmental applications. She participated in several research projects concerning radioactive waste, among others EURATOM projects related to the public involvement in radioactive waste management decision-making processes, like IPPA and PLATENSO, and IAEA CRPs. She has also supervised the projects concerning radioactive waste management and nuclear methods application financed from the national funds.

Katarzyna Kiegiel (F), PhD in chemistry at University of Warsaw, The Faculty of Chemistry, (1998); scientific assistant at University of Warsaw, the Faculty of Chemistry (1998-2000); Postdoctoral position at University of Kentucky, Department of Molecular and Cellular Biochemistry, Lexington, KY USA (2000-2001). She has a position of senior specialist at the Institute of Nuclear Chemistry and Technology, Warsaw, since 2011. At present she works in the field of uranium chemistry and new extracting agents for actinides; she is a specialist in separation process like solvent extraction and solid-liquid extraction. She participated in research projects, financed from structural and EC funds, as well as EURATOM projects like NEWLANCER and ARCADIA.

a list of up to 5 relevant publications, and/or products, services (including widely-used datasets or software), or other achievements relevant to the call content

1. Grazyna Zakrzewska-Trznadel, Advances in membrane technologies for the treatment of liquid radioactive waste, Desalination, 321 (2013) 119-130.
2. Wioleta Olszewska, Agnieszka Miskiewicz, Grazyna Zakrzewska-Koltuniewicz, Leszek Lankof, Leszek Pajak, Multi-barrier system preventing migration of radionuclides from radioactive waste repository, Nukleonika 2015;60(3);557-563.
3. Grazyna Zakrzewska-Koltuniewicz, Advancement in Membrane Methods for Liquid Radioactive Waste Processing: Current Opportunities, Challenges, and the Global Scenario. In: Handbook of Membrane Separations, Chemical, Pharmaceutical, Food and Biotechnological Applications, Second Edition, ed. by A.K. Pabby, S. S.H. Rizvi, A.M. Sastre, CRC Press Taylor & Francis Group (2015), Pages 665-708.
4. Method of obtaining and separating valuable metallic elements, specifically from low-grade uranium ores and radioactive liquid wastes, (G. Zakrzewska-Trznadel, A. Jaworska-Sobczuk, A. Miskiewicz, W. Lada, E. Dluska, S. Wronski) EP2604713, 2015.
5. Claire Mays, Jaroslav Valuch, Chiara Condry, Agnieszka Miskiewicz, Grazyna Zakrzewska, Marin Constantin, Daniela Diaconu, Irena Daris, Metka Kralj, Nadja Železnik, Tanja Perko, Looking for citizen-centered communication: Dialogues between radiological protection or nuclear safety specialists and media professionals, J. Radiol. Prot. **36** (2016) S143–S159.

a list of up to 5 relevant previous projects or activities, connected to the subject of this proposal

1. 2012-2015 Strategic Research Project: Technologies supporting the development of safe nuclear energy, Research Task. No 4: Development of technologies supporting the management of spent fuel and radioactive waste, Hybrid processes in the treatment of radioactive wastewater, financed by the National Centre for Research and Development.
2. 2011-2013 Project FP7-269849 Euratom, Implementing Public Participation Approaches in Radioactive Waste Disposal (IPPA)
3. 2013-2016 Safety of Actinide Separation processes (SACSESS)
4. 2013-2017 Development of safety assessment methodology and selection of optimum location of shallow repository for low and medium radioactive waste, Project financed by the Ministry of Economy.

5. 2017-2021 Horizon 2020, Characterization of conditioned nuclear waste for its safe disposal in Europe (CHANCE)
a description of any significant infrastructure and/or any major items of technical equipment, relevant to the proposed work; The INCT possesses the infrastructure relevant to the performed R&D activities. The main infrastructure consists of 9 electron accelerators, radiochemistry laboratories equipped with hot cell and glove boxes, technological halls with pilot installations (research installations for nuclear materials and radioactive waste processing), high activity gamma sources, EPR spectrometers, dosimetry systems, pilot plant for flue gas treatment, Single crystal X-ray diffractometer, TGA-DTA analysers, TOC analysers, Isotope Ratio MS, ICP-MS ELAN DRC II, liquid chromatographs (HPLC PERKIN ELMER, HPLC, Shimadzu), gas chromatographs, ion chromatographs, atomic absorption spectrometers, spectrophotometers UV-Vis, liquid scintillation alpha and beta counters, HPGe detectors, gamma counters, Multi-channel gamma analysers, Thin layer chromatography analysers (TLC) with radiometric gamma detector, Electron microscopes, autoclaves, laminar chambers, etc.
if operational capacity cannot be demonstrated at the time of submitting the proposal, describe the concrete measures that will be taken to obtain it by the time of the implementation of the task. N/A

	No	Name	Acronym
Participant	19	<i>Institut de Radioprotection et de Sûreté Nucléaire</i>	<i>IRSN</i>
Description of the legal entity The IRSN is a French public establishment of an industrial and commercial nature placed under the joint authority of the Ministries of the Environment, Health, Industry, Research and Defence. The IRSN's field of expertise covers all of the risks related to ionising rays used within industry or medicine, or even natural radiation rays. More precisely, the IRSN carries out missions relating to analysis and research in the following fields: the safety of nuclear installations, including those relating to defence; the safety of the transport of radioactive and fissile materials; the protection of man and the environment against ionising rays; the protection and control of nuclear materials and products likely to be used in the manufacture of weapons and the protection of installations and transport against acts of malevolence (theft or misappropriation of nuclear materials, or even sabotage). The research activities, most often carried out within the framework of international programmes, allows IRSN to maintain and develop its expertise. IRSN was involved in or coordinated several EC FP projects on waste safety (EVEREST, SPA, NFPRO, BENIPA, PAMINA, MICADO, FORGE, SITEX, JOPRAD).			
Description of main tasks in EURAD-1, with an explanation of how its profile matches the tasks - PMO WP: IRSN will participate in the PMO during the first 2,5 years (3 pm) - ACED WP: IRSN will participate (as task leader) in the task 2. The objective of the task 2 is to provide geochemical and coupled reactive transport models for assessing chemical evolution at steel/clay material and steel/cement material interfaces in terms of corrosion rates, geochemical alterations and physical alterations. These models will provide the bases of the up-scaling to waste package (Task 3) and near-field (Task 4) modelling. IRSN will work on a new in situ collaborative experiment (BACUCE) in the URL of Tournemire to study the interface between ambient temperature and 80°C between grout cement/CEM I and carbon steel cylinder until three years of interaction (with Mines Paris Tech, SUBATECH and ZAG). One of the focus points is on the influence of an imperfect contact. The BACUCE experiment started in 2017 to study the steel corrosion in contact with a cementitious environment (CEM I and grout cement) in a temperature range between 14°C and 80°C under the influence or no of bacterial activity and the influence of the interface quality. The first experiments were started in laboratory. New experiments will be start in in situ conditions in October 2018 at ambient temperature and 2019 at 80°C. The objectives of IRSN in ACED WP are: i/ to identify the corrosion speed of C-steel in alkaline and low alkaline environment and the influence of heterogeneities; ii/ to provide robust data for chemical model of the type of corrosion products and mineralogical evolution of cement materials with respect to temperature and spatial heterogeneity; iii/ to calibrate and refine the corrosion rates of steel under slightly alkaline conditions with respect to temperature and heterogeneities. - GAS WP: IRSN will participate in the work towards main objectives of this WP: ✓ <i>To improve the mechanistic understanding of gas transport processes in natural and engineered clay materials, their couplings with the mechanical behaviour and their impact on the properties of these materials;</i> IRSN will use its Lattice Boltzmann Model to study pore scale diffusion close to saturation with/without sorption to complete experimental results and deliver an interpretation basis with a strong link to the microstructure of materials. This work will also benefit from the previous work on development of 3D automatic segmentation mineral phases and pores in imaging data. The IRSN's Smoothed Particle Hydrodynamics code takes advantage of 3D images of material microstructure and is able to treat the mechanical deformation of the solid phase interacting with a two phase flow. It will serve to simulate small scale experiments conducted to better understand the relation between the microstructure and creation of dilatant pathways of gas in water saturated argillite.			

New gas injection in existing mock-up experiments will be performed on bentonite mixtures presenting an initial heterogeneous structural distribution, induced by the installation process, in order to investigate the effect of structural heterogeneities on gas transport processes. The samples will be subjected to hydraulic and gas loadings, both asymmetric to mimic real saturation scenario of shaft sealing systems: rapid increase of water pressure on top and independent control of lateral hydraulic boundary conditions and bottom gas pressure increase. In parallel a complementary cell in PMMA will be used to perform a microstructural analysis of the mixture at initial state and during gas /water injections by X-ray micro-tomography.

- ✓ *To evaluate the gas transport regimes that can be active at the scale of a geological disposal system and their potential impact on barrier integrity and repository performance.*

Based on previous experience in development of codes and simulations of gas migration within repository (participation in numerical benchmark in EC project FORGE), IRSN will construct, implement and use an extended 2-phase flow model for simulation of scenarios to be proposed within this project with the aim of increasing the predictivity of numerical simulations and reducing the gap between experimental data and ad-hoc parameters fits.

- DONUT WP: IRSN will participate in the task 2.

The goal of this task is to design and implement efficient numerical algorithms taking advantage of the latest research achievements for solving complex coupled problems. IRSN will participate to this task in developing numerical model aiming at improving physical representations of gas migration in porous media. This work will be focused on processes usually neglected in these models, such as hysteresis on relative permeability and retention curve, gas entry pressure in 2-phase-flow formula, hydro-mechanical behavior of interfaces at seals. The relevant processes among these will be implemented in THGas representations at large scales.

- UMAN WP: In the Task 2 related to Strategies, approaches and tools, IRSN will by notably share their experience with uncertainty and sensitivity analysis methods (subtask 2.3).

In the Task 3 of Characterization and significance of uncertainties for different categories of actors, IRSN will collect and synthesize relevant information on uncertainties associated with the site and geosphere. IRSN will notably have the ground to share the French experience related to the siting phase for geological and near-surface disposal projects (subtask 3.3).

For the Task 5 on Interactions between all categories of actors, in the subtask 5.1 of Preparation, support and reporting of pluralistic analyses, IRSN will be leader of Topic 2 related to Pluralistic analysis of uncertainty pictures. Thanks to the two hats profiles -both researcher and expert in safety assessments- of the IRSN participants as well as their experience in terms of dialog with Civil Society (through the French disposal project of Cigéo and through the SITEX European projects), IRSN will coordinate the development of materials to be discussed in two seminars and will lead the development of deliverable 5.2. IRSN will also take part to Topic 4 related to the Methods for a pluralistic assessment of uncertainties, contributing to the development of proposals of methods for a pluralistic assessment of uncertainties and to the development of deliverable 5.4.

As part of UMAN extension, IRSN will participate in the workshops organised by Subtasks 3.6 and 4.3 and contribute, as member of the subtask 3.6 expert group, to:

- the collection and synthesis of relevant information on uncertainties associated with the near field (including the French experience related to geological disposal)
- the development of the material for the workshop organized by Subtask 3.6 and the seminar organized by Task 5
- the writing of the deliverable of Subtask 3.6.

In this subtask, IRSN will notably have the ground to share the French experience related to the siting phase for geological and near-surface disposal projects.

After 30 years of development of the project of geological disposal, Cigéo is actually in phase of design. IRSN has thus a long experience in management of near-field related uncertainties. In particular, IRSN develops its own appropriate set of scenarios to evaluate the performance of the disposal. Radionuclides flux

from the near field to the far field environment (geosphere) is considered as the end point of the assessment. Therefore, R&D studies at the Tournemire URL on THMC processes contribute to the management of uncertainties being faced when assessing performance of the disposal system. Moreover, THMC processes and their related uncertainties allow to understand the disposal system behaviour at different stages of the disposal life cycle, in order to build confidence in the safety case.

Regarding the two French surface disposal facilities, one being in operation and the other in monitoring phase, IRSN has now the ability to identify the near-field parameters and their associated uncertainties which can have the highest impact on the disposal performance on the long term period.

- ROUTES WP:

IRSN will lead and coordinate the WP and will participate to the tasks 1, 2, 3, 4 and 6.

In this WP, IRSN will exchange on views, practices and radioactive waste management options available or not and bring the French experience. IRSN will share its feedback of safety relevant issues on waste management not only for disposal but also for pre-disposal including characterisation, treatment, conditioning and storage. Moreover, IRSN is involved in the assessment of the retrieval and conditioning processes for legacy waste which are of interest for a lot of countries involved in ROUTES WP.

As part of ROUTES extension, IRSN will ensure as coordinator to WP ROUTES the consistency and coherence of the work conducted in the ROUTES WP and in the ROUTES Extension to avoid any redundancy in the work plan and will coordinate together with the ROUTES Extension task lead the exchanges with EURAD WPs especially KM WP and other H2020 Projects (PREDIS).

- WP16-MAGIC :

Amongst others, IRSN is in charge of assessing the overall safety of the French geological deep repository project (Cigéo) for High-Level and Medium-Level Long-Lived Radioactive wastes, developed by Andra, which strongly relies on the mechanical properties of concrete barriers. In this framework, the LETIS Research Unit (specialized on Transfers and Interactions in Underground Environment), located in Fontenay-aux-Roses, has been carrying out for many years research activities related to the chemo-mechanical behavior of cementitious materials in this environment.

As WP leader, IRSN will lead the WP and will manage it through the Task 1.

The Task 3 of MAGIC WP focus on the chemo-mechanical state of cementitious materials depending on the chemical attack evolution with a nanoscale approach. Two studies proposed in this task 3 involved IRSN. Both follows the same approach in term of solid characterization (Figure 1.). Samples are immersed in a solution to initiate chemical attack. By coupling several technics, this approach aims at understanding the consequences of mineralogy and microstructure evolution due to chemical attack on the mechanical properties of the cement material. The first proposal named IMCB involves three partners: IRSN, university of Helsinki and HZDR. This study aims to fill the lack of knowledge about the chemo-mechanical behavior of low-pH cement in calcareous environment. The second proposal named PM2SH involves three partner IRSN, university of Helsinki and LMDC. The aim of this project is to estimate the mechanical properties of magnesium silicate hydrates (M-S-H).

- WP17-MODATS :

IRSN will coordinate subtask 2.5 dedicated to CSO activities

- IRSN will contribute to methodology development in subtask 2.5

- IRSN will develop induced polarisation in subtask 3.1 and take in charge the WTB in subtask 3.3

a curriculum vitae or description of the profile of the persons, including their gender, who will be primarily responsible for carrying out the proposed research and/or innovation activities

Dr. **Delphine Pellegrini** holds a PhD in physico-chemistry from the University of Besançon, (France). In 1997, she joined IRSN as an engineer and was in charge of research and safety assessment related to geochemical issues in the framework of geological disposal of radioactive waste. Then she was the technical lead of the review of the Dossier 2005 developed by the French waste management organisation for geological disposal of waste in clay. From 2007 to 2013, she was the manager of the Safety Assessment and Research Section for Radioactive Waste Disposal Facilities. She supervised in the last years several safety reviews and technical expertise for surface or geological disposal facilities. She was also deeply involved in

EC-SITEX project (2012-2013) and was the coordinator of EC-SITEX II project (2015-2017). Before that, she took part in several EC projects (BENIPA, NF-PRO, PAMINA, MICADO) including as a WP Leader within the FORGE project (2009-2013) and contributed to AIEA consultancies related to waste disposal. She is currently the IRSN head of the Department for Radioactive Waste and Transfers in the Geosphere. She is also the president of the association called SITEX_Network in charge of enhancing and fostering cooperation at the international level in order to achieve a high quality expertise function in radioactive waste management.

Mrs. **Elisabeth Salat** has more than 20 years' experience in the field of radioactive waste management. She is a physic engineer who graduated from the University of Clermont Ferrand. She worked 5 years as safety engineer on near surface disposal at the French national agency for radioactive waste management (ANDRA). She then joined the CEA (French nuclear research organization) and participated as project manager in several RWM projects. She was also engaged in programming and managing the dismantling projects at CEA facilities. She is currently deputy head of department for radioactive waste and transfers in the geosphere, in IRSN. She is responsible for supervising IRSN safety assessments of radioactive waste disposal and of all types of activities in relation with waste management (treatment, containment...). She was involved in the EC project JOPRAD (2015-2017) in particular in the conditions for implementing a join programme. She will be involved in the PMO from Month 1 to Month 30.

Dr **Alexandre Dauzères** holds a PhD in Geoscience and Physico-Chemistry of Material from University of Poitiers and CEA. He joined IRSN in 2010 after his thesis to manage and develop the research activities on the material interactions (clay/concrete and clay/steel) with a multi-scale approach through in situ and lab exp. and reactive transport modelling. He managed 7 PhD students and 2 postdocs, especially in the concrete ageing research field. Since July 2017, he is Head of the Research Laboratory on Transfers and Interactions in Underground Environment (LETIS). The laboratory is in charge to conduct researches on the geological waste disposal to support the IRSN safety expertise. Alexandre currently evolves in the EC CEBAMA project.

Dr. **Muriel Rocher** holds a PhD in Tectonics from Paris VI University, Department Earth Science and Gaz de France. Since 2004 in IRSN as a nuclear safety engineer, she carries out both research projects and safety assessments related to geological and hydrogeological issues, including siting and seismic hazard, for low or high level–long lived waste disposal facilities (respectively shallow-surface and deep underground projects), and is involved in the development of the national guiding principles for siting of such waste disposal facilities. From 2009 to 2017, she was the main contact person for the on-site follow-up of the Andra's R&D in the Bure underground laboratory. She recently led the regulatory review of the Cigéo "Safety Option Dossier", submitted by Andra before the request for the construction license application and, in the same time, was involved in EC-SITEX projects.

Dr **Magdalena Dymitrowska** holds a master degree in physics and a PhD in physical chemistry from University of Orsay. In her previous experiences, she worked as a scientific and teaching collaborator for several academic institutions and specialized in modelling of physico-chemical phenomena at mesoscopic level (gas adsorption isotherms in nano-porous solids, elastic disorder in black rubber, localized corrosion). She joined IRSN in 2002 as a research engineer to develop radionuclide large scale transport models within Melodie software. Since 2006 she is in charge of defining and implementing of a scientific program focused on understanding and quantification of gas migration within HLW repositories. She was/is involved in EC projects of the 6th and 7th PCRD (PAMINA and FORGE) related to this subject, as well in several French projects (ANR HydroGeoDam, Needs-MiPor, MoMaS).

Dr **Zakaria Saadi** Holds a master degree in Physics (Fluid Mechanics), then a PhD in Fluid Mechanics with applications to surface and subsurface hydraulics and hydrology (co-tutored thesis: Ibn Tofail University, Kenitra-Morocco; Joseph Fourier University, ENSHMG-INPG-CNRS, Grenoble-France). An accomplished professional with 20 years of experience in a solid analysis background. Possess thorough knowledge of specialised theories/principles in the fields of fluid mechanics, soil physics, agronomy, geosciences, watershed hydrology, physico-chemical and biological wastewater treatment technologies, formulations of mathematical problems of multiphase flow and contaminant transport processes and their applications. After 12-year experience as mathematical modeller in the above different disciplines during

his PhD and three postdocs (IFP, INRA, CNRS) he joined IRSN in 2010 and assigned as lead for risk assessment, especially risks attributed to radon transport from the geosphere to indoor and outdoor environments (e.g., project JURAD-BAT). Now, works on gases transport emanating from radioactive waste disposal facilities and their potential impact on barrier integrity and repository performance, especially development of THM-Gas models at different scales. During his carrier, he developed and validated several codes of two-phase flow and transport in porous media: VZM, TNT2-INRA, POWER-CNRS, CAPSIS-INRA, TOUGH2/EOS7Rn, iT2Rn. He supervised 2 post-docs (radon transport from soils and karst systems to buildings), and 1 PhD student (uncertainties on gas transport near radioactive waste repositories due to negligible air entry pressure and hysteresis effects).

Dr **Virginie Wasselin-Trupin** holds a PhD in radiochemistry from Paris XI university-Orsay. After a post doc in the institute for the transuranium elements (ITU) from the EC-JRC, she joined IRSN in 2002 as engineer in charge of the assessment of the safety of nuclear waste packages and waste management. She is since 2012 the head of the Safety Assessment Section for radioactive waste management. She is also involved in research activities dealing with the management of radioactive waste (such as radiolysis phenomena) and European research project like MICADO or FORGE. V. Wasselin-Trupin participates to the French working group on the National Management Plan for Radioactive Materials and Waste (PNGMDR). She is involved in European contracts dealing with the management of waste (Bulgaria, Vietnam, Morocco, Ukraine, Indonesia, China, Georgia) and in many training courses. In IRSN, she performs also the technical supervision of review teams for the European Commission involving European TSOs and development of safety standards for IAEA as consultant in the waste management field.

a list of up to 5 relevant publications, and/or products, services (including widely-used datasets or software), or other achievements relevant to the call content

- ✓ M. Dymitrowska, F. Smaï, F., A. Bourgeat. Thermodynamic modelling of hydrogen migration in argillite for a deep geological radioactive waste repository: IRSN contribution to FORGE, Geological Society Special Publication, 415 (1), pp. 167-188, 2015
- ✓ Dauzères, G. Achiedo, D. Nied, E. Bernard, S. Alahrache, B. Lothenbach, Magnesium perturbation in low-pH concretes placed in clayey environment - solid characterizations and modelling, Cement and Concrete Research: 79 (2016) 137 – 150.
- ✓ S. Grousset, M. Bayle, A. Dauzères, D. Crusset, C. Martin, V. Deydier, Y. Linard, P. Dillmann, F. Mercier-Bion, D. Neff, Study of irons sulfides in long-term iron corrosion processes: Characterizations of archeological artefacts, Corrosion Science, 112: (2016) 264-275.
- ✓ N. Seigneur, A. Dauzères, A. Dubus, P.E. Labeau, V. Detilleux, Numerical Elementary Representative Volume generation of a simplified cement paste and estimation of its diffusivity and comparison with dedicated experiments, Journal of Porous Media, 20, 1, (2017) 29 - 46.
- ✓ P. Lalan, A. Dauzères, L. De Windt, D. Bartier, J.-D. Barnichon, V. Detilleux, Impacts of 70°C temperature on an OPC paste in an in situ clayey environment: chemical and microstructural characterizations coupled with reactive transport modelling, Cement and Concrete Research, : 83 (2016) 164-178.

a list of up to 5 relevant previous projects or activities, connected to the subject of this proposal

- JOPRAD: the objectives of this project, in which IRSN was an active member, were to develop synergies and increase coordination at European level to go towards a joint programming on radioactive waste disposal. So the results of this project are the basis allowing building the EURAD EURAD.
- SITEX: IRSN coordinated the SITEX (EURATOM FP7, 2012–2013) and the SITEX-II (EURATOM Horizon2020 CSA, 2015-2017) projects. SITEX had the objective to build a sustainable network for independent technical expertise for radioactive waste disposal; the aim was to promote independent expertise function and participation of the civil society within the expertise function. The association SITEX_Network embarks the major part of TSOs and civil society organisations involved in the EURAD.
- MODERN2020: The overall objective of the Modern2020 Project is to provide the means for developing and implementing an effective and efficient repository operational monitoring programme, that will be

driven by safety case needs, and that will take into account the requirements of specific national contexts (including inventory, host rocks, repository concepts and regulations, all of which differ between Member States) and public stakeholder expectations (particularly those of local public stakeholders at (potential) disposal sites). The in situ experiments specifically developed by IRSN and partners in MODERN 2020 are linked to the research field of sealing using clay and concrete materials and will be certainly useful for the EURAD.

- CEBAMA: This project addresses key issues of relevance for long term safety and key scientific questions related to the use of cement-based materials in nuclear waste disposal applications. These materials are key components in the barrier system of repositories, independent on the actual host rocks. A wide part of the results of CEBAMA will be used in the EURAD, especially in the ACED WP. The results obtained by IRSN are concerned.

- FORGE: Objectives of the FORGE project were to study i/ the impact of gas migration on repository infrastructure and engineering performance, ii/ new models to describe the mechanisms and processes governing gas, water and radionuclide movement in repository components, iii/ new insights into the engineered barrier systems (EBS) properties, engineered disturbed zone (EDZ) behavior, far field interactions, gas generation and up-scaling. This project is clearly linked to the gas migration WP starting as part of the EURAD.

a description of any significant infrastructure and/or any major items of technical equipment, relevant to the proposed work;

✓ The Tournemire URL:

Acquired by IRSN in 1992, the Tournemire Underground Research Laboratory, is now one of the four underground laboratories in Europe in which it is possible to carry out researches on disposal in clay formation.

The Tournemire URL is solely used for scientific and technical researches. Located in a former railway tunnel built over 120 years ago, this station provides access to a clay formation that has similar geological characteristics than the site chosen by Andra. The research carried out will enable IRSN to examine specific processes that play an especially important role in ensuring the long-term safety of a geological repository.

Various experimental studies are carried out by IRSN to analyze:

- The mechanisms responsible for the transfer of water and natural substances present in the clay formation;
- The effects of excavation and of using the underground engineering structures on the rock's containment properties;
- The effects related to interaction between the rock and the materials added, such as concrete and metal components;
- The performance of components essential to the long-term safety of a geological repository, such as seals.
- To test the monitoring

✓ The LUTECE Laboratory

This IRSN laboratory located in Fontenay aux Roses is dedicated to carry out experiments and analyses (solid and liquid analyses). This laboratory is equipped for example with SEM-EDS, 2 X-Ray microtomographs, a ionic polishing system, a BET, a laser granulometer and different devices for liquid analyses: ICPMS, ICAP, IC, Spectro UV-Visible....

if operational capacity cannot be demonstrated at the time of submitting the proposal, describe the concrete measures that will be taken to obtain it by the time of the implementation of the task.

N/A

	No	Name	Acronym
Participant	20	Instituto Superior Técnico – Laboratório de Proteção e Segurança Radiológica	IST-LPSR
Description of the legal entity Instituto Superior Técnico (IST) is the School of Engineering of the University of Lisboa and aims to contribute to the development of society, promoting and sharing excellence in higher education in the fields of Architecture, Engineering, Science and Technology. Técnico offers Bachelor, Master and PhD programmes, lifelong training and develops Research, Development and Innovation (RD&I) activities, which are essential to provide an education based on the top international standards. Until 2012, the former Instituto Tecnológico e Nuclear (ITN) was a State laboratory that operated the Portuguese Research Reactor, the RW storage facility, the Radiation Protection and Safety Laboratory and provided support to the Government in the fields of Radiation Protection including RW Management. In 2012, ITN was extinguished by Decree-Law n. 29/2012, of February 9th and incorporated into IST. IST assumed all the responsibilities in the field of Radiation Protection and Nuclear Safety once attributed to ITN, including all human resources and infrastructures. As such, IST operates at its <i>Campus Tecnológico e Nuclear</i> the Portuguese Research Reactor, the Radiation Protection and Safety Laboratory, and the only RW Management facility in Portugal, a surface type facility for storage of very low, low and intermediate level wastes (Decree-Law n. 156/2013, of November 5th). In summary, IST acts as WMO and TSO and RE, respectively, waste management organization, technical support organization and research entity. Moreover, the Radiation Protection and Safety Laboratory of IST (IST-LPSR) performs all the activities related to radiation protection and safety, namely, national metrology of ionizing radiation, individual monitoring, environmental monitoring including radioanalytical techniques for the measurement of natural and artificial radionuclides in environmental samples, foodstuff, feedstuff, construction materials, water for human consumption radon in water and in dwellings, safety assessment of radiological facilities, transport of radioactive material, RW management and storage facility, as well as providing education and training and emergency preparedness and response in the field.			
Description of main tasks in EURAD-1, with an explanation of how its profile matches the tasks Portugal is a western European nation with 10.6 M inhabitants (approx.) facing the Atlantic Ocean with terrestrial borders with Spain only. Uranium ore extraction ceased in 2000 and all former U exploration sites have been or are presently being remediated, as there are no further plans to resume this activity. There are no nuclear power plants in the country although there is a 1 MW pool-type research reactor operated by IST, in transition to decommissioning since September 2017. In 2006 the research reactor was converted from high-enriched Uranium (HEU) to low-enriched Uranium (LEU) to improve proliferation resistance, in the framework of an agreement with the United States of America (USA) and the International Atomic Energy Agency (IAEA). All HEU was returned to the USA and at present there is no spent fuel (SF) at the reactor facility or anywhere else in the country. As a consequence, the radioactive waste (RW) generated in Portugal consists mainly of materials from past U and Ra mining and milling activities, spent and/or disused sealed sources, smoke detectors, lightning rods, contaminated scrap metal, depleted U from aircraft counterweights, materials contaminated with unsealed sources produced from the applications of ionizing radiation in the fields of Medicine, Industry and Research. The RW is of the very low, low and intermediate level waste types (VLLW, LLW and ILW) and is stored in a surface facility operated since the 1960s at IST's <i>Campus Tecnológico e Nuclear</i>. The first report of Portugal on the implementation of the Joint Convention of the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management was presented at the International Atomic Energy Agency (IAEA) in May 2012 and periodically updated since. Following the publication of Decree-Law n. 156/2013, of November 5th, that transposes Council Directive 2011/70/EURATOM into national law, IST prepares an inventory of the RW stored at its facility on an annual basis. RW records registered after the year 2000 are reliable but there is a strong uncertainty relative to the waste collected before, considered as legacy waste that requires characterization and classification. Prior to the publication of the Ministerial Ordinance 44/2015, of February 20th, adopting clearance and exclusion levels, all radioactive material with no further use, including materials that activated the radiation detection portals at the entrance of scrap metal yards, steel and iron melting facilities, landfills for dangerous materials, etc, were collected and brought to the RW storage facility at IST.			

Very recently, the first National Programme for the Management of Spent Fuel and Radioactive Waste (2015-2019) was approved by the Government and published in the official journal on the 7th of September of 2017, following the strategic environmental assessment and public consultation.

The first National Program specifically considers the following activities (among other): the characterization and identification of legacy waste, eventual preparation of exclusion processes for waste that no longer require storage at such a facility, restoration of enough room for waste of concern, and the improvement of the overall inventory of radioactive waste.

IST-LPSR will be actively involved in WP9-ROUTES:

Task n°2 - Identify challenging wastes to be collaboratively tackled within the Joint Programme - Mapping and shared understanding at EU level of practical issues on waste management routes

IST-LPSR will provide data on RW stored at the storage facility at IST, its classification, and on the identification of routes for disposal RW. Portugal is a country with a first programme on the Safe Management of RW (2015-2019) will benefit from the outcomes of the project.

Task n°3 - Description and comparison of radioactive waste characterisation approaches

IST-LPSR would like to benefit from the experience and knowledge on characterization of legacy RW with the aim to identify key radionuclides of concern and improve the inventory of its historic RW.

Task n°4 – Identification of WAC used in EU Member States for different disposal alternatives in order to inform development of WAC in countries without WAC/facilities

In Portugal there are no established WAC for the treatment and disposal of RW. IST-LPSR expects to improve its knowledge on this matter by sharing its limited experience on RW management balanced with the experience and the know-how from other advanced European member states.

Task n°5 - RWM solutions for small amounts of wastes

The RW generated in Portugal consists mainly of materials from produced from the applications of ionizing radiation in the fields of Medicine, Industry and Research, as there are no nuclear power plants in the country. On the other hand, Portugal is a country with its first programme on the Safe Management of RW (2015-2019). IST-LPSR will improve its knowledge on existing and potential disposal options and solutions for small amounts of radioactive waste.

Task n°6 – Shared solutions in European countries

IST-LPSR expects to learn from the possibilities for sharing technology and facilities available to European member states.

WP9-ROUTES extension :

IST-LPSR will contribute to ROUTES Extension by

- sharing their national experiences,
- evaluating the applicability of the developed solutions to their challenges and by
- reviewing the reports.

a curriculum vitae or description of the profile of the persons, including their gender, who will be primarily responsible for carrying out the proposed research and/or innovation activities

João Henrique Garcia Alves (male), born 10th of June of 1963, Portuguese, is the Head of the Radiation Protection and Safety Laboratory of Instituto Superior Técnico (IST-LPSR).

IST-LPSR performs all the activities related to radiation protection and safety, namely: metrology of ionizing radiation, individual monitoring, environmental monitoring including radioanalytical techniques for the measurement of natural and artificial radionuclides in environmental samples, as well as foodstuff, feedstuff, construction materials, water for human consumption radon in water and in dwellings, safety assessment of radiological facilities, transport of radioactive material, radioactive waste management, radioactive waste storage facility, education and training and emergency preparedness and response.

João Alves holds a PhD in Physics (Biophysics) by the Faculdade de Ciências e Tecnologia of Universidade Nova de Lisboa (2000); a MSc in Applied Nuclear Physics by the Faculdade de Ciências (FC) of Universidade de Lisboa (UL) (1992); and Graduation in Physics (Microphysics) by FC-UL (1987). Started working in Radiation Protection and Dosimetry matters in 1988 at the former Instituto Tecnológico e Nuclear and presently Instituto Superior Técnico (IST). Since 2000, is a researcher of (IST) at the Department of Nuclear Sciences and Engineering (DECN); Since 2013, is Deputy Director of the Radiation Protection and Safety Laboratory of IST (IST-LPSR). Since 2007 is a Council Member of the European Radiation Dosimetry association (EURADOS).

Has worked as Coordinator of IST teams and IST team member in 7 projects funded by international institutions; Coordinator of IST teams and IST team member in 2 projects funded by the national research foundation (FCT).

Reviewer of articles submitted to scientific journals for publication like Radiation Measurements and Radiation Protection Dosimetry, upon the request of the respective editorial board.

Is a member of the scientific committee and co-organizer of 3 international conferences, of 6 international short-term Training Courses on Individual Monitoring, Metrology of Ionizing Radiation and Radiation Protection, and of 5 Radiation Protection training actions at IST-LPSR.

Is an author and/or co-author of 40 original publications in international peer-reviewed journals and 7 national journals (approx.); Co-author of the EU *Technical Recommendations for Monitoring Individuals Occupationally Exposed to External Radiation*. Radiation Protection n. 160 (2009); Co-author of 18 technical reports (approx.). Author and/or co-author of 53 communications (oral and poster) presented at international conferences and symposia and 25 communications at national events. Is also a member of the teams awarded with 3 prizes at national events

Is also a member of the IST teams for the preparation of national legislation for the transposition of EU Directives, preparation Ordinances, and Technical Recommendations, etc on the Basic Safety Standards, Radioactive Waste management, National Programme for the Safe Management of Radioactive Waste and Spent Fuel, Assessment of radiological parameters in Water for Human Consumption, Metrological evaluation of ionizing radiation measurement devices;

Has collaborated with the International Atomic Energy Agency on the revision of Technical Documents, Technical Meetings (on the revision of IAEA Safety Guide n.º TS-G-1.2, 2002); and Training Actions (on *Emergency Preparedness and Response for Port and Maritime Emergencies*, Vienna, May 2018).

Has also collaborated with national institutions in several matters related to Radiation Protection issues, such as, the Ministry of Foreign Affairs, Directorate-General for Health, Portuguese Institute for Accreditation, National Commission for the Safety of Nuclear Facilities, Portuguese Environment Agency, National Authority on Civil Protection, NRBQ units of the Armed Forces.

Alfredo José Martins Nogueira Baptista (male), born 23rd of May of 1974, Portuguese, is the responsible for the Operational Radiation Protection nucleus at the Radiation Protection and Safety Laboratory (LPSR) of Instituto Superior Técnico (IST).

Alfredo Baptista holds degree in Physics Engineering by the Faculdade de Ciências e Tecnologia of Universidade Nova de Lisboa (2000).

His main tasks are the safety assessment of radiological facilities, transport of radioactive material, radioactive waste management at the storage facility, and emergency preparedness and response.

Started working in Radiation Protection matters in 2006 at the former Instituto Tecnológico e Nuclear and presently Instituto Superior Técnico (IST). Since 2015, is a technical officer at the Radiation Protection and Safety Laboratory of IST (IST-LPSR) and responsible for the Operational Radiation Protection nucleus.

Has worked as IST team member in projects funded by international and national institutions.

Is an author and/or co-author of 10 original publications in international and national peer-reviewed journals (approx.); Co-author of several technical reports. Author and/or co-author of 20 communications (oral and poster) presented at national conferences and symposia.

Has collaborated in the preparation of national legislation for the transposition of EU Directives, preparation Ordinances, and Technical Recommendations, etc on Radioactive Waste management, National Programme for the Safe Management of Radioactive Waste and Spent Fuel.

Has also collaborated with national institutions in education and training events and drills and exercises related to Radiation Protection and Emergency Preparedness and Response, such as, the Ministry of Foreign Affairs, Directorate-General for Health, National Commission for the Safety of Nuclear Facilities, Portuguese Environment Agency, National Authority on Civil Protection, NRBQ units of the Armed Forces.

a list of up to 5 relevant publications, and/or products, services (including widely-used datasets or software), or other achievements relevant to the call content W. Rühm, E. Fantuzzi, R. Harrison, H. Schuhmacher, F. Vanhavere, <u>J. Alves</u>, J. F. Bottollier Depois, P. Fattibene, Ž. Knežević, M. A. Lopez, S. Mayer, S. Miljanić, S. Neumaier, P. Olko, H. Stadtmann, R. Tanner, C. Woda. <i>EURADOS Strategic Research Agenda: Vision for Dosimetry of Ionizing Radiation</i>. Radiat. Prot. Dosim. 168 (2): 223-234 (2016). doi: 10.1093/rpd/ncv018. WOS: 000371607500010. J. Cardoso, J. Santos, L. Santos, <u>J.G. Alves</u>, C. Oliveira. <i>Characterization of an active dosimeter according to IEC 61526:2010</i>. Radiat. Prot. Dosim. 170 (1-4), 127-131, (2016). doi: 10.1093/rpd/ncw090. WOS: 000384713300030. M.F. Pereira, J. Pereira, S. Rangel, M. Saraiva, <u>J.G. Alves</u>. <i>Environmental monitoring with passive detectors at CTN in Portugal</i>. Radiat. Prot. Dosim. 170 (1-4), 342-345 (2016) doi: 10.1093/rpd/ncv479. WOS:000384713300077. M.J. Fartaria, C. Reis, J. Pereira, M.F. Pereira, J.V. Cardoso, L.M. Santos, C. Oliveira, V. Holovey, A. Pascoal, <u>J.G. Alves</u>. <i>Assessment of the Mean Glandular Dose using LiF:Mg,Ti, LiF:Mg,Cu,P, Li₂B₄O₇:Mn and Li₂B₄O₇:Cu TL Detectors in Mammography Radiation Fields</i>. Phys. Med. Biol. 61, 6384-6399 (2016). doi: 10.1088/0031-9155/61/17/6384. WOS: 000384209800012. S. Sarmento, J.S. Pereira, M.J. Sousa, L. Cunha, A.G. Dias, M.F. Pereira, A.D. Oliveira, J. Cardoso, L.M. Santos, J.A.M. Santos, <u>J.G. Alves</u>. <i>The use of needle holders in CTF-guided biopsies as a dose reduction tool</i>. J Appl Clin Med Phys, 19 (1), 250-258 (2018) doi: 10.1002/acm2.12234. WOS: 000427481300028. a list of up to 5 relevant previous projects or activities, connected to the subject of this proposal R. Trindade, I. Paiva, <u>A. Batista</u>, L. Portugal, J. Venâncio. <i>Radioactive Scrap Metal in Portugal: an overview</i>. Communication presented at the <i>International Conference on Control and Management of Inadvertent Radioactive Material in Scrap Metal</i>, Tarragona (Spain), February 2009. R. Trindade, I. Paiva, P. Duarte, F. Gomes, L. Portugal, <u>A. Batista</u>. <i>Exposição do Público Resultante das descargas de Efluentes Líquidos Radioativos na Rede Pública</i>. Communication presented at the XII Congresso Nacional de Medicina Nuclear, Coimbra (Portugal), November 2009. <u>J.G. Alves</u>. <i>Interim Storage, Regulation and Practical Aspects (the case of Portugal)</i>. Communication presented at the <i>NEA-Nuclear Energy Agency Workshop on the Management of Non-Nuclear Radioactive Waste</i>, Legnaro, Padova (Italy), May 2017. Collaboration with national Regulatory Commission for the Safety of Nuclear Facilities (Comissão Reguladora para a Segurança de Instalações Nucleares, COMRSIN) for the preparation of the following documents: <i>Guidelines for the Safe Management of Radioactive Waste for Storage at a Surface Facility</i> (2015) and <i>National Programme for the Safe Management of Radioactive Waste and Spent Fuel</i> (2015-2019) foreseen in Decree-Law n.º 156/2013, of the 5th of November. Preparation of the document, public discussion, published as Resolution of the Council of Ministers of the 7th of September. <i>Draft Safety Guide (DS469) Preparedness and Response for an Emergency during the Transport of Radioactive Material</i>. Revision of the document <i>Planning and Preparing for Emergency Response to Transport Accidents involving Radioactive material</i>, IAEA Safety Standards Series, <i>Safety Guide</i> n.º TS-G-1.2, (2002) (this work is on-going). a description of any significant infrastructure and/or any major items of technical equipment, relevant to the proposed work; IST-LPSR has laboratories to perform the following activities: laboratory of metrology of ionizing radiation, laboratory of individual monitoring, laboratory of environmental radioactivity for the measurement of natural and artificial radionuclides in environmental samples (foodstuff, feedstuff, construction materials, water, etc). At the RW management facility and related activities have access to the laboratories with the following techniques: high-resolution gamma spectrometry, insitu gamma spectrometry (NaI and HPGe), several portable dose rate meters and contamination monitors, activity concentration measurement device for large samples. if operational capacity cannot be demonstrated at the time of submitting the proposal, describe the concrete measures that will be taken to obtain it by the time of the implementation of the task. N/A

	No	Name	Acronym
		Associação do Instituto Superior técnico para a Investigação e Desenvolvimento	IST-ID
Participant	21		
Description of the legal entity Associação do Instituto Superior técnico para a Investigação e Desenvolvimento (IST-ID) IST-ID, the Association of Instituto Superior Técnico for R&D (http://www.ist-id.pt) is a private not-for-profit institution for which Instituto Superior Técnico (IST) is one of the founding associates. IST is part of the Universidade de Lisboa, and it is the largest and most reputed school of engineering, Science and Technology (S&T) in Portugal. Its mission is to provide top quality higher education in the areas of Engineering, S&T and Architecture, as well as developing RD&I activities that meet the highest international standards. IST-ID is the host institution of Centro de Ciências e Tecnologias Nucleares (C ² TN) where the proposed R&D activity will be carried out. Under agreements between IST and IST-ID, IST makes available the majority of facilities, infrastructures and services, where IST-ID R&D activities are carried out. Researchers from the Radiological Protection and Safety Group (GPSR) of C ² TN, mainly, will be involved in the project but collaborations with other C ² TN research groups are envisaged. They are members of the EU Research Platforms MELODI, EURADOS, Alliance, NERIS, IGD-TP and EURAMET and are involved in IAEA and NEA within radioactive waste management activities.			
Description of main tasks in EURAD-1, with an explanation of how its profile matches the tasks Portugal produces radioactive wastes from UMM, health and industry sectors, research, training and education, and from the operation, since 1961, of the Portuguese 1 MGW swimming pool research reactor (RPI) located at CTN, Campus of Loures of the Instituto Superior Técnico. Main categories of wastes produced are NORM, VLLW, LLW and ILW. Radwaste R&D activities in the Campus, started in the 90's, with: Radium and uranium industry tailings remediation; liquid effluents treatment from the chemical process with traditional and innovative methodologies (ion-exchange, filtration, co-precipitation, membranes and electrochemical processes, production and test of new molecules to encapsulate radwastes for safer disposal, etc.); characterization and evaluation of treatment methodologies for wastes from nuclear medicine and research; and implementation of safes methodologies to handle, dismantling and conditioning of sealed sources for long-term storage and disposal. Also R&D has been implemented to developing a specific Portuguese methodology for suitable places to host a near-surface repository with the identification of specific geomaterials with adequate properties to be used as engineering barriers. IST-ID has also participated in R&D projects focusing models application to waste management, actinide science, and studies contributing to the development, public acceptance and implementation of geological repositories. IST-ID has also been involved in specific E&T projects/activities to ensure knowledge is passed to future generations and a new pool of highly trained researches and technical personnel will be available in the future. All these activities have been carried within the objectives of the EU concerning safe and reliable solutions for radwaste management and the objectives of IGD-TP and the IAEA related to safe and reliable solutions for radioactive waste today and in the future energy market. The work is in tune with the National Framework Programme on Radioactive Waste, Decree-Law n. 156/2013, of November 5 th , (Council Directive 2011/70/EURATOM), IAEA Joint Convention Articles and NEA research recommendations. IST-ID is firmly engaged in pursuing the R&D efforts need to fulfil the vision, agenda and objectives of EURAD. IST-ID will be actively involved in WP9-ROUTES: • Task n°2 - Identify challenging wastes to be collaboratively tackled within the Joint Programme - Mapping and shared understanding at EU level of practical issues on waste management routes (subtask 2.2) IST-ID will identify R&D needs in Portugal and will collaborate with other partners needs as well in providing data on RW treatment technologies used, will identify disposal routes and how to achieve			

them, will contribute to reports content and questionnaires and will present work in the progress meetings, workshops and conferences.

- **Task n°3 - Description and comparison of radioactive waste characterisation approaches**
IST-ID will contribute with information and share experiences and R&D data on collection and treatment of data related to key radionuclides (^3H ; ^{14}C ; $^{99\text{m}}\text{Tc}$, iodine isotopes, etc.); Characterization and segregation of legacy waste from the different radioactive waste streams (from medical, research and industrial facilities as well as NORM. IST-ID will contribute to reports, questionnaires and will present work in progress meetings, workshops and conferences (subtask 3.1 & 3.2).
- **Task n°5 - RWM solutions for small amounts of wastes**
IST-ID will support JSI with conceptual model developed for long-term interim storage for decay at surface in terms of radwaste small inventories, contributing to reports, questionnaires and presenting work in progress meetings, workshops and conferences (subtask 5.1).
- **Task n°6 – Shared solutions in European countries**
IST-ID will contribute to the identification of gaps, needs and opportunities in R&D towards shared radwaste approaches and solutions by contributing to reports, questionnaires and presenting work in progress meetings, workshops and conferences (subtask 6.3).

IST-ID will also contribute to the continuation of:

- E&T of students in radwaste treatment technologies and management strategies through the implementation of the national and international Master's programmes (MPSR/IST and PETRUS/ENEN) and to increase competence maintenance, education and training (CMET)
- Promoting **application of Learning Outcomes (knowledge, skills and competencies) to ensure a future radioactive waste management work force highly knowledgeable and prepared for the new challenges**
- Production of written materials such as books, papers, oral presentations, posters and other divulgation materials for schools, experts and public towards a better comprehension of safe solutions for radwaste such as GD.
- Better interaction with public and other stakeholders, in matters of common European solutions for radwaste management, mainly, GD.

WP9-ROUTES extension :

IST-ID will contribute to ROUTES Extension by

- sharing their national experiences,
- evaluating the applicability of the developed solutions to their challenges and by
- reviewing the reports.

a curriculum vitae or description of the profile of the persons, including their gender, who will be primarily responsible for carrying out the proposed research and/or innovation activities

Maria Isabel Flausino de Paiva (Female) is a researcher of IST and was co-coordinator the GRRR (Radioprotection and Radioactive Waste Group) (2011-2012) of Nuclear and Technological Institute (ITN)). With the transition to the Lisbon University, she became a member of Department of Nuclear Sciences and Engineering (DECN), a researcher at Centre for Nuclear Sciences and Technologies (C²TN), a member of the Environmental Radioactivity Unit of LPSR and adviser for questions related to the Portuguese radioactive waste management facility.

She holds a Degree in Chemistry/Biochemistry (Lisbon University, 1987), a PhD in Chemical Engineering (Loughborough University of Technology, UK and Harwell Labs, 1992-1996) and a Post-Doc in Radiochemistry (Florida State University, 1999-2000), in radioactive waste treatment technologies.

Main areas of research are:

- Radioactive waste management and treatment technologies for interim storage and disposal
- Radiological protection and environmental radioactivity

- Radiological and nuclear emergencies
- Education and training throughout life, students and communication with public on radwaste

She is:

- Author/co-author of more than 30 works between original publications in Refereed Journals, proceedings, oral presentations and communications in national and international scientific events related to radioactive waste management and radiological protection.
- Responsible and professor for the curricular unit Radioactive Waste in the IST' Master on Radiological Protection and Safety (MPSR).

Other activities:

Participation and coordination, for PT, of several national and international Research Projects, financed by FP EURATOM/FISSION, Radiological Protection and E&T (FP4,6 and 7), FCT, ERAMIN and IAEA:

- CONFIDENCE - "Coping with uncertainties For Improved modelling and Decision making in Nuclear emergencies" (EURAD-CONCERT Call 2016, Radiation Protection Research in Europe) (2017- 2020).
- ENVIREE – ENVIRONMENTALLY friendly and efficient methods for extraction of Rare Earth Elements from secondary sources, (FCT/ERA-MIN). (2015-2019).
- IAEA & EC Project C.3, Contract Agreement 2013/313-757, Strengthening of an effective compliance regime in transport of radioactive material in the European Southern neighbourhood region (Mediterranean Sea) and associated shipping States (2013-2016).
- IAEA Project RER/09/080 - Strengthening National Capabilities in Radiation, Waste and Transport Safety in the Mediterranean Region. (2014-2017).
- CMET - Competence Maintenance, Education and Training – Concerted Action within Project SecIGD2, IGD-TP. (2013-2016).
- MetroNORM - Metrology for Processing Materials with High Natural Radioactivity. EMRP Project: JRP- IND57. (2013- 2016).
- ARIAS - Application of Ionizing Radiation for a Sustainable Environment, FCT-2012 RECI/AAG-TEC/O400/2012. (2013-2016).
- MetroMETAL – Ionizing Radiation Metrology for the Metallurgical Industry. EMRP Project: JRP-IND04. (2013-2014).
- PREPARE – Innovative integrative tools and platforms to be prepared for radiological emergencies and post-accident response in Europe. (EURATOM/FP7-Fission/NERIS-TP. (2013-2016).
- PETRUS III – Implementing Sustainable E&T Programmes in the Field of Radioactive Waste Disposal (FP7/Euratom for Nuclear Research and Training). (2013-2016).
- EAGLE Stakeholders Group - Enhancing education, training and communication processes for informed behaviors and decision-making related to ionizing radiation risks IST representative at stakeholders group. (EURATOM/FP7). (2012-2014)
- PETRUS II – Towards an European training market and professional qualification in Geological Disposal. Post-Graduation development of the PD and Pilot PD programmes. (FP7/Euratom for Nuclear Research and Training). (2009-2012).
- ACSEPT-ReCycling by SEparation and Transmutation (FP7/Fission,Radwaste). (2007-2012).
- KADRWaste – Study of the Adsorption Mechanisms and Kinetics in Geomaterials and Their Structural Characterization: Implications for Processes of Natural Attenuation of Heavy Metal Contamination and Radioactive Wastes Confinement (FCT 2008), (2006-2010).
- PT Directorate for Health Project n°6/01, DGIES - A Study of radioactive liquid discharges from national medical establishments, ITN/DPRSN/DGIES. (2000-2004).
- Project FP4/EURATOM/Fission1990 - Advanced processes for the treatment of low level radioactive liquid wastes at a pilot plant scale (Contrato DGXII F12-CT90-0057) (1990-1995). CEC DGXII Grantee).
- Post-Doc DOE project - Study of the actinide polyoxometalate systems, mainly the study of the interaction of the lacunary form P2W17 with the actinide DI-Oxo cation uranyl UO₂²⁺, DOE/USA, Dpt. Química, Florida State University, USA (1999-2000).

Collaboration with:

- GEOSAF – International Intercomparison and Harmonization Projecto in Demonstrating the Safety of Geological Disposal IAEA. (208-2010).
- Project IAEA RER/9/107 - Policy Formulation and Strategy Options for Radioactive Waste Management. (2011-2012).
- Project IAEA RER/0/031 - Strengthening Sustainability of Nuclear Research and Development Institutes in the Modern Science and Technology Environment. (2011-2012).
- Project RER/9/101, “Building Competence through Education and Training in Support of Radiation Protection Infrastructures”.
- Project IAEA RER/9/103, “Identifying and Managing Uncertainty for Post-Closure Safety Assessments in Support of Repository Development Programmes”.
- Project FP4/EURATOM/Fission1990, "Environmental impact assessments and geological repositories" (B4-070/97/000821/MAR/C3) (1997-1999).
- Project FP4/EURATOM/Fission1990, "Management and disposal of disused sealed radioactive sources in the EU" (B4-3070/96/000781/MAR/C3) (1997-1999).

She has been IST/PT representative in:

- IGD-TP platform (Implementing Geological Disposal) (
- MedNET Network on Transports of Radioactive Materials.
- EURATOM Treaty Art.º 37’ experts.
- OSPAR Convention, RSC.
- NCP for the Joint Convention on safety of spent fuel and safety of management of radioactive waste – The Joint Convention), Vienna, 2011-2012. Elaboration and presentation of the first national report at the Fourth Review Meeting of the Contracting Parties pursuant to Article 3, Vienna, May 14-23, 2012.
- NCP for the database NEWMDB (Enable Waste Management Database), IAEA, 2006-2008.
- ITN/PT representative in the AQG (scientific and technical support to REPER), Brussels, 2004-2008. Collaboration with the Council and EC in support of various technical and legislative proposals, mainly, Council Directive 2011/70/Euratom 19 July 2011, contributing with analysis and texts.
- PT representative in the Ad-hoc WG on Nuclear Safety, WPNS, Brussels, 2004-2008.
- PT representative in the CCE_Fission/ WG-Radioactive Waste, 2004-2006. Participation in the elaboration of a proposal for supporting and financing R&D in the area of radioactive wastes to be presented to the European Parliament.
- PT representative in the WASSC committee, Vienna, 2004 – 2011.
- Collaboration with the PT representative in the ACPM (Advisory Committee for Programme Management of Community Plan of Action in the Field of Radioactive Waste), by evaluating progress reports of the projects under the EURATOM framework program (FP5 e FP6), Luxemburg, 1998-2003.

Mário João Capucho dos Reis (Male) is a researcher of the IST since December 2002. He holds a Degree in Environmental Engineering, New University of Lisbon, Faculty of Sciences and Technology, Portugal (1987) and a PhD in Physics, Évora University, Portugal (2002).

He is responsible for the Environmental Radioactivity Nucleus (NRA) of the Radiological Protection and Safety Laboratory (LPSR) since November 2016.

He is also responsible and professor for the curricular units Environmental Radioactivity and Metrology of Radiation in the IST’ Master on radiological Protection and Safety (MPSR).

Main Scientific Areas of Research are:

- Environmental Radioactivity
- Radioactivity Measurements
- Radiation Protection

He has participated in Scientific Training Programmes:

- International Atomic Energy Agency Fellowship Programme, completed at the Gesellschaft fuer Strahlen – Umweltforschung GMBH Muenchen, Institut fuer Strahlenschutz, Neuherberg, Germany, on the field of Radiation Protection (3 months, from April to July 1991).

- International Atomic Energy Agency Fellowship Programme, completed at the Laboratoire de Mesure de la Radioactivité de l' Environnement (LMRE), Institut de Radioprotection et Sûreté Nucléaire (IRSN), Orsay, France, on the field of γ -ray spectrometry measuring techniques of low-level environmental samples, including both natural and anthropogenic nuclides (1 month, September 2003) and has been counterpart of IAEA research projects. He is representative of IST in the NERIS platform.

Scientific Works:

- Participation in several national and international Research Projects, financed by FCT, PT2020, EMRP and 7th Framework Programme;

- Author/co-author of more than 20 original publications in Refereed Journals;

- Author/co-author of more than 40 oral presentations and communications in national and international scientific events.

Pedro Vaz (Male) Coordinator Researcher of IST with Habilitation. President of Centro de Ciências e Tecnologias Nucleares (C²TN) and Coordinator of the Radiological Protection and Safety Group (GPSR) of C²TN.

Ph.D in Physics. Co-author of more than 300 peer-reviewed articles. Has participated in several EU EURATOM funded research projects as well as in CERN experiments related to the measurements of the cross-sections for neutron-induced reactions.

Portuguese delegate and representative to several international Committees and Groups under the EU, IAEA, OECD/NEA and EU platforms.

a list of up to 5 relevant publications, and/or products, services (including widely-used datasets or software), or other achievements relevant to the call content

- Paiva, R. Trindade, M. Gonçalves and A. Mateus, “Development of a specific methodology to assess suitable sites to receive a repository for L/ILW in the Portuguese territory” in ASME/ICEM Books of 15th International Conference on Environmental Remediation and Radioactive Waste Management, Bruxelas 8-12 Setembro. ISBN: 978-0-7918- 5601-7; WOS: 000337804600026 (2013)
- Paiva, R. Trindade. “The impact of council directive 2011/70/Euratom and IAEA Joint Convention on the ongoing establishment of the Portuguese regulatory framework and the future national radioactive waste national plan” in ASME/ICEM Books of 15th International Conference on Environmental Remediation and Radioactive Waste Management, Bruxelas, Setembro 8-12. ISBN: 978-07918-5601-7; WOS: 000337804600027 (2013)
- Reis, M., Freitas, M.C., Dung, H.M., Mateus, A., Paiva, I., Madruga, M.J., Gonçalves, M.A., Silva, L., Dionísio, I. “Characterization of geomaterials from NE Portugal using k (0)-based instrumental neutron activation analysis (k (0)-INAA) and gamma spectrometry methods”. Journal of Radioanalytical and Nuclear Chemistry, 294(3), 363-369. ISSN: 0236-5731; doi: 10.1007/s10967-012-1613-5; WOS: 000310995000006 (2012) (IF 1.467)
- Duarte, P., Mateus, A., Paiva, I., Trindade, R., Santos, P. “Usefulness of systematic in situ gamma-ray surveys in the radiometric characterization of natural systems with poorly-contrasting geological features (examples from NE of Portugal)”, Applied- Radiation and Isotopes, 69: 463-474. ISSN: 0969-8043; doi:10.1016/j.apradiso.2010.10.002; WOS: 000287063700031 (2011) (IF 1.179)
- E. Andrade, M.J.Madruga, I.Bobos, I. Paiva, F. Maia, A. Mateus, R. Trindade, M.C. Freitas, M.A. Gonçalves, "Characterization of Portuguese geomaterials, the clay component of rañas, as potential liners for low and intermediate radioactive disposal sites, J. Radioanalytical & Nuclear Chemistry, 286:777-783. ISSN: 0236-5731; doi: 10.1007/s10967-010-0715-1; WOS: 000285099700030 (2010) (IF 0.777)
- Paiva, C. Oliveira, L. Portugal, R. Trindade, Interim storage of spent and disused sealed source: optimization of external dose distribution in waste grids, using MCNPX code, ICRS10 /RPS2004; Funchal, 9-14 May 2004, Radiation Protection Dosimetry, Vol. 116, Edição 1-4, Part.2, 417-422.

ISBN: 019-856886-X; ISSN: 0144-8420; doi: 10.1093/rpd/nci246; WOS: 000234784800088 (2005) (IF 0.58)

- Duarte, P., Silva, I., Mateus, A. Araújo, M.F. Reis, M., Trindade, R., Paiva, I., Radiological and geochemical characteristics of an ultramafic massif (NE Portugal) and their significance in the assessment of the site aptness to host a near surface repository for low and intermediate level radwaste”, Environmental Earth Sciences, Vol. 68, Issue 2, Pages 547-557, DOI:10.1007/s12665-012-1758-0, Jan, (2013)
- A.R. Gomes, J. Abrantes, A. Libânio, M.J. Madruga, M. Reis, (2017). Determination of tritium in water using electrolytic enrichment: methodology improvements, J Radioanal Nucl Chem, 314, 669-674. doi: 10.1007/s10967-017-5456-y
- Vaz, P., Paiva, I., & Portugal, L., “Status of the safety and security of radioactive sources in Portugal in: Proceedings of the International Conference on Safety and Security of Radioactive Sources: Maintaining Continuous Global Control of Sources throughout Their Life Cycle”, Abu Dhabi, United Arab Emirates, Outubro 27-31 (2013), in IAEA Proceedings Series (ISSN: 0074-1884), STI/PUB/1667, pp. 493-498, ISBN: 978-92-0-105214-8 (2015)
- M. Palmu, M. Cantone, M.-C., Paiva, I., and Vivalda, C. , “The CMET working group actions within IGD-TP. Feasibility of voluntary accreditation in geological disposal using ECVET approach” in Proceedings of the Nuclear Education and Training International Conference, NESTet, Madrid, Novembro 17-21 (2013)
- N. Soares, I. Paiva e Leonor M. Monteiro, “Radionuclides in Waste Discharges from Health Establishments”. Conference “Proteção Radiológica na Saúde 2017 (PRS 2017)”, IST, Lisboa, Portugal, Setembro 27-29 (2017).
- Paiva, O. Monteiro Gil, M. Baptista, M. Reis, P. Vaz. An innovative vision on education and training programs in radiological protection, nuclear and radiation safety. Proceedings Conferência internacional RICOMET 2016, Bucareste, Junho 1-3. Book of Abstracts, pp 52, SCK CEN-BA_0076 publication (2016)
- S. Vogiatzi, A. Lagumdzija, J. Cremona, H. Bsai, S. Zeroual, I. Paiva. “Mediterranean Network (MedNet) - Overview of the regulatory infrastructure for the safe transport of radioactive material” in Proceedings of the 18th International Symposium on the Packaging and Transportation of Radioactive Materials, PATRAM 2016, Kobe, Setembro 18-23 (2016)

a list of up to 5 relevant previous projects or activities, connected to the subject of this proposal

Research projects:

- IAEA Project RER/09/080 - Strengthening National Capabilities in Radiation, Waste and Transport Safety in the Mediterranean Region. (2014-2017)
- PETRUS III – Implementing Sustainable E&T Programmes in the Field of Radioactive Waste Disposal (FP7/Euratom for Nuclear Research and Training). (2013-2016).
- PETRUS II – Towards an European training market and professional qualification in Geological Disposal. Post-Graduation development of the PD and Pilot PD programmes. (FP7/Euratom for Nuclear Research and Training). (2009-2012).
- ACSEPT-ReCycling by SEPARation and Transmutation (FP7/Fission, Radwaste). (2007-2012).
- KADRWaste – Study of the Adsorption Mechanisms and Kinetics in Geomaterials and Their Structural Characterization: Implications for Processes of Natural Attenuation of Heavy Metal Contamination and Radioactive Wastes Confinement (FCT 2008), (2006-2010).
- PT Directorate for Health Project nº6/01, DGIES - A Study of radioactive liquid discharges from national medical establishments, ITN/DPRSN/DGIES. (2000-2004).
- Project FP4/EURATOM/Fission1990 - Advanced processes for the treatment of low level radioactive liquid wastes at a pilot plant scale (Contrato DGXII F12-CT90-0057) (1990-1995). CEC DGXII Grantee).
- GEOSAF – International Intercomparison and Harmonization Projecto in Demonstrating the Safety of Geological Disposal IAEA. (208-2010).
- Project IAEA RER/9/107 - Policy Formulation and Strategy Options for Radioactive Waste Management. (2011-2012).

- Project IAEA RER/9/103, "Identifying and Managing Uncertainty for Post-Closure Safety Assessments in Support of Repository Development Programmes".
- Project FP4/EURATOM/Fission1990, "Environmental impact assessments and geological repositories" (B4-070/97/000821/MAR/C3) (1997-1999).
- Project FP4/EURATOM/Fission1990, "Management and disposal of disused sealed radioactive sources in the EU" (B4-3070/96/000781/MAR/C3) (1997-1999).

PT representative in:

- IGD-TP platform (Implementing Geological Disposal)
- MedNET Network on Transports of Radioactive Materials.
- EURATOM Treaty Art.º 37' experts.
- OSPAR Convention, RSC.
-

a description of any significant infrastructure and/or any major items of technical equipment, relevant to the proposed work;

IST-ID has access, among others, to the following facilities and equipment's:

- High resolution gamma spectrometry (NaI, HPGe and Si(Li))
- Gas flow proportional counter
- Liquid scintillation counting
- Low resolution gamma spectrometry
- Alpha spectrometry
- Portable radiation detectors
- IRMS, HPLC/ICPMS
- Electron microscopy
- **Acelerador Van de Graaff** de 2,5 MV, **Microssonda nuclear**, **Acelerador Tandem** de 3 MV, Hotbird
- Particle Induced X-ray Emission (PIXE), X-ray diffraction (XRD), XRF and Mössbauer spectroscopy
- Chemistry of f-elements
- Low Temperature and High Magnetic Field Laboratory (LTHMFL)
- Low and high activity samples measurement labs
- ⁶⁰Co irradiator

Simulation tools:

- COMSOL (in collaboration with Sweden)
- Monte Carlo

if operational capacity cannot be demonstrated at the time of submitting the proposal, describe the concrete measures that will be taken to obtain it by the time of the implementation of the task.

N/A

		Name	Acronym
Participant	22	Jožef Stefan Institute	JSI
Description of the legal entity Jožef Stefan Institute (www.ijs.si) is the leading Slovenian scientific research institute, covering a broad spectrum of basic and applied research. The staff of more than 900 specializes in natural sciences, life sciences, and engineering. The main areas include production and control technologies, information, communication and knowledge technologies, biotechnologies, new materials, environmental technologies, nanotechnologies, and nuclear engineering. JSI accumulates and disseminates knowledge through the pursuit of research, development, and education at the highest international level of excellence. This project will be supported by the Reactor Engineering Division (http://r4.ijs.si), Reactor Physics Division (http://f8.ijs.si) and Department of environmental sciences (www.environment.si). JSI also acts as a Technical and scientific support organization (TSO) to the Slovenian nuclear regulatory authority.			
Description of main tasks in EURAD-1, with an explanation of how its profile matches the tasks JSI is involved in 6 work packages of the Joint Programme, with all of the falling into the scope of its regular research and TSO activities. ACED: in-situ monitoring of corrosion of steels in the ongoing experiments and potentially in the new experiments proposed by IRSN (NE2-2/1) to assist at the identification of corrosion type, rate and corrosion products. The test fields at three hydroelectric dams on Drava River in order to get reliable samples of concrete in different locations of saturated zone of the dams. Laboratory investigation of samples in terms of microstructure characteristics Support by linked third party ZAG is foreseen. CORI: JSI will study degradation products of organic compounds after irradiation in research reactor by gamma radiation for different times and fluxes. In addition, sorption and diffusion of organic compounds in cementitious environment will be studied. SFC: Contribute to the theoretical study of SNF source terms and to definition and verification procedures to determine the source terms of SNF assemblies with realistic confidence limits. ROUTES: technical data on different radioactive waste types will be provided for Slovenia and all input information of different waste management routes will be collected and analysed. involved in the interaction with civil society is planned. Support by linked third party EIMV is foreseen. UMAR: contribution to common understanding among the different categories of actors on uncertainty management for RWM and contribution to analyses and mitigation procedures on activities related to risk & safety. Support by linked third party EIMV is foreseen. KM: Contributions to State of knowledge and guidance, with emphasis on early-stage of RWM programmes. Support by linked third party EIMV is foreseen WP9-ROUTES extension : JSI will contribute to ROUTES Extension by - sharing their national experiences, - evaluating the applicability of the developed solutions to their challenges and by - reviewing the reports.			

a curriculum vitae or description of the profile of the persons, including their gender, who will be primarily responsible for carrying out the proposed research and/or innovation activities

Prof. Dr. Leon Cizelj (male), scientific councilor and head of Reactor Engineering Division of the Jožef Stefan Institute. Full professor of Nuclear Engineering, Faculty of mathematics and physics, University of Ljubljana. Ph.D. physics, University of Ljubljana, 1993. Research interest in safety and reliability of complex technologies; integrity and ageing of safety related components of nuclear power plants; computational solid, fluid and fracture mechanics, multiscale and multiphysics computations. President of the Management board of the Slovenian radwaste agency ARAO (2013-2016). Member of the Scientific Council for Technology at the Slovenian Research Agency ARRS, 2006-2011; member of the Governing Board of SNETP, 2013-2015; President of the Board of Directors of European nuclear Education Network, 2016-2018.

Assist. prof. Marjan Kromar, PhD (male) is a leader of the nuclear power reactor group within the Reactor physics division of JSI. He received a PhD degree in nuclear engineering from the University of Maribor in 1992. He conducts researches for 35 years on the development of the nuclear design tools, methods, codes and their applications to the design PWR calculations. He is specialized on the nuclear fuel behaviour especially criticality safety, decay heat and shielding aspects of the spent fuel storage.

Assist. prof. Luka Snoj, PhD (male) received the Diploma and PhD thesis in Physics from the Faculty of Mathematics and Physics, University of Ljubljana, Slovenia in 2005 and 2009, respectively. In 2010, he was on 6 months postdoctoral position at Culham centre for Fusion Energy, where he was in charge of neutron transport calculations to support JET neutron yield calibration. In 2010 has been appointed head of TRIGA reactor at the Jozef Stefan Institute (JSI). Since 2014 he has been head of reactor physics division at the Jozef Stefan Institute. He is very active in teaching; reactor and radiation physics, experimental reactor physics at the Faculty of mathematics and physics where in 2014 he was elected assistant professor. He has been advisor to 12 master theses and is advisor to 6 PhD students. His research interest is mainly theoretical reactor physics related to practical applications in power and research reactors, in particular: Monte Carlo transport of neutrons and photons in fission and fusion nuclear reactors, integral reactor experiments, criticality experiments and calculations. He regularly performs evaluations and evaluation reviews of critical and reactor physics experiments for International Criticality Safety Benchmark Evaluation Project (ICSBEP) and International Reactor Physics Experiment Evaluation (IRPhE) Project working groups under OECD/NEA.

Klemen Ambrožič, MSNE (male) received his Diploma in Physics in 2013 and a Master Degree in Nuclear Engineering in 2015 from and is currently enrolled into PhD Nuclear Engineering programme at Faculty of Mathematics and Physics, University of Ljubljana. In year 2017 he performed part of his studies at CEA Cadarache, DEN, DER, SPEX, EPL laboratory for 2 months, where he was developing methods for experimental determination of delayed gamma fraction in fission nuclear reactors, and at CEA Saclay, DEN/DM2S/SERMA/LTSD laboratory, developing a detailed simulation model of the JSI TRIGA reactor for TRIPOLI 4 Monte-Carlo code, and studied computational methods for delayed particle transport. His research interest is mainly theoretical reactor physics and computational code development and reactor experimentation for code validation and radiation hardness testing.

Dr. Marko Štrok (male), research associate is Head of Radiochemistry laboratory at the Department of Environmental Sciences, JSI. 10 years of experience in analytical radiochemistry, mass spectrometry, migration of radionuclides, radioecology. His research interests are in migration of radionuclides in different environmental compartments, determination of radionuclides in different samples, application of isotope ratios in geochemistry.

Dr. Ester Heath (female), senior research associate is Head of Organic analyses group at the Department of Environmental Sciences, JSI. 20 years of experience in the field of organic analytical chemistry, particularly in environmental and biomedical research. Research topics: identification of pharmaceutical transformation products with GC-MS, determination of trace-level organic compounds in environmental or biological samples, water treatment technologies.

Dr. Vladimir Radulović (male), research associate is researcher at the Reactor Physics Department, JSI. 10 years of experience in the field of reactor physics. Research topics: development of new methods for the analysis of research and power reactors, neutron transport calculations, nuclear data, validation of nuclear data and sensitivity analysis, experimental reactor physics.
a list of up to 5 relevant publications, and/or products, services (including widely-used datasets or software), or other achievements relevant to the call content Smodiš, B., Štrok, M. Partitioning of natural radionuclides in sediments around a former uranium mine and mill. Journal of Radioanalytical and Nuclear Chemistry, 2013, 297, 201-207. Kotnik, K., Kosjek, T., Krajnc, U., Heath, E. Trace analysis of benzophenone-derived compounds in surface waters and sediments using solid-phase extraction and microwave-assisted extraction followed by gas chromatography-mass spectrometry. Analytical and bioanalytical chemistry, 2014, 406, 3179-3190. Radulović, V., Fourmentel, D., Barbot, L., Villard, J.F., Goričanec, T., Žerovnik, G., Snoj, L. Measurements of miniature ionization chamber currents in the JSI TRIGA Mark II reactor demonstrate the importance of the delayed contribution to the photon field in nuclear reactors. Nuclear instruments and methods in physics research. Section A, Accelerators, spectrometers, detectors and associated equipment, 2015, 804, 149-154. M. Kromar, B. Kurinčič, "Determination of the NPP Krško spent fuel decay heat", V: AIP conference proceedings : Thermophysics 2017, 22nd International Meeting of Thermophysics 2017, Terchova, 12-14 September 2017, (AIP conference proceedings, 1866), Anton Trník, ur., Jurij Avsec, ur., Igor Medved, ur., Terchova, American Institute of Physics, 2017, p. 050005-1. HURE, Jeremy, EL SHAWISH, Samir, CIZELJ, Leon, TANGUY, Benoit. Intergranular stress distributions in polycrystalline aggregates of irradiated stainless steel. Journal of nuclear materials, 2016, vol. 476, pp 231-242, doi: 10.1016/j.jnucmat.2016.04.017
a list of up to 5 relevant previous projects or activities, connected to the subject of this proposal - MASSTWIN Spreading Excellence and Widening Participation in Support of Mass Spectrometry and related techniques in Health, the Environment, and Food Analysis (H2020) - Epithermal neutron flux determination and validation of nuclear cross-sections and through activation measurements employing neutron spectrum filters (JSI-CEA collaboration project) - JOPRAD- Towards a Joint Programming on radioactive waste disposal (H2020 EURATOM) - NEWLANCER New Member States Linking for an Advanced Cohesion in Euratom Research (FP7 EURATOM) - "Characterization of the NPP Krško spent fuel for the purpose of storage in dry containers", project financed by Slovenian Nuclear Safety Administration (URSJV).
a description of any significant infrastructure and/or any major items of technical equipment, relevant to the proposed work; - Research reactor TRIGA MARK II - Hot cells facilities - Fully equipped radiochemical laboratories - Instrumentation for radiometric detection (gamma spectrometry, alpha spectrometry, liquid scintillation counters, proportional counters) - Instrumentation for mass spectrometry (MC-ICP-MS, laser ablation, quadrupole ICP-MS (ICP-QQQ, conventional ICP-MS), IRMS, QTRAP, MALDI MS)
if operational capacity cannot be demonstrated at the time of submitting the proposal, describe the concrete measures that will be taken to obtain it by the time of the implementation of the task.

Participant	No	Name	Acronym
	23	European Commission, DG Joint Research Centre	JRC
Description of the legal entity The Directorate General-Joint Research Centre is the European Commission's science and knowledge service. Its mission is to support EU policies with independent evidence throughout the whole policy cycle. Its work has a direct impact on the lives of citizens by contributing with its research outcomes to a healthy and safe environment, secure energy supplies, sustainable mobility and consumer health and safety. The JRC hosts specialist laboratories and unique research facilities and is home to thousands of scientists working to support EU policy. The JRC has ten Directorates and is located across five EU Member States (Belgium, Germany, Italy, the Netherlands and Spain). The Directorate involved in this project is Directorate G – Nuclear Safety and Security within which the JRC's nuclear work programme, funded by the EURATOM Research and Training Programme, is carried out. It contributes to the scientific foundation for the protection of the European citizen against risks associated with the handling and storage of highly radioactive material, and scientific and technical support for the conception, development, implementation and monitoring of community policies related to nuclear energy. Research and policy support activities of Directorate G contribute towards achieving effective safety and safeguards systems for the nuclear fuel cycle, to enhance nuclear security then contributing to achieving the goal of low carbon energy production. The research programmes are carried out at the JRC sites in Germany (Karlsruhe), Belgium (Geel), The Netherlands (Petten) and Italy (Ispra) and consist of research, knowledge management and training activities on nuclear safety and security. They are performed in collaboration and/or in support to the EU Member States and relevant international organizations. Today the Directorate G is one of the leading nuclear research establishments for nuclear science and technology and a unique provider of nuclear data measurements. Typical research and policy support activities are experimental and modelling studies covering nuclear reactor and fuel cycle safety, including current and innovative nuclear energy systems. Fundamental properties, irradiation effects and behaviour under normal and accident conditions of nuclear fuels and structural materials are studied. The activities cover also studies of structural integrity and functioning of nuclear components, emergency preparedness and radioactivity environmental monitoring, nuclear waste management and decommissioning, as well as the study of non-energy technological and medical applications of radionuclides. A dedicated functional entity is devoted to the management and dissemination of knowledge and to facilitate open access to JRC nuclear facilities including training and education. Description of main tasks in EURAD-1, with an explanation of how its profile matches the tasks 1. The work to be performed by JRC is divided into three parts. The first part deals with the quantification of radionuclide inventory, the second part with spent fuel rod stability under predisposal conditions and the last part with knowledge management. 2. JRC-Geel will act as the co-ordinator of the task 2: Fuel properties characterisation and related uncertainty analysis. The main contribution is on the development of innovative non-destructive analysis (NDA) methods and the improvement of existing ones to characterise SNF. JRC-Geel, in collaboration with JRC-Ispra, will develop a detection system to determine the neutron output of a SNF pellet; design and construct a system to define the nuclide inventory of a SNF pellet by NDA applying Neutron Resonance Transmission Analysis (NRTA) and investigate the potential of new radiation resistant neutron detectors. They will also produce a report describing the performance of existing and innovative NDA systems for SNF characterisation, which is the main deliverable of subtask 2.2. JRC-Geel/Ispra will also assist in defining correlation schemes between experimental observables from NDA measurements and contribute to the definition of recommended state-of-the-art procedures to determine the main source terms (decay heat, neutron and gamma-ray emission rate, reactivity) of a SNF assembly. Within subtask 3.1 "Thermo-mechanical-chemical properties of the SNF rods and cladding", JRC-Karlsruhe (JRC-Karlsruhe) will concentrate its experimental work on quantifying the effects of hydrogen load, hydride distribution and re-orientation as well as mechanical loading to create a knowledge base to evaluate the integrity of spent nuclear fuel rods affected by thermo-mechanical conditions as well as fuel/cladding chemical interaction after discharge from reactor but before final disposal. Additionally, the modification of the fuels mechanical and elastic properties due to alpha-damage formation and associated radiogenic helium production			

will impact the ensemble cladding/fuel and also determine the magnitude of the fuel fragmentation during impact tests.

In respect to the objectives in subtask 3.1 JRC-Karlsruhe will perform two bending and one impact tests on pre-treated and non-treated spent UO_2 and MOX fuels. Five ring compression tests will be performed after different treatments followed by characterisation of the compressed irradiated cladding. In respect to the alpha-damage studies ^{238}Pu -doped UO_2 samples will be conditioned and thereafter followed by post-characterisation of the alpha-damaged ^{238}Pu - UO_2 samples by regular XRD and Vicker's hardness measurements complemented by TEM analyses.

The JRC-Karlsruhe experimental programme fits the task 3.1 objectives as it is the only part where real irradiated spent fuel rods are tested and the outcome used to benchmark the non-irradiated rod experiments in this task.

The JRC is has a leading role in the knowledge management programme, providing the knowledge management (KM) programme coordinator in the overall EURAD Programme Management Office (PMO), but also contributing to the organization of work within the three KM workpackages. The role of the KM programme coordinator in the PMO includes ensuring that the KM programme is evolving in line with the overall agreed upon objectives and workplan; communicating the progress of the individual KM workpackages to the PMO; keeping the KM workpackages informed about the overall EURAD coordination work and decisions; managing the fund with financial resources used for meetings, workshops, training events, training motilities, external experts in addition to the in-kind contributions within the EURAD and the development and maintenance the knowledge platform, etc. The contributions within the individual KM workpackages includes development of initial proposal and follow-up of the knowledge platform population strategy and time schedule, managing and reviewing the knowledge platform population process, managing the process for up-dating the PLANDIS Guide and development of the subsequent detailed guidance, contributing to the management of training events, establishment of on-line training material, and the training mobility programme.

a curriculum vitae or description of the profile of the persons, including their gender, who will be primarily responsible for carrying out the proposed research and/or innovation activities

Dr. Peter Schillebeeckx (M) will coordinate Task 2 and is responsible for the activities related to NDA of SNF. He has been responsible for several other tasks (workpackages) of projects in FP6 and FP7. He has more than 30 year experience in the field of NDA of nuclear material (calorimetry, neutron and gamma-ray detection), production of nuclear data, sensitivity analysis and uncertainty evaluation. He is one of the main actors behind the development of the use of Neutron Resonance Analysis for the characterisation of materials and objects.

Dr. Gašper Žerovnik (M) worked since 2007 in the fields of nuclear data and reactor physics. He has experience with fuel depletion calculations, since he was the main contributor to two projects for the Slovenian Agency for Radwaste Management, i.e. "Calculation of isotopic composition and decay heat from spent nuclear fuel from NPP Krško" (No. 03-00-014-004-2, 2008) and "Code for optimization of spent nuclear fuel filling into canisters for terminal disposal regarding constraints on decay heat" (No. 08-1-03-00-014-003-1, 2009). Additionally, he has experience in uncertainty analysis of nuclear data, where he contributed to the Work Package 10 ("Development of nuclear data for Myrrha reactor safety analyses") of the EU CHANDA project. For the applied project, his role would be to perform fuel depletion calculations, and to estimate and propagate the uncertainties originating from nuclear data.

Dr. Bent Pedersen (M) has worked more than 20 years with non-destructive assay methods and instrumentation for applications in nuclear safeguards, security and waste characterisation. He specialises in passive and active neutron detection systems for the characterisation of fissile materials mainly for safeguards purposes and for waste characterisation. He also operates a pulsed neutron interrogation facility for R&D in active neutron methods on fissile materials. He contributed to the Euramet funded Metrodecom project that concluded in 2017, and he is currently work package leader in the MetroDECOM II follow-up project. This work concerns validation of a measurement facility for characterisation of low and intermediate level nuclear waste.

Dr. Dimitrios Papaioannou (M) is in charge of the non-destructive and destructive examinations of spent nuclear fuel rods, including expertise in handling and preparation of fuel samples (AREVA, BNFL, METAPHIX, NFIR, DECOSTOS, SPERUS and DISCO). His role would be to coordinate handling, characterisation and sample distribution of spent fuel rods/samples.

Dr. Gunnar Buckau (M), having being involved in the EURATOM indirect action programme since the early eighties (Project “Migration of radionuclides in the geosphere” (MIRAGE)), in particular coordinator of the Integrated Project Fundamental Radionuclide Migration Processes (IP FUNMIG) (FP 6) but also coordinating HUMICS (FP4), HUPA (FP5), and ReCosy (FP7) before leaving to the JRC in 2011. The contribution to the present EURAD is based less on the scientific background, but rather the administrative and policy development, the key tasks at the IAEA (1994 – 1996) and at the JRC. In the more recent years, responsibility at the JRC has shifted from being the coordinator of the JRC RWM R&D project to becoming the head of the project on KM in RWM and Decommissioning. It is in this role that he represents the JRC in coordination of the EURAD KM programme as member of the PMO, and participates in the three different KM WPs.

Dr. Thierry Wiss (M) is involved in radiation damage studies and in microstructural analyses of nuclear materials (mainly using electron microscopy). His activities are also related to the ageing of spent nuclear fuel and of waste matrices and more particularly on the effects of rare gas formation and defect interaction in nuclear materials. He has been previously involved in the EU projects NF-PRO, SFS, RECOSY, FIRST-Nuclides. He will perform the SEM-EDX investigations and make interpretations of the SEM-EDX analyses of the corroded spent fuel surfaces.

Dr. Paul Carbol (M) during the last 15 years has worked in the field of spent fuel corrosion under reducing conditions. He has been a key contributor to several programmes devoted to the investigation of the corrosion mechanisms and expected environment in a deep underground repository (EC 5th FP SFS, 7th CP ReCosy, input to FP 7th MICADO and FIRST-Nuclides, JOPRAD and DISCO). His role would be to coordinate the work progress within the JRC.

a list of up to 5 relevant publications, and/or products, services (including widely-used datasets or software), or other achievements relevant to the call content

P. Schillebeeckx, B. Becker, H. Harada and S. Kopecky, "Neutron resonance spectroscopy for the characterisation of materials and objects", JRC Science and Policy Report, Report EUR 26848 EN.

Gašper Žerovnik, Luka Snoj, and Matjaž Ravnik, "Optimization of Spent Nuclear Fuel Filling in Canisters for Deep Repository", Nucl. Sci. Eng. 163 (2009) 183-190.

R. Nasyrow, D. Papaioannou, V. V Rondinella, E. Vlassopoulos, K. Linnemann, V. Ballheimer, J. Sterthaus, A. Rolle, F. Wille, S. Caruso, Bending test device for mechanical integrity studies of spent nuclear fuel rods, in: 18th International Symposium on the Packaging and Transportation of Radioactive Materials, PATRAM 2016, Institute of Nuclear Materials Management, Kobe, Japan, 2016.

E. Vlassopoulos, R. Nasyrow, D. Papaioannou, V.V. Rondinella, S. Caruso, A. Pautz, Destructive tests for determining mechanical integrity of spent nuclear fuel rods, in: ANS IHLRWM 2017 - 16th International High-Level Radioactive Waste Management Conference: Creating a Safe and Secure Energy Future for Generations to Come - Driving Toward Long-Term Storage and Disposal, 2017: pp. 726–733.

V.V. Rondinella, R. Nasyrow, D. Papaioannou, E. Vlassopoulos, F. Cappia, O. Dieste-Blanco, T.A.G. Wiss, Mechanical integrity studies on spent nuclear fuel rods, in: ANS IHLRWM 2017 - 16th International High-Level Radioactive Waste Management Conference: Creating a Safe and Secure Energy Future for Generations to Come - Driving Toward Long-Term Storage and Disposal, 2017: pp. 734–740.

Wiss, T., Hiernaut, J.-P., Roudil, D., Colle, J.-Y., Maugeri, E., Talip, Z., Janssen, A., Rondinella, V., Konings, R., Matzke, H., Weber, W., 2014, Evolution of spent nuclear fuel in dry storage conditions for millennia and beyond, 2014, J. Nucl. Mater., 451, pp. 198-206.

Wiss, T., Thiele, H., Janssen, A., Papaioannou, D., Rondinella, V.V., Konings, R.J.M., Recent Results of Microstructural Characterization of Irradiated Light Water Reactor Fuels using Scanning and Transmission Electron Microscopy, JOM, 2012, vol. 64, pp. 1390-1395.

G. Buckau, A. van Kalleveen, V. Matuzas, “Horizontal Activities, Working Document for development of Integrated Knowledge Management System on Radioactive Waste Management at European Level“, Deliverable 3.6, EURATOM Coordination and Support Action “Towards a Joint Programming on Radioactive Waste Disposal” (JOPRAD), (to be published July 2018).

a list of up to 5 relevant previous projects or activities, connected to the subject of this proposal

JRC-Directorate G (former Institute for Transuranium Elements, ITU) and Institute for Reference Materials and Measurements (IRMM) has been involved in several international programs on nuclear waste characterisation, storage and disposal issues, and collaborates with research centres and agencies worldwide. JRC-Karlsruhe has participated in the Source Term Assessment project SFS in FP5. In FP6 and FP7 ITU contributed to the projects NF-Pro, MICADO, ReCosy, FIRST-Nuclides and DISCO, where it also has had workpackage leadership.

JRC-Karlsruhe has participated to the project SFTEST where two devices for mechanical testing on fuelled, pressurized spent nuclear fuel rod segments have been developed for gravitational impact and 3-point bending tests. Before installation in the hot cells, the equipment has been tested and optimized by performing a campaign of "cold" tests. Additional project in SPEND (WP SPERUS) which included experimental hot cell studies in conjunction with single effect investigation to extend and deepen the characterization of the spent fuel rod integrity and response to mechanical loading under accidental handling or transportation. The tests are performed on spent fuel using our home-developed 3-point bending and impact test equipment.

JRC (ITU/IRMM) contributed to the EURAMET funded Metrodecom project that concluded in 2017, and contributes in the MetroDECOM II follow-up project. JRC-IRMM participated in the EURAMET funded MetroRWM project and in the H2020 Insider project. JRC-IRMM was also responsible for a workpackage within the FP7 CHANDA project related to sensitivity analysis and uncertainty evaluation.

a description of any significant infrastructure and/or any major items of technical equipment, relevant to the proposed work;

The JRC Directorate Nuclear Safety & Security site in Karlsruhe has 24 concrete and lead hot cells with a capacity of up to 10^6 Ci along with a full range of shielded facilities in gloveboxes (optical microscope, SEM-EDX, EPMA, Knudsen cell, γ -spectrometers, gas-mass spectrometer for fission gas determinations etc.) for the handling, sample preparation, examination, and analysis of highly irradiated materials, including facilities to study electrochemical spent fuel corrosion using specific leaching and electrochemical techniques. The hot cells are configured to accept full-length fuel rods. Structural, micro-structural, micro-analytical, mechanical, thermo-physical, thermodynamic and chemical studies are performed on a wide array of irradiated fuels and materials.

A total of more than 300 gloveboxes in 30 laboratories equipped with instruments relevant for transuranium element investigations are available. The surface investigations are performed by electron-optical investigations made by SEM-EDX and TEM. The chemical analyses of highly radioactive aqueous solutions are performed in the chemical hot cells by ICP-MS, ICP-OES and γ -spectrometry.

In preparation for developing a KM platform, JRC at its “Science Hub” has established the web site “Managing decommissioning & radioactive waste management knowledge”. At this site, aspects relevant for the forthcoming RWM-EURAD-1 Knowledge Platform are developed and tested. As a test case for using multilinked web format, the state-of-knowledge for the three topical areas are developed for the project “Improved nuclear site characterization for waste minimization in decommissioning operations under constrained environment” (INSIDER). The process of coupling the SoK with training material and documenting and developing this in a web-based format is foreseen to be further implemented in the field of decommissioning, and may be directly used for the RWM-EURAD-1 or used as experience feedback and input for establishing the knowledge platform at another host.

if operational capacity cannot be demonstrated at the time of submitting the proposal, describe the concrete measures that will be taken to obtain it by the time of the implementation of the task.N/A

	No	Name	Acronym
Participant	24	Karlsruhe Institute of Technology	KIT
Description of the legal entity Karlsruhe Institute of Technology (KIT) is one of the biggest science and engineering research institutions in Europe and funded jointly by the Federal Republic of Germany and the State of Baden-Wuerttemberg. Its research and development program is embedded in the superordinate program structure of the Helmholtz Association of National Research Centers. KIT was established by the merger of the Forschungszentrum Karlsruhe GmbH and the Universität Karlsruhe (TH) on October 01, 2009. KIT combines the tasks of a university of the state of Baden-Württemberg with those of a research center of the Helmholtz Association in the areas of research, teaching, and innovation. In research and education, KIT assumes responsibility for contributing to the sustainable solution of the grand challenges that face the society, industry, and the environment. Project Management Agency Karlsruhe (KIT-PTKA): Since 1971 the project management agency KIT-PTKA is a service provider, partner, and codesigner of various customers of public organisations with a view to promote scientific research, technical development, and dissemination of research results in the field of nuclear waste management, environment and energy, water technology, production and services. Approximately 2000 projects/a are supervised by KIT-PTKA with a total volume of 135 Mio. EUR/a. In the competence area of nuclear waste management, KIT-PTKA is an agency of the Federal Ministry of Economics and Energy (BMWi) and supervises technical and administrative R&D projects in the fields of "Disposal of highly radioactive waste" and "Nuclear Safety Research". In 2017 ~ 50 Mio. EUR were invested by the BMWi to carry out R&D work in ~ 75 projects. Institute of Nuclear Waste Disposal (KIT-INE): The Institute for Nuclear Waste Disposal (INE) at KIT is strongly focusing on safety research for radioactive waste disposal by investigation of geochemical processes relevant for assessing long-term behavior of waste forms and (geo-)technical and natural barriers. The research contributes to the demonstration of safety within the disposal Safety Case for all types of host rock under consideration. Since several years, INE is one of the driving organizations developing of scientific knowledge which feeds the geochemically based long-term safety assessment for radioactive waste disposal. The competence of INE covers, amongst others, interactions of waste forms and barrier materials in disposal systems, basic radionuclide thermodynamics, the behavior of long-lived radionuclides in the geosphere, radionuclide transport properties in all host rocks considered in Europe, isotope-geochemistry and hydrology. In the area of the nuclear waste disposal Safety Case, it provides support in various national advisory bodies and interacts within several international collaborations.			
Description of main tasks in EURAD-1, with an explanation of how its profile matches the tasks Project Management Agency Karlsruhe (KIT-PTKA): In its role as a management agency, PTKA will not participate in individual work packages in the form of scientific activities. Rather, PTKA has the task of integrating relevant LTPs into the development of scientific content and implementing the corresponding legal link. Furthermore, PTKA will ensure that all administrative requirements in connection with the implementation of joint programming at national level are met at organisational level. Institute of Nuclear Waste Disposal (KIT-INE): KIT-INE will contribute to EURAD on several levels. Within CORI, KIT-INE will serve as the WP Coordinator and also contribute to the technical RD&D. In SFC, KIT-INE will serve as co-task leader and perform RD&D. In FUTURE, KIT-INE will contribute to the RD&D program. Additional activities of KIT-INE within EURAD are related to the Strategic Study UMAN and contributing to the Knowledge Management program. Given the high level of technical expertise at KIT-INE in all the fields relevant for the proposed work in EURAD, and the broad experience in coordinating national and international RD&D, KIT-INE is fully able to carry out the work proposed within EURAD.			

WP15-ConCorD :

KIT will perform its experiments in close cooperation with **GRS** namely in **Task 5 Transients**.

This work aims to determine the temporal evolution of rate and propagation of the degradation of spheroidal graphite cast iron GGG40 and copper alloy C71500 in contact with bentonite saturated with pore water in near field temperatures and chemical environments generated after the sealing process in deep geological repositories. The influence of the transient environment parameters temperature, pressure, trapped oxygen and the appearance of radiolysis products on the growth and long-term chemical and mechanical stability of the protective oxide films will be emphasized.

KIT will perform middle- and long-term transient experiments, using metal coupons. These experiments will be performed in closed reactors allowing to set nearfield transient conditions representative of geological disposal. Furthermore, using specially designed vessels allows applying a partial pressure of a selected gas and/or to probe the gas phase, and to perform experiments at elevated temperatures. The use of duplicate experiments will provide information on the temporal evolution of reacting interfaces (coupons/corrosion products and corrosion products/bentonite), including the evolution of the gas phase. At the end of the experiment, the corroding interface will be analysed using complementary microscopic and spectroscopic techniques.

The work is a part of a broader joint effort with other proposals within **Task 5**, SURAO(UJV) and **Task 6** by AMPHOS21, where irradiation experiments and advanced numerical modelling of the geochemistry and corrosion of the system, respectively, are targeted.

Contribution to SOTA in Task 1 is also envisaged.

WP10-UMAN extension:

The competence of INE covers a large range of topics, amongst others, interactions of waste forms and barrier materials in disposal systems, basic radionuclide thermodynamics, the behavior of long-lived radionuclides in the geosphere, radionuclide transport properties, isotope-geochemistry and hydrology. In the area of the nuclear waste disposal Safety Case, KIT provides support in various national advisory bodies and interacts within several international collaborations.

Within the extension phase of UMAN, KIT will continue its contribution to this WP and contribute its expertise to the work performed in the Subtasks 3.6 and 4.3. To a significant extent this will be focusing on the participation and contributions to the planned workshops in Subtasks 3.6 and 4.3.

a curriculum vitae or description of the profile of the persons, including their gender, who will be primarily responsible for carrying out the proposed research and/or innovation activities

Project Management Agency Karlsruhe (KIT-PTKA):

Since May 2010 Dr. Silvia Stumpf is working at the Project Management Agency Karlsruhe (KIT-PTKA) in the "Disposal" department, where she is responsible for "Nuclear Safety Research - Disposal Research" as project manager. Furthermore, S. Stumpf is in charge of all international tasks such as representing the national contact point for nuclear waste disposal, managing international relations and supervising international projects. In addition to the work as project manager, S. Stumpf was involved from 2010 to 2016 in the closure process of the German repository Asse as a member of the "Working Group on Closure Options" (AGO). For the period 2015-2016 she had the lead of the AGO office. In all mentioned functions, S. Stumpf assumes responsibility as a service provider for the federal ministries BMWi, BMBF and BMUB.

Institute of Nuclear Waste Disposal (KIT-INE):

Dr. Marcus Altmaier (male) is expert on aquatic chemistry and thermodynamics of actinides and long lived fission products. Dr. Altmaier joined KIT-INE in 2000, since 2012 he is head of the Radiochemistry Division at KIT-INE. In 2017 he was appointed deputy director of KIT-INE. Experimental research activities focus on radionuclide chemistry in aqueous media. Dr. Altmaier has a strong interest in radioanalytical techniques, actinide and fission product chemistry and the study of radionuclide solubility phenomena in dilute to concentrated systems. Dr. Altmaier has been involved in several national and international projects, ranging from fundamental scientific research on actinide chemistry to applied work related to the final disposal of nuclear waste in deep underground facilities. Dr. Altmaier served as Coordinator for the EC funded projects RECOSY (2010-2013) and CEBAMA (2015-2019), and is currently developing the WP CORI within EURAD.

a list of up to 5 relevant publications, and/or products, services (including widely-used datasets or software), or other achievements relevant to the call content

- [1] Altmaier, M.; Gaona, X.; Fanghänel, Th., Recent Advances in Aqueous Actinide Chemistry and Thermodynamics, Chemical Reviews (2013), 113, 901–943.
- [2] Altmaier, M. (Hrsg.), Montoya, V., Duro, L., Valls, A., Proceedings of the First Annual Workshop of the HORIZON 2020 CEBAMA Project; KIT Scientific Publishing, Karlsruhe, (2017). <http://dx.doi.org/10.5445/KSP/1000068889>.
- [3] Duro, L., Bruno, J., Grivé, M., Montoya, V., Kienzler, B., Altmaier, M., Buckau, G.; Redox processes in the safety case of deep geological repositories of radioactive wastes. Contribution of the European RECOSY Collaborative Project, Applied Geochemistry, Vol. 49, 206–217, 2014.
- [4] Geckeis, H., Lützenkirchen, J., Polly, R., Rabung, Th., Schmidt, M., Mineral–Water Interface Reactions of Actinides, Chemical Reviews (2013), 113, 1016–1062.
- [5] Kienzler, B., Duro, L., Lemmens, K., Metz, V., De Pablo, J., Valls, A., Wegen, D., Johnson, L., Spahiu, K., Summary of the Euratom collaborative project FIRST-nuclides and conclusions for the safety case, Nuclear Technology 198(3), pp. 260–276, 2017.

a list of up to 5 relevant previous projects or activities, connected to the subject of this proposal

EC projects:

- CEBAMA (Horizon 2020): Collaborative project on “Cement-based materials, properties, evolution, barrier functions”. June 2015 – May 2019. (Coord. KIT-INE).
- FIRST NUCLIDES (FP7): Collaborative project on “Fast / Instant Release of Safety Relevant Radionuclides from Spent Nuclear Fuel”. January 2012 – December 2015. (Coord. KIT-INE).
- RECOSY (FP7): Collaborative project on “Redox Phenomena Controlling Systems”. April 2008 - March 2012. (Coord. KIT-INE).

German projects:

- GRaZ (BMW/PTKA): Collaborative project on “Geochemical retention of radio nuclides on cement alteration phases”. September 2015 – August 2018.
- ENTRIA (BMBF/PTKA): Collaborative project on “Disposal Options for Radioactive Residues: Interdisciplinary Analyses and Development of Evaluation Principles”. 2013 - 2017

a description of any significant infrastructure and/or any major items of technical equipment, relevant to the proposed work;

Project Management Agency Karlsruhe (KIT-PTKA):

More than 100 employees at two locations at the main office in Karlsruhe and the branch office in Dresden use the excellent infrastructure of and vicinity to research at the Karlsruhe Institute of Technology.

Institute of Nuclear Waste Disposal (KIT-INE):

INE laboratories are fully licensed and equipped with all necessary infrastructures to perform research with radionuclides in the context of Safety Research for Nuclear Waste Disposal. This is including hot cells, alpha glove boxes, inert gas alpha glove boxes and radionuclide laboratories. State-of-the-art analytical instruments and methods and advanced spectroscopic tools exist for the sensitive detection and analysis of radionuclides. Trace element and isotope analysis is made by instrumental analytical techniques such as X-ray fluorescence spectroscopy (XRF), atomic absorption spectroscopy (AAS), ICP-atomic emission spectroscopy (ICP-AES) and ICP-mass spectrometry (Quadrupole-ICP-MS and high resolution ICP-MS). Methods available for surface sensitive analysis and characterization of solid samples include X-ray diffraction (XRD) and atomic force microscopy. A modern X-ray photoelectron spectrometer (XPS) and an environmental scanning electron microscope (ESEM) are installed. INE has direct access to a TEM instrument. A wide variety of Laser spectroscopic techniques are developed and are available including laser fluorescence spectroscopy (TRLFS), or laser-induced breakdown detection (LIBD). NMR analysis of radioactive samples is possible. INE operates the INE-Beamline at the Karlsruhe synchrotron source KARA (formerly ANKA) where extended X-ray absorption fine structure (EXAFS) spectroscopy and other techniques are available for investigations of radioactive samples. INE also uses different codes for modeling, multiphysics/geochemical codes like iCP COMSOL-PHREEQC amongst others.

if operational capacity cannot be demonstrated at the time of submitting the proposal, describe the concrete measures that will be taken to obtain it by the time of the implementation of the task.

All required operational capacity to carry out the work proposed by KIT-PTKA as well as KIT-INE within EURAD is fully available.

	No	Name	Acronym
Participant	25	Lietuvos Energetikos Institutas	LEI
Description of the legal entity Lithuanian Energy Institute (LEI) is a state scientific research organization with about 250 employees. LEI carries out fundamental and applied research in various fields related to radioactive waste and spent nuclear fuel (SNF) management, heat transfer, hydro and gas dynamics, alternative energy sources, materials science. LEI laboratories are participating in broad of international projects (COST, EUREKA, FP5, FP6, FP7, H2020, IAEA, Phare, etc.). Since 1994 the LEI Nuclear Engineering Laboratory (NEL) has been actively involved in the analysis of the radioactive waste management problems at Ignalina NPP covering planning and decommissioning of nuclear power plant, designing storage, treatment and disposal facilities, evaluating environmental impact of nuclear facilities and post closure safety of repositories. Implementing the research on SNF and long-lived intermediate level waste disposal in Lithuania, the researchers of LEI NEL with the assistance of experts from Sweden and other countries proposed the concept of deep geological repository in crystalline and clay rocks in Lithuania, and generic repository safety assessment was initiated. The concept on disposal and the safety assessment are constantly being updated taking into account international experience and thermal, groundwater flow, mechanical and chemical properties of a possible repository site.			
Description of main tasks in EURAD-1, with an explanation of how its profile matches the tasks LEI will contribute to five RD&D (“Mechanistic understanding of gas transport in clay materials”, “Influence of temperature on clay-based material behaviour”, “Assessment of chemical evolution of ILW and HLW disposal cells”, “Spent fuel characterisation and evolution until disposal”, “Development and improvement of numerical methods and tools for modelling coupled processes”), two Strategic Studies (“Waste Management routes in Europe from cradle to grave”, “Understanding of uncertainty, risk and safety”) and Knowledge Management Work Packages. WP16-MAGIC : LEI experts have an experience in modelling of coupled hydro-chemical processes in the field of radioactive waste disposal (changes of porewater chemical composition, radionuclide solubility, sorption, etc.), modelling of repository barrier mechanical behaviour under hydration with groundwater (participation in H2020 project BEACON). LEI experts also participates in Eurad 1st wave work packages related to chemical evolution modelling (ACED) and numerical tools for coupled processes modelling (Donut). Modelling tools COMSOL Multiphysics, PHREEQC, PHAST, etc. and supercomputer are available at LEI Nuclear Engineering Laboratory. LEI research in the Task 4 will be focused on HMC model development to take into account the impact of chemical interactions on mechanical properties. LEI will focus on field scale modelling of concrete mechanical ageing. Model will be applied on component scale. LEI will contribute to testing and benchmarking of model abstraction with experimental data taking into consideration the outcomes from tasks 2 and 3 and in close collaboration with UFZ and CSIC in task 4 (i. e. upscaled material properties, evolution of mechanical properties during degradation processes, etc.). WP9-ROUTES extension : LEI will support the development of expansion on existing predisposal routes for SIMS with regard to disposal options in Subtask 2.2. WP10-UMAN extension : Implementing the research on SNF and long-lived intermediate level waste disposal in Lithuania, the researchers of LEI NEL with the assistance of experts from Sweden and other countries proposed the concept of deep geological repository in crystalline and clay rocks in Lithuania, and generic repository safety assessment was initiated. The concept on disposal and the safety assessment are constantly being updated			

taking into account international experience and thermal, groundwater flow, mechanical and chemical properties of a possible repository site.

LEI would participate in the workshops organised by Subtasks 3.6 and 4.3.

a curriculum vitae or description of the profile of the persons, including their gender, who will be primarily responsible for carrying out the proposed research and/or innovation activities

Prof. Povilas Poskas is the head of Nuclear Engineering Laboratory with large and over 20 years experience in the field of radioactive waste and SNF management. He will be responsible for coordination of LEI contributions, development of methodologies/models and analysis of the results.

Dr. Dalia Grigaliuniene is a senior researcher with experience in numerical modelling of radionuclide transport and chemical processes interaction under different scenarios. She will be responsible for LEI activities in WP “Assessment of chemical evolution of ILW and HLW disposal cells”.

Dr. Darius Justinavicius is a researcher with experience in numerical modelling of gas transport and modelling of coupled thermo-hydro-mechanical processes. He will be responsible for LEI activities in WP “Mechanistic understanding of gas transport in clay materials”.

Dr. Ernestas Narkunas is a senior researcher with experience in numerical modelling of radiation transport, neutron activation, shielding and spent fuel characterization. He will be responsible for coordination of LEI activities in Knowledge Management WP.

Dr. Asta Narkuniene is a senior researcher with experience in numerical modelling of radionuclide transport from the repository under different evolution scenario, modelling of coupled processes and uncertainty/sensitivity analysis. She will be responsible for LEI activities in WP “Development and improvement of numerical methods and tools for modelling coupled processes”.

Dr. Gintautas Poskas is a researcher with experience in uncertainty, sensitivity and multi-criteria decision analysis. He will be responsible for LEI activities in Strategic Study “Understanding of uncertainty, risk and safety”.

Dr. Robertas Poskas is a senior researcher with experience in the field of radioactive waste and SNF management and investigations of the thermal processes. He will be responsible for LEI activities in WP “Influence of temperature on clay-based material behaviour”.

Dr. Arturas Smaizys is a senior researcher with experience in numerical modelling of activation processes and spent fuel characterization. He will be responsible for LEI activities in WP “Spent fuel characterisation and evolution until disposal”.

Dr. Audrius Simonis is a researcher with experience in management and characterization of institutional and decommissioning radioactive waste. He will be responsible for LEI activities in Strategic Study “Waste Management routes in Europe from cradle to grave”.

a list of up to 5 relevant publications, and/or products, services (including widely-used datasets or software), or other achievements relevant to the call content

Justinavicius D., Poskas P., Narkuniene A. Gas migration modelling in geological repository module in clay formation and sensitivity analysis. Engineering geology. 2016. Vol. 213, p. 158-168.

Narkunas E., Smaizys A., Poskas P., Ragaisis V. Modelling of RBMK-1500 SNF storage casks activation during very long term storage. Applied radiation and isotopes. 2016. Vol. 115. p. 100–108.

Poskas P., Grigaliuniene D., Narkuniene A., Kilda R., Justinavicius D. Modelling of irradiated graphite ¹⁴C transfer through engineered barriers of a generic geological repository in crystalline rocks. Science of the Total Environment. 2016. Vol. 569–570, p. 1126–1135.

Narkuniene A., Poskas P., Kilda R., Bartkus G. Uncertainty and sensitivity analysis of radionuclide migration through the engineered barriers of deep geological repository: Case of RBMK-1500 SNF. Reliability Engineering & System Safety. 2015. Vol. 136, p. 8–16.

Justinavicius D., Sirvydas A., Poskas P. Thermal analysis of reference repository for RBMK-1500 spent nuclear fuel in crystalline rocks. Journal of Thermal Analysis and Calorimetry. 2014. Vol. 118(2), p. 767–773.

a list of up to 5 relevant previous projects or activities, connected to the subject of this proposal

H2020 research projects: BEACON (2017-2021), THERAMIN (2017-2020);
 FP7 research projects: CAST (2013-2018), FORGE (2009-2013), CARBOWASTE (2008-2012);
 IAEA Coordinated Research Project: “The use of numerical models in support of site characterization and performance assessment studies for geological repositories” (2005-2010).

a description of any significant infrastructure and/or any major items of technical equipment, relevant to the proposed work;

LEI researches in the consortium will be focused on modelling activities (model development, validation and application). Range of modelling tools COMSOL, CODE-BRIGHT, COMPASS, GOLDSIM, MCNP, SCALE, PETRASIM, PHAST, PHREEQC and supercomputer available at LEI NEL will be used.

if operational capacity cannot be demonstrated at the time of submitting the proposal, describe the concrete measures that will be taken to obtain it by the time of the implementation of the task.

N/A

	No	Name	Acronym
Participant	26	Centre for Energy Research, Hungarian Academy of Sciences	MTA EK
Description of the legal entity Hungarian Academy of Sciences Centre for Energy Research was established in 2012 by a merger of two Institutes: KFKI Atomic Energy Research Institute and MTA Isotope Institute. MTA EK is mainly active in the field of basic and applied research related to nuclear energy. The activities of the Centre started in the 1950's. The main research areas of MTA EK are reactor physics, thermal hydraulics, fuel behaviour studies, and material sciences, health physics, environmental physics, nuclear electronics and chemistry. MTA EK is the chief technical consultant of NPP Paks and key player in the power-upgrade, safety, life extension and maintenance activity of the utility. At the same time MTA EK also serves as a technical support organisation (TSO) to the nuclear safety authority in Hungary. The Centre operates the 10 MW Budapest Research Reactor, providing the scientific community of Europe (see Budapest Neutron Centre for details) with research possibility for neutron physics and applications. The Centre has acquired important experience with VVER-type reactors, both in experimental and in analytical fields. MTA EK has been contributing to many EURATOM research programs and member of several expert associations. The Centre is the co-founder of V4G4 Centre for Excellence which organizes the research for the next generation gas cooled fast reactor. MTA EK is the coordinator of the National Nuclear Research Program focusing on radiation ageing of reactor structural materials, spent fuels and radioactive waste management and advanced modelling and simulation of nuclear reactor physics.			
Description of main tasks in EURAD-1, with an explanation of how its profile matches the tasks The work programme within EURAD-1 will be performed under Radioactive Waste and Decommissioning platform of MTA EK involving Fuel and Reactor Materials, Nuclear Security and Environmental Physics Departments and as LTP the Social Organization for Radioecological Cleanliness. RD&D is focused on spent fuels, RN mobility in clay, conditioning and deep geological disposal of radioactive waste. Environmental Physics and Nuclear Security Departments are interested in FUTURE and ACED WP's: - in FUTuRE Subtask 2.1-Mobility of radionuclides in compacted clay with following plan: MTA EK will carry out diffusion experiments on host rock samples with radiotracers (Eu, U, Ra, Se) assuming different perturbation effects and microscopic investigations of the diffusion front (inactive Se) and in FUTuRE Subtask 2.3- Reversibility of sorption; with plan: MTA EK will carry out test uptake experiments (Ni) involving thin sections for transferability of sorption phenomena, TEM identification of irreversibly formed phases on micro/nanoscale in natural rock sample, study of sorption reversibility using isotope exchange experiments (Ni, Ra) and modelling, experiments and modelling of competition of metal sorption in clay systems. In ACED Subtask 2.1-Steel/clay material interface reactivity; MTA will set up new experiment with KO-033 steel – plate and/or cylinder placed in contact with the Boda claystone formation between ambient temperature and 80°C. In ACED Subtask 2.2-Steel/cement material interface reactivity; MTA will set up new experiments with steel (KO33) – plate and/or cylinder emplaced with Portland concrete or other cementitious mixture from ambient temperature to 80°C. In ACED Subtask 3.1 – <i>Experimental analysis</i>; MTA EK will carry out different experiments in order to study the chemical evolution of a system borosilicate glass/steel/Boda-claystone formation (BCF). They focus on the understanding of the secondary phase formation (SEM, TEM, XRD, XPS methods). In ACED Subtask 3.2- Modelling of chemical evolution of HLW waste package scale; Using previous datasets, and the results from the planned experiments in subtask 3.1, MTA EK use GEMs, an advance sorption model (2SPNE CE/SC) and the GoldSim 8.02 software, which is suitable to model a complex system taking into account various conditions and mechanisms. Fuel and Reactor Materials Department is interested in SFC WP, in Subtask 3.1-Thermo-mechanical-chemical properties of the SNF rods and cladding;			

Creep tests will be performed with pre-hydrided and pre-treated at high temperatures Zr1%Nb samples. Hydride reorientation will be studied with pre-hydrided samples in mechanical tests at different temperatures and with different mechanical loads. Post-test investigation of the samples will be carried out with optical and scanning electron microscopy.

in Subtask 3.3- Pellet-cladding interaction under conditions of extended storage, transport and handling of SNF rods;

Cladding samples will be pre-treated in order to simulate the typical conditions for dry storage. Several samples will be charged with hydrogen, other samples will be treated in high temperature inert gas. Mandrel tests will be carried out to simulate crack propagation in cladding.

Through our LTP (Social Organization for Radioecological Cleanliness (SORC)) we are interested in DONUT WP.

In Task 2.- Numerical methods for high performance computing of coupled processes;

SORC will develop modules with numerical algorithms adapted to the resolution of multiphysic coupled problem on GPU-CPU Server platforms.

The lists of projects and publications indicate the experiences of MTA EK in spent fuel studies, the radionuclides transport in clay-rich rock systems and the conditioning of HLW. Our staff and equipment is suitable to serve the initiated program of EURAD-1.

a curriculum vitae or description of the profile of the persons, including their gender, who will be primarily responsible for carrying out the proposed research and/or innovation activities

CV of Zoltán Hózer who is responsible for SFC WP

Graduated as nuclear engineer from the Moscow Power Engineering Institute in 1984. Dr. Univ diploma for two-phase flow modelling at Budapest Technical University in 1988. PhD diploma for leaking fuel modelling at Budapest University of Technology and Economics in 2003. DSc diploma for experimental investigation of fuel integrity at the Hungarian Academy of Sciences in 2016.

Working at Centre for Energy Research, Hungarian Academy of Sciences (MTA EK) and at the KFKI Atomic Energy Research Institute (AEKI) since 1984. Head of the Fuel and Reactor Materials Department for more than twenty years. Leader of experimental programmes with VVER fuel components focusing on the behaviour of Zr claddings in normal operation, accident and storage conditions.

Member of programme review groups of international fuel projects (OECD Halden Reactor Project, SCIP III, Sandia Fuel Project, RASPLAV, MASCA). Co-ordinator of the OECD-IAEA Paks Fuel Project. Participant of several EU projects (OPSA, COLOSS, SARNET, ENTHALPY, COVERS, FIRST-Nuclides, ESNII Plus). Chairperson of the OECD Working Group on Fuel Safety.

Lecturer at the Budapest University of Technology and Economics. Former president of the Hungarian Nuclear Society.

Complete list of publications at https://www.kfki.hu/~hozer/Hozer_Zoltan_en.htm

CV of János Osán, who is responsible for FUTuRE WP

János Osán graduated in 1992 as a physicist at the Eötvös Loránd University in Budapest, Hungary. He received a Ph.D. degree in environmental physics and biophysics at the Semmelweis University, Budapest, Hungary, in 1997. He spent postdoctoral fellowship at the Department of Chemistry, University of Antwerp on methodological development and application of electron probe X-ray microanalysis of individual environmental particles, until 1999.

Since then, he has been working as a research scientist at the Environmental Physics Department of the Hungarian Academy of Sciences Centre for Energy Research. He has been involved in methodological development and application of modern X-ray microanalytical methods in environmental analysis, microscopic X-ray fluorescence and absorption spectrometry. His main research fields are microscale characterization of radionuclide uptake of the host rock of high-level radioactive waste repository, environmental evaluation of fossil, nuclear and renewable energy generation technologies, measurements and dispersion modelling of atmospheric aerosol particles.

In 2003, he received Young Scientist Award of the Hungarian Academy of Sciences based on his outstanding scientific achievement in environmental physics. In 2005, he received Certificate of Merit by the Hungarian Academy of Sciences, Advisory Board of the János Bolyai Research Fellowship, for outstanding research work between 2001 and 2004.

He is member of the Hungarian Synchrotron Board, Hungarian Aerosol Society within Hungarian Chemical Society and the European X-ray Spectrometry Association. He was asked as invited speaker at

various European scientific conferences and selected as a member of Editorial Board of journal Spectrochimica Acta Part B.

He was principal investigator of several national, bilateral and European projects, acted as coordinator of the Swiss-Hungarian Cooperation project “Development of a macro- and microscopic approach to investigate the geochemistry of radioactive waste disposal systems” between 2012 and 2015.

He spent two years (2016-2017) in the Nuclear Science of Instrumentation Laboratory of the International Atomic Energy Agency (IAEA), worked as consultant on development and environmental applications of X-ray fluorescence and absorption spectrometry.

He is co-author of 5 book chapters and 73 scientific papers for which he received 890 independent citations.

CV of Margit Fábián, who is responsible for ACED WP

Margit Fábián received her MSc degree from Babes Bolyai University of Cluj-Napoca, Romania and PhD degree in Theoretical and physical chemistry, materials science program at Eötvös Loránd University of Budapest in 2010. Between 2003 and 2011 she worked at the Wigner Research Centre for Physics, since 2012 she's research fellow at Centre for Energy Research in Department of Environmental Physics. Her research activity is focused on the development and study of amorphous and crystalline systems. She performed comprehensive work in the field of storage and management of radioactive waste, focused the preparation and characterization of special matrix systems for storage of high-level radioactive waste. She has extensive experience in the field of microstructural characterization (neutron and X-ray methods) and computer modelling of atomic structure. She develops a special sample environment - with High Temperature and Pressure Cell - at PSD neutron diffractometer where she is instrument scientist. She established a radiochemistry laboratory for preparation of glassy materials, installed special instruments and equipment's. She was principal investigator of several national and international-projects, acted as leader of the OTKA-PD 'Preparation, structural studies and optimization of borosilicate glasses for HLW storage applications' (2014-2016), 'Novel oxy-halide superionic glasses for safe rechargeable solid state batteries' (2018-2021) supported by the National Research, Development and Innovation Office, industrial R&D project 'Investigation of basaltic magmatic matrices' (2016-2017) etc.

She is Secretary of Hungarian Nuclear Society and president of Diffraction Committee of the Roland Eötvös Society of Physics. She is member of Solid State Physical Science Committee of Hungarian Academy of Sciences, member of the ASTM International Committee C26 on Nuclear Fuel Cycle and board member of the Budapest Neutron Centre.

Detailed List of Publications in MTMT database, with ID: 10013934 or in:

<https://vm.mtmt.hu/search/slist.php?lang=0&AuthorID=10013934>

CV of Tibor Kovács who is responsible for DONUT WP as LTP of MTA EK

Graduated as chemical engineer from the University of Veszprem in 1994. PhD in Biological effects of ionizing radiation at Semmelweis University in 2005.

Working at University of Pannonia since 1999. Head of the Institute of Radiochemistry and Radioecology.

The main research topics are measurements of alpha emitted radioisotopes, investigation of the resources of radon, parameters influencing its moving in buildings and in underground area, investigation of radon, thoron and daughter elements equilibrium, the sorption of daughter elements, their admission to the human body, investigation of radionuclide uptake of vegetable samples. Evaluation of dose contributions by radionuclide, study of natural originating alpha-emitter radionuclides by alpha spectrometry, development of new sample preparation methods, radiological assessment of drinking-, mineral-, and spring-water.

Member of the editor board in two scientific paper: Nature and Journal of Nuclear Chemistry. President of Social Organization for Radioecological Cleanliness. Lecturer at the Chemical and Environmental Sciences Doctoral School.

a list of up to 5 relevant publications, and/or products, services (including widely-used datasets or software), or other achievements relevant to the call content

1. Márton Király, Dániel Mihály Antók, Lászlóné Horváth, Zoltán Hózer: Evaluation of axial and tangential ultimate tensile strength of zirconium cladding tubes, Nuclear Engineering and Technology, 50,3 (2018) 425-431, DOI: [10.1016/j.net.2018.01.002](https://doi.org/10.1016/j.net.2018.01.002)

2. H. Hózer, Cs. Győri, L. Matus, M. Horváth: Ductile-to-brittle transition of oxidized Zircaloy-4 and E110 claddings, Journal of Nuclear Materials, 373 (2008) 415-423, DOI: [10.1016/j.jnucmat.2007.07.002](https://doi.org/10.1016/j.jnucmat.2007.07.002)

3. J. Osán, A. Kéri, B. Breitner, M. Fábián, R. Dähn, R. Simon, S. Török: Microscale analysis of metal uptake by argillaceous rocks using positive matrix factorization of microscopic X-ray fluorescence elemental maps, Spectrochimica Acta Part B 91 (2014) 12-23; DOI: 10.1016/j.sab.2013.11.002 4. D. Breitner, J. Osán, M. Fábián, P. Zagytai, C. Szabó, R. Dähn, M. Marques Fernandes, I. Sajó, Z. Máthé, S. Török: Characteristics of uranium uptake of Boda Claystone Formation as the candidate host rock of high level radioactive waste repository in Hungary, Environmental Earth Sciences 73 (2015) 209-219, DOI: 10.1007/s12665-014-3413-4 5. M. Fábián, E. Sváb, M.V. Zimmermann, Structure study of new uranium loaded borosilicate glasses, Journal of Non-Crystalline Solids 380 (2013) 71-77, DOI: 10.1016/j.jnoncrysol.2013.09.004
a list of up to 5 relevant previous projects or activities, connected to the subject of this proposal 1. Zirconium Materials Science Studies, 2017-2019, supported by the National Research, Development and Innovation Fund of Hungary (contract number: NVKP_16-1-2016-0014) 2. Hungarian Nuclear Research Platform, 2015-2018, supported by the National Research, Development and Innovation Fund (contract number: VKSZ_14-1-2015-0021) 3. Development of a macro and microscopic approach to investigate the geochemistry of radioactive waste disposal systems, 2010-2015, supported by the Swiss-Hungarian Cooperation Programme (contract number: SH/7/2/11) 4. Preparation, structural studies and optimisation of borosilicate glasses for HLW storage applications, 2014-2016, supported by the National Research, Development and Innovation Fund (contract number: OTKA-PD 109384) 5. OECD-IAEA Paks Fuel Project, 2005-2007, https://www.oecd-neo.org/nsd/docs/2008/csni-r2008-2.pdf
a description of any significant infrastructure and/or any major items of technical equipment, relevant to the proposed work; Our Institute is one of the most equipped knowledge base in Hungary in the Academic sector. - Isotope laboratory (Grade C) available with equipment necessary for wet chemistry experiments, diffusion cells - Gamma spectrometers, Liquid scintillation counters - ICP-MS instrument - Unique XRF, XRD equipment are in regular use for elemental mapping and bulk measurements - MTA EK hosts the Budapest Neutron Centre where different beamlines are provided (Neutron Diffraction, Neutron Tomography etc.) - Transmission electron microscopes with ion milling sample preparation - Scanning electron microscopes - Mössbauer spectroscopy
if operational capacity cannot be demonstrated at the time of submitting the proposal, describe the concrete measures that will be taken to obtain it by the time of the implementation of the task. N/A

	No	Name	Acronym
Participant	27	National Cooperative for the Disposal of Radioactive Waste in Switzerland	Nagra
Description of the legal entity Nagra (the Swiss national cooperative for the disposal of radioactive waste) is responsible for the safe management of all types of radioactive waste arising in Switzerland. Since it was founded by the Swiss electricity utilities and the government in 1972, Nagra has developed into an internationally recognised know-how centre in the field of nuclear waste management. Nagra's activities span the areas of development of disposal concepts, regional studies, field investigations and site characterisation, performance assessment, design of deep geological repositories as well as design, construction and operation of underground research facilities. Through operation of the Grimsel test site (GTS) and participation in the Mont Terri URL, Nagra's scientists have been and are involved in the planning, implementation and interpretation of research, development & demonstration programmes during the past 20 years addressing all major aspects of underground disposal of radioactive waste. Nagra's work is supported by an effective quality management system that is certified in accordance with ISO 9001.			
Description of main tasks in EURAD-1, with an explanation of how its profile matches the tasks <u>WP HITEC</u> Coordination of the Subtask 4.1: Guidance for safety case development and repository optimization, contribution to the SOTA, coordination of the THM URL FE experiment modelling benchmark. As an implementor and owner of the FE experiment Nagra is well placed to perform these tasks. <u>WP Gas</u> Technical coordination of Task 2 "Barrier integrity", including the elaboration of a detailed scope of work, FEP-screening, elaboration of a state-of-the-art report. Technical coordination of sub-task 2.1 ("Gas-induced impacts on barrier integrity"), emphasising an integrated laboratory programme for investigating the evolution of damage of clay-rich geomaterials when subjected to excessive water/gas pressures. <u>WP Uncertainty Management multi-Actor Network (UMAN)</u> Nagra will lead Subtask 4.2 "Compilation and review of [...] information on [...] management options" and actively provide input from the Swiss program to other tasks. Nagra has been dealing with uncertainty management through its safety analysis for several decades. <u>WP SFC</u> Since a large part of the Swiss HLW inventory to be disposed of consists of spent nuclear fuel (SNF, also high burn-up), Nagra has developed significant expertise in this domain in the last decades to ensure the optimization of the loading of disposal canisters and plan for the final disposal including the operational and post-closure safety assessment. As a consequence Nagra will coordinate the following subtasks: • 1.2 – State-of-the-art and Gap analysis • 4.1 – Accident scenario for fuel under dry interim storage conditions Moreover, Nagra will contribute to the following subtasks with activities and know-how: 1. 1.3 – Training materials 2. 2.1 – Theoretical study of SNF source terms 3. 2.3 – Determine the inventory of activation and fission products in cladding material 4. 3.1 – Thermo-mechanical-chemical properties of the SNF rods and cladding 5. 4.2 – Consequence analysis of postulated accidents WP15 ConCorD : Nagra will act as WP Leader of ConCorD and will be responsible for the overall scientific-technical coordination of the WP. Nagra will also act as the Leader of Subtask 1.4 (ERG). Extensive expertise in the design development and long-term performance assessment has been developed over the years through collaborations with research institutes, universities, and leadership of experimental programmes in Grimsel and Mont Terri URLs. Nagra has an extensive ongoing R&D programme on canister materials and corrosion,			

culminating in the modelling and probabilistic performance assessment. Internationally, Nagra has a close ongoing collaboration with NWMO on the development of copper coatings and is member of the EUG of several Canadian research programmes on corrosion. Nagra is also part of a consortium with NWMO, Ondraf-Niras and SKB concentrating on corrosion research in the field of radioactive waste disposal.

WP17-MODATS :

Nagra will be an executive Board member

- Nagra will be the leader of task 2 dedicated to Data Treatment for Increased Confidence in Repository Monitoring. The Full-scale Emplacement (FE) Experiment at the Mont Terri URL will be used as a test case in task 2. FE is underpinned by extensive THM modelling, several years of monitoring data and a database of monitoring results

- Nagra will develop data processing methods in task 3.2 for determinate strain using optical fibre.

WP10-UMAN extension :

NAGRA will coordinate Subtask 4.2 and participate in the workshops organised by Subtasks 3.6 and 4.3. The objectives of subtask 4.2 are (1) to develop an overview about different approaches and uncertainty management options to assess and where relevant to reduce risks and optimise safety and (2) to prepare the material needed by Subtask 4.3 and Task 5 to interact with different types of actors. NAGRA is coordinating subtask 4.2 in the EURAD 1st wave of activities and with its background as RWMO in the well advanced Swiss disposal program, is well suited to contribute its knowledge.

A curriculum vitae or description of the profile of the persons, including their gender, who will be primarily responsible for carrying out the proposed research and/or innovation activities

Irina Gaus (female) is currently head of research and development at Nagra and during 2017 also ad interim manager for the safety based comparison of the siting regions for the future repositories in Switzerland. Before joining Nagra in 2007 she worked for the French Geological Survey (BRGM) and the British Geological Survey. She obtained her PhD in hydrogeology at the University of Ghent (Belgium) in 1998 where she also graduated as a geologist. Her technical expertise covers environmental applications of the shallow and deep subsurface (radioactive waste disposal, thermo-hydro-mechanical-chemical impacts, carbon storage, groundwater management).

Paul Marschall (male) coordinates Nagra's geoscientific modelling activities with special focus on phenomenological analyses of repository induced effects. This includes the simulation of thermo-hydro-mechanical and -chemical (THM-C) coupled processes in the engineered barrier system (EBS) and the host rock, respectively, but also model-based assessments of the overall performance of a geological repository in response to repository induced perturbations (heat and gas emission of the wastes, perturbations of the initial stress and pore pressure conditions, hydro-chemical interactions of the EBS materials with the host rock). Paul's scientific interests are related to pore water flow and gas transport processes in low-permeability rock formations and to the geomechanical characteristics of indurated clays (claystones, shales), which exhibit transitional deformation behavior between hard soils and weak rocks.

Thomas Kämpfer (male) graduated as mathematics engineer in 1998 from Ecole Polytechnique Fédérale de Lausanne (EPFL), Switzerland. After his diploma, Mr. Kaempfer continued on with a Ph.D. in Computational Materials Science in the Faculty of Engineering at EPFL. From the completion of his Ph.D. until 2009, Mr. Kaempfer studied transport processes in geophysical materials with a focus on snow. Mr. Kaempfer joined AF-Consult (formerly AF-Colenco) in 2009 and has led the Department for Groundwater Protection and Waste Disposal from 2013 to 2017. Besides his management tasks he has participated in long-term safety analyses for the comparison and in sensitivity analyses of repository systems, as well as in software development projects. He focused on project acquisition and management but contributed actively to all phases of the projects. Since November 2017, Mr. Kaempfer is working at Nagra on the safety case for the Swiss radioactive waste repository program and since July 2018 is leading the safety analysis group. He and his group are providing the safety related argumentation for the site selection for

Switzerland's deep geological repositories and are responsible for the safety case that will be a key document of the general license application. In his role, Mr. Kaempfer is actively involved in uncertainty management activities at Nagra.

Berrak Firat Lüthi (female) studied Geological Engineering at Middle East Technical University, Turkey, between the years 2007-2012. Upon completion of her Bachelor she started working at borehole exploration sites as a site engineer for 6-month. In 2013, she has started her Master's Degree program in the Department of Engineering Geology at ETH Zurich and finished her studies in October 2015. Since 15.08.2016 Mrs. Firat Lüthi has been working at the Swiss National Cooperative for the Disposal of Radioactive Waste (Nagra).

Throughout her Master studies, she has had 4-month of industrial internship at Nagra. She has had the opportunity to work for the FE Project in the Mont Terri Underground Rock Laboratory in St. Ursanne during the instrumentation and the backfilling of the FE-Tunnel. After her graduation, she had the chance to start another internship, where she was responsible of preparing, conducting and analyzing the experiments with fiber optic cables by using active distributed temperature sensing method (active DTS) in bentonite to determine the thermal conductivity under varying density and water contents. Currently, Mrs. Firat Lüthi is working as a Scientific Assistant for the FE experiment, and is responsible of the data management, field measurements, reporting.

Stefano Caruso (male) have been working at Nagra for seven years as project manager, (from 2017 as principal project manager of the Inventory and Logistics unit), in the Radioactive Materials division. He is chief scientific investigator for the Nagra in the EURATOM/DoE I-NERI, and IAEA SPARV IV, as well as Swiss representative at the OECD/NEA WPNCs. Main responsibilities are in the area of spent fuel and high-level waste: spent fuel integrity for operational safety and long-term safety aspects in relation to geological disposability and criticality safety assessment. He got his M.Sc. in Nuclear Engineering at the University of Rome "La Sapienza" and obtained his PhD in reactor physics at the EPFL in 2007. He worked in complex multidisciplinary projects, engaged in a large variety of organisations including industrial companies as well as research institutions (e.g. five years as reactor engineer at the nuclear power plant Beznau for core surveillance). His technical expertise covers experimental as well as numerical/modelling studies in the following core competences: nuclear science, nuclear power plant, engineering, reactor physics, information technology, nuclear safety, radiation detection.

Olivier Leupin (male) has a background in mineralogy /petrology and a specialisation in aquatic geochemistry. At Nagra he is deputy to the head of Research and Development and advisor in scientific strategic planning. He coordinates and manages Nagra's RD&D activities in the underground rock laboratory of Mont Terri (Switzerland). Olivier Leupin is responsible for Nagra's main project on repository induced effects and responsible for their integration into safety assessment.

Ingo Blechschmidt (male) is the Head of the Grimsel Test Site (GTS) Section. He completed a bachelor in Geosciences in 1994 and a master in Geology (Dipl. Geol.) in 1998, at the Friedrich Schiller University Jena, Germany. In 2002, he obtained a PhD at the Institute of Geology at the University of Bern. Following his engagement as a leading field geologist in various projects in the Middle East, he joined Nagra in 2004 as a Project Manager, responsible for specific tasks in various experiments conducted at the GTS underground rock laboratory (URL), then became involved in the general operation and management of the GTS, first as a Scientific Coordinator, then later as a Manager. Since 2007 he is Head of the Section as well as Deputy Division Head of Nagra's International Services and Projects Division. In addition to his responsibilities for the Grimsel Test Site, its staff, its budget, the strategic planning and the coordination of RD&D activities in compliance with Nagra's RD&D programme and the goals pursued by international research partners, Ingo has been involved with and/or leading pioneering experiments - planning, implementation, interpretation - conducted at GTS. Ingo Blechschmidt represents Nagra in international organisations such as the IAEA/URL Network of Centers of Excellence, IGDTP and CRC (Crystalline Club), and he actively supports Nagra's public relations activities.

A list of up to 5 relevant publications, and/or products, services (including widely-used datasets or software), or other achievements relevant to the call content

Diomidis, N., Cloet, V., Leupin, O.X., Marschall, P., Poller, A., Stein, M. (2016): Production, consumption and transport of gases in deep geological repositories according to the Swiss disposal concept. Nagra Technical Report NTB 16-03.

Senger, R., Romero, E., Marschall, P. (2018): Modeling of Gas Migration Through Low-Permeability Clay Rock Using Information on Pressure and Deformation from Fast Air Injection Tests. *Transp Porous Med.*, July 2018, Volume 123, Issue 3, pp 563–579

Caruso, S. (2018): From a conservative approach to a BEPU implementation for spent nuclear fuel characterisation and safety assessment from the perspective of geological disposal, Key-note invited lecturer, ANS Best Estimate Plus Uncertainty Conference (BEPU 2018), Real Collegio Lucca, Italy, May 13-19 2018.

Vlassopoulos, E., Nasyrow, R., Papaioannou, D., Rondinella, V., Caruso, S. & Pautz, A. (2017): Destructive tests for determining mechanical integrity of spent nuclear fuel rods, International High-Level Radioactive Waste Management Conference, April 9-13, 2017, Charlotte, NC, Westin.

Blechs Schmidt, I. & Vomvoris, S. (2017): 5 - Relevance of underground rock laboratories for deep geological repository programs. - Geological repository systems for safe disposal of spent nuclear fuels and radioactive waste, Ahn J.; Apted M.J. (eds.), Woodhead Publishing Series in Energy: Number 9, Woodhead Publishing Limited, Oxford, 2017, S. 113-142

A list of up to 5 relevant previous projects or activities, connected to the subject of this proposal

- *FE experiment at the Mont Terri URL*: large scale 1:1 heater test to demonstrate the feasibility of the Nagra concept and assess the THM impact on the engineered barriers and Opalinus Clay
- *Grimsel Test Site – International GMT Project*: In-situ experiment on gas transport in sand/bentonite; *GAST experiment*: in-situ demonstration experiment on gas transport in S/B seal sections.
- *International Mont Terri Research Programme: HG-A* - In-situ experiment on gas transport along the EDZ of a sealed tunnel section; *HG-D* - Gas transport in fractures
- Several PhD Theses at EPFL (Lausanne) and UPC (Barcelona) related to two-phase flow properties of claystones, bentonites and sand/bentonite mixtures
- Several Nagra managed and financed projects on: Behaviour of spent nuclear fuel under conditions relevant for interim dry storage, handling and transportation; Criticality safety assessment; spent fuel characterisation; Core Surveillance and Safety Assessment (NPP Beznau); Characterisation of high-burnup LWR fuel rods through gamma tomography (PSI)

A description of any significant infrastructure and/or any major items of technical equipment, relevant to the proposed work

Databases, samples, laboratory programmes (examples)

- Data bases from the on-going GAST experiment at the Grimsel test site and the FE experiment at the Mont Terri URL will be provided.
- Advanced laboratory programmes have been sponsored by Nagra, aimed at investigating gas transport processes in claystones, bentonite and bentonite sand/mixtures. The experiments were carried out at EPFL and UPC. The experimental data bases will be made available to the participating modelling teams.
- Rock samples for laboratory experiments will be provided, which have been recovered in the framework of Nagra's recent site investigation programme (Opalinus Clay and other indurated claystone formations)
- Advanced laboratory programmes have been sponsored by Nagra (PSI, JRC Karlsruhe), aimed at spent fuel investigations for safety relevant aspects.

Grimsel Test Site (GTS - Nagra)

The GTS is a well-established underground research facility which contributes to the development and confirmation of safe geological disposal concepts and to the characterisation of suitable host rock formations. It is used by a wide range of research organisations and universities on a national and international level. The international community of organizations responsible for radioactive waste management and contributing researchers have always looked to the GTS with great interest. The facility lends itself to a large

spectrum of geoscientific and engineering experimental concepts. A special feature is its radiation-controlled zone (IAEA Level B/C) which allows work to be carried out with radioactive tracers in the geosphere under close-to-realistic boundary conditions. Nagra has used the GTS to provide scientific answers and technical experience for the Swiss national disposal program. However, the GTS is also an essential tool for public outreach which helps to improve understanding of the disposal program by the general public and provides answers to questions people may have.

International cooperation with other national waste management organizations and research institutes has been an important component of the research program since day one. As some geoscientific results and practical experience gained from experiments conducted at the GTS may be transferred to other repository concepts it is conducive to share the costs and knowledge invested, and profit from the added value gained from the synergy effects during analysis and interpretation. In the more than thirty years of operation the GTS has hosted partnerships between Nagra and more than two dozen organizations and research institutes from twelve countries and the European Union.

Another aspect of international cooperation exercised at the GTS is that of knowledge transfer through training. The GTS offers its infrastructure and databases for educational purposes. Nagra staff and experts from the International Atomic Energy Agency (IAEA) and other organizations use the underground facilities as a practice base to teach the next generation of scientists and engineers and to facilitate specific workshops for experienced specialists for support interdisciplinary knowledge transfer.

If operational capacity cannot be demonstrated at the time of submitting the proposal, describe the concrete measures that will be taken to obtain it by the time of the implementation of the task.

Operational capacity can be demonstrated

	No	Name	Acronym
Participant	28	National Centre for Scientific Research « Demokritos »	NCSR
Description of the legal entity The National Centre for Scientific Research “Demokritos” (NCSR) was founded in July 1961 as a Research Centre for Nuclear Research, Demokritos. Today it is the largest multidisciplinary Research Centre of Greece with approximately 180 Researchers in tenured and tenure-track positions and over 500 Research Personnel working in projects funded mainly by grants from State Funds, the European Union and Private Industries. It is governed by the Board of Directors and is supervised by the General Secretariat of Research and Technology, which is in the Ministry of Education, Research and Religious Affairs of Greece. The Centre consists of five independent Institutes focusing on different scientific fields: 1) Institute of Nuclear & Radiological Sciences and Technology, Energy & Safety (INRASTES); 2) Institute of Nuclear and Particle Physics (INPP); 3) Institute of Nanoscience and Nanotechnology (INN); 4) Institute of Biosciences & Applications (IBA); 5) Institute of Informatics & Telecommunications (IIT). The NCSR is a mandated RE in EURAD-RWMD. The INRASTES operates: 1) the Greek research reactor (GRR-1) by the Research Reactor Laboratory; 2) the centralized facility in Greece for interim storage of radioactive waste and sources by the Radioactive Waste & Material Laboratory (RWML). Furthermore, INRASTES possesses Laboratories who performing research and technological development in 1) sorption, multiphase flow, heat & mass transfer in porous materials; 2) reliability and safety of complex technological systems; 3) radioecology and radiation protection; 4) materials characterization by X-ray scattering, X-ray fluorescence spectroscopy, Positron Annihilation Lifetime Spectroscopy, Scanning and Transmission Electron microscopy in collaboration with the INN, mechanical testing, optical and thermal properties measurement in collaboration with the INN; 5) nuclear and radiation techniques (prompt gamma neutron activation analysis, gamma spectrometry, RBS, NRA, NAA in collaboration with the TANDEM accelerator laboratory/ INPP). The RWML research and development activities are related to radioactive waste and materials management as well as to the decommissioning of nuclear facilities. The main activity is the development of techniques as well as the elaboration and performance of studies for radiological characterization of waste (including historical waste) and facilities by destructive and non-destructive techniques. Furthermore, RWML elaborates studies for the safe storage of radioactive waste at the NCSR and provides services to the laboratories of the Centre as well as to hospitals, the Industry, companies and individuals.			
Description of main tasks in EURAD-1, with an explanation of how its profile matches the tasks The NCSR is a multidisciplinary Research Centre of Greece with infrastructure and technical equipment relevant to the proposed work. Furthermore, it is the main producer of radioactive waste in Greece and operates the centralized facility in the country for interim storage of radioactive waste and sources. Greece is a small inventory member state (SIMS) without NPP but possesses a research reactor and other applications of radioactive isotopes. The radioactive waste is producing in the same way, but in much smaller amounts. Furthermore, the disposal solutions have not been determined yet. The profile of the NCSR matches the tasks of the proposal in the following way: Task n°2 - Identify challenging wastes to be collaboratively tackled within the Joint Programme - Mapping and shared understanding at EU level of practical issues on waste management routes The NCSR will provide data about radioactive waste and sources kept at the centralized storage facility of the centre as well as about the waste that will arise from the future dismantling of facilities. NCSR will contribute in the analysis of the challenges encountered with small programmes including practical issues on waste management routes for challenging wastes. DMT (TLP) will support the NCSR as well as the other SIMS and collect the information from Task2 for the work in Task5. Task n°3 - Description and comparison of radwaste characterisation approaches			

The NCSR D will provide experience and knowledge on characterisation of radioactive waste from the Greek Research reactor and the other research facilities of the Centre. Furthermore, key radionuclides of concern and inventories in selected radioactive waste will be provided. DMT (LTP) will present the techniques and procedures used for characterisation of raw legacy/ historical wastes in SIMS including the case of NCSR D.

Task n°4 – Identification of WAC used in EU Member States for different disposal alternatives in order to inform development of WAC in countries without WAC/facilities

Since Greece is a country without WAC for treatment and disposal of radioactive waste, the NCSR D will be observer in the workshops of the Subtask 4.2 – Sharing experience on waste management with/without WAC available and Subtask 4.3 – R&D needs and opportunities of collaboration, in order to gain knowledge from the experience and the knowhow of other countries in Europe and understand the future needs for R&D as well as the possibility of collaboration.

Task n°5 - RWM solutions for small amounts of wastes

NCSR D will summarize the knowledge for existing and potential disposal options for small amounts of radioactive waste in a report (deliverable 5.1) where further needs of R&D on this issue will also be listed. Furthermore, NCSR D will support the preparation of the second report (deliverable 5.2) where the suitable predisposal routes for small amounts of waste will be determined, even without WAC for disposal. NCSR D will organize the first workshop of this task. DMT (LTP) will take over the management of the Task and give information about disposal options appropriate for SIMS like the use of old mines, tunnels, bunkers, caverns, deep shafts and boreholes (some 100 m). Furthermore, DMT will collect the necessary information for the work in Task5 from the other Tasks of the WP.

Task n°6 – Shared solutions in European countries

DMT (LTP) will participate in this Task instead of NCSR D and contribute by describing examples of sharing facilities in Germany as well as by providing feedback. DMT will share the information from the work in this Task with NCSR D.

WP9-ROUTES extension :

In ROUTES 1st wave WP, NCSR D participates in the task 2-4 and has major contribution in Task 5 “RWM solutions for small amounts of wastes” where it is responsible for the deliverable 9.10: Collection and Analysis of Actual Existing Knowledge about Disposal Options for SIMS. Furthermore, NCSR D will support the preparation of the second report (deliverable 5.2) of Task 5, where predisposal routes for small amounts of waste will be presented.

In continuation of the work at the ROUTES 1st wave and being the operator of the of the Centralized Facility for radioactive waste and disused sources in a Small Inventory Member State, NCSR D will make a major contribution to the qualitative assessment of the predisposal routes (Subtask 8.1 of ROUTES Extension) and it will contribute in the assessment of the disposal options for SIMS (Subtask 8.2 of ROUTES Extension).

a curriculum vitae or description of the profile of the persons, including their gender, who will be primarily responsible for carrying out the proposed research and/or innovation activities

Dr Anastasia Savidou (female), date of birth 8 December 1960, nationality Greek, will be the primary responsible from the NCSR D.

Dr Savidou has been working at the NCSR D since 1986. She is a Senior Researcher and since 2013 Head of the Radioactive Waste & Materials Lab (RWML) of the Institute INRASTES with main task the upgrading of the radioactive waste and sources facility at the Centre. Dr Savidou is a member of the National Radioactive Waste Management Committee and participates in the four-member technical group of this Committee. Also, she is the representative of the NCSR D at the EURAD-RWMD. Dr Savidou received her Bachelor degree in Physics from the National & Kapodistrian University of Athens (1978-1983) and her PhD in nuclear application techniques from the National Technical University of Athens (1986-1992). In 1997 she was trained on treatment and disposal of radioactive waste at the Institute for Energy Technology, Kjeller, Norway with IAEA fellowship. Dr Savidou was group leader for radiological characterization and drawing

up of the GRR-1 decommissioning plan at the Research Reactor Lab from 2007 to 2013, group leader for radioactive waste management from 1997 to 2006, Post Doctor at the Environmental Radioactivity Lab from 1992-1996 and PhD student at the TANDEM accelerator Lab from 1986-1991. She has experience in a wide range of analytical techniques and applications. She have large experience in gamma spectrometry, non-destructive techniques by MCNP simulations, radiochemical methods in combination with alpha spectrometry and liquid scintillation counting as well as in radon measurement methods including radon exhalation techniques. Dr Savidou coordinated R&D projects which concerned: 1) radiological characterization of waste and facilities; 2) development of clearance techniques for radioactive materials; 3) study of natural radioactivity and development of techniques for determination of radon exhalation. She dealt also with other R&D activities: 1) study of leaching mechanisms of ions; 2) development of Proton Induced Gamma-ray Emission (PIGE) techniques. She has over than 50 publications in scientific journals and conferences proceeding with more than 210 citations by others and over than 30 reports and scientific studies. Dr Savidou supervises a number of undergraduate student for the development of bachelor thesis as well as PhD students.

Dr Jörg Feinhals (male), date of birth 22 June 1955, nationality German.

Dr Feinhals obtained his Diploma in Physics (1976-1982) and his PhD (Dr. rer. nat.) (1982-1988) from the University of Hanover. He has been working at DMT GmbH & Co. KG, Hamburg as Senior Expert and Head of Project Group Radiation Protection and RadWaste Management since 2011. He was Member of the Directorate of the German Swiss Association for Radiation Protection and is Secretary of Working Group Disposal. From 1988 to 2011 Dr Feinhals was Senior Expert and Head of Group RadWaste Management and Decommissioning, Radiation Protection Commissioner and Project Manager Repositories at TÜV NORD SysTec GmbH & Co. KG, Hamburg. He was Member of the German Commission on Radiation Protection for Evaluation of State Licenses by order of the Federal Ministry of Environment and Reactor Safety from 1999 to 2009. Dr Feinhals was German Representative at IAEA, Hamburg/ Vienna, for the International Decommissioning Network, PRISM Project, GEOSAF II from 2007 to 2015. From 1986 to 1988 he was scientific assistant at the Institute of Radioecology of Lower Saxony, Hanover and dealt with the transfer of tritium from atmosphere to soil. Dr Feinhals has wide experience in safety assessment in the field of: 1) disposal of radioactive waste (conditioning and interim storage); 2) design of disposal facilities; 3) radwaste management, clearance of radioactive materials; 4) decommissioning of nuclear installations (NPP Greifswald, Rheinsberg, Stade). Furthermore, he has large experience in: 1) radiation protection, training of health physicists; 2) quality assurance; 3) project management; 4) consulting nuclear authorities and operators for licensing; 5) organizing international conferences. Dr Feinhals worked outside of Germany as Senior Expert of: 1) the TACIS Project “Evaluation and Development of the technical Basis for Ensuring the safe Decommissioning of Nuclear Facilities” (Russian Federation, 1998 – 2000); 2) the TACIS Bistro Project “Development of the requirements to the content of the basic documents for obtaining NPP unit decommissioning license of Gosatomnadzor of Russia by operating organization” (Russian Federation, 2001-2002); 3) Senior expert for the IAEA in three expert missions: Assistance of the Nuclear Regulatory Body of Romania to Improve Regulatory Skills (related to near surface disposal facility at Savigny) (Romania 2007-2008, 2011).

a list of up to 5 relevant publications, and/or products, services (including widely-used datasets or software), or other achievements relevant to the call content

List 5 Relevant Publications:

- 1) Tzika F., **Savidou A.** and Stamatelatos I.E., [Non Destructive Characterization of Radioactive Waste Drums by Gamma Spectrometry: A Monte Carlo Technique for Efficiency Calibration](#), Heath Physics Journal, 93(5) suppl 3:S174-S179, (2007)
- 2) Papadokostaki K. G., **A. Savidou**, [Study of Leaching Mechanisms of Caesium Ions Incorporated in Ordinary Portland Cement](#), Journal of Hazardous Materials, 171, pp. 1024–1031 (2009)
- 3) **Savidou A.**, I.E. Stamatelatos, [Non Destructive Technique to Verify Clearance of Pipes](#). Journal of Nuclear Technology Radiation Protection, Vol. 25, No. 2, pp. 133-137 (2010)
- 4) **Savidou A.**, S. T. Valakis, [Management of Materials that will Arise from the Dismantling of the Primary Cooling System of the GRR-1](#), Fresenius Environmental Bulletin, Vol. 22, No. 7a, pp. 2027-2034 (2013)

5) Feinhals J., Kemp D., **Savidou A.**, [*No Nuclear Plans–No Disposal Facility?*](#), GeoResources Journal 2 Mining, pp. 16-24, (2017)

Additional relevant publications

J. Feinhals, A. Savidou, D. Kemp, Disposal Facilities for Countries without a Nuclear Power Programme, RRFM2016/IGORR 13-17 March 2016 Berlin, Germany

J. Feinhals, H. Völkle et al., Results of the Workshop on Radiation Protection Culture in Waste Management, Swiss-German Association for Radiation Protection, 31 Aug – 02 Sep 2015 Schloss Böttstein, Switzerland

J. Feinhals, Disposal Strategies for Low Amounts of Radioactive Waste, IAEA TC-Project RER/3/009 Annual Meeting Athens, 1-3 Dec. 2009

J. Feinhals, General International Concepts on Waste Disposal of VLLW and Clearance – Today and in the Future (IAEA, OECD, EC), FS,SFRP, ÖVS Workshop on Clearance, Strasbourg, May 2009

J. Feinhals, J. Krause, D. Richter, S. Schappert, Evaluation of Disposal Strategies for Storages containing old Stock of Nuclear Waste in Nuclear Power Plants, Report to KONTEC 1999, Hamburg

a list of up to 5 relevant previous projects or activities, connected to the subject of this proposal

List 5 Relevant Previous Projects or Activities:

- 1) 1997-2003: Coordination of the internal project that concerned the clearance of historical radioactive waste (mentioned in a Joint Convention National Report)
- 2) 2004-2006: Coordination of the internal project that concerned the characterization of the drums containing ion exchange resin waste from the research reactor
- 3) 2007- 2011: Participation in the national project that concerns the refurbishment of the Greek Research Reactor
- 4) 2013- : Coordination of the internal project that concerned the upgrading of the radioactive waste management in the NCSR “Demokritos”
- 5) 2017-2021: Coordination of the project “Development of a Time and Cost Effective Technology for Radiological Characterization/ Segregation of Radioactive & NORM Waste” funded by POLYECO S.A. and the STAVROS NIARCHOS FOUNDATION

a description of any significant infrastructure and/or any major items of technical equipment, relevant to the proposed work;

RWML infrastructure for radiological characterization

- High-resolution gamma spectrometry system
- Low background total-beta/ total alpha counting system
- In-situ gamma spectrometry systems (HPGe, LaBr, NaI)
- a number of dose rate meters and contamination monitors
- The MCNPX code
- Fume hood and glove box

if operational capacity cannot be demonstrated at the time of submitting the proposal, describe the concrete measures that will be taken to obtain it by the time of the implementation of the task.

N/A

	No	Name	Acronym
Participant	29	Nuclear Engineering Seibersdorf GmbH	NES
Description of the legal entity			
Radioactive waste management organization of Austria			
Description of main tasks in EURAD-1, with an explanation of how its profile matches the tasks			
- Identify challenging wastes to be collaboratively tackled within the Joint Programme - Mapping and shared understanding at EU level of practical issues on waste management routes (Strategic WP ROUTES Task 2) - Collection and analysis of existing work on categorization and classification of radioactive waste regarding disposal options, identification of waste for which there is not yet a complete management plan in each Member State, identification of waste management routes for pre-disposal steps → provide national relevant input data; analyze the challenges encountered with small waste programs (Strategic WP ROUTES Task 2.1) - Understanding at EU level of the practical issues on waste management routes for challenging waste → Establish and share synthesis on practical issues on waste management routes for challenging wastes (Strategic WP ROUTES Task 2.2) - RWM solutions for small amount of wastes (Strategic WP ROUTES Task 5) - Collecting and analyzing actual existing knowledge about disposal options for SIMS → NES is contributing the subtask regarding long-term interim storage on surface for decay, participating in two workshops (Strategic WP ROUTES Task 5.1) - Describe the necessary predisposal routes for the disposal options of subtask 5.1 → NES will organize the workshop and write the report with partners (Strategic WP ROUTES Task 5.2) - Shared solutions in European countries (Strategic WP ROUTES Task 6) - State of the art on shared development and use of technologies and facilities → State of the art on shared development and use of technologies and facilities (Strategic WP ROUTES Task 6.1) : Case studies on shared development and use of technologies and facilities → Provide input and participate in workshop (Strategic WP ROUTES Task 6.2) - Assess the feasibility of developing further European shared solutions for waste management from cradle to grave → Provide input and participate in workshop (Strategic WP ROUTES Task 6.3)			
Nuclear Engineering Seibersdorf GmbH is the only WMO in Austria. NES has a profound knowledge of radioactive waste management, and can carry out all necessary predisposal steps on its premises.			
WP9-ROUTES extension :			
NES will contribute to Subtask 1 (Subtask 1.2) with organization of a workshop.			
Based on the profound knowledge and expertise in RAW treatment and storage NES will contribute to Subtask 2 (Subtask 2.1) in the analysis and the assessment of existing predisposal routes for SIMS.			
Through what has to be done in future NES is highly interested in content and findings of Subtask 3 and is willing to contribute to the development of the relevant questions from a needs perspective.			
a curriculum vitae or description of the profile of the persons, including their gender, who will be primarily responsible for carrying out the proposed research and/or innovation activities			
Eileen Langegger, f, born 1986 in Graz. Graduated 2011 with a Master of Science in Technical Physics from the Universities of Technology Graz and Vienna.			
Work experience: Consultancy at IAEA (2011-2012); scientific staff at Technical University Vienna (2012-2013), since 2013 at Nuclear Engineering Seibersdorf GmbH, since 2014 Head of Interim Storage. She started teaching at the Montanuniversity Leoben in 2015, since 2017 she gives courses at the Technical University Vienna, since 2018 at the University of Technology Vienna.			
Roman Beyer knecht, m, born in 1966, graduated in 1994 with a Master of Science in Technical Physics from the Technical University Vienna.			
Work experience: 1995 – 1999 Product Manager at Voith Sulzer AG; 1999 – 2007 Expert for Radiation Protection and Nuclear Topics for the Government of District Lower Austria, since 2007 at Nuclear Engineering Seibersdorf GmbH, 2007 – 2012 Head of Business Unit Radioactive Waste Management, since 2012 CEO of Nuclear Engineering Seibersdorf GmbH.			

a list of up to 5 relevant publications, and/or products, services (including widely-used datasets or software), or other achievements relevant to the call content

W.Neckel, Freimessung von Abfällen, RADOS Freimessanlagen Forum Hamburg, Germany, 2011

B. Wellens, Unsicherheitsbetrachtungen bei heterogenen Aktivitätsverteilungen, ÖVS Jahrestagung, 2013

E.Radde (Langeegger), Reduction of Radioactive Waste by improvement of Conditioning facilities, Nuclear Espana No. 354, Spain, 2014

R. Beyerknecht, State of the Art Management of LILW in a Small Non-Nuclear Country – The Austrian Case; Waste Management Symposia, Phoenix, Arizona, March 2015

R. Beyerknecht, Integrated Waste Stream Management in a Small Non-Nuclear Country; Annual Meeting of the International Radioactive Waste Technical Committee, IAEA Vienna, April 2016

a list of up to 5 relevant previous projects or activities, connected to the subject of this proposal

- Reconditioning of stored waste: Older radioactive waste packages stored at Nuclear Engineering Seibersdorf GmbH will be reconditioned, in order to ensure the state of the art conditioning of all the waste. This includes for example new packaging for high force compacted and for homogeneously cemented waste, if possible clearance of already decayed (mainly homogeneously cemented) waste and state of the art treatment of inhomogeneous cemented waste.
- Modernization of conditioning facilities – building of a New Handling Centre (NHC) for the treatment of non-burnable waste: optimization of workflow, logistics and working safety. Renewal of conditioning facilities such as 2 manipulation boxes, high force compactor, drum drying system, hot cell with underground storage, cementation and mixing equipment, decontamination chamber
- Ultra- filtration Facility(UFA): This plant, in operation since 2009, is used to clean contaminated water from the premises of the research campus. Decontamination is achieved without chemical pre-treatment. The water is later on released.
- Soil Measurement and Sorting Device: Processes soil, gravel, ballast crushed concrete and the like with a sieve curve less than 32 mm. β - and γ - detectors enable the separation of contaminated from clean material.

a description of any significant infrastructure and/or any major items of technical equipment, relevant to the proposed work;

- Water treatment facility:
 - UFA – see above
 - Filtrox – older facility, which is capable of radioactive water treatment towards release
- Incineration Plant – all burnable radioactive waste is burned in the incineration facility
- New Handling Center includes the following radioactive waste treatment facilities:
 - High Force Compactor: a 1500 t compactor for solid non- burnable wastes to achieve a maximum compaction. Rests of contained liquids are held back within the system and collected for further treatment
 - Drum Drying Systems – 32 drums can be dried in the system at max. 140°C. This guarantees a possible storage of the drums afterwards with physical and chemical stable material, without moisture.
 - Sorting and Manipulation Boxes- the so called “Caissons” are used for the handling of raw waste and for the reconditioning of old waste. In these 2 stainless steel boxes work with contaminated or alpha active waste is possible. There is also the possibility of handling of larger items.
 - Decontamination Chamber – a facility that enables the easy and safe decontamination of larger items.
 - Source Treatment – Sealed radioactive sources are identified and sorted and placed in the corresponding containers. A special lead castle was built to enable safe working conditions.
 - Hot Cell – High active sources can be brought into the Hot cell, identified and stored in the underground storage containers.
 - Cementation Facilities
- Soil Sorting Facility – for automatic measuring and sorting material like contaminated soil and building rubble
- Various plants and facilities for treatment, conditioning and interim storage of radioactive waste like take over building, buffer storages, interim storage buildings, radiochemistry laboratories, radiation protection equipment, ...

if operational capacity cannot be demonstrated at the time of submitting the proposal, describe the concrete measures that will be taken to obtain it by the time of the implementation of the task.

N/A

	No	Name	Acronym
Participant	30	Národný jadrový fond	NJF
Description of the legal entity National nuclear fund (NJF) was established in 2006 as a state fund for accumulation and management of resources for back end of nuclear facilities life cycle (which replaced the State Fund for the Decommissioning of Nuclear Energy Facilities and the Treatment of Spent Nuclear Fuel and Radioactive Waste existing from 1995). Its role is to ensure sufficient acquisition sources for decommissioning of nuclear installations and for construction of deep geological repository in Slovak Republic and supervise accounting of decommissioning and waste management projects and their consistence with National Policy and Program. Board of supervisors of the Nuclear Fund except of account control insure the evaluation, updating and continuous performance of tasks resulting from the National Policy and Program for the Management of Spent Nuclear Fuel and Radioactive Waste in cooperation with other central state administration bodies, license holders and other stakeholders.			
Description of main tasks in EURAD-1, with an explanation of how its profile matches the tasks NJF will take part in WP ROUTES task No. 6 Shared solutions in European countries providing input, feedback and participate in workshop. NJF is responsible for evaluation and updating of National Policy and Program for the Management of Spent Nuclear Fuel and Radioactive Waste, where one of the considered alternative along with national deep geological disposal is international repository. In near future, NJF will reassess recent national policy of SNF management according current national and international experiences in sharing of waste management solutions. As part of ROUTES extension, NJF as a representative of the country with advanced waste management pre-disposal system and experience in treatment of waste from various European countries will contribute to evaluation of waste management routes for pre-disposal steps requiring international collaboration or sharing waste treatment capacities.			
a curriculum vitae or description of the profile of the persons, including their gender, who will be primarily responsible for carrying out the proposed research and/or innovation activities Adela Mršková (F) graduated in 1995 at Slovak University of Technology. She has technical expertise in radioactive waste management and disposal, decommissioning of nuclear power plants, nuclear emergency preparedness and response, accident management modelling and safety assessment, radiation protection, national energy policy and strategy evaluation, public information and involvement. She has been involved in EURATOM projects, particularly those combining technical and societal knowledge in the area of waste disposal (IPPA, SITEX).			
a list of up to 5 relevant publications, and/or products, services (including widely-used datasets or software), or other achievements relevant to the call content Salzer P., Přítrský J., Mršková A., Richardson Ph.: The Status of Multinational Waste Management Solutions, EC IPPA project deliverable 3.3, Jan. 2012 Mršková, A. et al: Commonalities and differences in public participation between national and multinational options and Recommendations with regard to national and regional public involvement programmes, EC IPPA project deliverable 3.4, Dec. 2013 Vojtěchová H., Mršková A.: Strategy of public engagement for DGR development in Slovakia and analyzes of options of economic and non economic incentives supporting DGR project, study, ÚJP Praha, Deep geological repository - site selection 1. Stage, October 2015			
a list of up to 5 relevant previous projects or activities, connected to the subject of this proposal Contractor of SITEX II project Member of JOPRAD TSO working group			
a description of any significant infrastructure and/or any major items of technical equipment, relevant to the proposed work -			
if operational capacity cannot be demonstrated at the time of submitting the proposal, describe the concrete measures that will be taken to obtain it by the time of the implementation of the task -			

	No	Name	Acronym
Participant	31	Nuclear Research and Consultancy Group	NRG
Description of the legal entity NRG has been the lead organisation for research in nuclear technology and in geological disposal in the Netherlands for over 30 years. NRG operates the HFR research reactor, a Hot Cell Laboratory, a Waste Storage Facility and various other nuclear facilities. NRG has almost 500, employees, more than about 100 employees work The Research, Consultancy and Services departments of NRG NRG has been studying disposal options since the 1970's. NRG had a key role in the recently completed research program into disposal in Boom clay in The Netherlands, (https://covra.nl/en/downloads/operational-info) and provides the Dutch authorities with advice on various topics concerning radioactive waste disposal and radiation protection in general.			
Description of main tasks in EURAD-1, with an explanation of how its profile matches the tasks NRG contributes to the Workpackages DONUT, ROUTES and UMAN. As a TSO, NRG main activities are in the field of safety cases, safety studies and (total system) performance assessments IUMAN). This requires to be a knowledgeable and active user of the models developed to be able to understand and link the models to system performance models (DONUT)			
a curriculum vitae or description of the profile of the persons, including their gender, who will be primarily responsible for carrying out the proposed research and/or innovation activities Key experts of the NRG contributing team are: <i>Mr. Hans Meeussen</i> (PhD in Soil Chemistry and MSc in Environmental Science and Software Engineering) joined NRG in 2010. His main area of expertise is the chemical and migration behaviour of contaminants in soils, waste forms, and cement barriers. He has (co-)authored over 40 scientific papers in this area and is developer of the <i>ORCHESTRA</i> reactive transport modelling software (www.meeussen.nl/orchestra). This open source software framework is widely used to implement detailed chemical speciation and reactive transport models, but it is also suited to embed detailed migration models within PA code. Hans Meeussen is NRG partner in the US DOE funded Cement Barriers Partnership (cementbarriers.org), a consortium that aims to develop next generation simulation tools for the evaluation of performance and degradation of cement barriers and materials used in nuclear applications. <i>Mr. Jacques Grupa</i> (NRG), MSc Technical Physics, has more than 15 years of experience in the fields of risk assessments for nuclear power plants as well as performance assessments for geological radioactive waste repositories. His relevant expertise regarding the latter is a thorough understanding of the complex in-situ behaviour of the waste, package, backfill and sealing materials in both normal and deviating conditions, in-depth understanding of performance analyses and its role in the Safety Case for a repository. Mr. Grupa acted as coordinator of EC Concerted Action on the retrievability of long lived radioactive waste disposed in deep underground repositories and was component leader in the EU 6 th framework project PAMINA. Furthermore, he was project manager of several recent Dutch performance assessments studies for waste disposal in rock salt and clay formations. <i>Mr. Jaap Hart</i> (NRG) holds a PhD in chemical engineering and has more than 20 years of experience in the fields of risk assessments of nuclear reactors and safety assessments for radioactive waste facilities. In 2001, Jaap Hart joined the Department of Radiation and Environment of NRG and since then has been involved in a variety of national and international projects related to radioactive waste management, amongst others several Framework projects of the European Commission, and the international working groups ASAM (Application of Safety Assessment Methodologies for Near Surface Disposal Facilities) and PRISM (Practical Illustration and Use of the Safety Case Concept in the Management of Near-Surface Disposal) hosted by the NEA and IAEA. His relevant expertise relates to an in-depth understanding of the safety case of geological disposal concepts and methodologies to be applied in safety assessments for radioactive waste repositories. <i>Mr. Thomas Schröder</i> (NRG) has a PhD in Soil Chemistry and MSc in Environmental Sciences. He has worked several years on risk assessment of heavy metal contamination in terrestrial and aquatic environments and has strong experience in analytical chemistry, speciation and sorption modelling as well as in execution of field work. Employed at NRG since 2007, he works mainly in the field of geological disposal of radioactive waste and contributed to several national, bilateral, and European research projects			

on technical and methodological aspects of waste disposal (e.g. PAMINA, MoDeRn). His relevant expertise covers the understanding of speciation and surface processes on molecular scale and the ability to combine experimental and modelling work within the framework of performance and safety assessment. <i>Ms Ecaterina Rosca-Bocancea</i> (NRG) is employed as a risk consultant, model developer and data analyst. She started her international career with a graduation as a MSc in chemistry and chemical engineering at the State University of Moldova. After research assignments in Hungary and Romania she moved to the Netherlands. Mrs Rosca-Bocancea is fluent in Romanian and Russian and also masters English, Dutch and French. The consultant is involved in the Netherlands' national research program on safe disposal of spent fuel and radioactive waste and participates in associated international research programmes. Furthermore she supports consultancy assignments related to nuclear safety and radiation protection with her modeling and data mining & analysis skills. <i>Mr. Arjen Poley</i> (NRG) has about 20 years of experience in the field of geological was consortium leader of the ALSA-C consortium project (2002 – 2011) carried out by GRS, Braunschweig (D), AF Colenco, Baden (CH), and NRG, Petten (NL), regarding radionuclide migration as part of Long-Term Safety Assessment Project for closure of the Asse II research mine in Lower-Saxony (D) As team manager he is responsible for scientific supervision, reporting & quality control.
a list of up to 5 relevant publications, and/or products, services (including widely-used datasets or software), or other achievements relevant to the call content 1. Grupa J, Davis P Report on the OPERA Safety Case structure OPERA-PU-NRG2111 22 January 2014 http://www.covra.nl 2. Hart J., J. Prij, G-J. Vis, D.-A. Becker, J. Wolf, U. Noseck, D. Buhmann, Collection and analysis of current knowledge on salt-based repositories, OPERA-PU-NRG221A, 15 July 2015. http://www.covra.nl 3. J.C.L. Meeussen, T.J. Schröder, E. Rosca-Bocancea J.J. Dijkstra, C. Bruggeman, and N. Maes Prediction of Rd values for radionuclides in Boom Clay with an independent multi-surface model, Clays in Natural and Engineered Barriers for Radioactive Waste Confinement, Brussels, March 2015. 4. Verhoef E, Neeft E, Grupa J, Poley A, Outline of a disposal concept in clay, OPERA-PG-COV008 rev1, 2014 http://www.covra.nl 5. Meeussen, J.C.L., 2003. ORCHESTRA: an object-oriented framework for implementing chemical equilibrium models. Environ. Sci. Technol. 37, p.1175–1182. [] Additional information can be found on www.meeussen.nl/orchestra
a list of up to 5 relevant previous projects or activities, connected to the subject of this proposal 1. OPERA project (https://covra.nl/en/downloads/opera-info) 2. Modern 2020 (http://www.modern2020.eu/) 3. CAST (https://www.projectcast.eu/) 4. SITEX-II (http://sitexproject.eu/index_2.html) 5. CeBaMa (http://www.cebama.eu/)
a description of any significant infrastructure and/or any major items of technical equipment, relevant to the proposed work; NRG has a large research infrastructure and the direct contact between the researchers allows easy access to available knowledge. The main expertises to geological disposal are in developing safety studies and safety cases (relevant to Eurad Work package Uncertainty Management multi-Actor Network, UMAN) and geochemical modelling (reactive transport code ORCHESTRA) for the Work Package Development and Improvement Of NUMerical methods and Tools for modelling coupled processes (DONUT).
if operational capacity cannot be demonstrated at the time of submitting the proposal, describe the concrete measures that will be taken to obtain it by the time of the implementation of the task. Considering a team of 6 experts, the proposed operational capacity of about 5 man-months per year is available.

Participant	No	Name	Acronym
	32	Organisme National des déchets Radioactifs des matières Fissiles enrichies	ONDRAF/NIRAS
Description of the legal entity ONDRAF/NIRAS, the Belgian Agency for radioactive waste and enriched fissile materials, is a public agency established by law (08.08.80, modified by law of 11.01.91; royal decree of 30.03.81, modified by royal decree of 16.10.91 and 04.04.2003). In the meantime, several laws and royal decrees were voted for specific tasks of the agency. The mission of ONDRAF/NIRAS is to protect man and the environment, for the present and the future, against the potential hazards arising from radioactive waste, without thereby imposing any excessive obligations on future generations. Its competences cover transport, processing, conditioning, interim storage and final disposal of radioactive waste and spent fuel, as well as the decommissioning of nuclear facilities. The agency is also competent for technical research and RD&D in the field of radwaste management, especially with regard to disposal and the optimisation of current practices. Since 1997, the agency is also entrusted by law with the inventory of all nuclear liabilities on the Belgian territory. The policy pursued so far is to have its industrial tasks performed by subcontractors as far as transportation is concerned and by Belgoprocess, a 100 % subsidiary of ONDRAF/NIRAS, for the activities with regards to the treatment, conditioning and storage of waste awaiting disposal. Concerning the long-term management of radioactive waste, ONDRAF/NIRAS has the monopoly in Belgium. In this respect, it defines the RD&D needs, steers the RD&D projects and integrates the RD&D results. For the R&D in the field of final disposal of waste the Belgian research centre on nuclear energy SCK•CEN is one of its major contractors. The Belgian Underground Research Laboratory HADES is operated by EURIDICE, a joint Economic Interest Grouping (EIG) of ONDRAF/NIRAS and SCK•CEN.			
Description of main tasks in EURAD-1, with an explanation of how its profile matches the tasks ONDRAF/NIRAS will participate in the R&D WP6 (GAS) and the Strategic Studies WP9 (UMAN) and WP10 (ROUTES). The Linked Third Parties of ONDRAF, ULiège and EURIDICE, will additionally perform tasks in WP7 (HITEC), see section on LTPs for the description of these tasks. As Lead Participant of WP6 (GAS) ONDRAF/NIRAS tasks notably include the coordination of the work package which entails the follow-up of the R&D programme, fostering interactions between WP6 participants, a task ONDRAF/NIRAS is familiar with considering its mission. ONDRAF/NIRAS will ensure the production, cross reviewing and edition of WP6 deliverables and will also ensure interactions with other WPs. Besides the coordination of the work package, ONDRAF/NIRAS will also participate to Task 4 on the Repository Performance Aspects, providing a WMO perspective, and input from the Belgian programme, about the conceptualisation of gas migration at repository and the assessment of its impact in the context of the Safety Case. In WP9 (UMAN), ONDRAF/NIRAS will contribute to subtask 2.1 by participating in technical meetings, providing an input regarding the strategies considered in their national programme, collecting information on strategies developed and used in other national programmes, providing written material and reviewing the deliverable. ONDRAF/NIRAS will contribute to subtask 3.1 and will collect and synthesise the views of WMOs on the different types of uncertainties that need to be addressed in a safety case and their evolution. ONDRAF/NIRAS will also contribute to subtask 4.3 in order to provide an input on the pros and cons of different uncertainty management options from the viewpoint of the Belgian WMO and to the identification of needs for future activities. As part of UMAN extension, ONDRAF/NIRAS will participate in the workshops organised by Subtasks 3.6 and 4.3. In WP10 (ROUTES), ONDRAF/NIRAS will lead Task 4 on waste acceptance criteria, a topic it is familiar with considering its legal role as WMO in Belgium. ONDRAF/NIRAS will provide input to the WP based on its perspective on the management of radioactive waste from cradle to grave. As task leader, it will ensure the production, cross reviewing and edition of Task 4 deliverables as well as the interaction with other tasks of WP10. As part of ROUTES extension, ONDRAF/NIRAS will participate in reviewing the deliverables. WP17-MODATS : [ONDRAF-NIRAS (EURIDICE)] will participate in Task 2 on Data Management. Its main contribution is linked to the PRACLAY heater experiment, which is running now since five years in the HADES URL			

(managed by EURIDICE), and which is proposed as a Reference Experiment in this task. The extensive data set of this experiment, together with the data management protocols (from data acquisition to presentation), will be an important input for the different sub-tasks. Considering its experience with citizen stakeholder interaction (in particular through the local partnerships in Mol and Dessel), it will also play an important role in the related subtask (2.5).

a curriculum vitae or description of the profile of the persons, including their gender, who will be primarily responsible for carrying out the proposed research and/or innovation activities

Séverine Levasseur (F) will be the contact person for WP6 (GAS). Séverine obtained a PhD in geomechanics in 2007 at the university of Grenoble (Université Joseph Fourier, France) and worked as scientific researcher from 2007 to 2014 at Université de Liège (ULiège, Belgium) in the geotechnical engineering department. During this period, she participated to several projects on geological disposal of nuclear waste including TIMODAZ and FORGE EC projects. Currently at ONDRAF/NIRAS she is co-worker of the RD&D team for long-term management of high-level waste and spent fuel and is responsible of geomechanical studies.

Xavier Sillen (M) will assist Séverine Levasseur in the coordination of WP6. He has close to 30 years' experience as a civil and environmental engineer (University of Louvain, 1989) active in R&D. For the last 20 years, his work has been directly related to the geological disposal of radioactive waste. In 1998, he joined the performance assessment (PA) group at SCK•CEN, the Belgian research centre on nuclear energy. There, he became increasingly involved in the geomechanics research, development and demonstration (RD&D) activities performed by EURIDICE, an Economic Interest Grouping set up jointly by SCK•CEN and ONDRAF/NIRAS, the Belgian agency for radioactive waste management. In particular, he contributed to the design of the PRACLAY large scale in situ heater experiment. In 2009, he joined ONDRAF/NIRAS, where he has been in charge of the follow-up of the studies on the perturbations of the host rock induced by a repository. He also supervised the final stages of the preparation of the PRACLAY experiment until the switch-on in 2014. In 2017, he became Scientific Coordinator, in charge of ensuring the coherency and quality of the science and technology studies carried out in the Belgian programme on long-term radioactive waste management. He has participated in several EC projects in the fields of PA and geomechanics (SPA, BENIPA, BORIS, SPIN, MODEX-REP, NF-PRO, TIMODAZ) and has contributed to the definition of the scientific programme of others (PAMINA, FORGE).

Christophe Depaus (M) is a mining engineer awarded by the Faculty of Polytechnics of the University of Brussels (ULB, Belgium), holds a Master in Advanced Studies in Philosophy of Sciences (DEA) awarded by the Catholic University of Louvain (UCL, Belgium) and an Academic degree in International Nuclear Law awarded by the University of Montpellier (UM1, France). Since 2009, he works in ONDRAF/NIRAS in the field of safety assessment for the long-term management of high-level waste and spent fuel and is responsible of the interactions with the Belgian regulatory body for the geological disposal. As such, he tries actively to integrate the scientific, technical, societal and legal aspects in the geological disposal project. He is also involved in many international projects like IAEA GEOSAF dealing with the impact of the operational safety on the long-term safety where he leads the task group on the operational safety; EC MoDeRn 2020 (WP2 & WP5) dealing with the monitoring of geological disposal and he was also the team leader of the expert team of the IAEA ARTEMIS mission for Bulgaria (2018) to perform the peer review of the national strategy and programme within the framework of the EC Directive 2011/70/Euratom.

Chris De Bock (M) will lead Task 4 of WP "Routes". He holds a degree in civil engineering (university of Leuven, 1989). From 1989 to 2002 he worked for Westinghouse Electric Company, in the design and safety evaluation of nuclear power plants. He managed several smaller and medium-scale study projects for the improvement of safety and/or efficiency in the fields of pressure vessel mechanics, thermo-hydraulics, reactor physics, control instrumentation and emergency response procedures. Chris joined ONDRAF/NIRAS in 2002, where initially he was chairman of the working group on the re-design of the Belgian geological repository and the preparation of its Safety Case. He participated as Module leader in the R&D project ESDRED within the EURATOM 6th Framework Programme, targeted on developing new geological repository technologies. In 2008 and in 2013 he was project officer in charge of the five-yearly cost evaluation of the geological and also surface disposal projects, which lie at the basis of the waste tariffs. Since 2010 he has been performing a key role in the development and management of ONDRAF/NIRAS waste acceptance criteria. This includes the evaluation and judgment of cases of waste nonconformities. He

is also co-author of the Safety Analysis Report of the surface repository, planned to be constructed in Dessel (Belgium) in the next decade.

Maarten Van Geet obtained a PhD in geology at the university of Leuven, Belgium in 2001. He immediately started at SCK•CEN, the Belgian research centre on nuclear energy, to work on the characterization of clay materials as barrier within a geological disposal system. This work covered host rock characterization, hydro-mechanical behaviour of bentonites and perturbations of the host rock, including the follow-up and installation of several in-situ experiments in the underground research laboratory HADES in Mol, Belgium. In 2007 he joined ONDRAF/NIRAS, the Belgian agency for radioactive waste management. He first was in charge of the research on perturbations of the host rock. In 2008 he became RD&D coordinator for geological disposal, including the management of the next safety case. In 2016 he became RD&D Manager, steering all Belgian RD&D on radioactive waste management (treatment and conditioning, surface disposal and geological disposal). At international level he is involved in European research steering, collaboration with and/or member of advisory groups for several other waste management agencies and since 2014 member of the ‘Groupe Permanent d’expert sur les déchets’ (expert group on waste) of the French Autorité de sûreté nucléaire (French safety authority).

a list of up to 5 relevant publications, and/or products, services (including widely-used datasets or software), or other achievements relevant to the call content

- ONDRAF/NIRAS (2013) “ONDRAF/NIRAS Research, Development and Demonstration Plan for the Geological Disposal of High-Level And/Or Radioactive Waste Including Irradiated Fuel If Considered as Waste. State-of-the-Art Report as of December 2012.” NIRON-TR 2013–12 E. Brussels, Belgium.
- Gonzalez-Blanco, L., E. Romero, C. Jommi, X. L. Li, and X. Sillen (2016) “Gas Migration in a Cenozoic Clay: Experimental Results and Numerical Modelling.” Geomechanics for Energy and the Environment 6 (June): 81–100.
- Pardoën B., Levasseur S., Collin F. (2014) “Using local second gradient model and shear strain localisation to model the excavation damaged zone in unsaturated claystone”, Rock Mechanics and Rock Engineering, vol. 48(2): 691–714.
- Capouet M.; Depaus C.; Van Geet M.; Lalieux P. (2013) “RD&D steering of a geological disposal programme in poorly indurated clays”, in The Safety Case for Deep Geological Disposal of Radioactive Waste: 2013 State of the Art, Symposium proceedings, NEA R(2013)9.
- Topic NFRP-2018-5: “Development of a roadmap for decommissioning research aiming at
- safety improvement, environmental impact minimisation and cost reduction”, Euratom Work Programme 2018, Call on Nuclear Fission, Fusion and Radiation Protection Research.

a list of up to 5 relevant previous projects or activities, connected to the subject of this proposal

- As the Belgian WMO, ONDRAF/NIRAS has conducted several assessments of options for the long-term management of radioactive wastes in Belgium, including the feasibility and safety of geological disposal (such as the SAFIR and SAFIR-2 exercises in 1989 and 2001 or the 2013 Waste Plan) to support decisions by the Belgian authorities.
- ONDRAF/NIRAS and/or its employees have participated in many IAEA, NEA and EC projects related to radioactive waste management including disposal. In particular, connected to the topics in this proposal,
 - Séverine Levasseur participated in the FORGE EC project;
 - Séverine Levasseur and Xavier Sillen participated in the TIMODAZ EC project;
 - Christophe Depaus participated in the EC MoDeRn 2020;
 - Maarten Van Geet and Xavier Sillen participated in the NF-PRO EC project;
 - ONDRAF/NIRAS has participated to the CAST EC project and participates to the THERAMIN EC project.

a description of any significant infrastructure and/or any major items of technical equipment, relevant to the proposed work;

Through the EIG EURIDICE, ONDRAF/NIRAS ensures the functioning of the Underground Research Laboratory HADES in which it conducts a large part of its experimental R&D programme on many aspects of near-field and far-field THMC processes in Boom Clay.

if operational capacity cannot be demonstrated at the time of submitting the proposal, describe the concrete measures that will be taken to obtain it by the time of the implementation of the task.

N/A

	No	Name	Acronym
Participant	33	Posiva Oy	POSIVA
Description of the legal entity Posiva Oy from Finland is a nuclear waste management company whose main task is the disposal of the spent fuel of its owners' NPPs. It is jointly owned by Teollisuuden Voima Oy (TVO 60%) and Fortum Power and Heat Ltd (FPH 40%). POSIVA have been carried out a research, development and technical design programme for disposal in ONKALO Underground Rock Characterisation Facility (URCF). Posiva will be in charge of the disposal facility in Olkiluoto, Finland, which construction have been initiated. Posiva's ONKALO offers a unique site for practical learning experiences related to repository characterization and construction of underground facilities. Posiva is currently testing in ONKALO the EBS component emplacement and the early evolution of disposal system in full scale. POSIVA started operations in 1996 and has over 50 specialists engaged in research, development and technical design for an environmentally acceptable disposal solution. POSIVA's programme brings together the resources of Finnish research institutes, universities and consulting and contracting companies. POSIVA has unique specialization in Europe related to site characterization and underground site specific activities. POSIVA received the Decision in Principle for the site of the geological disposal facility in 2000 and 2002 and a construction license for a geological disposal facility and encapsulation plant in 2015 as the first in the world. As a part of the preparations for the start of the construction and operations, POSIVA has carried out and continues the planning a series of various full-scale tests and demonstrations on encapsulation and disposal technologies. These will be carried out partly in the ONKALO, the Olkiluoto underground rock characterization facility, partly in suitable surface facilities. POSIVA has participated in many EURATOM projects related to geological disposal since 4th framework program. POSIVA's most recent EURATOM projects include ReCoSy, FORGE, MODERN, SecIGD, SecIGD2, REDUPP, LUCOEX, BELBaR, Petrus II, Petrus III, DOPAS (in FP7) and in H2020 MIND and MODERN 2020. In addition, POSIVA is an end user in several other European R&D projects. POSIVA has gained years of experience in working with and applying R&D results into its underground repository development work. POSIVA has acted as the coordinator of SecIGD and DOPAS projects. In addition, POSIVA has led several work packages in the EURATOM projects with success.			
Description of main tasks in EURAD-1, with an explanation of how its profile matches the tasks Posiva is mainly participating in HITEC WP3 Tasks 3.1 and 3.2 and Task 4. Posiva is providing planning and review support for the Tasks and coordinating the R&D work by Finnish RE organisations. Posiva also follows other scientific work packages like EJP1 GAS and WP: Spent Fuel Characterization and Evolution Until Disposal. WP17- MODATS : Posiva participates to the MODATS steering committee and to the planning the detailed work in MODATS Task 2. Posiva will provide the data sets from POPLU to observe the possible interactions between site and EBS components. In Task 2 Posiva participates to the review of the work and reporting. Posiva is optimizing the different methods for operational period based on experiences on working in repository conditions. Within MODATS Task 3.2 Posiva will test novel applications for leakage mapping as part of the monitoring of hydrogeological conditions and interpretation of seismic events as part of the rock mechanical monitoring programme. The principle is to provide a tool for faster and more reliable interpretation of achieved data sets. a curriculum vitae or description of the profile of the persons, including their gender, who will be primarily responsible for carrying out the proposed research and/or innovation activities Ms. Johanna Hansen, (F) She holds M.Sc. in Geology and Mineralogy from the Åbo Akademi University. She has been working at Posiva since 1997 both with site investigations and currently with development of disposal technology in Engineering. She coordinated the FP7 project DOPAS 323273 and she acts as a Finnish WMO mandated actor deputy contact in Eurad programme. Ms. Sophie Haapalehto, (F). She holds M.Sc. in Geology from the University of Helsinki. She has been working at Posiva since 2016 and is currently responsible for rock mechanical monitoring programme at Posiva.			

Mr. Jyri Laakso, (M). He holds M.Sc. in Geology from the University of Helsinki. He has been working at Posiva since 2016 and is currently working as hydrogeologist and developing the hydrogeological investigation methods.
a curriculum vitae or description of the profile of the persons, including their gender, who will be primarily responsible for carrying out the proposed research and/or innovation activities <u>Dr. Mika Niskanen</u> (M) is the scientific contact of POSIVA in the Hitec Project. He graduated in 2011 from the University of Eastern Finland, where he completed his PhD in physical chemistry on modelling “metallic polymers” and examining atomic and molecular interactions. He joined Posiva in 2016 and works as R&D engineer in Posiva's Plant Engineering to maintain up-to-date thermal dimensioning for the planned repository design. Moreover, he is managing several projects that deal with bentonite clay early evolution. <u>Ms. Tiina Jalonen</u> (F) She holds M.Sc.in Metallurgical Engineering from the University of Oulu. She has been working at Posiva since 2001 with R&D and Development for Engineered Barriers. Currently she is Senior Vice President at Posiva and a member in Management Group of Posiva Oy. She acts as a Finnish WMO mandated actor representative in Eurad programme. <u>Ms. Johanna Hansen</u>, (F) She holds M.Sc. in Geology and Mineralogy from the Åbo Akademi University. She has been working at Posiva since 1997 both with site investigations and currently with development of disposal technology in Engineering. She coordinated the FP7 project DOPAS 323273 and she acts as a Finnish WMO mandated actor deputy contact in Eurad programme. <i>Other Posiva's staff members are also engaged in the Programme.</i>
a list of up to 5 relevant publications, and/or products, services (including widely-used datasets or software), or other achievements relevant to the call content - Juvankoski, M. 2013. Buffer design 2012. Report POSIVA 2012-14, Posiva Oy. ISBN 978-951-652-195-7. - Posiva Oy. Safety case for the disposal of spent nuclear fuel at Olkiluoto – performance assessment 2012. Report POSIVA 2012-04, Posiva Oy. ISBN 978-951-652-185-8. - Toprak, E., Mokni, N., Olivella S., Pintado, X. 2013. Thermo-hydraulic-mechanical modelling of buffer and backfill. Report POSIVA 2012-47, Posiva Oy. ISBN 978-951-652-230-5. - Pintado, X., Rautioaho, E. 2013. Thermo-hydraulic modelling of buffer and backfill. POSIVA 2012-48, Posiva Oy. ISBN 978-951-652-229-9. - Toprak, E. 2018. Long term response of multi-barrier schemes for underground radioactive waste disposal. Doctoral thesis, Universitat Politècnica de Catalunya.
a list of up to 5 relevant previous projects or activities, connected to the subject of this proposal - BELBaR – Bentonite erosion: effects on long term performance of the engineered barrier and radionuclide transport. FP7-EURATOM project, Grant Agreement No. 295487. POSIVA participated in evaluating the effects of bentonite erosion in dilute waters on the performance of engineered barrier system in repositories. - DOPAS – Full-scale demonstration of plugs and seals. FP7-EURATOM project, Grant Agreement No. 323273. POSIVA coordinated demonstration project, which targeted to implement full scale plugs and seals and evaluate their functions and workability in repository conditions. The plugs and seals may include swelling clay materials to ensure the tightness. The bentonite behaviour and related saturation process were modelled in many DOPAS Experiments. - FORGE – Fate of repository gases. FP7-EURATOM project, Grant Agreement No. 230357. POSIVA participated in the investigation of gas migration in the bentonite buffer. - Prototype Repository. Project was coordinated by SKB (EC project reference No. FIKW-CT-2000-00055) and was conducted as part of Nuclear fission and safety programme 1998-2002 and related Retrieval of Prototype Repository project 2010-2013. Within the project, the emplacement of EBS components was studied and, during retrieval phase, the buffer material in two deposition holes and backfill in above lying deposition tunnel was sampled, analysed and modelled. - FEBEX (I) / FEBEX II – Full-scale engineered barrier experiment in crystalline host rock. EC-supported (EC project reference No. FIKW-CT-2000-00016) joint project between multiple nuclear waste management organizations and research facilities. POSIVA participated in the monitoring the development of different parameters with on-line measurements at the Grimsel test site.

a description of any significant infrastructure and/or any major items of technical equipment, relevant to the proposed work; Posiva is currently testing the EBS concept including buffer and backfill emplacement and monitoring of early evolution in ONKALO facility in full scale. In addition Posiva has a ready set up for 1/3 scale deposition holes equipped for monitoring and access to ground water.
if operational capacity cannot be demonstrated at the time of submitting the proposal, describe the concrete measures that will be taken to obtain it by the time of the implementation of the task.

	No	Name	Acronym
Participant	34	Paul Scherrer Institute	PSI
The Paul Scherrer Institute (PSI), is the largest research institute for natural and engineering sciences within Switzerland. PSI performs world-class research in three main subject areas: Matter and Material; Energy and the Environment; and Human Health. By conducting fundamental and applied research, PSI works on long-term solutions for major challenges facing society, industry and science. PSI has a unique position in Switzerland with respect to nuclear energy research, due to its heavy infrastructure, namely the Hot Laboratory with so-called "hot cells", well equipped and shielded zones for work and research on radioactive material. Based on this infrastructure, PSI's large facilities (SLS and SINQ) and the know-how of its collaborators, the division is involved in three main topics of research: the safety of currently operating nuclear reactors, related fuel cycles, and long-term safety of deep geological repositories for nuclear wastes of all kind.			
In particular the Laboratory for Waste Management, (LES) is the Swiss competence center for geochemistry and multiscale radionuclide and mass transport in argillaceous rocks and cement and their application to deep geological systems and Swiss radioactive waste repositories. The mission of the LES is to carry out a comprehensive R&D programme in support of Swiss radioactive waste disposal options. Research activities within LES are performed on very different spatial and temporal scales to take advantage of all the information which can (potentially) be obtained from such an approach i.e. from the nano scale (molecular spectroscopy), to the micro scale (XAS), to the cm scale (laboratory) and to field and regional scales (Mont Terri Rock Laboratory, St Ursanne, Switzerland). During the last 30 years, LES researchers have been developing state of the art models for the mechanistic description of radionuclides transport and retention in argillaceous rocks. Particular strength of the research labs is the combination of experimental infrastructure with the state-of-the-art coupled reactive transport modelling capabilities covering the simulation scale from atomistic to pore and the field scales. These tools are applied for quantitative prediction of repository in situ conditions over geological time scales. In the WP-FUTURE PSI coordinates Task 2 on Experimental studies on radionuclides mobility in compacted clay, crystalline rocks and reversibility of sorption with strongly sorbing radionuclides, and conduct laboratory studies in this task. Diffusion experiments will be carried out with moderately sorbing tracers (Fe, Ni and evt. Mn) and a strongly sorbing tracer (Eu) in compacted illite and in intact Opalinus Clay. The speciation of the adsorbed metals will be explored using synchrotron-based techniques. This will help to evaluate the current knowledge on surface mobility of these kind of metals. PSI will carry out adsorption/desorption experiments with Ni/Zn on pure clay minerals (illite/montmorillonite) under different specific experimental conditions (pH, presence of competing ligands/metals, variation of equilibrium concentrations and time). The local structure environment of the surface species will be probed by P-EXAFS. PSI also co-coordinates Task 3 Redox and conduct laboratory studies in this task. Purified reference clays will be prepared to obtain different Fe(III)/Fe(II) ratios (i.e. CBD reduction) or will be altered by sorbing Fe(II) under electrochemically reducing conditions. The sorption of U, and Tc or Se on the different Fe/clay systems will be investigated by combining batch type sorption experiments under different conditions (pH, [RNs], [Fe], Eh), molecular scale speciation using X-ray absorption spectroscopy and sorption modelling. In the WP-ACED PSI coordinates Task 3 on the Modeling of chemical evolution in repositories for HLW and ILW at a scale of individual waste packages (conditioned waste, disposal container, overpack). In this work package, recently developed solid solution models for C-S-H, AFm, and AFt phases will be extended by Fe-uptake, based on wet chemistry and spectroscopic data, using a multi-parameter multi-property optimization method. The resulting internally consistent set of parameters will provide a chemical-thermodynamic basis for improved reactive transport modelling in iron-containing cementitious systems used by the other modelling partners. Further, PSI will carry out simulations on the chemical evolution and gas/water mass balances in waste packages containing metallic and/or organic waste with the GEM-Selektor chemical modelling package and OpenGeoSys-MP-LT, a multi-component two-phase reactive code developed in cooperation with UFZ Leipzig.			

In the **WP-DONUT** PSI co-coordinates Task 3 on Scale transition schemes for coupled processes and participate in Task 2 on Numerical methods for high performance computing of coupled processes. While optimized continuum and pore-level codes exist a cross-coupled overarching code is still missing. Therefore PSI will address multi-scale chemo-mechanical couplings by linking numerical methods and open-source software for integrating pore-scale reactive transport models with continuum-scale THM(C) codes.

In the **WP-GAS** PSI participates in the Subtask 2.1 – Experimental and modelling studies of diffusion and retardation of gaseous species in clay rocks. PSI will work jointly with SCK•CEN to perform diffusion experiments on Boom Clay, Opalinus Clay and sand/bentonite mixtures and the experimental results will be supported by pore network modelling. Experiments will be carried out at different degrees of saturation, with different gases. This will allow determining how the effective diffusion coefficient is influenced by desaturation. By using lattice-Boltzmann modelling, the gas partitioning in pores of different sizes will be estimated.

In the **WP-CORI** PSI participates in Task 2, and will perform hydrolytic degradation experiments of aged samples of cellulose and the identification of degradation products.

In the **WP-SFC** PSI co-coordinates Task 2 on Fuel properties characterization and related uncertainty analysis. PSI plans a characterization of inhomogeneous hydrogen distribution due to impact of pellet on cladding (irradiated samples) with analysis of radial and circumferential hydrogen distribution and quantification in the treated claddings with neutron radiography. Further PSI coordinates and contributes to the Subtask 2.1 – Theoretical study of SNF source terms. PSI plans synchrotron measurements of chemical and structural / crystallographic properties of irradiated doped/undoped fuel at the cladding/pellet interface to determine the bonding /PCI properties.

WP16-MAGIC :

R&D at LES covers processes and systems from the nano scale (molecular modelling and spectroscopy) to the micro scale (by X-ray CT) to the cm (i.e., laboratory) scale as well as to the field and regional scales (experiments at the Mont Terri Underground Rock Laboratory (Mont Terri URL), St. Ursanne, Switzerland). During the last 30 years, LES researchers have been developing state of the art models for the mechanistic description of coupled THMC processes in repository near field and numerical tools for quantitative predictions of repository in situ conditions over geological time scales. Since many years, PSI has a formal collaboration agreement, in the area of cement performance, with another research entity of the ETH Domain, Empa (Swiss Federal Laboratories for Materials Science and Technology). Empa's Concrete and Asphalt Laboratory is a world-wide leading competence center in the fields of thermodynamic modelling and experimental studies of cement hydration and cement interactions with the environment and of non-destructive characterization of respective degradation processes which impact the durability properties. Empa contributes to the project with unique and innovative expertise in developing and applying ultrasonic measurement methods for characterizing non-destructively the evolution of poro-mechanical properties of cementitious materials.

In Task 1, PSI is a member of management board and support WP-MAGIC leader with project coordination as well as contribute to the development of SOTA report. In Task 2 & Task 3, Empa & PSI performs non-destructive ultrasonic studies of cement samples degraded in contact with OPA pore water in ongoing large-scale experiments and conventional mechanical testing of samples at saturated and partially saturated conditions. Nonlinear Elastic Wave Spectroscopies (NEWS) and Coda Wave Interferometry (CWI) offer state-of-the-art methods for non-destructively measuring linear (needed for computational models validation) and nonlinear (visco-)elastic moduli (proxy variables of microstructural features as micro-cracks, delaminations of interfaces and dissolution pores). They entail extremely higher sensitivity to microstructural changes compared with, e.g., traditional measurements of linear ultrasound pulse velocities (UPVs). Therefore, they are the most advanced techniques for, e.g., the identification of cracking initiation and for its tracking. These techniques allow detecting the appearance/evolution of cracks at sub-micrometer scale. Thus, they are complementary to the most advanced high resolution CT methods. In Task 3 PSI works with SCK CEN on extending existing state of the art Lattice-Boltzmann based pore scale reactive transport model to simulate chemical evolution based on a given boundary condition and material microstructure and composition. In collaboration with HZDR PSI will presence /absence of biofilms on the reactivity and microstructure evolution. In Task 4, PSI in collaboration with UFZ, work on interface for transferring the

material parameters from pore scale Lattice Boltzmann simulations and THM-codes. Of particular interest is interplay of carbonation, role of bio-films and estimation of mechanical stresses due to precipitation of secondary phases in saturated and partially saturated conditions.

WP17-MODATS :

PSI will contribute in 2.3 to the definition of an interface between monitoring data from FE-experiment and different process models describing temperature evolution to allow detailed comparison of distributed experimental data and related model data.

- PSI will contribute in 2.4 to the development and modifications of numerical tools, which allow the comparison of monitoring and model data including the assessment of their uncertainty (range) in order to enhance system understanding for the FE-experiment contributing to a future decision support system repositories.

- For the interpretation of data and analysis of THMC processes several numerical tools are available at PSI for the description of processes from microscopic to macroscopic scale: MC, KMC, LB, MCOTAC, Open Geosys-GEMS, FLOTRAN, COMSOL, PHREEQC, including related thermodynamic data bases (<https://www.psi.ch/en/les/database>) and geochemical solvers (<http://gems.web.psi.ch/>).

WP10-UMAN extension :

PSI will participate in the workshops organised by Subtasks 3.6 and 4.3 and lead subtask 3.6 including:

- the collection and synthesis of relevant information on uncertainties associated with the near field (including the Swiss experience related to geological disposal)
- the development of the material for the workshop organized by Subtask 3.6 and the seminar organized by Task 5
- the writing of the deliverable of Subtask 3.6.

PSI will also ensure the consistency between the work performed in subtasks 3.6 and 4.2 and contribute, as member of the subtask 4.2 expert group, to:

- the compilation and review of available information on uncertainty management options and preferences
- the development of the material for the workshop organized by Subtask 4.3 and the seminar organized by Task 5
- the writing of Task 4 deliverable.

a curriculum vitae or description of the profile of the persons, including their gender, who will be primarily responsible for carrying out the proposed research and/or innovation activities

Dr. Bart Baeyens (Male) Leader of the Clay Sorption Mechanisms group at the Laboratory for Waste Management (NES/PSI); Expert in experimental radionuclides sorption studies and modelling.

Prof. Dr. Sergey Churakov (Male) Head of the Laboratory for Waste Management (NES/PSI) and full Professor of Mineralogy at the University of Bern. Expert in multiscale modelling of reactive transport processes, radionuclide adsorption and transport.

Dr. Martin A. Glaus (Male) Research Scientist at the Laboratory for Waste Management (LES/NES). Expert experimental studies of radionuclides diffusion in compacted clay systems and radionuclide retention modelling.

Dr. Georg Kosakowski (Male) Senior scientist in the Transport Mechanisms Group at the Laboratory for Waste Management (NES/PSI). Expert in reactive transport simulations.

Prof Dr. Barbara Lothenbach (Female) Head of the Thermodynamic Modelling Group, at the Laboratory Concrete and Construction Chemistry, Empa and Professor, International Chair at the Concrete Group, Department of Structural Engineering, NTNU Trondheim, Norway. Expert in thermodynamic modelling of cement systems.

Dr. Maria do Sameiro Marques Fernandes (Female) Scientist at the Laboratory for Waste Management (NES/PSI). Expert in radionuclides sorption modelling.

Dr. Nikolaos Prasianakis (Male) Head of the Transport Mechanisms Group at the Laboratory for Waste Management (NES/PSI). Expert in pore scale reactive transport simulations and upscaling.

Dr. Dimitri Rochman (Male) Scientist at the Reactor Physics and Thermal-Hydraulics laboratory (NES/PSI). Expert in spent fuel behaviour.

Dr. Luc Van Loon (Male) Head of the Diffusion Processes Group at the Laboratory for Waste Management (NES/PSI) and Deputy Head of the Laboratory for Waste Management. Expert in radionuclide diffusion and retention in compacted clay systems.

Dr. Erich Wieland (Male) Head of the Cement Systems Group at the Laboratory for Waste Management (NES/PSI). Expert in radionuclide uptake in cement systems and radionuclides – organics interaction.

a list of up to 5 relevant publications, and/or products, services (including widely-used datasets or software), or other achievements relevant to the call content

- Bradbury, M.H., Baeyens, B. (2005). Modelling the sorption of Mn(II), Co(II), Ni(II), Zn(II), Cd(II), Eu(III), Am(III), Sn(IV), Th(IV), Np(V) and U(VI) on montmorillonite: Linear free energy relationships and estimates of surface binding constants for some selected heavy metals and actinides. GEOCHIMICA ET COSMOCHIMICA ACTA 69 (4), Pages: 875-892.
- Glaus, M. A.; Baeyens, B.; Bradbury, M. H.; . Jakob, A.; Van Loon, L.R.; Yaroshchuk, A. (2007). Diffusion of Na-22 and Sr-85 in montmorillonite: Evidence of interlayer diffusion being the dominant pathway at high compaction. ENVIRONMENTAL SCIENCE & TECHNOLOGY 41 (2), Pages: 478-485.
- Kulik, D.A.; Wagner, T.; Dmytrieva, S.V.; Kosakowski, G.; Hingerl, F.F.; Chudnenko, K.V.; Berner, U.R. (2013). GEM-Selektor geochemical modeling package: revised algorithm and GEMS3K numerical kernel for coupled simulation codes. COMPUTATIONAL GEOSCIENCES 17 (1), Pages 1-24.
- Churakov, S. V.; Gimmi, T.; Unruh, T.; Van Loon, L.R.; Juranyi, F. (2014). Resolving diffusion in clay minerals at different time scales: Combination of experimental and modeling approaches. APPLIED CLAY SCIENCE 96. Pages: 36-44.
- Safi, M. A.; Prasianakis, N.; Turek, S. (2017). Benchmark computations for 3D two-phase flows: A coupled lattice Boltzmann-level set study. COMPUTERS & MATHEMATICS WITH APPLICATIONS 73 (3), Pages: 520-536.
- Rochman, D., Leray, O., Vasiliev, A., Ferroukhi, H., Koning, A.J., Fleming, M. (2016).
- A Bayesian Monte Carlo method for fission yield covariance information.
- ANNALS OF NUCLEAR ENERGY 95. Pages: 125-134.

a list of up to 5 relevant previous projects or activities, connected to the subject of this proposal

RECOSY Redox phenomena controlling systems (ID: 212287) FP7-EURATOM-FISSION

FIRST-Nuclides: Fast / Instant Release of Safety Relevant Radionuclides from Spent Nuclear Fuel (ID: 295722) FP7-EURATOM-FISSION

CATCLAY: Processes of Cation Migration in Clayrocks (ID: 249624) FP7-EURATOM-FISSION

FUNMIG: Fundamental processes of radionuclide migration (ID: 516514) FP6-EURATOM-NUWASTE

SKIN: Slow processes in close-to-equilibrium conditions for radionuclides in water/solid systems of relevance to nuclear waste management (ID: 269688) FP7-EURATOM-FISSION

a description of any significant infrastructure and/or any major items of technical equipment, relevant to the proposed work;

State of the art radiochemical laboratories (type A and C) in a hot laboratory and so-called "hot cells", well equipped and shielded zones for work and research on radioactive materials. Radiochemical laboratories are fully equipped with several lines of inert gas glove boxes and analytical equipment for conventional chemical analysis, gamma and beta counting, gas and liquid chromatography analysis.

if operational capacity cannot be demonstrated at the time of submitting the proposal, describe the concrete measures that will be taken to obtain it by the time of the implementation of the task.

N/A

	No	Name	Acronym
Participant	35	Public Limited Company for Radioactive Waste Management	PURAM
Description of the legal entity PURAM is the national radioactive waste management organization in Hungary, a 100% state-owned enterprise that was established by the Government in 1998. PURAM's responsibility is to prepare proposal for the national radioactive waste and spent fuel management policy and national programme as well as for their revision, take care of the final disposal of radioactive waste, interim storage of spent fuel and decommissioning of nuclear facilities. PURAM operates the Interim Spent Fuel Storage Facility (Paks), National Radioactive Waste Repository (Bátaapáti) and the Radioactive Waste Treatment and Disposal Facility (Püspökszilágý). The financial source of PURAM's activities is the Central Nuclear Financial Fund, a segregated state fund within the national budget, which is exclusively earmarked for radioactive waste and spent fuel management purposes that are defined in law.			
Description of main tasks in EURAD-1, with an explanation of how its profile matches the tasks PURAM is one of the participants in the Knowledge Management Programme, in the Guidance Work Package. Considering Hungary's HLW RWM programme, it is at an early stage of development, with an ongoing site selection process. Nevertheless, PURAM has gained significant knowledge in the site characterisation and licencing of a geological disposal facility, because after 15 years of investigation, in 2010, the Bátaapáti repository for LILW in a granitic formation was successfully put into operation. International experience was widely considered during site characterisation, facility design and safety assessment. Also, PURAM as a targeted end-user was involved into the finalisation of the PLANDIS 2015 Guide. This guidance was applied by PURAM for the compilation of Hungary's National Programme for the RWM. The updated version of PLANDIS Guide and the completed PLANDIS 2020 will contain a lot of useful information for PURAM and supports further development and implementation of the Hungarian RWM programme.			
a curriculum vitae or description of the profile of the persons, including their gender, who will be primarily responsible for carrying out the proposed research and/or innovation activities Péter Pál Molnár: He has been working for PURAM since 2011 and spent significant time on the High Level Waste siting project. Mr Molnár is the Head of Research department of PURAM. He is responsible for the management of the siting project. As a Head of the Research Department, he is also responsible for the management of the natural barrier research projects, compile and manage the research program, including data and knowledge management. He has MSc in Geology and has a degree in nuclear environmental engineering. He participates in the activities of the Knowledge Management Programme. Balint Nös: He is the Strategic and Engineering Director of PURAM since 2014. Mr Nös graduate from Budapest University of Technology and Economics, Faculty of Engineering physics and working in nuclear industry and radioactive waste management from beginning of his career. He is responsible for the technical coordination of the safety analyses completion, define the requirements of development and investment projects. Hungarian national policy and national program was completed with his contribution. Mr Nös directs and supervises the Research Department of PURAM. Gerda Marianna Németh: She has been working for PURAM since 2013. She finished a Master degree in Environmental engineering from the faculty of Budapest University of Technology and Economics and has a degree in nuclear environmental engineering. She will be involved in the Guidance Work Package and will be the administrative coordinator of PURAM.			
a list of up to 5 relevant publications, and/or products, services (including widely-used datasets or software), or other achievements relevant to the call content 1. Current Status of Geological Disposal Projects in Hungary, A. Baksay, K. Benedek, B. Molnár, P. Molnár, B. Nös and Gy. Tungli, to appear in the Proceedings of the Fifth Worldwide Review (WWR-5), a workshop in May 2016 hosted at Lawrence Berkeley National Lab 2. Benedek, K., Molnar, P.: Combining structural and hydrogeological data: Conceptualization of a fracture system. Engineering Geology 163, (2013): 1-10.			

3. 4. Benedek, K., Mező, Gy., Szabó, Zs., Molnár, P., Böthi, Z., Geiger, J., Sidló, T., Dankó, Gy.: The Hydrogeological Modelling of the Bataapáti Site. Annual Report of the Geological Institute of Hungary 2009: 149-165 4. Benedek, K., Böthi, Z., Mező, Gy., Molnár, P.: Compartmented Flow at the Bataapáti Site in Hungary. Hydrogeology Journal. 17 (2009): 1219-1232. 5. Nős, B., Fritz, A., Fritz, L., Molnár, P., Tungli, Gy.: Site Investigation Programme of the Boda Claystone Formation 2018. Manuscript, PURAM report RHK-N-005/18.
a list of up to 5 relevant previous projects or activities, connected to the subject of this proposal PURAM is a member of IGD-TP Executive Group. In the past years it has participated in the end-user groups of several EU projects (e.g.: PLANDIS, CAST, DOPAS, JOPRAD). PURAM is the member of various expert groups under RWMC of NEA: Integration Group for the Safety Case of Radioactive Waste Repositories (IGSC), Clay Club, Forum of Stakeholder Confidence (FSC), Preservation of Records, Knowledge and Memory across Generations (RK&M), Vision Document for the Radioactive Waste Repository Metadata Management Project (REPMET) and Working Party on Decommissioning and Dismantling (WPDD). PURAM also participates in a number of IAEA networks: International Decommissioning Network (IDN), Underground Research Facilities Network (URF), International Low Level Radioactive Waste Disposal Network (DISPONET), Data Analysis and Collection for Costing of Research Reactor Decommissioning
a description of any significant infrastructure and/or any major items of technical equipment, relevant to the proposed work; There aren't any significant infrastructure or any major items of technical equipment necessary to complete the proposed work. The proposed work is based on the feedback of existing information and experiences.
if operational capacity cannot be demonstrated at the time of submitting the proposal, describe the concrete measures that will be taken to obtain it by the time of the implementation of the task. N/A

	No	Name	Acronym
Participant	36	Regia Autonoma Tehnologii pentru Energia Nucleara	RATEN
The Technologies for Nuclear Energy State Owned Company (RATEN) is a strategic Romanian legal entity coordinating the R&D activity in the nuclear energy field, which maintains and develop the scientific and technologic support for the National Nuclear Energy Program. RATEN manages two subsidiaries: Institute for Nuclear Research Pitesti (RATEN ICN) and Center of Technology and Engineering for Nuclear Projects (RATEN CITON). The activities proposed by RATEN under this proposal will be carried out in the Institute for Nuclear Research Pitesti. The Institute for Nuclear Research Pitesti (RATEN ICN) is a complex R&D centre created in 1971 to provide the scientific and technical support to the national nuclear energy program. Its activity covers a wide range of nuclear fields such as nuclear safety, radioactive waste, radioprotection, nuclear fuel and materials, reactor physics. Under the Radioactive Waste Management R&D program, RATEN ICN specialists developed treatment and conditioning technologies for LLW/ILW, established and applied new methodologies for radioactive waste characterization, in parallel with performance and safety assessments mainly for the future LLW/ILW repository designed mainly to dispose of the radioactive waste generated by Cernavoda NPP but also for geological repository for CANDU spent fuel and long-lived waste. The research activity is founded on a modern and complex infrastructure consisting of TRIGA reactor, Hot Cells Facility, Radioactive Waste Treatment Department, radiochemical laboratories operating modern investigation techniques, and sustained by specialists with large experience in the nuclear field.			
Description of main tasks in EURAD-1, with an explanation of how its profile matches the tasks RATEN will be involved in two R&D work packages, FUTURE and CORI, and two strategic WPs, ROUTES and UMAN. In FUTURE WP, RATEN is involved in Task n°3: Redox. Under this task, RATEN will carry out sorption/desorption experiments, under controlled conditions (O₂ content and Eh) to study the retention mechanisms of Tc on individual clay minerals and on the natural and “model” red clay. The influence of FeII/FeIII ratio in clay minerals, change in redox state and reversibility of sorption/incorporation will be studied. Diffusion and sorption experiments will be carried out on natural red clay samples and on a compacted “model” red clay sample. At the end of these experiments the location of Tc (Re) will be investigated using spectrometric and microscopic techniques. The sorption/desorption tests will be sustained by experimental investigations to characterize the individual minerals (clays and iron oxides) and the natural compacted clay used in experimental programme. The total and redox active Fe content and the location of Fe(II) and Fe(III) in clay minerals and in red clay will be evaluated. In CORI WP, RATEN is involved in Task n°2: Organics-Cement-Interactions and Task n°3: Radionuclide-Organics-Cement-Interactions. Under CORI Task n°2, RATEN proposed to investigate the interaction (sorption/desorption) of C-14 bearing organic compounds generated by CANDU spent ion exchange resins degradation with non-degraded and degraded HCP (state II, III and carbonated). The potential competitive effect of Fe on organic compounds sorption will be also investigated. Under CORI Task n°3, RATEN has proposed to investigate the effect of organics generated by spent ion exchange resins degradation on Ni (as divalent radionuclide) mobility in cementitious environments. Ni sorption kinetic and isotherms and the effect of organics on Ni sorption will be investigated by batch sorption/desorption tests. Effect of single organics and cocktails of organics and role of iron on Ni sorption on non-degraded and degraded HCP will be investigated, as well as the effect of Ca. In the frame of ROUTS WP, RATEN will contribute to Taks n°2 and Task n°4. Under Task 2 “Identify challenging wastes to be tackled in collaborative way within the Joint Program - Mapping and shared understanding at EU level of the practical issues on waste management routes”, RATEN will provide the current status in Romania regarding the RW classification, describe the waste management routs for institutional radioactive waste and for radioactive waste generated from Cernavoda NPP (in close collaboration with Romanian WMO), and will identify the RW generated in Romania that are not complying the WAC for the foreseen near surface and geological repositories in Romania. Under Task n°4 “Identification of WAC used in EU Member States for different disposal alternatives in order to inform			

development of WAC in countries without WAC/facilities”, RATEN will lead the sub-task 4.1 “Current use of waste acceptance criteria” and will organize (together with ONDRAF/NIRAS and GSL) and host a workshop under sub-task 4.2 “Sharing experience on waste management with/without WAC available”. As part of ROUTES extension, the experience gained by analysing the answers received to ROUTES questionnaire related to WAC development and use in member states will be used in the analysis to be carried out in new proposed ROUTES Extension related to the predisposal and disposal options for SIMS.

In the frame of **UMAN WP**, RATEN will lead Task n°3 “Characterization and significance of uncertainties for different categories of actors” contributing to identification of different types of uncertainties that need to be addressed in a safety case; collection and analysis of relevant information on uncertainties associated with the site and geosphere. As part of UMAN extension, RATEN will organize the workshop organised by Subtask 3.6 and participate in the workshop organised by Subtask 4.3.

RATEN will facilitate the integration of Sub-task 3.6 activities at Task 3 level, will bring its experience in radionuclide migration in different near-field materials (cementitious materials, bentonite), as well as its experience in event organisation.

For the R&D work packages, RATEN ICN has quite well equipped laboratories used for sorption and diffusion experiments carried out during site selection and characterisation for Romanian near surface repository. Even in this programme we worked with different geologic materials (mostly clays, limestone and loess), different radionuclides and in different chemical conditions (redox or anoxic conditions were not involved in this programme), RATEN specialists have the needed background to continue the sorption studies. The experience gained by participating in EURATOM projects on waste management such as CEBAMA, CAST, FORGE, and CARBOWASTE is useful for the experimental activities proposed by RATEN under FUTURE and CORI WPs. Radiochemical laboratories of RATEN ICN allow performing experiments under anoxic and controlled redox conditions. We are doing experiments in anoxic conditions under CEBAMA project to investigate C-14 and Ra-226 sorption on fresh and degraded HCP, and we carried out leaching/corrosion experiments in controlled conditions under CAST project.

The expertise gained participating in CHANCE project, the knowledge in treatment of uncertainty associated with a near surface repository, as well as the good collaboration with Cernavoda NPP, the main waste generator in Romania and ANDR, Romanian WMO, substantiates RATEN involvement in networking work packages.

a curriculum vitae or description of the profile of the persons, including their gender, who will be primarily responsible for carrying out the proposed research and/or innovation activities

Dr. Crina Bucur (f) - senior researcher, she holds PhD in Physics, has experience in experimental measurements of radionuclide transport parameters in different materials component of natural and engineered barriers of a disposal facility, as well as in performance assessment for LIL waste disposal. She was involved in experimental work performed by ICN under FORGE and CAST projects, coordinating the experimental programs carried out by RATEN ICN. She is developing and coordinating the experimental programme designed to investigate the effect of cement based materials degradation on C-14 and Ra-226 sorption (under H2020 Project CEBAMA, as scientific responsible of the RATEN ICN contribution to the CEBAMA project). She coordinate for RATEN the CHANCE project.

Dr. Daniela Diaconu (f), senior researcher, she holds a PhD in Condensed Matter Physics, has experience in site characterisation, performance and safety assessment, and uncertainty analysis in near-surface and geological disposal in Romania. She coordinated and developed experimental and modeling studies in national and European research projects (CARBOWASTE, FORGE, CAST) and coordinated the 7th FP projects NEWLANCER and ARCADIA.

Eng. Mirela Olteanu (f), senior researcher, she holds a master degree in materials and nuclear technologies, has experience in radionuclide chemistry in different redox conditions, batch sorption/desorption experiments, source term modeling and safety and performance assessment for near surface repository.

Dr. Alina Constantin (f), young researcher, she holds a PhD in Chemistry, has experience in safety assessment of near-surface and geological disposal in Romania.

Eng. Ionut Florea (m), young researcher, he holds a master degree in materials and nuclear technologies, has experience in cement based materials degradation, and radionuclide diffusion in different natural and cementitious materials

a list of up to 5 relevant publications, and/or products, services (including widely-used datasets or software), or other achievements relevant to the call content - FEHM, GOLDSIM, RESRAD - Crina Bucur, Ionut Florea, Pascal E. Reiller, Dorin Dumitrescu, ¹⁴C Content in CANDU spent ion exchange resins and its release under alkaline conditions, accepted to be published in Radiocarbon Journal. - Crina Bucur, Ionut Florea, Relu Dobrin, Nicolae Dulama, Nicoleta Deneanu, Ra-226 sorption on intact cement pastes based on CEM I and CEM V, Cebama 3rd Annual Workshop, 17 - 18 April 2018, Nantes, France - Daniela Diaconu, Alina Constantin, Sensitivity analysis of C-14 radiological impact for a generic concept of spent fuel disposal in Romania, NUCLEAR 2018, May 23-25, 2018, Pitesti, Romania - Crina Bucur, Radionuclide behaviour in geological media, ISBN 978-606-560-292-2, Ed. University of Pitesti, p.1-204, 2012
a list of up to 5 relevant previous projects or activities, connected to the subject of this proposal - CEBAMA Project, WP2 – Radionuclide retention in high pH concrete - CAST Project, WP 6 - Relevance of results in national contexts and safety assessments - CHANCE Project, WP2 - Methodology for conditioned radioactive waste characterization: Problematic wastes and R&D proposal
a description of any significant infrastructure and/or any major items of technical equipment, relevant to the proposed work - Well-equipped radio-analytical laboratories - Refrigerated Centrifuge, model Sigma 6-16 K, max. speed: 15.000 rpm, max. gravitational field: 25.155 g - Liquid Scintillation analyser, model TriCarb3110TR with QuantaSmart Software, TR-LCS background electronics, High Sensitivity Count Mode and Ultra Low Level Count Mode (capable to measure as low as 0-20 CPM above background) - Gamma (with AntiCompton system) and alpha spectrometers - DTG/TG analyser, model Shimadzu DTG-60/60H, allowing to simultaneously performing differential thermal analysis (DTA) and measurement of thermogravimetry (TG); temperature rage: room temperature – 1000°C, measurement in air and inert gas. - Electronic microscope, model TESCAN VEGA/LMU for EDS/SEM investigations, with spectral resolution of 3.5 nm, pressure range: 1 – 270 Pa, zoom: x7 – x1.000.000 - Mercury intrusion porosimeter, model PoreMaster Quantachrome Instruments, with low pressure and high pressure
if operational capacity cannot be demonstrated at the time of submitting the proposal, describe the concrete measures that will be taken to obtain it by the time of the implementation of the task. N/A

	No	Name	Acronym
Participant	37	Radioactive Waste Management	RWM
Description of the legal entity Radioactive Waste Management (RWM) is a wholly-owned subsidiary of the Nuclear Decommissioning Authority (NDA), which is an Executive Non-Departmental Public Body of the Department for Business, Energy and Industrial Strategy (BEIS). Our vision is simple: A safer future by managing radioactive waste effectively, to protect people and the environment. All our activity is in support of realising this Vision and is a critical enabler in UK Government Policy, Implementing Geological Disposal. Our Activities support and will eventually fulfil our Mission, to: Deliver a geological disposal facility and provide radioactive waste management solutions. In order to fulfil our mission we will deliver through four key activities: Key Activity 1: Implement government policy on geological disposal of Higher Activity Waste (HAW) – we are working to develop a GDF for the long term management of higher activity radioactivity waste with a view to providing disposal capability for the UK in line with the Government’s 2014 White Paper, Implementing Geological Disposal. Key Activity 2: Work proactively with waste producers, planning for and delivering waste management solutions – we provide solutions for our parent organisation, the NDA, its Site Licence Companies and waste producers in the management of radioactive waste. We aim, to help them retrieve, condition and package wastes now, in ways that make them suitable for disposal later. Key Activity 3: Deliver a robust Technical Programme, support the GDF programme and waste management – The technical programme will provide designs and safety case capability to support the GDF programme and waste management, and will work with the site characterisation team as potential sites are identified. In preparation, RWM needs to acquire capability in business-critical areas e.g. developing GDF designs, disposal concepts, the making of Development Consent Order applications and other permits, environmental assessments, as well as safety and security cases. Key Activity 4: Develop RWM into a high performing delivery organisation – our people are central to our strategy and we need to attract and retain the very best if we are to meet our commitments. RWM needs to be credible both internationally and for the communities we intend to work with, so we plan to build our business to be a high performing delivery organisation. Radioactive waste management is a complex subject, so our vision demands that we employ leaders in this field.			
Description of main tasks in EURAD-1, with an explanation of how its profile matches the tasks RWM will participate in the EURAD Programme Management Office (PMO), two of the R&D WP’s (GAS and HITEC) and two of the Strategic Studies (UMAN and to a lesser extent ROUTES). RWM will support delivery of the EURAD PMO. In this role we will primarily provide scientific and technical coordination/integration between the RD&D, Strategic Studies and KM activities (Task 2). We will also support the proposed Bureau and General Assembly in SRA/Roadmap extension/update exercises (Task 3) and help to identify suitable subject matter/theme experts from the EURAD colleges. In particular RWM will act to co-ordinate the proposed WMO college and its interactions with the existing IGD-TP. RWM will act as a member of the project steering committee and as task co-leader in the GAS WP. RWM’s involvement will include leading subtask 4.1 conceptualization of gas migration at repository scale. RWM will provide a WMO perspective, and input from the UK programme, about the conceptualisation of gas migration at a disposal facility/repository scale and the assessment of its impact in the context of the Safety Case. Additionally, RWM will co-fund the activities of the British Geological Survey in the GAS WP, noting BGS is the other UK mandated actor and carries expertise in the WP specification.			

In HITEC RWM will co-fund work of another mandated actor, BGS, to deliver a matrix of laboratory tests. These tests will evaluate the self-sealing capability of clay based materials under thermal loads. For subtask 2.1 tests will consider the near field, where damage from excavation may exist, and subtask 2.2 will consider the far field, where clay based material is intact. For Task 3 laboratory tests at >100C will be undertaken to evaluate the behaviour and evolution of a range of bentonites in response to thermal load. RWM will share knowledge and expertise arising and prepare a synthesis report regarding the relevance of the findings to RWM. This synthesis will underpin RWM's contribution to Task 4, which consolidates the impacts of the learning from the experiments. RWM will also contribute knowledge from our programme to subtask 1.2 which establishes the state of knowledge.

In UMAN, RWM will contribute to subtask 2.1 (generic strategies for managing uncertainties) by participating in technical meetings, providing input regarding the strategies considered in our national programme, exchanging on the pros and cons of strategies and reviewing the deliverable. We will also contribute towards subtask 2.2 (uncertainty identification, classification and quantification) by participating in technical meetings, providing input regarding the approaches considered in our national programme, providing written material and reviewing the deliverable. Likewise RWM are involved in subtask 2.3 (methodological approaches to uncertainty and sensitivity analysis) and will do this via participation in technical meetings and sharing our experience. RWM will also contribute to subtask 5.1 and 5.2. This will be done via a contribution to the development of materials related to Topics 1 and 2, to be discussed in seminars. We will also contribute to the development of deliverables 5.1 and 5.2.

In the ROUTES WP, RWM will act as an observer/contributor. We have not requested any financial support for this involvement as such activities are already funded elsewhere within our national programme (i.e. within the UK Problematic Waste Integrated Project Team).

WP17-MODATS:

RWM will support activities in Task 2.1 and Task 3.3.

In Task 2.1, RWM will lead identification of the future R&D development needs for different programmes moving forward. RWM and GSL are particularly well placed to develop the data requirements aspect of this task based on ongoing work in the RWM programme focused on development of the RWM strategy, identification of monitoring parameters using an adapted version of the Modern2020 Screening Methodology, and development of a structured review of monitoring technologies.

In Task 3.3, RWM will lead contribute to the FEP analysis which will form the basis for the research activities, in particular identifying a common set of technologies and sensors to be evaluated, a set of type engineered barriers systems under consideration across Europe, undertaking FEP analyses in collaboration with safety case experts, and preparing an integration report that draws conclusions on the interactions and that can be used as a reference document moving forward. RWM is particularly suited to this activity as it has safety case experts that have detailed understanding of post-closure safety functions and the application of FEP analysis methods to understanding of the interactions between equipment and the multi-barrier system.

a curriculum vitae or description of the profile of the persons, including their gender, who will be primarily responsible for carrying out the proposed research and/or innovation activities

Robert Winsley (M) is a Materials Scientist, who obtained a PhD in Corrosion Science at the University of Birmingham, UK in 2008. He worked at SERCO (now Wood), as a corrosion specialist for 4 years, before joining NDA's Radioactive Waste Management Directorate (now RWM) in 2012. Robert is currently a Senior Research Manager within RWM, responsible for RWM's underpinning science knowledgebase in the areas of spent fuel evolution, container corrosion and criticality safety. Robert is the current Secretary General of the Implementing Geological Disposal Technology Platform (IGD-TP). He is responsible for the development and maintenance of the groups Strategic Research Agenda, Deployment Plan and website. Robert will be involved in the EURAD PMO and will act as a link between the WMO College, the IGD-TP and the EURAD programme.

Simon Norris (M) will be the RWM contact person for the GAS WP. He is an Earth Scientist with 25 years' experience in geoscience research relating to the long-term safety case for the geological disposal of radioactive waste. Simon coordinated the EC CAST and GASNET projects, and led EC FORGE project

activities on implications of gas generation and migration for the safety case. In addition to EC work, Simon represents the UK at the NEA Clay Club, and works extensively with IAEA. Simon is RWM's subject matter expert for gas generation and migration.

Matt Bailey will be the contact person for HITEC, and he will be supported by Sally Thompson.

Matt (M), positioned as RWM's Research Manager for the bentonite engineered barrier systems since September 2017, is responsible for leading RWM's research agenda in this field. He has managed and reviewed work conducted by external contractors on coupled processes in bentonite and represented the UK's programme at SKB's Engineered Barrier System Task Force. Matt is an environmental geochemist with over 10 years' experience, a fellow of the Geological Society of London and Chartered Scientist (UK) since 2013, obtaining his PhD in hydro-geochemical engineering from the University of Newcastle upon Tyne in 2016.

Sally (F) obtained a PhD in Hydrogeology from the University of London in 2001. She worked in industry and as an environment regulator, in ground and groundwater improvement projects. She joined RWM in 2014, taking the lead on bentonite and groundwater projects. She has lead RWM's involvement with national and international projects that consider the evolution of bentonite buffers when heated, where these involve experimental, in-situ tests and numerical modelling tasks.

Lucy Bailey (F) will be the RWM contact person for the UMAN WP. She is a physicist with 25 years' experience in developing safety cases for the geological disposal of radioactive waste and leads RWM's post-closure safety and environment team. Lucy is also the current Chair of the OECD NEA's Integration Group for the Safety Case (IGSC) and also co-chairs an IAEA safety case project on human intrusion (HIDRA). Lucy has worked on a number of EC projects in the nuclear safety area and has been an expert reviewer of a number of international safety cases and is an experienced presenter.

Mark Cowper (M) will be RWM's contact for the ROUTES WP. Mark is part of the Core Team of the Problematic Waste Integrated Project Team supporting the NDA strategy which was established in April 2016 to develop a UK wide solution for the improved management of Problematic Radioactive Wastes which either has no treatment solution or the current solution is sub-optimal. Mark joined the nuclear industry in 1990 and, before joining RWM in 2016, specialised in laboratory studies underpinning geological disposal, managing on-site work in support of decommissioning projects at Sellafield and on Magnox Ltd sites and managing experimental programmes involving spent fuel and nuclear materials. From 1999-2002, whilst working for AEA Technology, Mark was the Programme Coordinator for the European Commission 5th Framework "Rates and Mechanisms of Radioactive Release and Retention inside a Waste Disposal Canister "In can processes" programme.

a list of up to 5 relevant publications, and/or products, services (including widely-used datasets or software), or other achievements relevant to the call content

- Radioactive Waste Management, Geological Disposal - Overview of the generic Disposal System Safety Case, NDA Report no. DSSC/101/01, December 2016.
- Radioactive Waste Management, Geological Disposal - Science and Technology Plan, NDA Report no. NDA/RWM/121, May 2016.
- Radioactive Waste Management, Geological Disposal - Methods for Management and Quantification of Uncertainty, NDA Report no. NDA/RWM/153, January 2017.
- J.F. Harrington, C.C. Graham, R.J. Cuss and S. Norris, Gas network development in a precompacted bentonite experiment: Evidence of generation and evolution. Applied Clay Science 147 (2017) 80–89. <http://dx.doi.org/10.1016/j.clay.2017.07.005>. 2017.
- S. Baxter, D. Holton, S. Williams and S. Thompson, Predictions of the wetting of bentonite emplaced in a crystalline rock based on generic site characterization data, Geological Society, London, Special Publications, 482, 7 September 2018, <https://doi.org/10.1144/SP482.8>

a list of up to 5 relevant previous projects or activities, connected to the subject of this proposal

- As the UK WMO, RWM has produced a number of generic geological disposal facility safety cases for UK's inventory of higher activity radioactive wastes, including the recent 2016 Generic Disposal System Safety Case (gDSSC).

- RWM and/or its employees have participated in many NEA and EC projects related to radioactive waste management and disposal. In particular, connected to the topics in this proposal,
 - Simon Norris recently co-ordinated the EC CAST project and also participated in the completed EC FORGE and MODERN projects, as well as the ongoing MODERN 2020 project.
 - Lucy Bailey currently chairs the NEA OECD Integration Group for the Safety Case (IGSC)
 - Robert Winsley current acts as Secretary General for the Implementing Geological Disposal Technology Platform (IGD-TP).
 - RWM were central to the recently completed EC JOPRAD project that established the groundwork for Joint Programming in the Radioactive Waste community.
 - RWM currently participate in the ongoing CEBAMA, BEACON, THERAMIN, DISCO, and CHANCE projects.

a description of any significant infrastructure and/or any major items of technical equipment, relevant to the proposed work N/A

if operational capacity cannot be demonstrated at the time of submitting the proposal, describe the concrete measures that will be taken to obtain it by the time of the implementation of the task. N/A

	No	Name	Acronym
Participant	38	Belgian Nuclear Research Center	SCK•CEN
Description of the legal entity SCK•CEN (www.sckcen.be) is a foundation of public utility and is one of the largest research institutions in Belgium, with activities dedicated to the development of peaceful applications of radioactivity. Our developments have already resulted in a long list of innovative and forward-looking applications for the medical world, industry and the energy sector. In the course of our work, there are three main research topics: • <u>The safety of nuclear installations</u> • <u>The well-considered management of radioactive waste</u> • <u>Human and environmental protection against ionising radiation</u> We offer various services and operate BR2, a Material Test Reactor (MTR) with a very high neutron flux, BR1, a graphite-gas research reactor, GUINEVERE a zero-power-critical-facility, several gamma irradiation facilities, a laboratory for High and Medium Activity and Nuclear analysis, as well as different chemical laboratories. Through the EIG EURIDICE, an economic interest grouping between SCK•CEN and ONDRAF/NIRAS, we run our Underground Research Laboratory HADES. Also noteworthy are our European demonstration programs for PWR dismantling and MYRRHA (Multi-purpose hYbrid Research Reactor for High-tech Applications), an Accelerator Driven System (ADS) under development in Mol. SCK•CEN began R&D on geological disposal in clay in 1974 and since then has been an active participant in all EC FP's and the R&D programs of ONDRAF-NIRAS, performing R&D on many aspects of near-field and far-field processes including laboratory experiments in its hot and cold dedicated facilities, state-of-the-art multi-scale and coupled modelling, in-situ tests in the HADES URL and performance and safety assessment for both surface and geological disposal concepts. SCK•CEN actively contributes to the Belgian programme for radioactive waste disposal as a main contractor for the Belgian waste management organisation, ONDRAF-NIRAS, in two projects: 1) the surface disposal facility for short-lived low and intermediate level waste in Dessel, and 2) research on a potential geological disposal facility in poorly indurated clay formations. SCK•CEN received the mandate as research entity (RE)-type programme manager by our programme owner. Also noteworthy is the SCK•CEN Academy for Nuclear Science and Technology (academy.sckcen.be), which has a specific task to foster the transfer of nuclear knowledge, skills and attitudes towards students and professionals who are active in the nuclear field. Following topics are part of the SCK•CEN Academy's mission: 1) guidance for young researchers; 2) organisation of academic courses and customised training for professionals; 3) policy support regarding education and training in nuclear domains; 4) caring for critical-intellectual capacities.			
Description of main tasks in EURAD-1, with an explanation of how its profile matches the tasks SCK•CEN contributes to different tasks in EURAD-1: • RD&D work packages: as the largest Belgian nuclear research organization and a major international player in the field of radioactive waste management RD&D, we contribute to different RD&D work packages to a varying degree, reflecting both our own interest and the interest of the Belgian waste management programme in the different studies that will be undertaken. We also coordinate one RD&D WP (Assessment of the Chemical Evolution of a Disposal cell – ACED), for which we have particular interest, because it combines both an experimental programme and coupled process modelling, two items where we score strongly. • Strategic Studies work packages: within the Strategic Studies work packages we follow up the international progress related to several hot topics, including uncertainty management and dealing with legacy waste. In the first topic there is also a more specific interest in looking at the societal aspects related to uncertainty treatment, while in the second topic there is also an interest because we dispose of several difficult-to-manage waste forms on site given our large nuclear heritage.			

- Within the Knowledge Management work packages we coordinate the work package on Training&Mobility, where we use the return of experience from the SCK•CEN Academy.

WP15-ConCorD :

SCK CEN will be responsible for subTask 1.3 development of training materials. Furthermore, SCK CEN will focus on the question at which bentonite dry density H₂ consumption originating from the anoxic corrosion from carbon steel by the indigenous community of the bentonite is inhibited. Moreover, SCK CEN will investigate the impact of the produced sulphides on the corrosion of carbon steel. Fully saturated bentonite plugs of varying dry densities with an in-house developed oedometer based experimental setup will be investigated with & without carbon steel plates (P355QL2 carbon steel), with & without additional hydrogen and with & without microorganisms in anoxic conditions. The fully saturated bentonite will be percolated with natural Boom Clay water (with or without hydrogen). A chemical and microbial analysis of the percolate is monitored in time. At appropriate time points, the experiments will be dismantled. Then, the microbial community within the bentonite is investigated in detail by a combination of cultivation independent and cultivation dependent techniques. Moreover, corrosion of the carbon steel plates embedded in the bentonite is investigated (weight loss, SEM/EDX) and the mineralogy of the bentonite is studied (SEM/EDX).

The microbiology group has the know-how and techniques for studying microbial communities from different (extreme) environments. We were involved in the MIND project and we have been involved for many years in the in situ BN experiment in Mont-Terri. In addition, we are involved in monitoring microbial activity in the HADES URL at EURIDICE. The corrosion group has a vast experience in studying corrosion processes via a wide range of techniques (weight loss measurements, electrochemical techniques). We are specialized in studying corrosion under complete anoxic conditions. We have been involved in many EU R&D projects in the past (EC FP3, EC FP4 and EC FP5) as well as EU Thematic Networks (e.g. COBECOMA).

WP16-MAGIC :

SCK-CEN have significant experience in accelerated degradation tests (carbonation, leaching and coupled degradation), and concrete-clay interaction. SCK-CEN is experienced with microstructural and mineralogical characterization, for example, SEM/EDX, TGA, MIP, N₂-adsorption, XRD, FTIR, 3D-reconstruction, and transport properties. SCK-CEN have long experience on in situ tests in the URL HADES or on surface mock-up and associated modelling skills to investigate the THM-C behaviour of different geo-materials. The microbiology group has the knowhow and techniques to study microbial communities in different environments. SCK-CEN studied microbial activity in cementitious environments in the MIND project and *in situ* BN experiment in Mont-Terri and in monitoring microbial activity in the HADES URL.

SCK-CEN is the developer of a generic lattice-Boltzmann based pore scale model to capture reactive transport in an evolving multilevel porous medium, including numerical techniques for acceleration of processes. SCK-CEN have experience in numerical homogenization of mechanical properties of cement microstructure to determine elastic properties, coefficient of thermal expansion and drying shrinkage strains in both CAST3M and COMSOL, which is extendable to a degrading material. SCK-CEN have experience in microscale simulations of combined leaching and carbonation of hardened cement paste using COMSOL-PFLOTRAN under diffusion and advection-diffusion conditions.

SCK-CEN is currently involved in Task 2 and Task 3. In **Task 2**, a comprehensive experimental program including percolation, batch and in-situ experiments (at HADES underground research facility) is proposed in order to study the combined chemical and microbial degradation on the mechanical properties of OPC based materials. Various boundary conditions (CO₂ partial pressure, hydraulic pressure, microbial biofilm) relevant for geological disposal context will be investigated. Multiple techniques will be used to quantify the alteration in mineralogy (TGA, XRD, FTIR) and mechanical properties (E-modulus, compressive strength, tensile strength, triaxial compression tests in collaboration with LaMcube, CNRS) of degraded cement pastes due to combined chemo-bio-mechanical degradation at multiscale. SCK-CEN will also monitor the microbial communities in percolated solution, biofilm formation and analysis on cementitious material and identification of mineral phases precipitated by microbes – via flow cytometry, ATP, IC. STEM/HAADF, SEM/EDX, fluorescence microscopy, Field Emission Electron Microscope associated with Raman Spectroscopy

(EEM/RS), and sequencing technologies. Furthermore, the microbiology group of SCK CEN will be involved in **Task 2** in a research activity on the chemo-mechanical behaviour of cementitious materials on the meso/macro scale, performed in close collaboration with COVRA and FZJ.

In Task 3, SCK-CEN intend to develop a chemo-mechanical model of leaching and carbonation processes at the microscale. This will be achieved by extending an existing state of the art lattice-Boltzmann based pore scale reactive transport model to simulate chemical evolution based on a given boundary condition and material microstructure and composition, including the effects of microbial activity (reflected in the boundary conditions). Chemically degraded microstructure at a given point in time is imported into a voxel based microscale FEM mechanical model for numerical homogenization to yield degraded elastic properties, which will then be further homogenized to concrete scale that can be compared with the experimental data obtained in **Task 2**.

WP10-UMAN extension :

SCKCEN has a long experience in research of geological disposal near-field processes and uncertainties and due to its large involvement in ACED will ensure the consistency between the work packages.

SCKCEN would participate in the workshops organised by Subtasks 3.6 and 4.3 the seminar in Task 5 and contribute, as member of the subtask 3.6 expert group, to:

- the collection and synthesis of relevant information on uncertainties associated with the near field with special attention to the knowledge gained in the ACED project
- the writing of the deliverable of Subtask 3.6.

a curriculum vitae or description of the profile of the persons, including their gender, who will be primarily responsible for carrying out the proposed research and/or innovation activities

- **Christophe Bruggeman** (1976) (M) (PhD in Bio-Engineering Science) is the head of the Expert Group Waste&Disposal and Deputy Director of the Environment, Health and Safety Institute at SCK•CEN. As such, he is responsible for the coordination of the RD&D related to radioactive waste disposal on an administrative, financial and scientific level. His scientific career started at the Katholieke Universiteit Leuven where he studied the geochemical behaviour of selenium and technetium oxyanions under Boom Clay environment. In January 2007, he joined SCK•CEN as a scientific collaborator focussed on the drawing of phenomenological models for RN migration behaviour under Boom Clay conditions. He has experience as an experimentalist, geochemical modeller (Phreeqc, CHESS, GWB), and with XAS spectroscopy. Later on he became project leader and in January 2015 he became head of the Expert Group.
- **Elie Valcke** (1966) (M) (PhD in Bio-Engineering Science) joined the SCK•CEN in 1995 as a postdoc in the Radioecology Laboratory. In September 1996 he switched to the Waste and Disposal Expert Group, where he started working on degradation and compatibility studies of various waste forms (bituminised, cemented, and vitrified waste), partly performed within EC co-funded projects, where he co-ordinated the EC 4FP CORALUS project and 5FP CORALUS-II project on the CORrosion of Alpha-doped HLW gLass in Underground Storage conditions. Through the years he became task leader and later project leader for mainly the characterization and compatibility studies on Eurobitum bituminised long-lived intermediate-level waste, funded by ONDRAF/NIRAS, covering both geomechanical and geochemical aspects, and including experimental and modelling work. Since September 2013 he is the head of the Research Unit "R&D Waste Packages", that performs experimental and modelling studies on the long-term behaviour of vitrified waste, spent fuel, different intermediate-level waste forms, and on the corrosion of metallic barriers and container materials.
- **Norbert Maes** (1969) (M) (PhD in Chemistry) joined the SCK•CEN in 1996 as a postdoc in the Waste and Disposal Expert Group, where he developed a new fast technique to determine radionuclide migration parameters in Boom Clay by the use of electromigration. After his post-doc, he became task leader for several contracts with NIRAS/ONDRAF and co-ordinated the EC 5FP TRANCOM-II project (Migration Case Study: Transport of radionuclides in a reducing Clay sediment). In 2005 he became head of the research unit "R&D Disposal" which covers the characterisation of host rocks (including perturbations) and barrier materials (clays, concrete,...), geochemistry and radionuclide migration. His research lines are i) transport of gas and radionuclides through low permeable materials (Boom Clay, Ypresian Clay, bentonite, concrete,...) ii) phenomenological understanding of the impact of humic substances on radionuclide transport: complexation, sorption, colloid transport iii) degradation processes of cement based

materials and their impact on microstructure and transport processes. Participated in numerous EU projects (EURATOM): as researcher in TRANCOM-Clay (4FP), researcher in ResealII (FP5), co-ordinator of the project TRANCOM-II (FP5), WP-leader in FUNMIG (FP6), researcher in NF-PRO (FP6), WP leader in CATCLAY (FP7), researcher in FORGE (FP7), Researcher and Chairman General Assembly CEBAMA-Cement Based Materials (H2020).

- **Diederik Jacques** (1971) (Phd in Bioscience Engineering) joined SCK•CEN in 2000 as a postdoctoral-student on the development of a coupled reactive transport code (HYDRUS-PHREEQC). After his post-doc, he worked in the Performance Assessment unit as a numerical modeller combining his previous expertise on flow and transport phenomena in porous media with newly developed skills on geochemistry. Throughout a number of national and international EU projects, he worked on applications in degradation of cementitious materials used in engineered barriers, flow and transport in the near field of surface and geological disposal systems, geochemical evolution of these systems and flow and transport including colloids in soil systems. He is involved in model development both at pore- and continuum-scale. Furthermore, he has built expertise in safety and performance methodologies for surface and deep radioactive waste disposal systems or NORM sites. In 2001, he became the group leader of the unit now called Engineered and Geosystem Analysis of the Waste&Disposal expert group. Management skills are developed as group and project leader (e.g., cAt project for surface disposal of low level and intermediate level short-lived radioactive waste in Belgium). He author and co-authored more than 100+ publications listed in SCOPUS.
- **Nele Bleyen** (1981) (F) (PhD in Bioscience Engineering) joined the SCK•CEN in 2009 as a scientific collaborator, and is mainly involved in studying the compatibility of bituminised radioactive waste (Eurobitum) with geological disposal. These studies are performed to investigate the potential geomechanical (due to water uptake and related swelling of the waste and due to gas production) and geochemical (due to leaching of salt and organics) perturbations of the host rock due to disposal of Eurobitum in the Boom Clay and include both experimental (in lab and in situ) and modelling work. Furthermore, characterisation of the bituminised waste form and degradation studies are performed. In 2014, she became the project leader for these studies, which are funded by ONDRAF/NIRAS.
- **Elke Jacobs** (1982) (F) (PhD in Sciences: geology) joined SCK-CEN in 2005 as a staff collaborator. In 2008, she started the project “measuring gas diffusion in clay-based materials”. This project lead to the development of a new and innovative technique which has been applied by now on a broad range of materials (Boom Clay, Callovo-Oxfordian Clay, Opalinus Clay, bentonite, shale and concrete), leading to a large set of reliable diffusion coefficients of dissolved gases. From 2009 on, she was task leader of all gas-related experiments, performed at SCK-CEN. In the period 2009-2013, she was strongly involved in 3WP’s of EC FORGE (FP7). In 2013, she started her own PhD project (at KU Leuven and RWTH Aachen), which was successfully finished in 2018.
- **Eric Laloy** (1978) (M) (PhD in Bio-Engineering) joined the SCK•CEN in 2011 as a scientific collaborator in the Engineered and Geosystems Analysis unit of of the Expert Group Waste & Disposal. He is doing research on sensitivity analysis, uncertainty quantification and calibration of numerical simulators such as reactive radionuclide transport models. He is also an expert in machine learning, which he uses to construct computationally cheap statistical emulators of CPU-demanding reactive transport models. The derived CPU-efficient emulators can then be used to perform otherwise computationally intractable tasks such as global sensitivity analysis and uncertainty assessment of the original CPU-demanding models.
- **An Bielen** (1987) (F) (PhD in Biological Science) joined the SCK•CEN in 2015 as a scientific collaborator in the department Management of Waste and Liabilities and is working on a method to determine uncertainties which are related to radiological characterization of the nuclear waste of SCK•CEN, taking into account the uncertainties of the measurements itself, as well as the correlation factors included in the isotope vectors. These uncertainties might have an important effect in determining the level of activity in waste packages, and in the acceptance of waste for disposal. Furthermore, she studies and digitizes all available data concerning characterization which can lead to new characterization methodologies.
- **Marc Verwerft** (1965) (M) (PhD Physics) joined SCK•CEN in 1994, became head of the microstructure group in 1996 and is since 2002 head of the Fuel Materials group. He has coordinated the EC 5th Framework Project “OMICO” (2000-2006, 2 M€) on advanced nuclear oxide fuels, the 6th Framework Project “LWR-DEPUTY” (2006-2011, 2.5 M€) on advanced nuclear fuels (CERMET), and thoria-based fuels, and also initiated and led several industry funded projects on the nuclear fuel cycle (front-end, in-reactor performance and back-end) with partners from Europe, Asia and USA. He started his scientific career as fellow of the National Fund for Scientific Research (FWO) in materials science at the University

of Antwerp and as post-doctoral researcher at the University of Groningen. Author and co-author of 60+ publications in international journals with referee system (“A1” publications).

- **Kevin Govers** (1982) (M) (PhD in applied sciences) joined the SCK•CEN in 2008 as researcher in the fuel material group. He has participated to several European projects (Actinet, F-Bridge, Inspyre, ...) modelling fuel performance in a multi-physics / multi-scale framework, and is today responsible of research projects oriented towards spent fuel isotopic inventory and source term, such as the Joint International Program REGAL. Next to his position at SCK•CEN, he is also scientific collaborator at the Université Libre de Bruxelles (ULB) in the department of nuclear metrology of the Faculty of Applied Sciences. In 2016-2017 he was the chairman of the Belgian Nuclear Society (BNS) Young Generation, and acts today as Secretary of the BNS.
- **Yves Parthoens** (1972) (M) (MSc in engineering technology) joined SCK•CEN in 2001 as Technical Staff member in the section Fysico-Chemistry and works now in the group Microstructure & Non-destructive Analysis of the Nuclear Material Science institute. He is currently working on different research projects on irradiated fuel as primary engineer in the Laboratory for High and Medium Activity. He is responsible for the exploitation of the instrumentation for non-destructive analyses in the laboratory, such as gamma spectrometry on spent fuel. He performs within SCK•CEN quality assurance and internal audits. Was the lead engineer for the build and validation of the BONAPARTE (installed at SCK•CEN) and BONA4INL instrumentation (installed at INL USA) for detailed fuel plate swelling measurements on irradiated low enriched MTR-fuel.

a list of up to 5 relevant publications, and/or products, services (including widely-used datasets or software), or other achievements relevant to the call content

- Jacops, E., M. Aertsens, N. Maes, C. Bruggeman, R. Swennen, B. Krooss, A. Amann-Hildenbrand and R. Littke (2017). The Dependency of Diffusion Coefficients and Geometric Factor on the Size of the Diffusing Molecule: Observations for Different Clay-Based Materials. *Geofluids* 2017: 16.
- Liu, S. and D. Jacques (2017). Coupled reactive transport model study of pore size effects on solubility during cement-bicarbonate water interaction. *Chemical Geology*, 466:588-599
- Maes, N., Bruggeman, C., Govaerts, J., Martens, E., Salah, S. & Van Gompel, M. (2011) A consistent phenomenological model for natural organic matter linked migration of Tc(IV), Cm(III), Np(IV), Pu(III/IV) and Pa(V) in Boom Clay. *Physics and Chemistry of the Earth*. 36, 17-18, p. 1590-1599
- Phung Q.T., Maes N., Jacques D., De Schutter G., Ye G. (2016) Investigation of the changes in microstructure and transport properties of leached cement pastes accounting for mix composition. *Cement and concrete research*. 79, 217-234.
- Patel, R.A., J. Perko, D. Jacques, G. De Schutter, G. Ye and K. Van Breugel (2018). A three-dimensional lattice Boltzmann method based reactive transport model to simulate changes in cement paste microstructure due to calcium leaching. *Construction and Building Materials*, 166: 158-170
- G. Leinders, R. Bes, J. Pakarinen, K. Kvashnina, and M. Verwerft (2017) Evolution of the Uranium Chemical State in Mixed-Valence Oxides. *Inorganic Chemistry*, 56(12): p. 6784-6787
- The SCK•CEN Academy for Nuclear Science and Technology (<http://academy.sckcen.be>) has, among others, large experience in organising customised training and academic courses for professionals and the larger civil society. The SCK•CEN Academy services will be of great value for the WP4 on Dissemination and Communication.

a list of up to 5 relevant previous projects or activities, connected to the subject of this proposal

- SCK•CEN has an extensive framework agreement with NIRAS/ONDRAF, covering a wide suite of RD&D domains related to waste management and disposal:
 - Evolution and degradation of waste forms in disposal conditions (HLW glass, spent fuel, bituminised ILW, cemented cellulose-based waste, metallic container materials and wastes)

- Evolution and degradation of engineered barriers (metals, cementitious) in disposal conditions
- Geological and hydrogeological site characterisation; long-term evolution of a potential disposal site
- Radionuclide/solutes/contaminants/gas transport throughout the engineered and natural barriers of a disposal system
- Influence of microbial processes on the disposal system
- Societal impact and acceptance of a geological repository
- Monitoring and safeguarding a geological repository
- SCK•CEN also performs extensive safety assessment and safety calculations in support of the surface repository site for short-lived LILW for NIRAS/ONDRAF
- SCK•CEN is active as either WP leader or contributor in the following active EC projects
 - MIND (www.mind15.eu)
 - CHANCE (www.chance-h2020.eu)
 - DISCO (www.disco-h2020.eu)
 - THERAMIN (www.theramin-h2020.eu)
 - CEBAMA (<https://www.cebama.eu>)
- SCK•CEN is an active partner of the Mont Terri consortium and is involved in the following in situ experiments or projects at the Mont Terri Rock Laboratory (www.mont-terri.ch)
 - Bitumen-Nitrate-Clay Interaction
 - Cement-Clay Interaction
 - Geochemical Data

a description of any significant infrastructure and/or any major items of technical equipment, relevant to the proposed work;

- SCK•CEN has a wide array of radioactive and non-radioactive laboratories for waste degradation studies, which include glove boxes for working under relevant oxygen-free conditions, with radioactive (alpha-bearing) material, oedometer set-ups to investigate the volume deformation behaviour of waste forms, slow strain rate testing autoclaves for metal corrosion studies, and a variety of analytical and material preparation techniques which can be used to obtain and study standardised reference materials. SCK•CEN has also several gamma-irradiation facilities.
- SCK•CEN also has dedicated laboratories for studying the geochemical behaviour of compacted clay systems, and its impact on the speciation, solubility, transport and mobility of radionuclides. The infrastructure includes glove boxes for working under relevant oxygen-free conditions, specific radionuclide transport cells for a wide range of different setups, analytical techniques for studying colloidal properties of organic materials and for elucidating the pore water chemistry in compacted systems. SCK•CEN also disposes of dedicated cement laboratories for studying the long-term behaviour of these engineered barriers.
- SCK•CEN has a strong tradition and a large pool of people experienced with compiled and/or interpreted programming languages. We have both developed our own coupled models or used commercially available software. As a non-exhaustive list are mentioned here: HP1 (in-house developed coupled model between Hydrus and Phreeqc), Yantra (in-house developed pore scale model based on lattice Boltzmann formalism), COMSOL-Phreeqc, Geochemist's WorkBench, ALEPH2 (in-house developed Monte Carlo burn-up code).
- Together with NIRAS/ONDRAF, we run the underground research lab HADES through the EIG EURIDICE

if operational capacity cannot be demonstrated at the time of submitting the proposal, describe the concrete measures that will be taken to obtain it by the time of the implementation of the task.

N/A

	No	Name	Acronym
Participant	39	Swedish Nuclear Fuel and Waste Management Company	SKB
Description of the legal entity Svensk Kärnbränslehantering AB (Swedish Nuclear Fuel and Waste Management Company), SKB, is responsible for safe management of all nuclear waste arising in Sweden. Over the past few decades SKB has built and operated an underground final repository (SFR) for final repository for short-lived radioactive waste generated by nuclear power plants, hospitals etc., a central interim storage facility for spent fuel (CLAB) and a specially-built vessel for transportation of the wastes and the spent fuel. SKB has also planned, constructed and is operating an underground research facility – the Äspö Hard Rock Laboratory, a chemical laboratory, a bentonite laboratory and an canister laboratory. These facilities are used to execute essential research, development and demonstration before construction of the spent fuel repository and the encapsulation plant. A license application for the final repository for spent nuclear fuel was submitted in 2011 and an application to extend the SFR facility was submitted in 2014. Reviewing is ongoing. The plan is to start construction of the SF repository around 2022 and the extension of SFR some years later.			
Description of main tasks in EURAD-1, with an explanation of how its profile matches the tasks SKB will participate in the RD&D WP7-HITEC and WP8-SFC, as well as the Strategic Studies WP10 (ROUTES). <u>WP HITEC</u> Coordination of the Subtask 3.1– Characterisation of material treated by high temperature. Analyse the chemistry and mineralogy of blocks of the MX80, DepCAN (Milos), Asha505 (Kutch) and Calcigel bentonites from the ABM5 experiment. Provide ABM5 information and samples to other collaborating partners within HITEC. <u>WP SFC</u> SKB will be the leader of WP8 SFC, coordinating the scientific and technical content of the WP. SKB will coordinate task 1 (S/T coordination, State-of-the-art and training material) and will contribute to the subtask 2.2 (Develop, improve and demonstrate NDA methods/systems from SNF characterisation) UU, In-Kind Contribution against payment of SKB according to Article 11 of the AMGA is contributing to the coordination of the WP, to task 1 and to the implementation of subtasks 2.2 and 2.4. The in-kind contribution will not be used on SKB's premises. <u>WP ROUTES</u> SKB will participate in subtask 2.1 (provide national contribution at exchange meetings) and in subtask 2.2 (Establish and share synthesis on practical issues on waste management routes for challenging wastes), and in task 3.2 (Characterization and segregation of legacy waste) WP17-MODATS : SKB will participate in tasks 2.1 to task 2.3			
a curriculum vitae or description of the profile of the persons, including their gender, who will be primarily responsible for carrying out the proposed research and/or innovation activities Petra Christensen (Female) Master of Political Science with a major in EU integration, holds the position of Legal Entity Appointed Representative (LEAR) at SKB. She is also the project Coordinator of the MIND Project, Administrative Coordinator of the DISCO Project and responsible for the SKB financial reporting of the Modern2020 Project. Petra Christensen is proposed to be the administrative coordinator and Primary Coordinator Contact for the SFC WP			

Dr. Anders Sjöland (male) is Sr. Co-ordinator of fuel issues at SKB and Executive Secretary of SKB:s Research and Development Council. He has previously been Director of SKB:s Äspö Hard Rock Laboratory. He has a Ph.D. in Nuclear Physics from Lund University, Sweden, and Master on Engineering Physics from the same university. He has been with SKB since 2004. Before he held research and research director positions in the European Commission's JRC and the Swedish-Danish cooperation Committee for Research and Development of the Öresund Region (Öforsk).

Doctor of Philosophy in Nuclear Physics, Lund Institute of Technology, Sweden (1996)

'Licentiate' degree in Nuclear Physics, Lund Institute of Technology, Sweden (1994)

Master of Science in Engineering Physics, Lund Institute of Technology, Sweden (1992)

Theoretical Philosophy, Lund University, Sweden (20 p - one term's studies) (1990)

Positions and work experience:

- Co-coordinator nuclear fuel issues, SKB (2014-)
- Executive Secretary, Research and Development Council, Swedish Nuclear Fuel and Waste Management Company Co (SKB AB), (2007-)
- Director Äspö Hard Rock Laboratory, Swedish Nuclear Fuel and Waste Management Company Co (SKB AB) (2004-2006)
- Director of Research, from 2003, before Research leader, Committee for Research and Development of the Öresund Region (Öforsk) (2000 -) (Lund University, Malmö University)
- Temporary agent (Grade A), European Commission, Joint Research Centre (JRC), Institute for Reference Materials and Measurements (IRMM), Geel, Belgium (1997-2000)
- Auxiliary agent (Grade A), European Commission, Joint Research Centre (JRC), Institute for Reference Materials and Measurements (IRMM), Geel, Belgium (1997)
- Ph.D. position - Department of Nuclear Physics, Lund Institute of Technology, Sweden (1992-1997)
- Employed in a project (Neutron measurement project), Department of Nuclear Physics, Lund
- Barsebäck Nuclear Power Plant (summer 1988)
- Barsebäck Nuclear Power Plant (summer 1987)

Dr. Daniel Svensson (male) graduated as chemist in 2004 from Lund University, Sweden. After his diploma, he was employed at SKB as an industrial Ph.D. student in Materials Chemistry at the Faculty of Engineering at Lund University. From 2006 he has been working with analysis and project management of bentonite field experiments running at high temperatures (90-130 C) with copper or iron heater materials, responsible for various projects (ABM; alternative buffer materials; Prototype repository analysis) running at the Äspö Hard Rock Laboratory, Sweden. Finished his Ph.D. in 2015 with the thesis "The Bentonite Barrier - Swelling properties, redox chemistry and mineral evolution", and has since then continued his work with bentonite clays at SKB with focus on material characterisation, quality control, specialising in X-ray diffraction (XRD) analysis. Also involved in studies with sulphides in bentonite, microbial activity in bentonite, chemical erosion, and bentonite - gas phase interaction. Responsible for SKBs research laboratory for bentonite clays at Äspö, Sweden.

Patrik Sellin (male) is a civil engineer and has worked at SKB since 1988. He is manager of the R&D programme for buffer and backfill long-term performance. He has been scientific coordinator and WP leader of the 7th framework project BELBaR and WP leader of e.g. PEBS and Forge. Patrik Sellin is the scientific and technical coordinator of Beacon.

Claes Johansson (male) is a Senior Specialist in Waste Management and Decommissioning at SKB He had a position as General Manager at SVAFO 2010-2013 and worked as a project leader of low – and intermediate level waste at SKB 1999 -2010.

a list of up to 5 relevant publications, and/or products, services (including widely-used datasets or software), or other achievements relevant to the call content

Simulation of Spent Fuel Assemblies in Differential Die Away Instrument

Aaron G. Tumalak¹, Holly R. Trelue¹, Garrett E. McMath¹, Vladimir Henzl¹, John S. Hendricks¹, Jianwei Hu², and Anders Sjöland³

¹Los Alamos National Laboratory

²Oak Ridge National Laboratory

³Svensk Kärnbränslehantering Aktiebolag (SKB)

April 11, 2018, INMM proceedings (2018)

NDA Measurement Analysis of Spent Nuclear Fuel Assemblies at the Swedish Clab Facility Using the INDEPTH Code

B. R. Grogana,^{*}, A. Favalli^b, P. Jansson^c, H. Liljenfeldt^a, V. Mozin^d, P. Schwalbach^e, A. Sjöland^f, S. J. Tobin^b, H. Trellue^b, S. Vaccaro^e, D. Vo^b

^a Oak Ridge National Laboratory, Oak Ridge, TN (USA)

^b Los Alamos National Laboratory, Los Alamos, NM (USA)

^c Uppsala University, Uppsala (Sweden)

^d Lawrence Livermore National Laboratory, Livermore, CA (USA)

^e European Commission, DG Energy, Directorate Safeguards, Luxemburg (Luxemburg)

^f Swedish Nuclear Fuel and Waste Management Company, Stockholm (Sweden),

INMM proceedings (2016)

Jansson P., et al.; "**Gamma-Ray Spectroscopy Measurements of Decay Heat in Spent Nuclear Fuel**"; Journal: Nuclear Science and Engineering; Vol: 141; No: 2; DOI: <http://dx.doi.org/10.13182/NSE02-A2272>; (2002)

Jansson P., Tobin S., Liljenfeldt H., Fugate M., Favalli A., Sjöland A.; "**Axial and azimuthal gamma scanning of nuclear fuel - implications for spent fuel characterization**"; Journal: Journal of Nuclear Materials Management; Vol: 45; No: 1; (2016)

P. Helgesson and H. Sjöstrand, "**Fitting a defect non-linear model with or without prior, distinguishing nuclear reaction products as an example**", (editors-pick), Review of Scientific Instruments 88, 115114; DOI: <https://doi.org/10.1063/1.4993697> (2017)

Dueck, A, Goudarzi, R, Börjesson, L, 2014, **Buffer homogenisation, status report 2**. SKB Technical Report TR-14-25, Svensk Kärnbränslehantering AB

Börjesson, L, Åkesson, M, Kristensson, O, Malmberg, D, Birgersson, M, Hernelind, J, 2015, **Modelling of critical H-M processes in the engineered barriers of SFR**. SKB Technical Report TR-14-27, Svensk Kärnbränslehantering AB

Sellin P, Leupin O (2014), **The use of clay as an engineered barrier in radioactive-waste management – a review**. Clays and Clay Minerals 61 (6), 477-498

SKB 2011, **Long-term safety for the final repository for spent nuclear fuel at Forsmark. Main report of the SR-Site project**. SKB Technical Report TR-11-01, Svensk Kärnbränslehantering AB

Åkesson, M, Kristensson, O, Börjesson, L, Dueck, A, Hernelind, J, 2010, updated 2015-08, **THM modelling of buffer, backfill and other system components. Critical processes and scenarios**. SKB Technical Report TR-10-11, Svensk Kärnbränslehantering AB

a list of up to 5 relevant previous projects or activities, connected to the subject of this proposal

- Fuel characterisation I (2016-18) SKB
- Fuel characterisation II (2018-) SKB
- Action sheet 50 (2015-) (US DoE, Euratom and others)

Relevant to the knowledge field of bentonite mechanical evolution SKB has more than 30 years of research experience, starting with the buffer mass test (BMT) in the Stripa mine, and has participation in a number of projects. Some have had financing from the EU like FORGE (<https://www.bgs.ac.uk/forged/home.html>), PEBS (www.pebs-eu.de), and BELBaR (www.belbar.eu), where the proposed scientific coordinator of Beacon, Patrik Sellin, has participated in different roles. Some SKB projects to mention could be KBP1001 Operation and retrieval of the prototype repository, KBP1003 System design of backfill.

a description of any significant infrastructure and/or any major items of technical equipment, relevant to the proposed work;

Clab: Clab is the central interim storage facility for all Swedish spent fuel, situated outside Oskarshamn, Sweden. It represents a broad and complete collection of at present more than 8000 tU of spent fuel. SKB in itself and in various broad collaborations has used Clab to perform systematic characterisation on spent fuel, which represent the world reference in several respects.

Fuel database: SKB:s database on the properties and history of its spent fuel represents an important information cache for understanding of the spent fuel in conjunction with characterisation.

Via Uppsala University, the work proposed can utilize large-scale storage and know-how of high-performance computing (HPC) that is part of the Swedish National Infrastructure for Computing (SNIC: <http://www.snic.se>). There are six universities that host HPC resources for SNIC: Lund University, Chalmers University of Technology, Linköping University, KTH Royal Institute of Technology, Uppsala University and Umeå University. With computer clusters located in these centres, several thousand computer cores and very large memory may be allocated for calculations in the proposed work.

The Äspö Hard Rock Laboratory.

The Äspö Hard Rock Laboratory (HRL), constitutes an important part of the Swedish Nuclear Fuel and Waste Management (SKB) work with design and construction of a deep geological repository for final disposal of spent nuclear fuel. It is a facility for research, development and demonstration in a realistic and undisturbed rock environment down to repository depth. Most of the research has concerned processes of importance for the long-term safety of a future final repository and the capability to model the processes taking place at repository depth. Demonstration addresses the performance of the engineered barriers and practical means of constructing a repository and emplacing the canisters containing spent fuel. Äspö HRL includes a research village with office space for 100 persons, a chemistry laboratory, the bentonite laboratory, a material science laboratory and an underground research laboratory to a depth of 460m. Hundreds of laboratory and full-scale experiments and studies on buffer and backfill materials have been performed at Äspö over the last two decades and both the facilities and results from these earlier studies and experiments will be available

if operational capacity cannot be demonstrated at the time of submitting the proposal, describe the concrete measures that will be taken to obtain it by the time of the implementation of the task.

Operational capacity can be demonstrated

Participant	40	State Enterprise “State Scientific and Technical Center for Nuclear and Radiation Safety”	SSTC NRS
Description of the legal entity The State Scientific and Technical Center for Nuclear and Radiation Safety (SSTC NRS) is a Technical Safety Organization to the national nuclear regulatory authority of Ukraine since 1992. The SSTC NRS mission is to provide scientific, engineering and expert support to the State Nuclear Regulatory Inspectorate of Ukraine (SNRIU) in all areas of its activity to ensure nuclear and radiation safety, protection of public health and safety, and protection of the environment. In the field of management of radioactive waste (RW) and spent nuclear fuel (SNF), SSTC NRS has above 25-year experience in expert, analytical and scientific support to SNRIU. SSTC NRS possesses advanced methodological, analytical and technical infrastructure, and developed capabilities for review of safety-related documentation and development of regulatory documents related to RW and SNF management. About 140 researchers and experts in safety-related areas are presently involved in the SSTC NRS scientific and technical activities. In particular, SSTC NRS employs highly qualified experts in the area of RW and SNF management. In addition, the SSTC NRS staff has solid background and experience gained during their work at Ukrainian RW management enterprises, Ukrainian NPPs (including Chornobyl NPP), in research and design institutes, as well as in technical support organizations in the nuclear industry. Description of main tasks in the proposal, with an explanation of how its profile matches the tasks in the proposal WP17-MODATS : The SSTC NRS profile shows relevant level of expertise, and SSTC NRS will contribute in: Subtask 3.3 - Determination of conditions of the sensors operation - Analysis of conditions of the sensors operation (including resistance of sensors to external impacts), requirements to sensors reliability, longevity, repairability (if applicable), etc. Within Sub-Task 3.3, in interaction with Sub-Task 3.2, it is proposed to perform analysis of: - possible environmental impacts on sensors at places of their location, taking into account design duration of performing monitoring functions by these sensors; - possibilities for maintenance and replacement of sensors. According to the results of analysis, there will be defined the requirements to the following characteristics of sensors: - resistance to external impacts (thermal, chemical, mechanical, radiation, etc.); - reliability and durability of sensors, limitations for maintenance. Task 4 - Coordination of activities related to interaction with KM Work Packages. - Participation in organization of Monitoring Training School and Monitoring Conference. - Participation in development of the Project Synthesis document. WP9-ROUTES extension : The SSTC NRS profile shows relevant level of expertise, and SSTC NRS will contribute in: Subtask 2.1 1. SSTC NRS will prepare the review on experience of creation of the Centralized Facility for Long-Term Storage of Disused SRS (CSDSRS) developed in Ukraine. The creation of this facility will be shared as a good example of ensuring long-term safety of DSRS, in view of the fact that the disposal option for DSRS has not been finally selected in many countries. There is envisaged transfer of all DSRS in Ukraine to this centralized facility, characterization, conditioning and safe long-term storage of these DSRS. The design solutions for DSRS characterization and sorting at CSDSRS take into account possible disposal options for DSRS in the absence of WAC for disposal. At that, in course of licensing of CSDSRS, SSTC NRS has performed studies on the key safety issues of CSDSRS operation. SSTC NRS will also contribute to analysis of this case study.			

2. With regard to the second case study (legacy waste), there will be prepared the generic review on Ukrainian requirements and practices of safety assessment of the legacy sites and management of legacy waste, ranking of sites by the degree of hazard, examples of pilot cases for remediation of legacy sites. In Ukraine, as country with huge amount of various types and categories of RW (LIMS), there is accumulated an experience of management of legacy RW (for example, RW placed in Radon type facilities; RW in former military units; Chornobyl origin RW). SSTC NRS has performed studies on the key safety issues for legacy waste. SSTC NRS will also contribute to analysis of this case study.

3. SSTC NRS will also contribute to interaction with the initial ROUTES WP task 2 (Challenging wastes), where SSTC NRS is a Task Co-Leader.

The SSTC NRS profile shows relevant level of expertise, and SSTC NRS will participate in the workshops organised by Subtasks 3.6 and 4.3.

	No	Name	Acronym
Participant	41	Slovak University of Technology in Bratislava	STUBA
Description of the legal entity Slovak University of Technology in Bratislava (hereinafter referred to as "STUBA") is an educational and scientific institution. At present, it consists of seven faculties. All the faculties provide a study in accredited study programmes within the complex system of a bachelor, master and PhD. study. Faculties realise credit system compatible with the European credit transfer system enabling mutual mobility of students within European Union member countries and a larger European space. In the area of scientific and research activities the STU successfully joints European Union programmes. STU is a public university and offers education mainly in technical, technological, technical-economical, technical-information and technicalartistic fields of study. International cooperation is a significant area based on interactive contact with educational as well as scientific-research institutions of the countries all over the world. First of all, it is focused on solution of the joint projects within the EU framework and other international programmes, mobility of students, ect. Institute of Nuclear and Physical Engineering (STUBA-INPE) at Faculty of Electrical Engineering and Information Technology of Slovak University of technology is focusing on research of operation and decommissioning of NPPs, material science, nuclear fuel cycle and decommissioning of NPPs and radiation protection. STUBA-INPE staff is based on 10 professors in physics, nuclear power engineering and material science. There are actually 50 employers (scientific or research workers) and about 20 PhD students. This institute is also a base for activity of Slovak Nuclear Society (SNUS) and the Slovak Centre for operation and Decommissioning of Nuclear Facilities. STUBA-INPE has a long tradition in the NDS investigation of RPV materials by use of Positron Annihilation Spectroscopy and Mossbauer spectroscopy. The partner role to the project: research organisation. The partner contribution to the project: performance of R&D work mainly in field of development of proper methodology for mapping of radioactive material behaviour during its decommissioning, transport and long term storage. Knowledge management in dismantling, decommissioning and geological disposal characterisation is one of the main task in education and research at the University level.			
Description of main tasks in EURAD-1, with an explanation of how its profile matches the tasks STUBA will contribute in characterization of actual state of art, mapping and development of activities in decommissioning of Slovak nuclear facilities and knowledge management including organization of seminars for graduate and PhD students WP9-ROUTES extension : STUBA will contribute in characterization of actual state of art, mapping and development of activities in decommissioning of Slovak nuclear facilities and knowledge management including organization of seminars for graduate and PhD students Prof. Vladimír Slugen, DSc. (Male) graduated at the Slovak University of Technology (MSc. 1985, PhD. 1993, Prof. 2005, DSc. 2010). Professional experience in: operation and safety of NPPs, radiation damage of			

nuclear materials, nuclear fuel cycle, non/destructive testing methods. President of European Nuclear Society (2009- 2011). President of Slovak Nuclear Society (since 2004). Member of several EC framework projects as: PERFECT, COVERS, TRASNUSAFE, LONGLIFE. About 70 CC scientific publications and 300 citations

WP10-UMAN extension :

STUBA will participate in the workshops organised by Subtasks 3.6 and 4.3.

The members of STUBA team involved for participation in the UMAN extension have experience on wide spectrum of issues in decommissioning including uncertainties identification, prioritisation and analyses as well as application of different numerical methods and tools and sensitivity analysis of different types of uncertainties.

a curriculum vitae or description of the profile of the persons, including their gender, who will be primarily responsible for carrying out the proposed research and/or innovation activities

Prof. Vladimír Slugen, DSc. (Male) graduated at the Slovak University of Technology (MSc. 1985, PhD. 1993, Prof. 2005, DSc. 2010). Professional experience in: operation and safety of NPPs, radiation damage of nuclear materials, nuclear fuel cycle, non/destructive testing methods. President of European Nuclear Society (2009- 2011). President of Slovak Nuclear Society (since 2004). Member of several EC framework projects as: PERFECT, COVERS, TRASNUSAFE, LONGLIFE. About 70 CC scientific publications and 300 citations.

Assoc. Prof. Gabriel Farkas, PhD. (Male) obtained his master Degree (2000) and his PhD. degree (2007) and assoc. Prof. (2014) at the Slovak University of Technology. Professional experience in: operation and decommissioning of NPP, nuclear fuel behaviour, simulation of neutronic physical parameters of nuclear fuel using MCNP code. 9 CC scientific publications and 16 citations.

Dr. Kristína Kristífova (Female) obtained his master Degree (1995) and her PhD. degree (2000) at the Slovak University of Technology. Professional experience in: dismantling and decommissioning performance, cost estimation and nuclear knowledge management. 5 CC scientific publications and 10 citations.

a list of up to 5 relevant publications, and/or products, services (including widely-used datasets or software), or other achievements relevant to the call content

Slugeň, V., Lipka, J., Tóth, I., Haščík, J., Hincá, R., Lehota, M.: Corrosion of steam generator pipelines analysed using Moessbauer spectroscopy. In: Nuclear engineering and design 235 (2005) 1969-1976

Mikloš, M., Slugeň, V.: SCALE calculation for evaluation of spent fuel condition during long-term storage. In: Nuclear Engineering and Design 238, (2008), p.2811-2814

Slugen, V.: Safety of VVER-440 reactors: barriers against fission products release. Springer-Verlag London limited, (2011), ISBN 978-1-84996-419-7, 178pp.

Slugen, V. et al: Nuclear fuel cycle, (ed. SNUS) Didaktis, (2015), ISBN:80-88682-62-2, 180pp.

Slugen, V.: European Decommissioning Academy (EDA): Ready to Start. In International Journal for Nuclear Power. Vol. 60, No. 2 (2015), p. 82-84.

a list of up to 5 relevant previous projects or activities, connected to the subject of this proposal

FP6 PERFECT no. F16O-CT-2003-508840 (2004-2008): Prediction of Irradiation Damage Effects in Reactor Components

FP7 TRASNUSAFE no. 249674 (2010-2014): Training schemes on nuclear safety culture FP7 NUGENIA Plus no. 604965 (2013-2016): Preparing NUGENIA for HORIZON2020

H2020 MEACTOS, Project of the European atomic energy community. (2017-2020)

Centre for operation and decommissioning of NPP (CEPPVYJZ) - Grant of Slovak Ministry of education No 001STU-2/2014 resulted in creation of European Decommissioning Academy 2015

a description of any significant infrastructure and/or any major items of technical equipment, relevant to the proposed work;

Several laboratories for radioactivity measurements and simulations, dosimetry, release measurements, decontamination etc. are available at the STUBA laboratories in Bratislava. Different non-destructive techniques (MS, PAS, CDB, SEM, TEM, AFM,...) are available as well. Since 2014 the STUBA Material

science centre for non-destructive testing of high treated materials is in operation in Jaslovské Bohunice NPP. Relevant computer codes as well as computing capacities are available, too.

if operational capacity cannot be demonstrated at the time of submitting the proposal, describe the concrete measures that will be taken to obtain it by the time of the implementation of the task.

N/A

	No	Name	Acronym
Participant	42	Sprava ulozist radioaktivnich odpadu	SÚRAO
Description of the legal entity The Radioactive Waste Repository Authority (SÚRAO) is a Czech state organisation and its activities and management are regulated by Article 113 of Act 263/2016 (the Atomic Act). SÚRAO's mission is to ensure the safe disposal of existing and future radioactive waste in compliance with the requirements of nuclear safety and human and environmental protection. SÚRAO's most important responsibilities include the operation of 3 low- and intermediate-level radioactive waste repositories. SÚRAO also coordinates the considerable work necessary regarding the development and construction of a deep geological repository for high-level radioactive waste and spent nuclear fuel, the commencement of operation of which is planned in 2065 according to the Policy of Radioactive Waste Management as approved by the Government of the Czech Republic and for which a Strategic Environmental Assessment (SEA) was granted last year as part of the Nuclear Action Plan covering the next few decades.			
Description of main tasks in EURAD-1, with an explanation of how its profile matches the tasks SÚRAO is involved in 6 EURAD RD&D work packages as well as in two Strategic Study WPs; SÚRAO also leads the KM Guidance WP (WP 12). WP HITEC: SÚRAO and its LTPs (CTU, CU and UJV Rez) have been involved for many years in the characterisation and modelling of the thermo-mechanical behaviour of bentonite both through Czech and wider European projects. All the previous research experiments were limited to a temperature of 95°C. SÚRAO and its LTPs propose to conduct the characterisation and to model the thermo-mechanical behaviour of bentonite at temperatures in excess of 100°C. WP CORI: SÚRAO will work with the following LTPs: UJV Rez and the Czech Technical University (CTU). Experimental work will focus on the degradation of concrete organic additives and ion-exchange resins and the migration of radionuclides and their complexes. WP FUTURE: SÚRAO, together with the LTP UJV Rez, is interested in attaining a more detailed understanding of radionuclide mobility in crystalline rocks. Determining a fundamental understanding of radionuclide mobility makes up the basic prerequisite for the performance of a credible safety assessment of the future radioactive waste repository. WP ACED: SÚRAO will work with the LTP UJV Rez to study the effect of steel corrosion on bentonite at different temperatures – geochemical modelling of this interface will be carried out. WP DONUT: SÚRAO and its LTPs (CTU, CU, TUL, UJV Rez) will contribute towards the development of robust and efficient numerical methods for the simulation of thermo-hydro-mechanical (THM) processes in bentonite barriers and host rocks. Development will include the use of parallel computing algorithms for the solving of complex associated issues. WP GAS: SÚRAO and its LTPs (UJV Rez and CTU) already have the technical and instrumental infrastructure for the research of gas migration in bentonite materials. The research programme will involve laboratory gas injection tests on bentonite samples using air and hydrogen. SÚRAO would like to attend debates in order to be able to determine the deliverables and form conclusions of the both Strategic Study WPs. SÚRAO is the leader of the knowledge management Work Package (WP 12) which aims to clarify and justify the priorities of Guides for the pre-disposal and siting processes. It is intended that these Guides will lead to the determination of guidelines for the further development of National Programmes in countries with early-stage ones and which will help in terms of differentiating between them and countries with small programmes. The optimisation and adaptation of such programmes to the coming decades which will be characterised by the digital economy and the development of robotics will provide inspiration with respect to			

identifying the advantages of a common approach in several areas that meets the challenges of the new public environment, safety requirements and security with concern to the final disposal projects adopted in countries with early-stage programmes. The collection of positive arguments for decision-makers employing *inter alia* recommendations/conclusions from SITEX and IGD-TP - the outputs will be very useful for developing Summer schools and the exchange of researchers throughout the European Research Area thus improving mutual communication, reducing costs via the sharing of knowledge and experience, etc.

WP15-ConCorD :

SURAO will be involved in close cooperation with its **TLP ÚJV** and **TUL** in the complex contribution in **Task 3, 4** and **5**. **SURAO** will contribute in **Task 1** contributing to SOTA. **SURAO** will provide metal samples (carbon steel) and bentonite supply (CZ Ca-Mg bentonite) in **Task 3, 4** and **5**.

WP16-MAGIC :

The work will be performed by a multidisciplinary Czech team covering all needed types of analyses (mechanical, microstructure, chemical, microbiological) - LTPs CTU, ÚJV, TUL and the CVREZ (RE) – see separate proposal.

Experience of the team related to Magic - investigation on OPC and/or LPC in the field of microstructural, mechanical, chemical and microbiological laboratory and in-situ testing: EU CEBAMA, DOPAS, MIND, EURAD CORI, PREDIS and national projects (e.g. ALMARA, Interaction experiment at the Bukov URF, Research support for the safety assessment of a deep geological repository).

Equipment related to MAGIC: geotechnical lab (mechanical tests, hydraulic and gas conductivity); nanomechanical lab CE-NANO; microscopy lab CE-SEM; chemical and analytical laboratory (AAS, CE, ICP-MS, UV/VIS), complete equipment for performing both microbiological and molecular genetic analyses (i.e. NGS sequencing, metagenomics, real-time PCR quantification, DNA concentration).

SURAO will contribute to the Task 1, 2 and 3. Generally it will focus on the evolution of mechanical behaviour of a low-pH cementitious material under repository-like conditions during an operational phase (10-30°C, saturated and partially saturated; aerobic conditions).

The simultaneous effect of a multi-ionic attack and a microbial impact will be studied on mechanical and chemical properties of the low-pH concrete in fully saturated conditions. The set of existing witness samples of the in-situ “Interaction experiment” ongoing in the Bukov URF (by **SURAO**; in the Bukov URF since 2018) will be used as the source of the low-pH material for the proposed experiment. After the initial characterisation two ageing phases (sampling after approx. 12 and 24 months) will occur.

SURAO will compile samples preparation (drilling, cutting of witness LPC samples); preparation and running of experiment (various perturbing environment – primarily concrete/ groundwater/ bentonite interaction); analyses of samples (after 12 and 24 months) and interpretation.

Studied parameters are summarized below related to relevant tasks:

Task 2 – non and destructive mechanical testing (elasticity, strength tests, hydraulic conductivity...), porosity, chemical analyses (composition, TOC), physical-chemical properties (pH, ORP, conductivity) of liquid phases after interaction, microbiological analyses of water, bentonite and concrete samples based on molecular-genetic and microscopic methods (DNA extraction, NGS - 16S rDNA sequencing for microbial characterization, real-time PCR for microbial quantification, epi-fluorescence microscopy to detect microbial presence and distinguish between living and dead cells).

Task 3 – nanoindentation and microstructural analyses; related chemical and microbiological works and analyses of samples and perturbing environment (the same as in Task 2).

WP10-UMAN extension :

SURAO will participate in the workshops organised by Subtasks 3.6 and 4.3 and contribute, as member of the subtask 3.6 expert group, to:

- the collection and synthesis of relevant information on uncertainties associated with the near field (including the experience from the Bukov Underground Research Facility)
- the development of the material for the workshop organized by Subtask 3.6 and the seminar organized by Task 5

- the writing of the deliverable of Subtask 3.6.

a curriculum vitae or description of the profile of the persons, including their gender, who will be primarily responsible for carrying out the proposed research and/or innovation activities

Ing. Dmitry Lukin (male) is a safety analysis specialist; he has been working for SÚRAO in the Safety and Licensing Procedures Department since 2013. He is an expert in performance assessment and THM modelling and he is also responsible for preparing different models of the three radioactive waste repositories currently in operation in the Czech Republic. He has been involved in several national and international projects (PAMINA, DOPAS, etc.) and now manages the Czech modelling teams involved in the SKB Task Force Groundwater Flow and Transport of Solutes project.

Ing. Lucie Hausmannova, Ph.D. (female) has been working for SÚRAO since 2017 as a materials specialist. She is responsible for the design and development of engineered barriers (especially the buffer and backfill) for the future Czech deep geological repository. She is currently managing several projects and is involved in the CEBAMA and BEACON R&D EU projects.

She studied at the Czech Technical University in Prague, Faculty of Civil Engineering, where she defended her doctoral thesis in 2017. The doctoral thesis focused on the research of bentonite under DGR conditions.

Ing. Zdena Lahodova (female) has been working for SÚRAO since 2017 as a safety assessment technical specialist. She is responsible for the evaluation of the term source (especially the spent fuel inventory) intended for disposal in the future Czech deep geological repository. She studied at the Czech Technical University, Prague, Faculty of Nuclear Sciences and Physical Engineering.

Ing. Jan Smutek, Ph.D. (male) has been working for SÚRAO since 2017 as an in-situ experiment specialist at the Bukov Underground Research Facility (URF). He is responsible for the organisation of development work at the Bukov URF, the preparation of the experimental programme and the management of research projects at the facility.

He studied at the Czech Technical University in Prague, Faculty of Civil Engineering, where he defended his doctoral thesis in 2017. The title of his thesis was the Research of Rock Mass Gas Permeability based on Experimental In-situ Measurement.

Ing. Antonin Vokal, Ph.D. (male) joined SÚRAO in 2012 after working for more than 15 years in the field of nuclear waste management at the Nuclear Research Institute, Rez. He is currently managing a comprehensive project focusing on the gathering of information on the basis of which it will be possible to reduce the number of potential DGR sites considered. He is responsible for preparing site specific safety cases accompanied by supporting safety assessments for all the potential DGR sites. He holds a Ph.D. from the University of Chemistry and Technology in Prague.

Mgr. Lucie Mareda (female) has been working in SÚRAO since 2020 as a technical specialist in geology department. She is responsible for evaluation of geochemical and transport properties of host rock. She studied Geochemistry of Environment at Charles University in Prague and worked in commercial sector as a geologist.

Ing. Marketa Dohnalkova (female) has been working for SÚRAO since 2009 as a tunnel engineering specialist. She is responsible for the design and development of engineered barriers and components for the future Czech deep geological repository. She is currently managing several projects and was involved in the DOPAS R&D EU project.

She studied Geotechnics and Underground Engineering at the Technical University in Ostrava, Faculty of Civil Engineering.

Mgr. Simona Hechtová (female) is a materials specialist; she has been working for SÚRAO since the beginning of the 2020. She is the part of the team in charge of the design and development of engineered barriers for the future Czech deep geological repository. She is responsible for the design and long term live of the container. She studied at the Masaryk University, Prague, Faculty of Science and Programme Chemistry and technology of materials for conservation -restoration.

Ing. Jiří Faltejsek (male) worked for SÚRAO from 1997 to 2011 as a Quality manager, from year 2000 he was responsible for operation of all Czech radioactive waste repositories. He was deputy managing director from 2000 and in year 2010 he became acting managing director. In 2012 he left SÚRAO for IAEA. During 2012-2020 he worked in waste disposal team of IAEA. After his return he is in-house consultant in SÚRAO. He graduated the Czech Technical University, Prague, Faculty of Nuclear Sciences and Physical Engineering.

a list of up to 5 relevant publications, and/or products, services (including widely-used datasets or software), or other achievements relevant to the call content • Smutek J., Hausmannova L., Svoboda J. (2016) The gas permeability, breakthrough behaviour and re-sealing ability of Czech Ca-Mg bentonite, Geological Society London Special Publication 443(1), London • Vetesnik A., Landa J., Vopalka D., Vokal A. (SÚRAO), (2015): A sensitivity and probability analysis of the safety of deep geological repositories situated in crystalline rock. Journal of Radioanalytical and Nuclear Chemistry 304(1): 409-415, 2015 • Lahodova Z., Viererbl L., Koleska M., Cernousek T., Cerny Z. (2016): Research of the radioactive properties of geopolymers carried out at the LVR-15 nuclear research reactor, PHYSOR 2016, Idaho, USA • Dvorakova M., Lukin D., Trpkosova D. (SÚRAO and UJV Rez, a.s.), (2016) • DOPAS Work Package 5, Deliverable D5.7: Models and modelling summary report for EPSP, February 2016 • Cerny J., Elias M., Dufek J. (2005): GIS - SÚRAO - Final Report. Report on the “Performing geological and other work for assessing and limiting sites for the deep repository” project. AQUATEST a.s., Prague.
a list of up to 5 relevant previous projects or activities, connected to the subject of this proposal EC projects: • CEBAMA (Horizon 2020): Collaborative project on “Cement-based materials, properties, evolution, barrier functions”. June 2016 – May 2019. (Coord. KIT-INE) • BEACON (Horizon 2020): Collaborative project on: “Bentonite mechanical Evolution”. June 2017 - May 2021(Coord. SKB) • FORGE (FP7): Collaborative project on the “Fate of Repository Gases”. February 2009 – September 2013. (Coord. Natural Environment research council) • DOPAS (FP7): Collaborative project on “The Full-Scale Demonstration of Plugs and Seals” September 2012 – August 2016. (Coord. POSIVA) • NF-pro (FP6): Collaborative project on “Understanding and the Physical and Numerical Modelling of the Key Processes in the Near-Field and their Coupling for Different Host Rocks and Repository Strategies” January 2004 – December 2007 (Coord. SCK-CEN) International project: LTD: Collaborative project on: “Long term diffusion”. 2004 – 2018 (Coord. NAGRA)
a description of any significant infrastructure and/or any major items of technical equipment, relevant to the proposed work; N/A
if operational capacity cannot be demonstrated at the time of submitting the proposal, describe the concrete measures that will be taken to obtain it by the time of the implementation of the task. N/A

No		Acronym
Participant	43	Statni ustav radiacni ochrany, vvi (National Radiation Protection Institute) SURO
Description of the legal entity SURO is a non-profit research institution and mandated TSO in radiation protection and nuclear safety. SURO was founded by State Office for Nuclear Safety (SUJB) in 1995. The mission of SURO is focused on research in the field of radiation protection, emergency preparedness and nuclear safety, including radioactive waste management, providing SUJB with research, expertise, methodologies, supervision, legislative support and consultation activities. SURO operates the main part of Czech National Radiation Monitoring Network including independent monitoring of nuclear power plants and radioactive waste disposal sites. SURO is an accredited laboratory in radioactivity measurements. SURO is engaged in training and tutoring in the field of nuclear safety and radiation protection, hosting IAEA trainees (based on signed Memorandum between IAEA and SURO) and cooperating with ENSTTI. With respect to the statutory request (new Atomic law, 263/2016), the Research Centre Rez (CV REZ) has agreed with SUJB on building of an independent technical and expert support in the area of nuclear safety, including RWM, inside the SURO. Due to this decision, human and material resources of CV REZ TSO group have gradually started to be transferred from CV REZ into SURO to ensure a high level of competent and independent expertise in all basic areas related to the evaluation of nuclear safety. This process has started in January 2017 based on signed Agreement between CV REZ and SURO.		
Description of main tasks in EURAD-1, with an explanation of how its profile matches the tasks SURO is engaged in both Strategic studies Wokpackages and in Knowledge programme. ROUTES - (T2, T4, T5, T6), UMAN (T4): SURO including TSO team transferred from CV REZ can provide an experience with more than 60 years of national nuclear energy development, including RWM programme establishment and implementation and identification of relevant research needs, in particular in radwaste disposal. SURO team can also provide experience with different kind of waste. Concerning research reactors operation when a certain part of generated liquid and solid waste was put in stores without proper documentation; thus, they have been missing information about their origin, amount, and radiochemical composition. These wastes were contaminated mostly by fission products, but also by transuranium elements. To remove those waste, procedures for their characterisation, retrieval, and re-processing in line with waste acceptance requirements for their disposal have been developed. These activities were accompanied by the assessment of the environmental pollution, esp. monitoring of underground water, airborne measurements; dose risks of involved personnel, and the effectiveness of applied procedures. This knowledge will be completed by experience from both national and international RWM programmes establishment, in particular for countries with small amount of radwaste with different disposal solution. Due to a large international experience in RWM, expert team can contribute to the shared solutions for RWM. Based on experience gathered within national RWM programme development and knowledge obtained at international level, SURO team can contribute to the identification and characterisation of different actors across necessary phases of disposal programme with respect to the management of different types of uncertainties and their management options. WP9-ROUTES extension : SURO will participate in the work coordination and results dissemination. SURO will contribute to the exchange with KM WPs and other related WPs or international external institutions (IAEA, NEA) Suro will be Task 8 co-leader together with DMT. Subtask 8.1: SURO will contribute to the qualitative analysis/assessment of the predisposal routes with regard to disposal options. Subtask 8.2.: SURO will contribute to the analysis of possible disposal options in relation to the implementation of different predisposal routes. SURO will be engaged in the evaluation of waste routes		

resulting from subtask 8.1.. SURO will contribute to the Task 8 Deliverables development. SURO will contribute to the organisation and implementation of the both Task 8 Workshops.

WP10-UMAN extension :

SURO will organize the workshop organised by Subtask 4.3 and participate in the workshop organised by Subtask 3.6.

a curriculum vitae or description of the profile of the persons, including their gender, who will be primarily responsible for carrying out the proposed research and/or innovation activities:

Ms. Jitka Mikšová received her MSc. in applied geophysics and hydrogeology at the Charles University in Prague (CZ) in 1984. Currently, she is providing services to the national regulatory body (SUJB) at SURO in the Section of the Deputy Director for Nuclear Safety, in the field of RWM, in particular in radwaste disposal issues and relevant legal aspects.

She is also working as a scientific researcher-expert in CV REZ, in Nuclear Fuel Cycle Department, leading a TSO group, responsible for research related to the RWM.

She has been actively participating in the national RWM programme since its very beginning in 90s. As a member of expert group established at Czech Geological Survey she was involved in siting, data and information management, GIS implementation, radon programme establishment, etc. Then, she was working in the Radioactive Waste Repository Authority in the Geological Repository Development Department, as a technical development project manager responsible, in particular, for far field research, natural analogues, siting issues, GIS, project management, strategic documents development etc.

During her professional carrier she has led or supervised both national and international projects and participated in EC FP6, FP7 and H2020 projects focused on RWM, e.g. Funmig, MoDeRn, CROCK, FORGE, MIND, JOPRAD, SITEX-II, etc. She was involved in IGD TP Joint Activities focused on Knowledge management and on Monitoring of disposal facilities.

She has been engaged in the WG on the Operational safety in the IAEA GEOSAF II, now in GEOSAF III projects, in two ETSON expert groups (i) on the safety of Waste Management, Decommissioning & Remediation and, (ii) Knowledge Management. She is a member of Natural Analogues Working Group and SURO representative in the Management Board of SITEX network.

She has been involved in the IAEA training and scientific visits activities, organising training courses, tutoring and lecturing within ENSTTI and, lecturing for a state administrative.

Mr. Lumir Nachmilner graduated at Institute of Chemical Technology Praha in Inorganic Chemical Technology and got his PhD in Technology of Nuclear Fuel. His significant working positions were as follows: (i) NRI Rez (Division Director), (ii) SÚRAO (DGR Section Head), (iii) IAEA (Disposal Group Leader – Waste Technology Section) and, since 2012 Freelance Consultant (IAEA, NEA/OECD, EC, CV REZ).

Over 40 years, he has been engaged in research and development, safety studies, planning, budgeting, strategic studies, managerial posts in the field of radioactive waste management (waste treatment, conditioning, acceptance for disposal, safety analyses, near surface disposal, deep geological disposal), R&D regarding the development of a near surface and a deep geological repository; preparatory activities for establishing Radioactive Waste Repository Authority (SÚRAO), and the development of its corporate management system (EC Phare project)

He has more than 9 years as the IAEA staff member (2003-2012) - responsibility for the development of IAEA documents, establishing DISPONET network. He has been involved in lecturing at courses and meetings on establishing national infrastructure for managing radioactive waste (more than 20 countries worldwide) and tutoring RWM issues at Czech universities (an external lecturer).

a list of up to 5 relevant publications, and/or products, services (including widely-used datasets or software), or other achievements relevant to the call content

- 1) J. Miksova, L. Nachmilner (2017): Geological disposal programme. SITEX training course on regulatory review of the safety case for geological disposal. LEI/ENSTTI, Lithuania.

- 2) J. Miksova, L. Nachmilner, F. Bernier, P. Janssens, M. Tichauer, D. Ilett (2017): Optimisation of radiological protection applied to the development and implementation of a geological disposal system. Eurosafe Forum 2017. ISBN 978-2-9545237-8-1. IRSN. France.
- 3) V. Detilleux, D. Pellegrini, F. Bernier, G. Heriard-Dubreuil, J. Miksova, A. Narkuniene (2017): Overview of the Strategic Research Agenda in the field of safety of radioactive waste geological disposal developed by the Expertise Function in the EC-H2020-SITEX-II project. Eurosafe Forum 2016. ISBN 978-3-946607-33-5. GRS. Cologne. Germany.
- 4) F. Besnus, P. Metcalf, V. Wasselin-Trupin, W. Pfingsten, O. Schmit, J. Miksova, O. Tokaresvski (2016): The ETSON Study on Treatment Processes for the Sustainable Management of Radioactive Waste. International Conference on the Safety of Radioactive Waste Management. IAEA-CN-242. Austria.
- 5) L. Nachmilner (2013): Monitoring of Geological Disposal Facilities”. Internal NEA report within the framework of the RK&M International project.

a list of up to 5 relevant previous projects or activities, connected to the subject of this proposal

SURO is:

- 1) an active member of SITEX Network,
- 2) involved in EU research platforms NERIS, EURADOS and MELODI
- 3) engaged in the IAEA and ENSTTI training and tutoring activities
- 4) SURO experts were involved in:
 - EU H2020 JOPRAD project focused on EURAD preparation,
 - EU H2020 SITEX-II project aimed at practical implementation of sustainable independent expertise function in the field of geological disposal safety.
 - IAEA publication development, e.g.:
Radioactive Waste Management Objectives (IAEA Nuclear Energy Series NW-O); Policies and Strategies for Radioactive Waste Management (IAEA Nuclear Energy Series NW-G-1.1); BOSS: Borehole Disposal of Disused Sealed Sources a Technical Manual (IAEA-TECDOC-1644); Options for Management of Spent Nuclear Fuel and Radioactive Waste for Countries Developing New Nuclear Power Programmes (IAEA NES NW-T-1.24),
 - the development and implementation of the IAEA-EC project TC Project INT9176 Strengthening Cradle-to-Grave Control of Radioactive Sources in the Mediterranean Region 2010-2015,
- 5) SURO is a National Project Manager for EU JP Concert - European Joint Programme for the Integration of Radiation Protection Research.

a description of any significant infrastructure and/or any major items of technical equipment, relevant to the proposed work;

SURO can exploit its experience and knowledge from laboratory work and/or to use relevant codes for modelling purposes as GoldSim, Geochemist’s Workbench, SERPENT 2.1 etc.

The SURO laboratories are equipped with high-tech instruments, among others: alpha and beta spectrometers, low-background alpha-beta counters, radio-chemical laboratories, semiconductor gamma spectrometers in special shielding designed for measurement low activities of radionuclides in environment, MEDIPIX/TIMEPIX pixel detectors, devices for collection of aerosols including cascade impactors enabling determination of size distribution of aerosol particles, equipment for collection of radioactive gases, and chemical laboratories equipped for determination of alpha and beta radionuclides. A high-tech Radon chamber is operated for research, development and calibration of new radon monitors, CTP laboratory is operated for monitoring of internal contamination, TLD and OSL laboratory for measurement of external doses, special low energy HPGe detectors are used for in vivo detection of transuranium radionuclides in lung and skeleton of people.

if operational capacity cannot be demonstrated at the time of submitting the proposal, describe the concrete measures that will be taken to obtain it by the time of the implementation of the task.

Not relevant.

	No	Name	Acronym
Participant	44	TNO (Alwina Hoving, Jasper Griffioen)	TNO
Description of the legal entity The Netherlands organisation for applied scientific research TNO (TNO) is an internationally oriented knowledge organisation for private industry, government and governmental organisations. It is active in technical, earth, environmental, life, societal and behavioural sciences and has a staff of c. 3,500. The unit Geological Survey of the Netherlands TNO is nationally responsible for all geoscientific data and groundwater monitoring information. As such TNO-GSN is the national information provider on subsurface data, including the 3D groundwater information products REGIS, GeoTop and webservices such as Groundwater Tools. It has built up leading experience in the development of environmental databases. TNO has several laboratories among which a geochemical laboratory, that is shared with Utrecht University and knowledge organisation Deltares. The laboratory comprises analytical and experimental facilities for environmental geochemical and also sedimentological, stratigraphical, paleontological, and petrological applications. In addition, the laboratories comprise electron microscopic and advanced mass spectrometric facilities. TNO has extensive expertise in environmental geochemical characterisation of the subsurface both within the framework of its responsibility as geological survey and for individual purposes. TNO has over 30 years of experience in supporting industries and authorities in groundwater and subsurface management where environmental issues aimed at a sustainable use and environmentally responsible management of groundwater and other subsurface resources become addressed. All kinds of risk assessment studies of anthropogenic, subsurface activities have been performed by TNO: Carbon Capture and Storage, oil and gas production, geothermal energy production, high temperature - aquifer thermal energy storage, storage in salt caverns, etc. It has also been strongly involved in the Dutch, national research programs on disposal of radioactive waste among which the last OPERA program.			
Description of main tasks in EURAD-1, with an explanation of how its profile matches the tasks TNO will contribute to WP FUTuRE (Fundamental understanding of radionuclide retention). Here, we will participate in Subtask 1.2 where we will contribute to the preparation of the State-of-the-art report and update with our focus on redox reactivity. We will also contribute to Task 3 where we will carry out the geochemical and mineralogical characterization of various model clay minerals, including the electrochemical redox reactivity and we will carry out batch experiments to assess the redox reactivity of model clay minerals towards Se as a radionuclide. This fits well in the overarching goal of task 3 “Redox”, which is to contribute to a better understanding of the coupled sorption and electron transfer interface reactions governing the retention of redox-sensitive radionuclides on Fe(II)/Fe(III) bearing minerals so as to improve the capacity to model, and thus predict, the fate of these elements within the safety assessment of radioactive waste storage.			
a curriculum vitae or description of the profile of the persons, including their gender, who will be primarily responsible for carrying out the proposed research and/or innovation activities Alwina Hoving (Geochemist, Female) is a scientist at the Geological Survey of the Netherlands, TNO (2016-date). For the past six years, as part of PhD research at Utrecht University, she has investigated redox processes of Boom Clay, a potential host rock for radioactive waste in the Netherlands and Belgium, in relation to retention of selenium and uranium. To evaluate the redox properties of the sediment, she tested mediated electrochemical methods on relevant mineral standards, such as various clay minerals and pyrite, and on actual (altered) Boom Clay samples. Batch experiments with Se, U and (altered) Boom Clay samples were performed and the resulting Se and U speciation could be linked to the electrochemical redox characterization of the sediment. The interplay of adsorption and reduction of radionuclides in Boom Clay was investigated in detail. Besides this project, she works on various projects involving geochemistry and the subsurface of the Netherlands, incl. nutrient dynamics, geochemical parameterization for 3D subsurface models etc. Jasper Griffioen (Geochemist, Male) is expert researcher at TNO Geological Survey of the Netherlands (1991 to date) and professor of Water Quality Management at Utrecht University (2011 to date). He specialised in environmental hydrology and geochemistry within the framework of sustainable			

management of soil and water resources. He performed studies for a wide variety of geographical settings and a broad range of environmental management issues, ranging from an acid crater lake in Indonesia to disposal of radioactive waste in the deep subsurface of the Netherlands. Many of his projects refer to the risks and impact of anthropogenic measures on groundwater and subsequent effects on drinking water and groundwater-dependent ecosystems. Preferably, he combines field campaigns with modelling studies. He contributed chapters to several text books among which “UNESCO Groundwater Studies” and “Sustainable Groundwater Resources in Africa” in addition to his peer-reviewed publications. As member of the former ministerial Dutch Technical Committee on Soil, he was involved in c. 100 ministerial advices during October 2007 - March 2016; he has been an expert in several cases for Dutch Courts of Justice, too.

a list of up to 5 relevant publications, and/or products, services (including widely-used datasets or software), or other achievements relevant to the call content

- A.L. Hoving, M. Sander, C. Bruggeman, T. Behrends. 2017. Redox properties of clay-rich sediments as assessed by mediated electrochemical analysis: Separating pyrite, siderite and structural Fe in clay minerals, *Chemical Geology*, 457, 149-161
- T. Behrends, I. van der Veen, A. Hoving, J. Griffioen. 2016. First assessment of the pore water composition of Rupel Clay in the Netherlands and the characterization of its reactive solids. *Netherlands Journal of Geosciences*, 95, 3, 315-335
- M.L. Koenen & J. Griffioen 2016. Characterisation of the geochemical heterogeneity of the Rupel Clay Member in the Netherlands. *Neth. J. Geosci.*, 95, 269-281.
- Griffioen, J., Van Wensem, J., Oomes, J.L.M., Barends, F., Breunese, J., Bruining, H., Olsthoorn, T., Stams, A.J.M. & Van der Stoel, A.E.C. 2014. A technical investigation on tools and concepts for sustainable management of the subsurface in the Netherlands. *Sci. Total Environ.*, 485-486, 810-819.
- A.L. Hoving, M.A. Münch, C. Bruggeman, D. Banerjee, T. Behrends. Submitted. Kinetics of selenite interactions with Boom Clay: adsorption-reduction interplay

a list of up to 5 relevant previous projects or activities, connected to the subject of this proposal

- PhD project on effects of redox properties on the interactions of selenium and uranium with Boom Clay.
- TNO research project on geochemical characterisation of Boom Clay in the Netherlands
- TNO research project on geochemical interactions and groundwater transport in the Rupel Clay at the geological time scale

a description of any significant infrastructure and/or any major items of technical equipment, relevant to the proposed work;

- Set-up for mediated electrochemical measurements inside a glovebox.

if operational capacity cannot be demonstrated at the time of submitting the proposal, describe the concrete measures that will be taken to obtain it by the time of the implementation of the task.
not relevant

	No	Name	Acronym
Participant	45	TS Enercon Ltd.	TSE
Description of the legal entity			
TS Enercon Ltd. is a Budapest-based engineering and consulting organization specializing in radioactive waste and spent fuel management issues, safety and reliability of fuel cycle facilities, design of fuel storage methodologies both for nuclear power plants and research reactors, radioactive waste management, storage and disposal technologies. TS Enercon carries out safety assessments, safety cases, and feasibility studies for both nuclear and radioactive waste management installations.			
Description of main tasks in EURAD-1, with an explanation of how its profile matches the tasks			
TS Enercon Ltd. is participating in DONUT WP, since it has experience in modelling of contaminant migration in various media. Modelling of coupled processes is important for the safety assessments of the Hungarian radioactive waste and spent fuel disposal program, therefore it is essential to be involved in activities that aim to improve modelling tools. Participation in the UMAN WP is based on the experience gained regarding the uncertainties in safety cases as the sensitivity analyses are important to understand as well. Experiences in the field of inventory uncertainties are planned to be shared, further developed in the strategic study aiming to examine uncertainties. TS Enercon Ltd. has been involved in several projects connected to safety upgrade and remediation of radioactive management legacy sites, so the experience regarding management of historic waste and development of WAC is planned to be shared in the strategic study for the radioactive waste management.			
a curriculum vitae or description of the profile of the persons, including their gender, who will be primarily responsible for carrying out the proposed research and/or innovation activities			
Mr. Ferenc Takáts graduated in Moscow Power Engineering University as a physicist in 1973. He was working with the planning and startup phases of Paks NPP as a chief engineer in Hungary's major Power engineering design company: ETV Erőterv. He continued his carrier in the IAEA from 1989 to 1997 as the Team Leader of the spent fuel management unit. He is the founder of TS Enercon Ltd. Since then, he works in the field of spent fuel and radioactive waste management. Mr. Attila Baksay graduated in Budapest University of Technology and Economics in 2003, as an engineer physicist. He was working for Golder Associates Hungary Ltd and Public Limited Company for Radioactive Waste Management. He is specialized in, radiation protection, modelling for contaminant migration and nuclear safety. He worked as project manager for safety cases for Hungarian radioactive management sites. He works for TS Enercon Ltd. since 2017.			
a list of up to 5 relevant publications, and/or products, services (including widely-used datasets or software), or other achievements relevant to the call content			
1. Disposal of Low and intermediate waste in Hungary. Bulletin of Mining School, Zagreb, Attila Baksay Attila, Bálint Nős, Péter Molnár, 2013 2. Safety assessment for the optimized disposal concept of National Radioactive Waste Repository in Bataapáti, Attila Baksay, Regional seminar, Budapest 2014 3. Stochastic inventory calculations and stochastic radiation protection assessment in the safety case for Bataapáti NRWR, Attila Baksay, Hajdúszoboszló, 2015 4. Post-closure safety assessment of Püspökszilágy RWTDF, Attila Baksay, Hajdúszoboszló, 2016 5. Waste Acceptance System for Bataapáti National Radioactive Waste Repository, Attila Baksay, András Fritz, Workshop on Waste Acceptance Systems, Brussels, 2014			
a list of up to 5 relevant previous projects or activities, connected to the subject of this proposal			
1. Sensitivity analyses for contaminant migration in Bataapáti National Radioactive Waste Repository. 2. Safety assessment for Tehran Radioactive Waste Management Facility, assessments of airborne and waterborne releases. 3. Safety assessment for Kozloduy Incineration plant, waterborne releases. 4. Post closure safety assessment for Bataapáti National Radioactive Waste Repository.			

5. Post closure safety assessment for Püspökszilági Radioactive Waste Treatment and Disposal Facility.
a description of any significant infrastructure and/or any major items of technical equipment, relevant to the proposed work; Modelling infrastructure: GoldSim, AMBER, FeFlow, FracMan, Scale, MCNP, VisiPlan
if operational capacity cannot be demonstrated at the time of submitting the proposal, describe the concrete measures that will be taken to obtain it by the time of the implementation of the task. N/A

	No	Name	Acronym
Participant	46	TECHNICAL UNIVERSITY OF SOFIA	TUS
Description of the legal entity Technical University of Sofia (TUS) in Bulgaria is the biggest higher technical educational and research complex in the fields of thermal-, nuclear- and electrical power engineering, computer science and technologies, communications, etc. with close contacts and cooperation with governmental energy institutions and nuclear regulatory body. TUS has national role for the distribution of safety engineering knowledge and analysis, and for development of the Energy and Nuclear Energy Research Area in Bulgaria. The Research and Development Sector (R&DS) of TUS organizes, administrates and services of the research activities of TUS. The Safety and Environmental Engineering Laboratory (SE&EL) by the Electrical Power Department at TUS, has significant experience regarding VVER safety analysis and studies, Environmental Impact Assessment of NPPs with caution to the radwaste management, ASTEC benchmark calculations, post-test analysis, etc. In these activities the team of SE&EL often works together with involved experts from Kozloduy NPP plc, Bulgarian Academy of Science and other institutes and companies. TUS, in particular SE&EL has an experience in the nuclear and severe accident research in the frame of 5FP Projects - PHEBEN2 and RMPS; 6FP Projects - SARNET, COVERS and NEPTUNO; 7FP Projects SARNET2, NEWLANCER, ASAMPSE-E and ARCADIA. Since 2002 TUS was participant in the PHEBUS FP Programme. TUS, in particular SE&EL was initiator for preparation and implementation joint with CEA and KIT (then FZK) teams different experiments (2003-2006) for VVER conditions in experimental program PLINIUS - COLIMA tests, and in LACOMERA platform – COMET-1 (MCCI), DISCO-L2 (DCH) and LIVE-L1 tests, etc.			
Description of main tasks in EURAD-1, with an explanation of how its profile matches the tasks The profile of TUS shows relevant level of expertise and matches the tasks in EURAD-1, and namely TUS' main tasks in the WPs tasks are: WP SFC: T2: To contribute in Subtasks 2.4.1 and 2.4.2 – TUS joint with JSI is responsible to define the big SNF data set packages A to C, collect the relevant information, standardize it and make it ready-to-use for the other partners, and to lead the evaluation of results of both code categories (best practice industry and sophisticated) used. T3: To contribute in Subtasks 3.1 with modelling work, numerical simulations and analysis for evolution studies of SNF rods. To lead the preparation of D 3.1.9 Development of a numerical tool for the evolution studies of SNF rods. T4: To contribute in Subtasks: • ST 4.1 with listing, grouping, ranking and prioritization of internal and external hazards (natural disasters and human factors) which can cause accidents and emergency conditions during extended storage, transport and emplacement of the SNF; Study and description of potential accident scenarios and ranking of the most probable and worst 1-3 scenarios related to the transport and long-term dry interim storage of SNF; Participation in the development of an engineering methodology capable of assessing the scenarios. To lead the preparation of D 4.1.1 Identification and description of potential accident scenarios. • ST4.2 with numerical simulations and consequence analysis of postulated accidents and expert assessment of criticality safety for accident scenarios (fuel release). Participation in the criticality safety analysis for different loading schemes for transport/storage casks. WP DONUT: T4: To contribute with generalised review on the developed and proposed benchmarks for the evaluation of numerical tools and methods for coupled processes; evaluations of the efficiency and applicability of new algorithms by strong non-linearity and non-monotonic systems, and sensitivity analysis of large-scale mathematical models for conditions of pre-disposal and of geological repositories. WP ROUTES: T2: To contribute in Subtasks 2.1, 2.2, 2.4 and 2.5 with providing national data on radioactive waste categorisation/classification, check and complete synthesis on practical issues on waste management routes for challenging waste, and participation in T2 exchange meetings.			

T3: To contribute in Subtask 3.1 with collection, analysis and comparison of the existing knowledge about techniques and practices for characterisation of RWs and identification of the needs for future R&D concerning Bulgaria, and to participate in information exchange for Subtasks 3.2 and 3.3.

T4: To provide input and participate in workshops of the WP.

WP UMAN:

T2: To contribute in Subtasks 2.2 to the compilation, assessment and improvement of approaches for the ranking, selection and prioritisation of uncertainties, reviewing the deliverable, and participating in technical meetings.

T4: To contribute in Subtasks 4.2 to the compilation and review of uncertainty management options, provide an input regarding the options considered in the Bulgarian programme, and to the writing of D4.2.

T5: To contribute in Subtasks 5.2 to the development of materials related to Topic 2 for seminars 2 and 3, and to the development of D5.2. TUS will be responsible for the practical organisation of seminar 2 and preparation of the minutes.

In addition to the above tasks:

TUS could host some project/WPs meetings in Bulgaria.

TUS, on the basis of his experience in previous EC projects, could organize issue of dissemination materials of EURAD project with high quality and good competitive price.

WP10-UMAN extension :

TU Sofia will participate in the workshops organised by Subtasks 3.6 and 4.3.

The members of TUS' team involved for participation in the UMAN extension have experience on uncertainties identification, prioritisation and analyses from one hand and application of numerical methods and tools, and sensitivity analysis of different types of uncertainties on other hand, in particular these with influence on the safety analysis and risk assessment in nuclear energy area. Their profiles match in high degree with the tasks in the proposal, in particular Subtasks 3.6 and 4.3, and Task 5. If needed, additional persons from TUS and Bulgarian Academy of Science could be involved in the team.

a curriculum vitae or description of the profile of the persons, including their gender, who will be primarily responsible for carrying out the proposed research and/or innovation activities

Prof. Dr. Ivan Ivanov (male) is the person in charge of TUS for participation in this project of EURAD-1 and he is primarily responsible for carrying out the all proposed research and innovation activities of TUS. Currently Dr. Ivan Ivanov is a Research Projects Manager at R&DS of TUS, Professor and Head of the "Safety and Environmental Engineering Laboratory" (SE&EL) at Electrical Power Department of TUS. He has completed a MSc and PhD in Electrical Power Engineering at TUS. He has more than 30 year's research experience in the field of the safety and environmental risk assessment and analyses. His key expertise and studies are on Technical- and Nuclear Safety and Severe Accidents Phenomena Investigations; Environmental Impact Assessment (EIA), Risk Analysis and Assessment; Waste and RAW Management; Assessment of Emissions from NPPs and TPPs and Modelling of Emission Propagation in the Atmosphere; Environmental and Radioecological Monitoring. He has more than 50 completed projects and 140 publications in this fields. He is a Team leader of the EIA of Kozloduy NPP (1999-2000), and a Team leader of the EIA of the Investment proposal of Belene NPP (2004-2005). Prof. Ivanov was a person in charge of TUS for the 5FP, 6FP and 7FP Projects, PHEBUS FP Programme activities and for the carried out experiments in CEA and KIT for VVER conditions mentioned above. Prof. Dr. Ivan Ivanov is an EIA registered expert (for Atmospheric air, RAD Waste, Harmful radiations) and Team leader for EIA in the Ministry of Environment and Water (1983-), member of Bulgarian Scientists' Union (1979-), Bulgarian Nuclear Society (2001-), APCEO „Asia-Pacific CEO Association Worldwide” (Senior Expert 2011-), GSTF “Global Science & Technology Forum” (2013-), etc.

Key persons and experts involved in the Team of TUS for this project of EURAD-1 are:

Prof. Dr. Angel Tzolov – Head of Electrical Power Department at TUS. He is completed MSc Engineer, Specialty “Electrical Power Engineering”, TUS (1985) and PhD degree at TUS (2001) with subject “Electric power stations and substations”. His main expertise and studies are on Programming Assembler, C, Basic, Fortran; Specialized software applications for mathematical modeling and process studies and systems in the EES; Development and implementation of software applications for analysis of the power system; Specialized packages of Atmel, SGS Thompson, Specific management algorithms, etc. Some previous professional him positions are: Engineer R&D, Assist. Professor, Assoc. Professor, Vice Dean on R&D and Staff Development of Electrical Engineering Faculty at TUS (2007-2015). Prof. Dr. Angel Tzolov will participate as leader in some TUS' tasks in DONUT WP.

Assoc. Prof. Dr. Dimitar Bogdanov is a lecturer and researcher at the Electrical Power Department of TUS. He is completed MSc Engineer, Specialty “Electrical Power Engineering” at TUS (1998) and PhD degree at TUS (2009) with subject “Reliability of the NPP’ safety systems”. He has specializations on “Nuclear Power Generation” in JICA, Japan 2004 and “Protection of future networks with distributed generation” in University of Manchester, UK 2011. He has more than 10 years’ experience in the field of the accidents and safety systems analyses and participation in the reconstructions and modernisation programmes of Kozloduy NPP, Technical Safety Assessment and PSA of the VVER440 and VVER1000 Units of Kozloduy NPP. Assoc. Prof. Dimitar Bogdanov will participate as leader in some TUS’ tasks in UMAN, SF and Route WPs.

Prof. DSc. Ivan Dimov is involved in the TUS’ team as tasks leader in DONUT and UMAN WPs. Hi has higher education completed at Moscow Research University at 1977, PhD in Mathematical modelling, 1980 Moscow, and DSc in Numerical Analysis, 1984 Moscow, Russia. His main expertise and studies are on Parallel algorithms and GRIDs, Stochastic numerical methods, Monte Carlo solution of PDE, error analysis and Statistical numerical methods with super-convergent probable error. Some of professional positions of Prof. DSc. Ivan Dimov are: Scientific Secretary of the Bulgarian Academy of Sciences 2014-2016, Chair of Scientific Council of IICT 2009- till now, Director of the Institute for Parallel Processing, BAS, Bulgaria, 1996-2004, Head of the Bulgarian Information Society Centre of Excellence for Education, Science and Technology in 21 Century (BIS-21), 2000-; President of Scientific Council of IPP-BAS, 2004-.

a list of up to 5 relevant publications, and/or products, services (including widely-used datasets or software), or other achievements relevant to the call content

- i. Ivanov I., Overview on the national R&D nuclear strategies in the New Member States (NMS) and in the Old Member States (OMS), NEWLANCER, April 2-4, 2012, Budapest.
- ii. Ivanov I., S. Andonov Emergency&Risk zoning reflection in the Environmental Impact Assessment of the Investment proposal for Belene NPP construction in Bulgaria. Proceedings ‘Emergency & Risk Zoning around Nuclear Power Plants’, 26-27 April 2005, EC, DG JRC, Institute for Energy, Petten, The Netherlands.
- iii. Ivanov I., D. Bogdanov. The climatic changes and their impact on the extreme external factors on NPP safety. Proceedings of “Energy Forum”, Varna, 2016. Vol. III. pp. 10-16. ISSN 2367-6728.
- iv. Alsmeyer H., A. Miassoedov, M. Cranga, R. Fabianelli, I. Ivanov, G. Doubleva, The COMET-L1 experiment on long-term concrete erosion and surface flooding. The 11th International Topical Meeting on Nuclear Reactor Thermal-Hydraulics (NURETH-11), Popes’ Palace Conference Center, Avignon, France, Oct.2-6, 2005. Paper: 087.
- v. Miassoedov A., H. Alsmeyer, L. Meyer, M. Steinbruck, P. Grudev, I. Ivanov, G. Sdouz, Results of the QUENCH-L2, DISCO-L2, and COMET-L2 Experiments Performed Within the LACOMERA Project at the FzK, Proceedings of ICONE14 International Conference on Nuclear Engineering, July 17-20, 2007, Miami, Florida, USA and Nuclear Engineering and Design, 238, 2008, pp.2017-2026.

a list of up to 5 relevant previous projects or activities, connected to the subject of this proposal

1. SARNET (*Severe Accident Research Network of Excellence*), 2004-2008 and SARNET2 (2009-2012), EURATOM, 6FP and 7FP, EC.
2. COVERS (*VVER Safety Research*), 2005-2008, EURATOM, 6FP of EC.
3. Environmental Impact Assessment (EIA) of the “Kozloduy” NPP, 1999-2000, MOEW and ME, Bulgaria.
4. EIA of the Investment Proposal for the Construction of the “Belene” NPP, 2004-2005, MOEW and ME, Bulgaria.
5. BIS-21 (Bulgarian information society center of excellence for education, science and technology in 21 century) ICA1-CT-2000-70016, Central laboratory for parallel processing, BAS, 2001-2004, CORDIS, EC.

a description of any significant infrastructure and/or any major items of technical equipment, relevant to the proposed work;

For the aims of the project the TUS’ team will use the existing Supercomputer System Avitohol installed 2015 in the Institute of Information and Communication Technologies of Bulgarian Academy of Sciences (IICT-BAS). It is built with HP Cluster Platform SL250S GEN8 (150 servers), Intel Xeon E5-2650 v2 8C 2.6GHz CPUs (300 CPUs), non-blocking InfiniBand FDR, 300 Intel Xeon Phi 7120P co-processors. The storage system is with 96 TB of raw disk capacity.

In collaboration with experts of Kozloduy NPP will be used in the plant relevant to the tasks laboratories, modelling systems, simulators and other equipment.

if operational capacity cannot be demonstrated at the time of submitting the proposal, describe the concrete measures that will be taken to obtain it by the time of the implementation of the task.

N/A

	No	Name	Acronym
Participant	47	University of Cyprus	UCY
Description of the legal entity The University of Cyprus (UCY) has been established under the University Law 144/1989. UCY is a public corporate body and is operating subject to the provision of its Law, Regulations, Rules and Internal Guidelines. The main objectives of the University are twofold: the promotion of scholarship and education through teaching and research, and the enhancement of the cultural, social and economic development of Cyprus.			
Description of main tasks in EURAD-1, with an explanation of how its profile matches the tasks The Radioanalytical-Environmental Chemistry Lab of UCY is the only Lab in Cyprus, which activities include research related to the chemical behaviour of radionuclides in the environment and particularly their interaction with inorganic and organic surfaces present in natural systems. Moreover, the Radioanalytical-Environmental Chemistry Lab of UCY is in close collaboration with the local radiation protection authorities and supports (when needed) governmental labs dealing with radiation/radionuclide measurements. WP9-ROUTES extension : Subtask 2: Qualitative analysis of the predisposal routes • subtask 2.1: Analysis and assessment of existing predisposal routes for low-level activity sources (e.g. calibration standards, uranium and thorium salts) and (as far as possible) lightening rods. • subtask 2.2: Participate in workshops and review proposals related to expansion of existing predisposal routes for SIMS with regard to disposal options in order to apply/adopt them in Cyprus. Subtask 3: Qualitative analysis of the disposal options • subtask 3.1: Participation on workshops/meetings related to analysis/assessment of existing disposal options for SIMS for low-level activity sources. • subtask 3.2: Evaluation of waste routes resulting from subtask 3.1 on disposal options for SIMS in/for Cyprus • subtask 3.3: Participation on workshops/meetings related to case studies			
a curriculum vitae or description of the profile of the persons, including their gender, who will be primarily responsible for carrying out the proposed research and/or innovation activities Mr. Ioannis Pashalidis, is Professor at the Chemistry Department, University of Cyprus and head of the Radioanalytical-Environmental Chemistry Lab. He obtained his Diploma in Chemistry and PhD at Technical University of Munich (TUM) and served at TUM as post-doctoral researcher (1991-1994). In 1994 he joined the University of Cyprus as post-doctoral researcher/visiting professor and became Lecturer (1999), Assistant Professor (2003), Associate Professor (2008), and became Professor (2015). His research interests are in Aquatic and Radioanalytical Chemistry. He has over 100 publications in international refereed journals, and over 100 participations in International Conferences and two Chapters in books. He has supervised 7(+2 ongoing) PhD and 16 (+1 ongoing) MSc theses. Prof. Pashalidis has extensive work on the interaction of (radio)toxic inorganic species (e.g. B(III), Cu(II), U(VI), Ra(II) etc.) with natural organic matter (humic acids and biomass by-products), and metal oxides and mineral surfaces. Other research activities include analysis and speciation of uranium and boron in Cypriot ground and seawaters, as well as phosphogypsum disposal at a coastal area in Cyprus. More recently, he has been investigating non-treated and chemically modified plant fibers for effective and selective removal of (radio)toxic metal ion from waters.			
a list of up to 5 relevant publications, and/or products, services (including widely-used datasets or software), or other achievements relevant to the call content - KILIARI T., PASHALIDIS I.: Selective Separation of Actinyl(V, VI) Cations from Aqueous Solutions by Chelex-100, <i>Radiochimica Acta</i>, 100 (2012) 439-443 - LYSANDROU M., PASHALIDIS I.: Uranium Chemistry in Stack Solutions and Leachates of Phosphogypsum Disposed at a Coastal Area in Cyprus, <i>J. Environmental Radioactivity</i>, 99 (2008) 359-366. - PASHALIDIS, I., CZERWINSKI, FANGHAENEL TH., K.R., KIM, J. I.: A Study of Solid-Liquid Phase Equilibria of Pu(VI) and U(VI) in Aqueous Carbonate Systems. Determination of the Carbonate Stability Constants, <i>Radiochimica Acta</i> 76 (1997) 55-62			

- PASHALIDIS, I., KIM, J. I., LIERSE, CH., SULLIVAN, J. C.: The Hydrolysis of Pu(VI) and Time-Dependent Polynucleation Reactions, <i>Radiochimica Acta</i> 61 (1993) 29-34
a list of up to 5 relevant previous projects or activities, connected to the subject of this proposal - EU-Project (FP5, 2001-2004): “Humic Substances in Performance Assessment of Nuclear Waste Disposal: Actinide and Iodine Migration in the Far-Field”. - EU-Project (FP6, 2005-2008): Fundamental Processes of Radionuclide Migration, as Contractor. - Research Promotion Foundation Program (2004-2007), “Assessment of the Radiological Impact on the Environment nearby a Phosphate Fertilizer Industry”, Principal Coordinator/Investigator. - EU-Project (FP7-212287, 2008-2012): “Redox Phenomena Controlling Systems”, Participation as Contractor.
a description of any significant infrastructure and/or any major items of technical equipment, relevant to the proposed work; N/A
if operational capacity cannot be demonstrated at the time of submitting the proposal, describe the concrete measures that will be taken to obtain it by the time of the implementation of the task. N/A

	No	Name	Acronym
Participant	48	University of Helsinki	UH
The University of Helsinki, established in 1640, is the most versatile research university in Finland. It includes eleven faculties. The University has ca. 31 000 students and 7 800 employees. (https://www.helsinki.fi/en/university/the-university-of-helsinki-in-brief). High-level research is carried out at the departments of the faculties and departmentally affiliated research stations, as well as at independent research institutes. In 2017, the University of Helsinki placed 56th in the Shanghai Ranking, 90th in the Times Higher Education World University Ranking and 102th in the QS World University Ranking and 81th in the Taiwan (NTU) ranking. The University lays special emphasis on the quality of education and research. The University monitors the research quality by organising research assessment exercises using international peer review process approximately every six years. The University of Helsinki is a member of the League of the European Research Universities (LERU). The Research Funding Services of the University of Helsinki was established in 1994 with an aim to provide centralised research administration and management services for the researchers of the University. The unit is part of the Research Services, which is one of the six sectors of the University Services. In the previous EU's Framework Programmes the unit has gained valuable experience from providing support services to over 800 projects, out of which to 240 FP7 and currently over 140 Horizon 2020 funded projects. The Department of Chemistry is the leading hub of chemistry teaching and research in Finland. The research carried out at the department is highly valued internationally, and it is divided into three research programmes: Materials Chemistry, Molecular Science, and Synthesis and Analysis. The molecular research unit of the Department of Chemistry combines many complementary molecular and methodological approaches, both experimental and theoretical. The main directions of experimental studies are exhaled human air monitoring, photochemistry, low-temperature chemistry, fundamental reaction studies, gas kinetics, solid phase and surface reactions, and combustion chemistry. We actively develop infrared optical frequency combs, precision laser spectroscopy and mass spectrometric techniques, to name a few. In parallel to experimental techniques, we develop and employ a multitude of theoretical and computational methods. The radiochemistry research is a part of molecular science research programme. The radiochemistry research is focused on four areas, the largest one of them being study on behaviour of radionuclides in the geosphere in reference to final disposal of spent nuclear fuel. Another are related to nuclear waste is the development of inorganic ion exchangers for the selective removal of radionuclides from nuclear waste effluents. Third area is radiopharmaceutical chemistry and fourth environmental radioactivity. The Disposal of nuclear waste team is based at the Department of Chemistry on the Kumpula Science campus. The research is focused on providing realistic parameters for safety analysis of the final disposal of nuclear waste and improving the understanding of chemical and physical processes of elements in geomaterials. The team provides a wide range of services from structure characterization to transport modelling.			
Description of main tasks in EURAD-1, with an explanation of how its profile matches the tasks EURAD-1 FUTURE: Sample characterisation by C-14 PMMA autoradiography, XRD, SSA and X-μCT. Sorption and matrix diffusion experiments with ^{226}Ra on pure minerals and rock samples and interpretation of the results from sorption and matrix diffusion experiments. EURAD-1 HITEC: Batch type tests to follow bentonite mass loss and characterization of the clay properties in micro or nanoscale after the heat treatment. Determination of the rheological (flow) properties as a function of temperature (20 – 150 °C) of sol, sol-gel, gel and colloidal phases. WP16-MAGIC : Helsinki U. have long experience in doing research focused on providing realistic parameters for safety analysis of the final disposal of nuclear waste and improving the understanding of chemical and physical processes of elements in geomaterials. The team provides a wide range of services from structure characterization to transport modelling. Helsinki U. participates in Task 3 by characterising with the C-14-PMMA autoradiography method and STED nanoscopy of the cementitious materials from the experiments of co-operators (IRSN especially). PhD students within this task are partly working in University of Helsinki under supervision of RIP team researchers. C-14-			

PMMA autoradiography will provide information on changes in the spatial distribution of porosity on centimetre scale samples. The porosity values provided take into account the connected porosity ranging from nanometre scale upwards, while individual porous features can be resolved to 20 µm resolution. STED nanoscopy is used to provide information on the pore and mineral structure on micrometre and nanometre scale from the exact same samples which were analysed with C-14-PMMA. The data obtained in this proposed work can be used as input/comparison for the chemo-hydro-mechanical modelling to be performed in Task 4, spanning from the sample scale to the structure scale.

a curriculum vitae or description of the profile of the persons, including their gender, who will be primarily responsible for carrying out the proposed research and/or innovation activities

Marja Siitari-Kauppi is a University Lecturer at the radiochemistry unit at the Department of Chemistry. She has been the group leader of the Radionuclides migration in porous bedrock group since year 2000. Siitari-Kauppi has 30 years of experience in the research field of spent nuclear fuel disposal. Her interests are in sorption and diffusion of safety relevant radionuclides in the engineered and natural barriers of the spent nuclear fuel repository. In addition she has developed in collaboration with the Finnish Radiation and Nuclear Safety Authority STUK a method for analyzing the porosity and pore structure of low porous materials with C-14 PMMA autoradiography technique.

Siitari-Kauppi completed her Ph.D. thesis within the framework of Cotutelle agreement that granted her the Ph.D. both in Finland and in France leading to the strong research connections in France. These include the Institut de Chimie des Milieux et Matériaux at Poitiers University, French Institute for Radiological Protection and Nuclear Safety and the French Geological Survey. Siitari-Kauppi has been a member of the International Steering Committee for Grimsel Test Site (GTS) Phase VI since 2004 and her group has worked in the in situ projects in GTS together with an international research groups managed by Nagra, Switzerland. During years 2009-2013 she had an EU project together with Poitiers University and ERM company to transfer the knowledge and build them a shared laboratory for the use of C-14 PMMA method. She has research collaborations also with Posiva, Finland, University of Jyväskylä, Finland, Geological Survey of Finland, University of Bern, Switzerland, JAEA, Japan, VTT Technical Research Centre of Finland, NRI-Rez, Czech Republic, Royal Institute of Technology, Sweden and Technical University of Gothenburg and Geosigma, Sweden. She is also an expert member in the national CCE fission group in the Ministry of Economic Affairs and Employment in Finland.

Pirkko Hölttä is a University Researcher at the radiochemistry unit at the Department of Chemistry and has 30 years of experience in the research field of spent nuclear fuel disposal. She has her M.Sc. and Ph.D. degree from the University of Helsinki, majoring in radiochemistry. Her Ph.D. thesis was about radionuclide migration in crystalline rock fractures and demonstration of matrix diffusion affecting the transport and retardation behaviour of radionuclides in fracture flow. Her research is related to the safety relevant radionuclide migration in granitic rock and the long-term performance of the bentonite buffer. Her projects are on the bentonite erosion, the stability of formed colloids, the radionuclide-colloid interaction and the colloid-facilitated transport of radionuclides. She is collaborating with Helmholtz-Zentrum Dresden-Rossendorf (HZDR), Karlsruher Institut für Technologie (KIT) and Nagra Grimsel Test Site programme Colloid Formation and Migration (CFM). She is also an expert member in the national CCE fission group in the Ministry of Economic Affairs and Employment in Finland.

Mikko Voutilainen is a University Researcher with a strong experience in research concerning transport radionuclides in bedrock from both experimental and modeling perspectives, X-ray microtomography, and porosity and pore structure characterization. He has a Ph.D. degree focused in Applied Physics from University of Jyväskylä. Topics of his doctoral dissertation were experimental characterization of structural heterogeneities in crystalline rock and effect of heterogeneities to transport of elements in it. The focus of the work was on safe disposal of highly radioactive spent nuclear fuel. After his PhD he has been working in University of Helsinki, first as a Postdoctoral Researcher and from 2017 as University Researcher. His current research projects are related to transport of radionuclides in conditions of deep geological repositories of spent nuclear fuel and paleo-hydrogeological evolution of pore and fracture waters in crystalline rock formations.

a list of up to 5 relevant publications, and/or products, services (including widely-used datasets or software), or other achievements relevant to the call content

Kuva, J., Sammaljärvi, J., Parkkonen, J., Siitari-Kauppi, M., Lehtonen, M., Turpeinen, T., Timonen, J. & Voutilainen, M., 2018. Imaging connected porosity of crystalline rock by contrast agent-aided X-ray microtomography and scanning electron microscopy. *Journal of Microscopy* 270, 1, 98–109.

Muuri, E. M., Sorokina, T., García, D., Grivé, M., Bruno, J., Koskinen, L., Martin, A. & Siitari-Kauppi, M. K., 2018. Modeling Transport of Cesium in Grimsel Granodiorite With Micrometer Scale Heterogeneities and Dynamic Update of K_d. <i>Applied Geochemistry</i> 92, 188–195. Muuri, E. M., Matara-aho, M. H., Puhakka, E. H., Ikonen, J. O., Martin, A., Koskinen, L. & Siitari-Kauppi, M. K., 2018. The sorption and diffusion of ^{133}Ba in crushed and intact granitic rocks from the Olkiluoto and Grimsel in-situ test sites. <i>Applied Geochemistry</i> 89, Voutilainen, M., Kekäläinen, P., Siitari-Kauppi, M., Sardini, P., Muuri, E., Timonen, J. & Martin, A., 2017. Modeling Transport of Cesium in Grimsel Granodiorite With Micrometer Scale Heterogeneities and Dynamic Update of K_d. <i>Water Resources Research</i> 53, 11, 9245–9265. Elo, O., Müller, K., Ikeda-Ohno, A., Bok, F., Scheinost, A. C., Hölttä, P. & Huittinen, N., 2017. Batch sorption and spectroscopic speciation studies of neptunium uptake by montmorillonite and corundum <i>Geochimica et Cosmochimica Acta</i>. 198, 168–181.
a list of up to 5 relevant previous projects or activities, connected to the subject of this proposal Finnish Research Programme on Nuclear Waste Management (KYT) 2015-2018 projects: Behaviour of radionuclides in the geosphere; in situ studies and Bentonite erosion and radionuclide interaction processes Posiva: Retention properties of rock matrix (Repro) and Paleohydrogeology projects Grimsel Test Phase VI: Ling Term Diffusion (LTD) and Colloid Formation and Migration (CFM) EU/BELBaR: WP3 Colloid radionuclide & host rock interaction
a description of any significant infrastructure and/or any major items of technical equipment, relevant to the proposed work; B- and C-type radiochemistry laboratories Wide range of modern instruments for the measurement of all types of radiation Digital autoradiography (FLA) and Electronic autoradiography (Beaver™) ZetaSizer Rheometer UV/VIS spectrometer GC-MS, HPLC-ICP-MS LA-ICP-MS and ICP-OES FE-SEM/EDAX and FIB-SEM/EDAX XRD, SAXS He gas diffusion and permeability Ar gas pycnometer Optical microscopes Electro migration equipment C-14 PMMA method for pore structure characterization
if operational capacity cannot be demonstrated at the time of submitting the proposal, describe the concrete measures that will be taken to obtain it by the time of the implementation of the task. N/A

	No	Name	Acronym
Participant	49	British Geological Survey – United Kingdom Research and Innovation	BGS-UKRI
Description of the legal entity The British Geological Survey (BGS) is an applied geoscience research centre that is housed in UK Research and Innovation (UKRI) and affiliated to the Natural Environment Research Council (NERC). It is a world leading geological survey that provides a core science mission to inform government of science related to the subsurface and its interfaces and also undertakes applied research for solutions to earth and environmental processes, both in the UK and globally. It is funded directly by UKRI as well as through research grants and via private sector contracts. BGS has an annual budget of approximately £60 million and employs 650 people. It has two main sites, a head office in Keyworth near Nottingham and the Lyell Centre, which is a joint collaboration with Heriot Watt University in Edinburgh. BGS works with more than 150 private sector organisations as well as having close links with 40 universities and sponsors approximately 100 PhD students each year.			
Description of main tasks in EURAD-1, with an explanation of how its profile matches the tasks BGS contribution will be within work package: Mechanistic understanding of gas transport in clay materials (GAS) . Within this, BGS in partnership with ONDRAF/NIRAS will co-lead subtask 1.2 State-of-the-art (SOTA) , producing a SOTA report based on the state of knowledge before EURAD-1. This will be available by month 12. BGS will contribute to subtask 2.1 Diffusion and retardation which focuses on diffusion and gas adsorption experiments. Specifically BGS, specifically will perform and model experiments on clay simulants to investigate the impact of mineralogy on the diffusion coefficient. A series of tests will be performed providing reference values for different mineral combinations, yielding data of interest to multiple end-users. This main body of experimental work be undertaken between month 6 and month 36 with reporting following this. BGS will lead subtask 2.2 Advection performing experiments to identify the governing processes for natural and engineered materials and on simulant materials to explore the dependency of transport mechanisms to petro-physical properties. Pathway imaging techniques will also be used. Finally, observations will also be up-scaled to include in-situ measurements of gas migration at a repository-relevant scale using the Lasgit facility at the Äspö URL managed by SKB. Experiments will run from month 6 to month 48 with reporting to follow. BGS, in partnership with CNRS (GeoResources – Nancy and IC2MP – Poitiers) will contribute to Subtask 3.1 Gas induced impacts on barrier integrity undertaking phenomenological experiments using a direct shear rig for water/gas injection experiments. Shear fractures will be created within the apparatus while tensile fractures will be created externally. Quantitative textural information of all fracture surfaces will be determined prior, and after, detailed experimental work by BGS. This will be undertaken between month 6 and month 24. Under subtask 3.2 Pathway closure and sealing processes , BGS, in partnership with CNRS will extend the experimental work in subtask 3.1 beyond the shut-in phase to visualise at pore scale the complex HM-C interactions, which are associated with the self-sealing process. BGS will contribute to HITEC subtask 2.1 Near field studies (<120°C) performing experiments on Opalinus Clay, Callovo Oxfordian claystone, and Boom Clay. BGS will conduct a series of experiments to investigate the self-sealing performance of the materials as a function of temperature. Unlithified and indurated host rock material will be fractured (defining peak, shear and residual strengths) and then heated to mimic the near field repository setting looking at fluid flow at elevated temperatures. BGS will contribute to HITEC subtask 2.2: Far Field Studies performing experiments on a range of host rocks subject to a range of thermal loads representing the distribution of temperatures encountered within			

far field zone subject to representative thermal gradients. Data from these tests will be used to assess the evolution of pore pressure (overpressure) and permeability (which will strongly influence the size of the overpressure) during heating. Subtask 2.2 will provide a key insight into the magnitude, and duration and impact of overpressures caused by thermal loading and its impact on the capacity of host rocks to self-seal.

BGS will contribute to HITEC **subtask 3.2: Clay Buffers (<120°C)** performing experiments using bespoke apparatus specifically designed for high temperature, low permeability studies. The evolution and hysteresis of permeability and swelling pressure will be defined as a function of temperature and initial dry density, the latter reflecting the heterogeneous conditions observed within engineered clay buffers as they hydrate.

BGS will contribute to meetings, reporting and dissemination throughout the lifetime of the project.

a curriculum vitae or description of the profile of the persons, including their gender, who will be primarily responsible for carrying out the proposed research and/or innovation activities

Dr Jon Harrington (Male) is Head of the fluid processes Research Laboratories and a senior principal scientist at the British Geological Survey. He has 26 years of research experience examining the multiphase flow and associated rock deformation behaviour of low permeability materials. In 1995, he co-founded the Transport Properties Research Laboratory, a state-of-the-art experimental facility undertaking custom-designed laboratory and field-scale experiments. Since then his research has focussed on issues relating to mass-transport and the coupled deformation of clay-rich media, cements and halite, with particular application to the underground disposal of radioactive waste, the sequestration of carbon dioxide, unconventional hydrocarbons, domestic waste disposal, and gas storage. He has extensive experience of managing and delivering multidisciplinary research for a host of organisations including national waste management companies, and provides expert advice and guidance on containment properties of low permeability materials to industry and government. He has co-chaired sessions and given keynote talks at international conferences and workshops and has presented evidence on multiple occasions to the Commission Nationale d'Evaluation, (France) as part of the French legislative framework on the treatment of gas in radioactive waste disposal. He currently coordinates TASK A of DECOVALEX, an international multi-phase flow modelling consortium comprising of 10 world-leading numerical modelling teams. As part of his research, Jon has also designed numerous bespoke experimental systems and has pioneered the development of a new conceptual model describing the immiscible flow of gas in clays, mudrocks and shale. This work has included development of novel tracer techniques including nano-particle injection and the use of deuterium based porewaters. He also designed and continues to manage the 'Lasgit' experiment in Sweden, and was instrumental in the development of the EU FORGE project and the current EURAD WP on gas.

Dr Caroline Graham (female) is a Senior Geomechanics Specialist at the BGS with nearly 15 years experience in the field of rock mechanics. During the majority of that time she has conducted research testing on natural and engineered barrier materials, within the context of the disposal of radioactive waste and other forms of geological containment. She became manager of the Transport Properties Research Laboratory in 2013, which specialises in conducting world-class, bespoke, multi-phase flow experiments on low and ultra-low permeability geomaterials. Caroline has worked on hydromechanical properties of clays and rocks for geological disposal concepts in a range of countries including the UK, Sweden, Switzerland and the Netherlands. Her experimental work includes hydraulic and gas flow permeametry, examination of hydromechanical coupling and gas flow in bentonite under variable pore-pressure conditions (Graham et al., 2014a; Graham et al., 2016), investigating the influence of density gradients on gas flow in bentonite and tracing of gas migration pathways in clays (Harrington et al., 2012). In 2012 she was one of a UK delegation of six, sent to Beijing to participate in a UK-China collaborative workshop on the geological disposal of radioactive waste, as part of the BIS Global Innovation Scheme.

Dr Robert Cuss (male) is a Principal Scientist at the BGS specialising in multi-phase flow in low permeable material. With a PhD in rock mechanics he joined BGS in 1999 and has specialised in detailed investigations of host rock and engineered barriers, with complementary research in the fields of CCS, shale gas, and underground gas storage. In 2013, he setup the Fracture Physics Laboratory, a constituent of the Fluid Process Laboratory, to study multi-phase flow in fractures using conventional and novel techniques. Robert

has experience of flow problems related to radioactive waste disposal from a theoretical, laboratory-scale, and field-scale prospective. Robert has participated in numerous projects for many of Europe's Waste Management Organisations, including work for UKAEA & RWM (UK), SKB (Sweden), Andra (France), Nagra & ENSI (Switzerland), Ondraf (Belgium), and Covra (Netherlands). These studies have included coupled flow in host rocks, engineered barriers, and fracture flow. Research has been conducted as direct commissions or through several EC projects (NF-Pro, FORGE, CeBaMa), working at the forefront of the gas research topic.

Dr Elena Tamayos-Mas (female) is a mathematical modeller at the BGS with nearly 10 years' experience in developing mathematical models to improve our understanding of physical phenomena. With a PhD in applied mathematics (within the Civil Engineering School at Universitat Politècnica de Catalunya, Spain) and a postdoc in computational fluid dynamics (within the Mining and Materials Department at McGill University, Canada), she joined BGS in 2016. Since then, her research has focused on developing mathematical models to address a wide range of issues relevant to hydrological and groundwater processes and the safety of deep geological disposal of radioactive waste. She is actively collaborating with the coordination of TASK A of the current phase of the Decovalex project, where she assesses and validates the different numerical approaches that the participating modelling teams are developing to describe advective movement of gas in low-permeability materials.

a list of up to 5 relevant publications, and/or products, services (including widely-used datasets or software), or other achievements relevant to the call content

J.F. Harrington, C.C. Graham, R.J. Cuss and S. Norris, Gas network development in a precompacted bentonite experiment: Evidence of generation and evolution. *Applied Clay Science*, 147, pp.80-89, 2017. <http://dx.doi.org/10.1016/j.clay.2017.07.005>.

Harrington, J.F., Cuss, R.C. and Talandier, J. (2017). "Gas transport properties through intact and fractured Callovo-Oxfordian mudstones." In: Rutter, E. H., Mecklenburgh, J. & Taylor, K. G. (eds) *Geomechanical and Petrophysical Properties of Mudrocks*. Geol. Soc. London, Spec. Pub. 454, <https://doi.org/10.1144/SP454.7>.

R.J. Cuss, J.F. Harrington, R. Giot and C. Auvray, Experimental observations of mechanical dilation at the onset of gas flow in Callovo-Oxfordian claystone. In: *Clays in Natural and Engineered Barriers for Radioactive Waste Confinement*; S. Norris et al. (Eds), 400, Geological Society Special Publications: London, United Kingdom, Geological Society of London, pp. 507-519, 2014. doi:10.1144/SP400.26

C.C. Graham, J.F. Harrington and P. Sellin, Gas migration in pre-compacted bentonite under elevated pore-water pressure conditions. *Applied Clay Science*, 132, 353-365, 2016.

Harrington, J.F., Milodowski, A.E., **Graham, C.C.**, Rushton, J.C., and **Cuss, R.J.** (2012). "Evidence for gas-induced pathways in clay using a nanoparticle injection technique." *Mineralogical Magazine*, 76 (8), 3327-3336, doi: 10.1180/minmag.2012.076.8.45.

a list of up to 5 relevant previous projects or activities, connected to the subject of this proposal

Gas migration behaviour in compact bentonite (for SKB and RWM): BGS has undertaken extensive studies examining the processes and mechanisms governing gas migration in pre-compacted bentonite. Laboratory and field scale experiments have been undertaken to better understand key phenomenological processes including the conditions governing: gas entry; peak gas pressure; gas breakthrough pressure; the coupling between gas flow, stress and porewater pressure; the stability of gas pathways; the amount of water displaced during gas flow. In combination with other studies, the output from this research has shaped the way in which gas migration is treated within performance assessment and has led to the development of a new conceptual model governing gas flow.

Gas migration in Callovo-Oxfordian mudrock (Andra): In 2007 BGS began an experimental study to examine the fundamental conditions governing gas migration in the Callovo-Oxfordian mudrock (COx). This

project questioned the validity of gas transport models then applied to CO_x, and defined a new conceptual model based around micro fracture and rock dilatancy. This work remains ongoing and key issues focused around the processes controlling dilatancy, the coupling of gas flow to stress and the impact on gas flow on the integrity of the host rock.

DECOVALEX-2019 (Task A): BGS is the task leader for this activity. The purpose of Task A is to better understand the processes governing the advective movement of gas in both low-permeability repository host rocks and clay-based engineered barriers. Based on laboratory scale experiments, new numerical representations for the quantitative prediction of gas migration fluxes have been developed. Work is ongoing, with the project scheduled to finish in December 2019.

FORGE (EC FP7 Euratom) BGS led the co-ordination of the Fate Of Repository GasEs (FORGE) project, a 12 M euro pan-European project studying gas generation and migration in a repository context. BGS also led Work Package 4: Disturbed host rock (DHR) formations undertaking small scale laboratory experiments, large scale field tests (performed at a number of underground research laboratories throughout Europe), data and numerical modelling to understand the roles of the stress tensor, the stress path and associated mechanical deformation in determining permeability changes affecting the sealing efficiency of the host rocks.

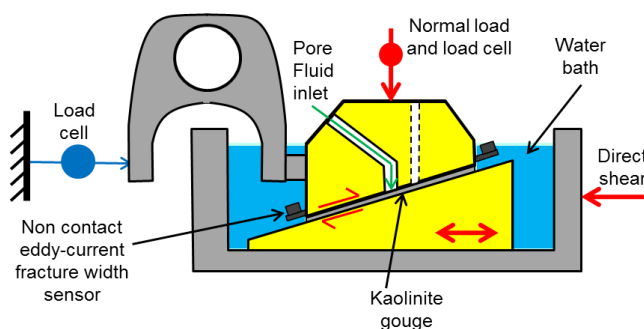
a description of any significant infrastructure and/or any major items of technical equipment, relevant to the proposed work;

The research proposed in the project will be undertaken in the *Transport Properties Research Laboratory (TPRL)*.



The TPRL is one of the leading centres in Europe for the study of fluid movement in ultra-low permeability media. The facility is well known within the radwaste and CO₂ sequestration sectors for long-term high quality experimental work and process-based interpretation. Focus is on multi-phase flow in natural and engineered, low permeability geomaterials (e.g. caprocks, well bore cements and engineered clays), and their associated deformation behaviour. Measurements include: saturation and consolidation properties; intrinsic permeability (or transmissivity); anisotropy; specific storage; coupled flow parameters (e.g. osmotic permeability); capillary entry,

breakthrough and threshold pressures; gas permeability function; drained and undrained compressibilities; and rheological (creep) properties. Laboratory experiments are performed under simulated in situ conditions (stress, pore pressure, temperature and chemical environment). Three key areas explored are: (i) baseline characterisation of hydromechanical properties, (ii) influence of stress path and stress history on transport properties and (iii) transmissivity of fractures, faults and discontinuities (e.g., wellbore interfaces). Tests are designed to provide quantitative data for mathematical modelling of ultra-low permeability materials, together with process understanding of key transport mechanisms. Key equipment includes: high pressure isotropic permeameters (70 MPa); constant volume permeameters (70MPa); high pressure triaxial permeameter (70 MPa); heavy-duty, high-precision shear-rigs; high temperature, high pressure geochemical flow reactor (130 MPa at 140° C); and novel tracer systems (nano particle injection or radiological tagging of gas) to characterise and identify potential migration pathways.



Operational constraint:

High pressure isotropic permeameters - Up to 70 MPa

High pressure triaxial permeameter – Up to 70 MPa

High temperature, high pressure geochemical flow reactor – Up to 130 MPa at 140 C

if operational capacity cannot be demonstrated at the time of submitting the proposal, describe the concrete measures that will be taken to obtain it by the time of the implementation of the task.

Not applicable

	No	Name	Acronym
Participant	50	Teknologian tutkimuskeskus VTT (VTT Technical Research Centre of Finland Ltd)	VTT
Description of the legal entity VTT Group is the largest public applied research activity in Northern Europe with a staff of 2600 and turnover of M€ 279. VTT has 75 years of experience in addressing the needs of industry and the knowledge-based society. Over the years, VTT has participated in more than 1000 European R&D Framework Programme projects, within various thematic programmes. VTT is currently involved in over 10 H2020 Euratom projects and is an active member of IGD-TP. VTT has partnership agreements and works in close cooperation with both the waste management producers and repository operators (Fortum, TVO, Fennovoima, Posiva) and the Finnish Nuclear Regulatory Authority (STUK). VTT is a multi-technological research organisation providing high-end technology solutions and innovation services.			
Description of main tasks in EURAD-1, with an explanation of how its profile matches the tasks VTT is a mandated actor, reporting to the Ministry Economic Affairs and Employment within the Finnish government. VTT (Erika Holt), together with Posiva and University of Helsinki, coordinate the Finland partners' involvement in EURAD.			
Regarding specific WPs identified in the 1 st wave, VTT participates to the following: - WP HITEC: Coordinator (Markus Olin). - WP ACED: Task 4 leader (Pauliina Raijala, Markku Leivo) - WP SFC: Contributor (Silja Häkkinen) - WP UMAN: Contributor (Marja Ylönen, Rafael Popper)			
VTT also has the coordinator role for the Finnish Research Program on Nuclear Waste Management (ongoing KYT2018, in planning KYT2022), where there may be complimentary domestic R&D compared to EURAD. http://kyt2018.vtt.fi/en/			
WP15-ConCorD :			
The VTT proposed contribution set in the subtask 2.2 . The main aim of the proposed activity is to evaluate and study the degradation mechanisms of novel container materials, focus on high level waste (HLW) and granitic disposal. The most probable corrosion and failure mechanisms of each potential novel container materials, including copper alloys and other novel metallic materials is the main focus of this work. Corrosion mechanisms, including stress corrosion cracking (SCC) and localized corrosion mechanisms, of novel container materials in environment that reflects the complexity of real repository conditions (i.e. temperature, chemical environment, biological functions) will be studied. Also, the possibility of micro-galvanic corrosion due to the possible impurities in novel materials will be considered. The uptake and diffusion of hydrogen and its interactions with the matrix will be investigated in this work for selected “novel” materials (especially copper alloys). The relationship between hydrogen diffusion into the matrix, creep rate and SCC crack growth in sulphide (HS-) containing ground water environment will be assessed by performing complementary experimental testing and molecular dynamics (MD) simulations. This work will allow to understand material performance at multi-scale and leads to cooperation with others on multi-scale modelling. The results will contribute to the overall WP goals by - providing understanding of corrosion mechanisms of novel container materials within the engineered barrier system and tools for optimization of container performance - clarifying the term source and formation of hydrogen and hydrogen uptake selected novel canister materials (link Task 1) and Cu grades in the repository environment - providing more detailed insights on hydrogen-material interactions (e.g. transport/diffusion, trapping, etc.) in copper and its impact on lattice structure and mechanical strains on the atomistic scale			
WP17-MODATS :			

Within MODATS, VTT's research activities focus on the activities in Task 2. VTT will develop methods to support the data management and techniques for system monitoring and analytics for enhancing system understanding. VTT combines physics-based and data-driven modelling approaches as the basis of reliable and robust analytics. Physics-based knowledge enhances the data processing steps throughout analysis, from data validation up to being able to understandably justify analysis results, and hence enhance system understanding. VTT's activities provide major input with regards to (1) data quality and acquisition plans, (2) contributions to data management and data system architecture, (3) definition of a repository data ontology and metadata catalogue for the collected data and (4) system monitoring and analysis framework, including a modular layered structure of models and version control to facilitate traceability and justifiability of computed results.

WP10-UMAN extension:

VTT will participate in the workshops organised by Subtasks 3.6 and 4.3 and contribute, as member of the subtask 4.2 expert group, to:

- the compilation and review of available information on uncertainty management options and preferences
- the development of the material for the workshop organized by Subtask 4.3 and the seminar organized by Task 5
- the writing of Task 4 deliverable.

a curriculum vitae or description of the profile of the persons, including their gender, who will be primarily responsible for carrying out the proposed research and/or innovation activities

Dr. Erika Holt (F, Ph.D. 2001) has degrees in Civil and Environmental Engineering, with an emphasis in construction materials, from the University of Washington, Seattle USA. She also has training in geotechnical engineering and tunnelling. She has been a Principal Scientist, Project Manager, and Research Team Leader for a team of 28 experts in the field of Infrastructure Materials at VTT. Her expertise is in concrete material durability, sustainability and nuclear waste containment. She has worked with Posiva on the performance of low-pH grouting material, as well as bentonite product manufacturing and bentonite performance for buffer design, quality management, tunnel plug demonstrations. She has participated in EU FP5-7 projects and serves as a project evaluator for the EC. She has over 25 publications in journals and conference proceedings. In EURAD, her roles are within the Finnish program coordination and scientific advising/review.

Professor Markus Olin, (M, Ph.D. 1994) earned his degree in Physics from the University of Helsinki. He is a Research Professor having more than 30 years of experience in the field of modelling spent nuclear fuel disposal. His research is concentrated on thermodynamics, surface chemistry and transport in porous media with an emphasis on nuclear waste containment (bentonite and rock materials). He has been involved in over ten EU and national funded large (multi-year) studies as a researcher and project manager. He is an author over 150 article and reports, 2 chapters in books and over 50 conference presentations. He has had leading technical roles in the EU-BELBAR, EU-THERAMIN and EU-BEACON projects most recently. In the HITEC WP of EURAD, he serves as the coordinator and technical supervisor of VTT's activities on high temperature clay performance in crystalline rock environments.

Dr. Markku Leivo, (M, D.Sc.Tech, 2005) earned his degree in Civil Engineering and Surveying from Helsinki University of Technology. He is a Principal Scientist has more than 30 years of experience on building materials research and coordination. His research is concentrated on the performance of buildings, material properties and manufacturing processes. He has been involved in over ten EU-funded studies as a researcher and project manager. He is an author of tens of scientific papers and presentations from 1985 on. Most recently he has been working on the EU-DOPAS (plug demonstration) and EU-CEBAMA (cement-bentonite) projects in the technical lead roles. In the ACED WP of EURAD, his expertise contributions are related to concrete material evolution.

Dr. Pauliina Rajala, (F, D.Sc., 2017) has a degree in Microbiology, specializing in Microbially Induced Corrosion, from University of Helsinki, Finland. She has worked with nuclear repositories related topics since 2011 at VTT as a Research Scientist and Project Manager in the field of Material Performance. Her expertise is in deep biosphere corrosion, biofouling and microbiology, with a special emphasis on geological repository environments. She has over 30 scientific publications on these topics. In the EURAD WP ACED her expertise is in corrosion of steel materials and general understanding of geological repository concept and chemical changes taking place during the repository time scale.

Mr. Veli-Matti Pulkkanen (M., MSc (Tech.), 2010) has a degree in Engineering Physics from Aalto University School of Science and Technology with an emphasis on continuum level material modelling and numerical methods. He has worked at VTT over 10 years on modelling nuclear waste management related problems ranging from radionuclide transport calculations for safety analysis to complex, strongly coupled bentonite models. Currently, he is finalizing his Doctoral Thesis on bentonite modelling and working within the BEACON project. He will contribute to the HITEC WP.

a list of up to 5 relevant publications, and/or products, services (including widely-used datasets or software), or other achievements relevant to the call content

- Pulkkanen. 2018. A large deformation model for chemoelastic porous media – bentonite clay in spent nuclear fuel disposal. Dr. (Tech.) Thesis, Aalto University. expected ready autumn 2018.
- Holt, Olin, Jalonen. 2016. Recent Research and Technology Highlights for Finnish Implementation of Geological Disposal of Radioactive Waste. ATS Ydintekniikka, 1/2016, Vol. 45, Suomen Atomiteknillinen Seura, Finland, pp. 26-29.
- Holt, Koho, Hansen. 2016. Posiva's Tunnel End Plug POPLU Experimental Summary Report, DOPAS project Deliverable D4.5, European Commission Contract #FP7-323273, 170 p.
- Hakola, Kivikoski, Löija, Marjavaara. 2015. Designing, Commissioning and Monitoring of 40% Scale Bentonite Buffer Test. Posiva Working Report 2015-08, 148 p.
- Itälä, Laitinen, Tanhua-Tyrkkö, Olin. 2014. Modeling Transport of Water, Ions, and Chemical Reactions in Compacted Bentonite: Comparison Among Toughreact, Numerrin, and Comsol Multiphysics, Nuclear technology 187(2), 169-174.

a list of up to 5 relevant previous projects or activities, connected to the subject of this proposal

- “Full-Scale Demonstration of Plugs and Seals (DOPAS, 2012-16)”, FP7-EURATOM project, Grant Agreement No. 323273. VTT and Posiva participation evaluating low-pH concrete recipes & performance, as well as monitoring of EBS performance.
- “Cement-based materials, properties, evolution, barrier functions (CEBAMA, 2015-19), H2020-Euratom project Grant Agreement No. 662147, VTT conducting experiments and long-term safety modelling of concrete-bentonite interaction for crystalline host rock.
- “Development and Demonstration of monitoring strategies and technologies for geological disposal (MODERN2002, 2015-19), H2020-Euratom project Grant Agreement No. 662177, VTT and Posiva participating on monitoring strategies and methods in the near-field during repository operation phases.
- “Development of the safety case knowledge base about the influence of microbial processes on geological disposal of radioactive wastes (MIND, 2014-18)”, H2020-Euratom project Grant Agreement No 661880, VTT participating with evaluating influence of microbial processes on waste forms and their behaviour, and the technical feasibility and long-term performance of repository components
- “Thermal treatment for radioactive waste minimisation and hazard reduction (THERAMIN 2017-2020)”, H2020-Euratom project Grant Agreement No 755480. VTT coordinator, developing methods for gasification and characterization of materials during waste reduction processes.
- “Bentonite Mechanical Evolution (BEACON, 2017-2021), H2020-Euratom project Grant Agreement No 745942. VTT modelling thermal-hydro-geo-chemical-mechanical evolution of bentonite, for process understanding of homogenization for repository safety.

a description of any significant infrastructure and/or any major items of technical equipment, relevant to the proposed work;

Over 10 000 m² of experimental lab space in divisions of radioactive waste management and building materials (over 100 000 m² whole VTT). VTT's Centre for Nuclear Safety (CNS) includes class A, B and C facilities for experimental research and handling of radioactive materials. Most relevant EURAD equipment includes radiological material characterization labs (gloveboxes, optical microscopy, TEM, SEM, ESEM, XRF, Xray diffractometer, EDS, AFM, MIP, thermal analysis, ICP-MS, wet chemistry). Building materials (metals, bentonite, cementitious) production and characterization labs (i.e. mixers, sieves, high-speed centrifuge, rheometers, calimetry, diffusion cells, shrinkage, creep, chloride diffusion & migration, sulphate attack, chemical leachate, resistivity, accelerated weather simulation, strength testing, etc). Radiochemistry and hotcells for irradiated material studies (gamma cell, alpha spectrometry, neutron measurements, etc). Micronova laboratories for sensor development. Biorukki pilot plant for gasification of waste and associated characterizations. Non-destructive evaluation laboratory (ultrasound, eddy current, radiography, etc). Water chemistry and microbiology laboratory. Infrastructure also includes computational modelling tools and

associated licenses (such as COMSOL, TOUGH2, TOUGHREACT, GEMS, @Risk, Abaqus/Ansys, GOLDSIM, Geochemists's Workbench, Serpent, ORIGEN, FDS2FEM, etc).

NOTE! VTT has "Large Research Infrastructure" (LRI) costs calculated based on working hours of the project and according to VTT's ex-ante assessment of the methodology on Direct Costing for Large Research Infrastructures (LRI), approved by the Commission on 24th February 2015.

VTT's methodology on LRI complies with the clauses of the H2020 Grant Agreement (Capitalised and operating costs of large research infrastructure Article 6.2.D.4, the extent verified during the audit) and therefore, the LRI costs should be considered as direct costs of the project.

LRI Rf Nuclear Safety description: Centre for Nuclear Safety (CNS) will include class A, B and C facilities for experimental research and handling of radioactive materials. Research facility consists of hot cells and equipment used in CNS. Hot cells that protect employees from radiation are situated in class A laboratory in two separate floors. Equipment that are used to examine the properties of radioactive material samples are located inside the hot cells. Samples are handled behind lead glass utilizing manipulators and cameras. Opening of transport capsules of radioactive materials, storing of radioactive samples and specimens as well as handling of radioactive waste will also occur in class A laboratory. A Comprehensive set of microscopes will be linked to the class A laboratory.

if operational capacity cannot be demonstrated at the time of submitting the proposal, describe the concrete measures that will be taken to obtain it by the time of the implementation of the task.

N/A

	No	Name	Acronym
Participant	51	VUJE, a.s.	VUJE
Description of the legal entity VUJE a.s. is an engineering company that performs design, supply, implementation, research and training activities, particularly in the field of nuclear and conventional power generation.			
Description of main tasks in EURAD-1, with an explanation of how its profile matches the tasks VUJE, a.s. shall be involved in Task No. 3 “Description and comparison of radwaste characterisation approaches”. Its profile matches the following subtasks: - Identification of characterisation techniques for radioactive waste (selected in Task 2); - Comparison of the characterisation methods applied for the same radioactive waste in different counties; - Analysis of the existing approaches and identification of the knowledge gaps; - Recommendations for the future R&D to eliminate knowledge gaps; - Recommendations for characterisation approaches for countries with non-developed waste management concept.			
a curriculum vitae or description of the profile of the persons, including their gender, who will be primarily responsible for carrying out the proposed research and/or innovation activities Dr. Pítrský is a senior research worker with wide experience in implementation of safety analyses of RAW management facilities. He has detailed knowledge of decommissioning and radioactive waste management, including legal aspects and practical skills in safety assessment. Since 1997, he has been involved in numerous projects in Slovakia and abroad. He is author/co-author of more than 120 papers and studies in: - safety assessment of the radioactive waste repositories, - identification of the appropriate waste management concept, - development and improving models and computer codes.			
a list of up to 5 relevant publications, and/or products, services (including widely-used datasets or software), or other achievements relevant to the call content Publications: • Novak, M., Pítrský, J., Daniska, V., Juhar, P.: Conditional Clearance of Radioactive Demolition Waste in Motorway Scenario. Progress in Nuclear Science and Technology, Volume 4 (2014) pp. 854-857, ISSN: 2185-4823, April 2014. • Pítrský, J., Nečas, V.: Impact of Advanced Nuclear Fuel Cycle IMF on Geological Repository Performance. In: Progress in Nuclear Energy, Volume 54, Issue 1, January 2012, pp. 36-40. • Pítrský, J., Frankovská, J.: Derivation of clearance levels for solid radioactive materials from nuclear installations decommissioning. Proceedings of the 20th International Conference on Nuclear Engineering ICONE20, July 30 - August 3, 2012, Anaheim, California, USA • Pítrský, J.: Radiological Limits and Conditions for Conditional Release of Materials from Nuclear Installations Decommissioning. 15th Regional Seminar on Radioactive Waste Disposal. Třešť, 4-6 September 2012. • Matejovic, I., Hok, J., Madaras, J., Slaninka, I., Pítrský, J.: Status of the Deep Geological Disposal Program in the Slovak Republic. In: Geological Challenges in Radioactive Waste Isolation. Fourth Worldwide Review. Ernest Orlando Lawrence Berkeley National Laboratory, University of California Berkeley, California 94720 U.S.A. April 2006. Report LBNL-59808, pp. 173-190. • Pítrský, J., Matejovič, I., Ondra, F., Nečas, V.: Safety assessment of gas producing radioactive waste disposal. In: Journal of Electrical Engineering No. 4/2006. ISSN 1335-3632.			
a list of up to 5 relevant previous projects or activities, connected to the subject of this proposal • CND - Coordination Network on Decommissioning of Nuclear Installations • IPPA - Implementing Public Participation Approaches in Radioactive Waste Disposal • SITEX - Sustainable network for Independent Technical Expertise of Radioactive Waste Disposal - Interactions and Implementation			

• SAPIERR – Support Action on a Pilot Initiative for European Regional Repositories • CONRELMAT - Conditional Release of Materials • Alliance - ALLEGRO Implementing Advanced Nuclear Fuel Cycle in Central Europe • COMPASS - The Comparison of Alternative Waste Management Strategies for Long-lived Radioactive Wastes • ARGONA - Arenas for Risk Governance • RedImpact – Impact of Partitioning, Transmutation and Waste Reduction Technologies on the Final Nuclear Waste Disposal • BIDSF - Bohunice International Decommissioning Support Fund: ○ B6.1 The V1 NPP Conceptual Decommissioning Plan, ○ B6.2 The Environmental Impact Assessment Report of V1 NPP Decommissioning, ○ B6.3 The V1 NPP Decommissioning 1st Stage Plan & Other Documentation
a description of any significant infrastructure and/or any major items of technical equipment, relevant to the proposed work; Laboratory: - Test laboratory for radiation dosimetry - Test laboratory for chemical regimes and physiochemical analysis - Calibration laboratory temperature and pressure gauges - Test laboratory for chemical regimes and physiochemical analysis Software: - software intended for radiation safety assessment (GoldSim, AMBER), - PRIMAVERA, MS Project, MS Office, - OMEGA - computer code for decommissioning calculations, - graphics (AutoCAD, Adobe Photoshop, Corel Paint Shop Pro, Graphic Surfer), - relational databases (Oracle).
if operational capacity cannot be demonstrated at the time of submitting the proposal, describe the concrete measures that will be taken to obtain it by the time of the implementation of the task. N/A

4.2.Third Parties involved in the project

1/ Andra

Does the participant plan to subcontract certain tasks (please note that core tasks of the project should not be sub-contracted)	Y
The subcontractors have been selected in accordance with the requirements of Article 13 of the grant agreement. Andra plans to subcontract the following activities under WP1 – Programme Management: - Andra plans to get support from TBEEnvironmental Services Ltd for its work under WP1 and more specifically under: • task 3 - Extension/update of the Roadmap/SRA; • task 4 - Identification of Experts; • task 5 - Internal communication/meetings and • Task 6 – Dissemination. Total budget: around 207 877,50 € - As specified in the Consortium Agreement Andra plans to get support from a Chief Scientific Officer and an External Advisory Board. Piet Zuidema has been proposed as CSOff. External Advisory Board members were approved by EURAD General Assembly: Pierre Toulhoat (Chair), Hans Wanner (Co-Chair), Philippe Lalieux and Saida Engström. Total budget: around 200 000 € (150 000 € for CSOff and 50 000 € for EAB members) - A temporary Roadmap advisory committee is planned. The foreseen subcontractors are Johan Andersson and Neil Chapman. Total budget: 30 500 € - External experts will be requested for SoK documents (demonstration cases, roadmap documents), Guidance documents (See task 4 of WP1). Total budget: 330 000 € (150 000 € for SoK and 180 000 € for Guidance) LMDC, as a linked third party of Andra, plans to subcontract part of Task 2 of WP MAGIC. TTT (=Toulouse Tech Transfer) will be involved in Task 2 to carry out degradation tests on fissured reinforced concrete in carbonated media. Total Budget TTT: 60 000 €	
Does the participant envisage that part of its work is performed by linked third parties	Y
BRGM is a public institute and acts as the French Geological Survey. It embraces activities in the field of applied Earth Sciences, e.g. geology, hydrology, hydrogeology, geochemistry, geophysics, biotechnologies, hydrometallurgy, and analytical chemistry. For 20 years, BRGM cooperates with Andra in the framework of a scientific partnership. Thanks to this partnership and its implication in many EU projects, BRGM has acquired internationally renowned experience in several fields including coupled geochemistry-transport modelling, validation of the concepts of storages, transfers of pollutants in the environment, performances of the barriers and durability of materials of the artificial barriers. Within EURAD, BRGM, as a linked third party of Andra, will be involved in - WP3 DONUT - o BRGM is the WP leader of DONUT and contribute to task 1 Coordination - o Task 2 - BRGM will 1) develop numerical schemes to include advective transport in reactive transport codes dealing with the presence of a charged diffuse layer in the porosity; 2) develop a Poisson-Nernst-Planck model in Openfoam and 3) make available a toolbox to the community to help in the interpretation of laboratory studies (e.g. in-situ	

experiment running in Underground Research Laboratories) with state-of-the-art reactive transport codes capabilities.

- Task 3 – BRGM will apply pore-scale and micro-continuum models to pore-scale data sets to derive Darcy-scale properties of electrochemical transport.
 - Task 4 - BRGM will investigate advanced techniques to take into account uncertainties from coupled process in nuclear waste disposal : development of surrogates in the time-space-parametric (such as polynomial chaos expansions (PCEs)), use of adapted method to sensitivity analysis with dependent parameters (estimation of a posteriori distributions in order to minimize the difference between observations and simulations)
- WP5 FUTURE
- Task 2 – Mobility: Task 2.3: BRGM will contribute as follows: Fine characterization of U-bearing phases/surfaces in clay-rocks and of radionuclides (or their stable isotopes counterpart). Adsorption processes on clay minerals surface using wet chemistry and spectroscopic, diffractometric and microscopic techniques. Unravelling of retention mechanisms from site localization as a function of chemical conditions and linking to the reversibility or irreversibility of the processes and thus the type of thermokinetic description that should be considered (surface adsorption, incorporation, co-precipitation etc.). Modelling of reversible adsorption processes using electrostatic surface complexation models adapted to the specificities of clay minerals surfaces.
 - Task 3 - Redox reactivity of radionuclides on mineral surfaces: BRGM is the leader of this task. BRGM could prepare and provide sample to the partners: an anionic, a cationic clay, and an iron oxide of interest for the partners. These samples could be provided in various Fe oxidation states (various Fe(II)/Fe(III) ratio and different structural location of Fe). The abundance and structural location of Fe(II) and Fe(III) will be determined using a combination of methods: Mossbauer spectrometry and chemical methods for macroscopic average Fe oxidation state, transmission electron, and diffractometric methods (powder X-ray diffraction and synchrotron techniques) to determine the crystal chemistry of the samples.
- WP7 HITEC:
- Task 3.2: [Andra (BRGM)] will measure swelling pressure during the hydration of a bentonite (Kunipia-G or MX-80) at temperatures between 100 and 150°C with solutions of different compositions (cations and ionic strength) using an oedometer cell suitable for X-ray tomography acquisition to visualize in situ the evolution of the microstructure evolution. Swelling experiments will be simulated accounting for both mechanical compaction, temperature changes, water flow and chemical effects. A comparison of modelling approaches will be made with the Charles University hypoplastic model for swelling clays.
- WP3 CORI :
- Task 2 Organic degradation –BRGM will perform g-radiolytic/hydrolytic degradation of Superplasticizer/PVC or IER with identification of degradation products by complementary work with ISTO
- WP2 ACED:
- Task 3.2 - modelling the selected reference experiments studied in subtask 3.1 and the evolution of a HLW waste package for vitrified waste consisting of a glass core encapsulated in an iron/steel canister and in contact with a cement or cement/clay backfill.
It will involve testing and comparing different conceptual models including different features (description of heterogeneities, e.g. voids) and processes, and/or waste alteration models and/or different corrosion models and/or degradation of concrete materials models and/or different reactive transport codes (PhreeqC, Hytec, Crunch, OpenGeoSys-GEM, etc.).

- Task 3.3 - modelling the long-term chemical evolution of ILW waste packages and to provide upscaled effective parameters for usage in disposal cell scale reactive transport models. investigate the chemical evolution considering different scenarios and different processes. This task will involve testing and comparing different models, including different features and processes, like waste alteration models, corrosion models or concrete degradation models with different reactive transport codes. The choice of scenarios and processes has to be coordinated with task 4 in order to avoid inconsistencies between waste package and disposal cell scale. The planned scenarios are related to intermediate storage of waste packages (important for definition of initial state at emplacement), after emplacement the evolution under fully liquid saturated conditions and the evolution under partially saturated conditions.

LMDC (University Paul Sabatier, Toulouse III) is a French academic laboratory in civil engineering with 150 persons. LMDC is a laboratory specialized in characterization of construction materials from micro-scale to structural scale, including chemo-mechanical model developments. LMDC participates to the MAGIC project as LTP of ANDRA. The MAGIC program will be affected to the pole Material and building durability.

Andra has a long collaboration with the LMDC on experiments and simulation of specimens and concrete structures under leaching conditions. For the latter a large number of characterization and computing equipment's will be available for MAGIC.

Andra is proposing jointly with LMDC (3rd part of Andra) and other partners to study the chemo-mechanical evolution due to the effect of corrosion (through mechanical degradation with / without carbonation) of the reinforced concrete with/without loading, with/without mechanical degradation.

The studied scenario will be displayed in all the tasks, in a way to guarantee a complete interface from the nano to macro scale testing program until the structural modelling scale.

In order to assess the chemo-mechanical evolution of concrete structures, LMDC will work mainly for task 4 and 2. The main objective of LMDC is, starting from its current finite element model for homogenized reinforced concrete (CEM I) implemented in code Castem, to build a macroscopic chemo-mechanical model able to assess aging of reinforced concrete structures subjected to chemical and mechanical damages. Among the considered damages are the degradations of the concrete matrix by underground water and the corrosion of steel reinforcements due to atmospheric carbonation, in link with other partners' contributions. The aim is to study the mechanical impact of the corrosion (experiments of ANDRA-LMDC in task 2) and of the matrix evolutions (experiments and micro modelling with an other partner in task 3) on mechanical behaviour of homogenized reinforced concrete, including damages of steel-concrete-steel interfaces, crack openings and transfer properties evolutions during mechanical and chemical damages evolutions. In addition to samples prepared in the laboratory (tensile tie and pull out test), Andra will provide specimens chemically degraded taken from Andra's URL in Bure.

EMSE-Laboratoire Georges Friedel (CNRS UMR 5307)

The Georges Friedel Laboratory (LGF, CNRS UMR 5307) is a unit of the French National Center for Scientific Research (CNRS). Located at the École des Mines de Saint-Étienne and under the administrative authority of both École des Mines de Saint-Etienne / Institut Mines-Télécom (EMSE/IMT) and CNRS, the laboratory gathers all of the potential of EMSE in the fields of Materials Science, Mechanics and Process Engineering. LGF is an academic research actor, in strong partnership with Industry, being one of the major actors in addressing the following issue: Durability and energy efficiency of components and factory. From grain to factory / From material to component. The research unit is structured into 6 instrument platforms and 6 technological and digital platforms to support research activities, organized into 4 research teams. The laboratory at a glance: 345 teacher-researchers, 50 engineers, technicians or administration people, and 60 graduate or post-graduate students. 70 "Web of Science" publications a year. 20 PhD Theses a year. A budget of 2 M€ a year, of which 50% comes from industry.

EMSE, as a linked third party of Andra, will contribute to task 2 on novel materials program (silica-alumina ceramics and copper:alumina coatings) as in-kind contribution against payment. The proposed work will be done on the premises of EMSE. EMSE will be involved in Task 2 in both two subtasks and will aim to improve and better understand the properties of novel materials for nuclear waste containers: - subtask 2.1: in this task based on ceramic applications for container, work will be to enforce microwave processing for ceramics sealing, using the materials developed at CNRS (IRCER). This EMSE work will be based on the results obtained in previous project, who selected sealing materials (glass compositions) for their ability to couple with microwaves and their performance against radiations and lixiviation. In a first step, the work will consist in performing microwave heating on isolated materials to test their ability to couple with microwaves. In parallel, the dielectric properties of the materials and their temperature dependence will be measured using an experimental set-up currently in development at LGF. Then, sealed ceramics will be prepared by heating the sealing materials in a microwave furnace. The last point of the proposal for subtask 2.1 is the characterization of the sealed assemblies. Mechanical properties of the assemblies (4-points bending on samples extracted from the sealing area and ultrasonic testing on bulk materials to evaluate the elastic modulus) and lixiviation tests will be realized on the assemblies. The data acquired will be transmitted to WP6 for integration of ceramics in new concepts. - subtask 2.2: The proposal aims to the development of a Cu-Al₂O₃ corrosion barrier coating for nuclear waste container obtained by cold spray coating method. It covers both the process aspects of the coating and its corrosion performance under long-term storage conditions in deep geological repositories, in anoxic and aerated-to-anoxic conditions. The conditions of localized corrosion and stress corrosion cracking under mechanical loadings will be particularly studied insofar as intrinsic defects in the microstructure of porosity-type (less than 1% porosity but still present), or other scratch-type defects often at the origin of these phenomenon, may be present in the coatings. The work will be organized in three main parts: Part 1: Studying cold spray deposition process of Cu + alumina Part 2: Studying corrosion and localized corrosion of cold spray coating in deep geological repository conditions Part 3: Studying stress corrosion cracking in deep geological repository conditions	
Does the participant envisage the use of contributions in kind provided by third parties (Articles 11 and 12 of the General Model Grant Agreement)	N
Does the participant envisage that part of the work is performed by International Partners (Article 14a of the General Model Grant Agreement)?	N

2/ ARAO

Does the participant plan to subcontract certain tasks (please note that core tasks of the project should not be sub-contracted)	N
Does the participant envisage that part of its work is performed by linked third parties	N
Does the participant envisage the use of contributions in kind provided by third parties (Articles 11 and 12 of the General Model Grant Agreement)	N
Does the participant envisage that part of the work is performed by International Partners (Article 14a of the General Model Grant Agreement)?	N

3/ BEL V

Does the participant plan to subcontract certain tasks (please note that core tasks of the project should not be sub-contracted)	N
Does the participant envisage that part of its work is performed by linked third parties	N

Does the participant envisage the use of contributions in kind provided by third parties (Articles 11 and 12 of the General Model Grant Agreement)	N
Does the participant envisage that part of the work is performed by International Partners (Article 14a of the General Model Grant Agreement)?	N

4/ BGE

Does the participant plan to subcontract certain tasks (please note that core tasks of the project should not be sub-contracted)	N
Does the participant envisage that part of its work is performed by linked third parties	N
Does the participant envisage the use of contributions in kind provided by third parties (Articles 11 and 12 of the General Model Grant Agreement)	N
Does the participant envisage that part of the work is performed by International Partners (Article 14a of the General Model Grant Agreement)?	N

5/ CEA

Does the participant plan to subcontract certain tasks (please note that core tasks of the project should not be sub-contracted)	N
Does the participant envisage that part of its work is performed by linked third parties	Y
EDF (<i>Electricité de France</i>) group is the world's leading electricity company and global leader for low-carbon energy production. Particularly well established in Europe, especially France, the United Kingdom, Italy and Belgium, as well as North and South America, the Group covers all businesses spanning the electricity value chain – from generation to distribution and including energy transmission and trading activities – to continuously balance supply and demand. The R&D Division is made up of 13 technical departments. Their skills cover all the Group's field of activities: renewable energies and storage, networks, nuclear generation, thermal, hydropower, energy management, environment. EDF and CEA are linked through a cooperation agreement, which includes research activities on radioactive waste and spent fuel management, and on the behaviour of engineered/natural barriers in disposal. The tasks performed by the third party concern thermo-mechanical modelling of clay rocks. EDF will contribute to the development of numerical methods for high performance computing of coupled processes (WP DONUT), to numerical modeling of gas induced damage and self-sealing of barrier (WP GAS), and to the benchmark exercise on THM modelling of effect of temperature in near and far field using the code_Aster. EDF launched a glass/steel/cement buffer/clay experiment in April 2018. In the framework of WP ACED, EDF will provide characterization of this experiment at various time steps, in collaboration with CEA. This experiment is complementary to the long-term glass/steel/clay experiment, proposed by CEA. Since a long-time, ORANO Cycle (previously AREVA-NC) has been the industrial partner of CEA in the development of innovative processes and technologies for the nuclear fuel cycle, from the mine to the treatment of spent fuel. ORANO Cycle develops solutions for the management of radioactive wastes produced by spent nuclear fuel treatment operations. The most famous one is the vitrification process developed for the confinement of high-level wastes. In parallel, ORANO Cycle develops also new conditioning processes for ILW. In the framework of EURAD, ORANO Cycle will contribute to the WP ROUTES by sharing its experience on methodologies of characterization of radioactive wastes and waste conditioning. ORANO is particularly involved in the task dedicated to the development of shared solutions in European countries for the management of radioactive wastes.	
Does the participant envisage the use of contributions in kind provided by third parties (Articles 11 and 12 of the General Model Grant Agreement)	N
Does the participant envisage that part of the work is performed by International Partners (Article 14a of the General Model Grant Agreement)?	N

6/ CIEMAT

Does the participant plan to subcontract certain tasks (please note that core tasks of the project should not be sub-contracted)	N
Does the participant envisage that part of its work is performed by linked third parties	Y
Third Party: The Spanish National Research Council (CSIC) is a public institution dedicated to research in Spain. Belonging to the Spanish Ministry of Science, Innovation and Universities through the Secretary of State for Universities, Research, Development and Innovation, its main objective is to develop and promote research that will help bring about scientific and technological progress, and it is prepared to collaborate with Spanish and foreign entities in order to achieve this aim. The Institute for Construction Sciences “Eduardo Torroja” (IETcc) belongs to CSIC. Its mission is to develop research and technology in the construction field infrastructures and its materials. The IETcc is specialized in: physic-chemistry of cement and concrete, raw materials, sustainability, nanotechnology and multifunctional building materials, structural engineering, risk and safety of structures, roads, building energy saving, environment, durability, circular economy and life cycle analyses. • Link of the participant to the third party: CSIC and CIEMAT subscribed a framework agreement entitled “Convenio marco de colaboración entre el centros de investigaciones energéticas medioambientales y tecnológicas y el consejo superior de investigaciones científicas” and since June 1989 with ref. UCA1989010008 that establishes the will and conditions for continuous collaboration in the research in all the fields of CIEMAT R&D including nuclear technology. The framework agreement is every 4 years updating and both institutions have used this agreement to collaborate in a number of projects on research programs cooperation, nuclear advice and management, personal exchange and training in different areas of nuclear research including topics on waste management. • Tasks to be performed by the third party: 1.- Cement-Organics-Radionuclides-Interactions (CORI). Within this WP, CSIC will contribute in Task nº3 - Organics-Cement-Interactions. CSIC will study the interactions that take place between different organic species (tentatively ISA, Acetate, EDTA and carboxylic acid) when they are incorporated (individually and combined) into HCP (CEM V, with pH < 12.5 and alkali-free as possible) through different transport mechanisms (adsorption, natural diffusion and electrically-driven diffusion). In addition to the plain cement, twin samples with an extra addition of Fe will be incorporated when casting to decipher the role of iron. 2.- Assessment of chemical evolution of ILW and HLW disposal cell. T2: Steel Concrete Interface: The CSIC contribution consist in the study the chemical evolution of the steel corrosion phenomena due to the interaction with the concrete in variable environmental conditions: Concrete pH, type of aggressive ion, T^a, moisture content and oxygenation level) will be under the focus of research. The main objective is to obtain reliable kinetic and microstructural data of the relevant parameters causing steel corrosion and further instability in the concrete that allow to understand the phenomena occurring at the interface and contribute to the modelling of the long-term service life of the repository. 3- WP-16 MAGIC: CSIC will contribute to Task 4, being sub-task leader of ST4.2 on Upscaling methods from nano to micro to REV. The main tasks will consist in developing a novel multi-scale method, perform predictive modelling of multi-scale hydro-chemo-mechanical behaviour of cementitious materials (concrete) under repository conditions using the developed multi-scale framework (in collaboration with UFZ), and to calibrate and test the developed numerical framework using experimental data described in the literature or provided by partners in Task 2 and Task 3 (in collaboration with UFZ). Third Party: Universidad Politécnica de Cataluña (UPC) is a public university created in March 1971, aims to offer high-quality training and education leading to prestigious degrees, diplomas and courses. Regarding research and technology. The research group of the Geotechnical Engineering and Geosciences Division of the Department of the Department of Civil and Environmental Engineering has developed an	

advanced state-of-the-art in-house computer code (CODE_BRIGHT) able to perform coupled thermo-hydro-mechanical (THM) analyses. The code also incorporates constitutive laws appropriate for the description of the behaviour of the types of material involved in nuclear waste disposal. The group has an advanced laboratory to perform THM tests on materials often used in radioactive waste disposal such as bentonite and argillaceous rock. The group has also access to facilities such as ESEM (environmental electron microscope) and MIP (mercury intrusion porosimeter) to determine microscopic features of the materials.

- Link of the participant to the third party: UPC and CIEMAT subscribed a framework agreement entitled “Convenio marco de colaboración entre el centros de investigaciones energéticas medioambientales y tecnológicas (CIEMAT) y la universidad politécnica de Cataluña (UPC)” since February 2018 with ref.8266/2018 that establishes the will and conditions for continuous collaboration in the research in all the fields of CIEMAT R&D including nuclear technology. CIEMAT and UPC are using this agreement to collaborate in the nuclear research including topics on radiological protection, waste management, environment protection, computational studies, materials studies and fission & fusion Energy. In addition CIEMAT and UPC are members of the CEIDEN Spanish nuclear platform for nuclear research where they collaborate on the definition and development of research projects on nuclear technologies including aspects of the nuclear waste management.

- Tasks to be performed by the third party:

1.- Mechanistic understanding of gas transport in clay materials (GAS) into the Modelling of experimental work by CIEMAT will be developed by UPC team. The main effort will be devoted to the modelling of laboratory data sets in order to interpret the results and offer directions for future experimental work. The focus will be on the identification and quantification of the phenomena that govern gas flow behaviour. Heterogeneity will be introduced via consistent random and auto-correlated distributions of properties or parameters that will be coupled between them. A special type of finite element formulation will be used that allows the simulation of discrete gas flow paths embedded in a continuum. The information and expertise gathered during the performance of the modelling work will be put into operation in the final synthesis of the results and in the evaluation of the scientific achievements.

2.- Influence of temperature on clay-based material behaviour (HITEC) UPC will make available a recently developed advanced stress-strain law for clay rocks which includes non-linearity and plasticity before peak strength, softening after peak, anisotropy of stiffness and strength, creep (visco-elastic and visco-plastic) and permeability variation due to damage and self-sealing. The law will be further developed by introducing thermo-plasticity. Another key development will be the simulation fracture generation due to overpressure and/or temperature and their propagation. A non-local formulation has proved capable of predicting the development and propagation of discontinuities under isothermal conditions. The formulation will be generalised to include specific thermal effects taking into account the variation of permeability in the discontinuity.

Third Party: Universidad Autónoma de Madrid (UAM) hosts one of the largest scientific communities in Spain whose research meets international standards which is recognized as “Campus de Excelencia” that incorporates highly qualified research groups from the Spanish National Research Council (CSIC).

- Link of the participant to the third party: UAM and CIEMAT subscribed a framework agreement “Convenio de colaboración entre la Junta de energía nuclear (CIEMAT) y la Universidad Autonoma de Madrid” since October 1985 with ref. 25/84 that establishes the will and conditions for continuous collaboration in the research in all the fields of CIEMAT R&D including nuclear technology. The framework agreement is still valid and CIEMAT and UAM have used this agreement to collaborate in a number of projects on different areas of nuclear research including topics on waste management.
- Tasks to be performed by the third party: 2.- Influence of temperature on clay-based material behaviour (HITEC) into the Task 3.1 UAM will focus on the post mortem analyses of the laboratory-scale thermo-hydraulic cells performed by CIEMAT in Task 3.3, mainly concerning mineralogical

changes that could explain the macroscopic changes observed. The research group involved, belonging to the Department of Geology and Geochemistry in the Faculty of Sciences, is devoted to the study of geochemical reactions in the clay-waste system. The group has expertise, acquired during at least 20 years, in mineralogy and geochemistry of clay minerals (sheet silicates, oxides, zeolites, salts...). In this field they manage the main techniques used for materials characterization, including XRD, surface analysis and electron and optical microscopy.

Third Party: IDOM Nuclear Services is an area of IDOM Consulting, Engineering and Architecture company. Its experience in the nuclear sector has its origins in the early nuclear generation projects in Spain in the late 70s and 80s. IDOM NS develops projects where effective protection measures are integrated at all stages of the life cycle of nuclear fuel and radioactive waste: Ageing Management, Operation Consultancy, Engineering, Accident Evaluation, Project Management, Advanced Analysis, Decommissioning.

- Link of the participant to the third party: IDOM and CIEMAT have subscribed a framework agreement since April 2011 that establishes the will and conditions for continuous collaboration in all activities related to the Nuclear field. The framework agreement is removable and still valid and both institutions are using such agreement to collaborate in a number of projects on different areas of nuclear research including topics on waste management and training. In addition CIEMAT and UPM are members of the CEIDEN Spanish nuclear platform for nuclear research where they collaborate on the definition and development of research projects on nuclear technologies including aspects of the nuclear waste management.
- Tasks to be performed by the third party: Spent Fuel characterisation and evolution until disposal (SFC) IDOM will identify the main BWR and PWR fuel data that would affect the evolution of accidents, in order to understand the relationship between the data used in the fuel characterisation task and the accident analysis during storage, transport and fuel management. This activity (included in Subtask 4.2) contributes to the main goal of the WP helping to understand fuel behaviour under normal and postulated accident scenarios.

Third Party: Technical University of Madrid, (UPM) is the largest Spanish technological university as well as a renowned European institution. With two recognitions as Campus of International Excellence, it is outstanding in its research activity together with its training of highly-qualified professionals, competitive at an international level. More than 2,400 researchers carry out their activity at the UPM, which is committed to transforming this knowledge into advances applied to the production sector.

- Link of the participant to the third party: UPM and CIEMAT has been collaborating under the framework agreement entitled “Convenio de cooperación científica entre la Junta de energía nuclear (CIEMAT) y la Universidad politécnica de Madrid” since November 1983 still valid that establishes the will and conditions for continuous collaboration in the research in all the fields of CIEMAT R&D including nuclear technology. The framework agreement is still valid and CIEMAT and UPM have used this agreement to collaborate in a number of projects on different areas of nuclear research including topics on waste management. In addition CIEMAT and UPM are members of the CEIDEN Spanish nuclear platform for nuclear research where they collaborate on the definition and development of research projects on nuclear technologies including aspects of the nuclear waste management.

- Tasks to be performed by the third party:

1.- Spent Fuel characterisation and evolution until disposal (SFC) UPM group plans experiments on unirradiated cold-worked stress-relieved Zirlo™ cladding samples according to the following activities such as experimental reproduction on unirradiated cladding of the hydride geometry observed in spent fuel cladding, after discharge, drying, transport and long-term dry interim storage. Mechanical testing of pre-hydrided samples. It is proposed to perform ring compression (RCT) and three-point bending (TPB) tests on unirradiated pre-hydrided samples before and after the simulated drying treatment at three temperatures: 20°C (worst case), 135°C (representative of long term dry interim storage) and 300°C (representative of

operation conditions). 3. Analysis of failure mechanisms of unirradiated pre-hydrated cladding to elucidate the fracture micro-mechanisms. The fracture surfaces of broken samples after the ring compression and three-point bending tests will be studied by means of a scanning electron microscope (SEM). The three tasks are the ones that UPM group is going to perform in subtask 3.1 (Thermo-mechanical-chemical properties of the SNF rods and cladding) and therefore its profile matches perfectly the tasks defined in EURAD-1.

2.- Knowledge Management Work Package, UPM will provide educational materials and lectures developed by professors and teachers experts into the nuclear field.

Third Party: Universidad de Granada (umbrella agreement – Microbiological characterization) : The University of Granada (UGR), founded in 1531, is one of the largest and most important university in Spain. With over 60.000 undergraduate and postgraduate students and 6.000 staff. UGR offers a total of 89 bachelor degrees, 110 master's degrees and 28 doctoral programmes through its 123 departments and 27 centres. Consequently, the UGR offers one of the most extensive and diverse ranges of higher education programmes in Spain. The UGR has awarded with the "Human Resources Excellence in Research (HRS4R)", which reflects the UGR's commitment to continuously improve its human resource policies in line with the European Charter for Researchers and the Code of Conduct for the Recruitment of Researchers. UGR is also a leading institution in research, located in the top 5 of Spanish universities by a variety of ranking criteria, such as national R&D projects, fellowships awarded, publications, or international funding. The research group of Dr. Merroun possess large expertise in the field of Microbiology of deep geological repositories. They have been working in different research projects supported by EC (MIND, RADONORM) and Spanish government in the different aspects of the impact of microbial processes on the safety of Deep geological disposal of radioactive wastes.

- Task to be performed by the third party :

WP15-ConCorD: The work plan to be conducted by UGR team aimed to investigate the effect of gamma radiation and dry density on the microbial diversity and survival of microbial populations, particularly SRB, in compacted bentonites under different water saturated conditions. In addition, characterization of microbial sulfate reduction products (e.g., biogenic sulfides) on the bentonites studied will be conducted. The data obtained will allow as to determine dry density and gamma radiation dose threshold needed to reduce microbial presence and activity (particularly SRB) in compacted bentonites.

The team has all the needed facilities to conduct the different experiments proposed in this workpackage. These instruments and facilities include microbiological laboratories which are equipped with apparatuses for the cell cultivation, harvesting and cell disruption of cultures, a fluorescence microscope, 1D gel-electrophoresis systems including documentation, thermocyclers, nanodrop, microbiological cabinets and anaerobic glove boxes. In addition, the team will have access to the central facilities of the Scientific Instrumentation Center “Centro de Instrumentación Científica” at the University of Granada. This center has a globally unique state-of-the art microbiological cell biology (flow cytometry, etc.). This center provide access to microscopic techniques (STEM/HAADF, HRTEM/EDX, FESEM/EDX, ESEM), spectroscopic (XPS, ATR/IR, Raman, NMR, X-ray diffraction, etc).

WP16- MAGIC : UGR will collaborate with SCK CEN in task 3 to study the impact of microbial processes on the alteration of cement through the analysis of the presence of microbial biofilm on the surface of cement and through the identification of microbial generated alteration productions (sulfur attack, etc.). These studies will be conducted using a combination of microscopic techniques (STEM/HAADF, HRTEM/EDX, FESEM/Raman).

Does the participant envisage the use of contributions in kind provided by third parties (Articles 11 and 12 of the General Model Grant Agreement)	N
Does the participant envisage that part of the work is performed by International Partners ⁶ (Article 14a of the General Model Grant Agreement)?	N

⁶ International Partner' is any legal entity established in a non-associated third country which is not eligible for funding under Article 10 of the Rules for Participation Regulation No 1290/2013.

7/ ChRDI

Does the participant plan to subcontract certain tasks (please note that core tasks of the project should not be sub-contracted)	N
Does the participant envisage that part of its work is performed by linked third parties	Y
National Science Center Kharkov Institute of Physics and Technology, (NSC KIPT, PIC Number: 969818320, information about NSC KIPT on site: http://www.kipt.kharkov.ua/en). Kharkov Institute of Physics and Technology (the KIPT, earlier referred to as Ukrainian Institute of Physics and Technology), being one of oldest and largest centers of physical science in Ukraine, was created in 1928 for the purpose of developing urgent lines of research (at that time - nuclear physics and solid-state physics). By the decree of the President of Ukraine in 1993 the Institute was given the status of the first in Ukraine National Science Center (the NSC KIPT), and Cabinet of Ministers of Ukraine confirmed "Program on atomic science and technique of the NSC KIPT". According to the Decree, in the NSC KIPT on the basis of scientific departments there were formed the Institute of Plasma Physics, the Institute of Solid-state Physics, Materials Science and Technologies, the Institute of Plasma Electronics and New Methods of Acceleration, the Institute of Theoretical Physics, the Institute of High-energy Physics and Nuclear Physics. Also there were created R&D Complex "Accelerator", the Technological Complex "Nuclear Fuel Cycle", Research-and-production Complex of Renewing Sources of Energy, Division of Nonproliferation and International Relations, as well as corporation "Pyatikhatki" for marketing purposes. Significant part of research in the NSC KIPT is executed within the framework of international agreements, on contracts with foreign organizations and companies of the USA, France, Germany, Italy, Austria, Spain, Holland, Brazil, Poland, Korea, China, Japan. The Center supports and develops relations with research institutes of Moscow, Saint-Petersburg, Protvino, Novosibirsk (all - Russia), many international organizations and centers of science (IAEA, CERN, JLAB (USA), Joint Institute of Nuclear Research in Dubna), research centers of Uzbekistan and Kazakhstan. The Kharkov Institute of Physics and Technology conducts scientific research in the field of nuclear physics and solid state physics. And also is one of the most active participants in scientific and research work in the field of nuclear fuel cycle. Tasks to be performed by the third party: NSC KIPT - WP7- HITEC. NSC KIPT will contribute to work package: Task 3.1 Assessment of the impact of high temperatures over long time periods on the clay buffer properties, from specific laboratory tests. Task 3.2 Measurement/processes at high temperature + process modelling. Using data from T3.1 and T3.2, we will be able to develop the model to simulate material behaviour for temperatures more than 150 °C. Bentonite clay MX 80 will be used for reserach tests. The scientific institutes of Ukraine did not yet participate in the research programs of the European Commission. We do not have samples that were got before within the framework of joint researches with foreign partners. Therefore, the fresh samples of bentonite clay will be prepared for tests. We plan to use saturated and unsaturated samples with various dry densities: from 1400 to 1800 kg/m3. The maximal parameters of swelling pressure will be determined for each samples and relationship between	

initial dry density, water content and treatment time will be obtained. Analytical investigations will be carried out to investigate the structure and chemical/transport changes in bentonite during 150°C heat treatment.

WP15-ConCorD :

The KIPT contribution will be connected with participation in task 2: Identifying and testing novel container materials and processes. The entity will contribute to both subtasks of the novel material thematic (Ti, Cu, Cr, TiO₂ and CrN - based coatings, as well as SiC-based ceramics):

subtask 2.1: In this part, KIPT proposes to evaluate both ceramic coatings and bulk ceramic (SiC) solutions for overpacks.

For ceramic coating approach, the proposal activities are dedicated to:

- Optimization of the process to obtain ceramic (TiO₂, CrN) coatings on steel substrates by PVD method, preparation of a batch of specimens for corrosion tests.
- Studies of the structure and physico-mechanical properties of the obtained metal/ceramic coatings with the use of XRD, SEM, determining the micro- and nano-hardness (before and after corrosion tests)

For SiC bulk ceramic solution, the program will be:

- Optimization of the sintering process for manufacturing the composite materials based on SiC doped with Cr.

2. Institution State "Institute of Environmental Geochemistry of the National Academy of Science of Ukraine", (IEG NAS of Ukraine, PIC Number: 953812253, information about IEG NAS of Ukraine on site: <http://www.igns.gov.ua/>).

State Institute "Institute of Environmental Geochemistry of the National Academy of Sciences of Ukraine" (SI "IEG NAS of Ukraine") is a state (a public research organization, PIC: 953812253) nonprofit scientific institution with the rights of a legal entity.

SI "IEG NAS of Ukraine" is a leading scientific institution dealing with the problems of radioactive waste management, and ecological and radiation safety. The Institute is subordinated to the National Academy of Sciences of Ukraine as a part of the Nuclear Physics and Energy Department.

The Institute staff carries out fundamental and applied research on:

- scientific support of nuclear fuel cycle;
- geochemistry, radiogeochemistry;
- technogenic and environmental safety;
- problems of decontamination of territories and equipment;
- instrument-making in the sphere of nuclear, radiation and environmental safety.

Institute has contributed into development of the scientific basis for long-lived radioactive waste disposal in stable geological formations and technological concepts for creation of barrier materials for ensuring safety of radioactive waste repositories.

Since 2004, the Institute participates in the project "Technologies for the disposal of radioactive waste in underground research laboratories". The Institute supported the scientific program of the European Commission project "European Technology Platform - Implementation of the Geological Waste Disposal" and became its member (<http://www.igdt.eu>).

The Institute was responsible for management many international projects:

- CAST project (CARbon-14 Source Term #604779, 7 FP EURATOM)
- "Feasibility Study for an Underground Repository for Long-lived Non-heat-generating Radioactive Waste in Ukraine" / EUR 17631, Contract № B7-6340/95/001028/MAR/C3/, 1999.

Institute took part in coordinated research projects of IAEA:

- "Extrapolation of short term observations to time period's relevant to the isolation of long-lived radioactive waste ", IAEA-TECDOC-1177, IAEA, 2000; - "Characterization and performance studies and demonstration in underground research laboratories of swelling clays as engineered barriers of geological disposal", IAEA-TECDOC-1718, IAEA, Vienna, 2013; Tasks to be performed by the third party: SI "IEG NAS of Ukraine"- have been involved for many years in the characterisation and modelling of the thermo-mechanical behaviour of bentonite both through Ukrainian and IAEA projects. All the previous research experiments were limited to a temperature of 22°C. SI "IEG NAS of Ukraine will contribute to work package 7 - HITEC: Task 3.1 Assessment of the impact of high temperatures over long time periods on the clay buffer properties, from specific laboratory tests, two of the materials included in EURAD-1. Task 3.2 of the impact of elevated temperature (> 100°C) on geochemical mineralogical properties of a suite of different bentonites.	
Does the participant envisage the use of contributions in kind provided by third parties (Articles 11 and 12 of the General Model Grant Agreement)	N
Does the participant envisage that part of the work is performed by International Partners (Article 14a of the General Model Grant Agreement)?	N

8/ CNRS

Does the participant plan to subcontract certain tasks (please note that core tasks of the project should not be sub-contracted)	N
Does the participant envisage that part of its work is performed by linked third parties	Y
• Université de Poitiers (UPoitiers) Founded in 1431 by Pope Eugene IV, then confirmed by the patent letters of King Charles VII, the University of Poitiers consists from the outset of five faculties: theology, canon law, civil law, medicine and arts (letters). After the Revolution, which suppresses provincial universities, the University of Poitiers is reborn and enriched with new faculties: letters, sciences ... Today, the University of Poitiers, it is 28000 students, 4000 international students from 136 different countries, 3000 staff, 14 faculties, institutes and schools, 1000 professors-researchers, 1100 doctoral students, 37 laboratories, 8 doctoral schools, 2000 national diplomas, 180 PhD thesis defended each year, 500 partner institutions around the world and 1600 professional speakers participating in the teachings . • The Centre National de la Recherche Scientifique (CNRS) will participate in the EURAD WP Gas project via the IC2MP laboratory which is a Joint Research Unit (UMR 7285) between the CNRS and the University of Poitiers (UP). Thus the University of Poitiers is a third party linked to CNRS. Personnel with permanent positions in this project (Rochard Giot, Stephen Hédan, Baptiste Dazas) are employees from the University of Poitiers (UP). The Institute of Chemistry of Poitiers: Materials and Natural Resources (IC2MP) is a multidisciplinary research institute that specializes in the study of materials, the natural environment, and reactions. The Institute particularly focuses on the synthesis, decontamination and exploitation of natural resources. The Institute is composed of a total of ~250 persons including a staff of 100 researchers (75 faculty members from the University of Poitiers and 25 CNRS), 50 Engineers & Technician staff, ~80 PhD students and ~20 postdoctoral researchers. More specifically, they belong to the research tem E2 "HydrASA" of IC2MP laboratory. The IC2MP HydrASA team's scientific objective is the study of multiscale transfers in surface and sub-surface geosystems. The activities of the team are organized into three themes: ○ Functioning of reactive geosystems (soils, sedimentary basins, aquifers, hydrothermal systems and more widely alteration systems), ○ Properties and reactivity of clay mineral solutions systems ○ Spatialization and multi-scale modeling of reactive transfer.	

Reactive geosystems refer to a wide variety of natural objects with very different characteristic dimensions: clay minerals and their aggregates (from nanometers to hundreds of microns), clay soil profiles (from centimeters to tens of meters) and large geological systems (from a hundred meters to a hundred kilometers). The general topic of the team is the understanding and modeling of transfers in reactive geosystems, which is based on two strong cognitive issues: the relationship between the different scales of space brought into play through these objects and the integration large time scales (geological time) in its approaches. More specifically, the team is internationally recognized thanks to its ability to mobilize multiple skills (mineralogical, crystallochemical, microstructural and geomechanical) for the study of clay media and materials.

Link of the participant to the third party: The University of Poitiers is a co-partner together with the CNRS of the Institute of Chemistry of Poitiers: Materials and Natural Resources.

Tasks to be performed by the third party:

It contributes in WP6 GAS: experimental study of the micro-structural and mineralogical changes of claystones in relation with self-sealing and gas migration on the one hand, and to the micro-macro upscaling and development and implementation of a numerical HM model accounting for gas migration and self-sealing. It fits in the scope of the priorities of the research thematic developed and the IC2MP regarding the understanding of the microstructure of clays and clayey rocks as well as upscaling of their hydro-mechanical properties.

- **Université de Montpellier (UMontpellier)**

Since 800 years, the University of Montpellier (UM) has played important scientific and societal challenges. It is composed of 16 faculties, high schools and institutes. The 78 research units are involved in 9 scientific departments, working in the fields of science and technology, medicine, pharmacy, law, economy, sport and management. The university gathers 48,000 students and 4,800 employees (teachers, researchers and administrative). In the field of chemistry, the research activities are structured in the Pôle Chimie Balard composed by four institutes (Institute Charles Gerhardt, Institute of Biomolecules Max Mousseron, Membranes European Institute and Institute of Separative Chemistry). In particular, concerning the activities devoted to nuclear energy, the University of Montpellier is involved in the Institute of Separative Chemistry of Marcoule (ICSM, Joint Research Unit shared with CEA, CNRS and High School of Chemistry of Montpellier - ENSCM). This institute is involved in several aspects dealing with the nuclear fuel cycle (separative chemistry, nuclear materials, spent fuel reprocessing, waste management,...).

- Since ICSM is a Joint Research Unit (UMR in French) between CNRS, CEA, University of Montpellier and ENSCM, several researchers from the University of Montpellier will be involved in the project. The CNRS will solicit from University of Montpellier, i.e. 1 professor: Nicolas Dacheux and 1 assistant professor: Laurent Claparède, will be involved in the project and will particularly contribute to all the tasks included in the WP Spent Fuel Characterization and Evolution until Disposal.

Link of the participant to the third party: The University of Montpellier is a co-partner together with the CNRS, the CEA and the ENSC Montpellier Institute Max Planck Chemical Physics Solids of the Institute for Separative Chemistry in Marcoule.

Tasks to be performed by the third party:

It contributes in WP8 SFC: UMontpellier will be involved in in the WP Spent Fuel characterization and evolution until disposal (Subtask 3.2. Behavior of SNF pellets under interim storage conditions). The main actions proposed by CNRS and University of Montpellier deal with the development of a micro-/macro-dual approach to examine the role of several families of FP on the behavior of UO₂ sintered samples during leaching tests. The proposed action is divided in 3 parts. The first one focuses on the role of lanthanide elements incorporated in the UO₂ ceramic during alteration (especially in terms of chemical durability and surface reactivity modifications). The second one deals with the role of platinum group metals (PGM)

elements (especially as metallic particles) as well as molybdenum present in UO₂. The last aspect will be the role of perovskite type phase on the inventory of the released elements.

- **IMT Atlantique**

The **IMT Atlantique (IMTA)** is leading French engineering school, a public Technical University created on January 1, 2017 through the merger of the École nationale supérieure des mines de Nantes and Telecom Bretagne, administered by the french General Council for the Economy, Industry, Energy and Technologies. Research is organized within thirteen departments of teaching and research : Automation, Computer-Integrated Manufacturing and IT (Nantes), Electronics (Brest), Information Technology (Brest), Image and Data Processing (Brest), Languages and International Culture (Brest), The Logic of Practices, Social and Information Sciences (Brest), Microwaves (Brest; Toulouse), Optics (Brest), Subatomic Physics and Related Technologies (Nantes), Social Science and Management (Nantes), Signals and Communications (Brest), Energy and Environmental Systems (Nantes), Network Systems, Cyber Security and Digital Law.

- All tasks of the LTP IMTA in the EJP EURAD will be performed by the department SUBATECH, which is a Joint Research Unit with the CNRS, the IMT Atlantique and the University of Nantes, headed by Dr. Gines Martinez. Principal research subjects of Subatech are in the area of nuclear physics and radiochemistry. SUBATECH has a staff of about 190 engineers, scientists and technicians, including as well post docs and PhD students. Research on nuclear waste management of relevance for the EJP is conducted by the radiochemistry group which consists of a staff of about 40.

Link of the participant to the third party: IMT Atlantique is a co-partner together with the CNRS and the University of Nantes of the joint research laboratory Subatech.

Tasks to be performed by the third party:

- 1) It contributes in Participation in the WP1 PMO
- 2) WP2 ACED : Participation in Subtask 2.1 on Steel/clay material interface reactivity with the characterization of interface experiments and in the Subtask 2.2 on Steel/cement material interface reactivity IMTA participates in the characterization in existing interface experiments between Portland cement or grout cement in contact with steel in saturated conditions and in the subtask 3 (waste package scale), IMTA will support the CEA in the dismantling and characterization of an ongoing Glass/steel/clay experiment (5 year, 50°C) and it supports SCK.CEN in the dismantling and characterization of a glass/steel/cement system experiment, already ongoing since 30 month.
- 3) In the WP10 UNAM IMTA will contribute to the Subtask 2.3 on Methodological approaches to uncertainty and sensitivity analysis and IMTA is the leader of the task 3.1 Subtask 3.1 on the the identification of the types of uncertainties relevant to the safety analysis and the safety case. IMTA will participate also in task 4.3 on Preferences of the different actors on uncertainty management options
- 4) In the WP15 ConCorD IMTA will study the effect of gamma irradiation on the physicochemical evolution of the interface of container material and buffer. Traditional (copper, carbon steel) and novel materials will be used as well as the buffer material (bentonite, bentonite mixes, geopolymers). We have been studying the effect of gamma radiation on a variety of systems and materials under simulated repository-relevant conditions (dose rate, integrated dose, temperature, water saturation, water composition) for the last two decades. Among the materials investigated we distinguish waste matrices (spent nuclear fuel, nuclear glasses, ceramics, graphite), engineered barriers (cement, concrete, containers) and host rock (in particular clays). The interface material/buffer will be irradiated in a Cs-137 gamma irradiator under controlled atmosphere and relative humidity. The radiolysis products will be analysed, and the solid samples will be characterised. The main outcome would be the material corrosion kinetics and secondary phases that will be used for modelling activities.

Principal actors of IMTA in its role as LTP are:

-Abdesselam Abdelouas (CNRS/IMT-A, male) is Professor of Radiochemistry and Nuclear Materials at IMT Atlantique, and Head of the Radiochemistry Group at Subatech Laboratory,

Nantes. He graduated from the University of Strasbourg, and spent a US DoE-funded Postdoc working on radioactive waste management. He was named an Expert for the European Commission in the field of Education & Training for the nuclear sector. He is also Adjunct Professor at Mody University, India. He is coordinator of the recently accepted ERASMUS mundus project SARENA. He will participate in WPs ACED and GAS

-Bernd Grambow (CNRS/IMT-A, male) is Professor of Excellence at IMT Atlantique, Nantes, holding a Chair on nuclear waste disposal and former director of Subatech laboratory. He received his PhD from the FU Berlin, and held research positions at the Pacific Northwest National Laboratory, Hahn Meitner Institute Berlin, and Forschungszentrum Karlsruhe. He is an expert in radiochemistry, nuclear waste disposal science, geochemical modeling, and radionuclide migration in the environment. He will participate in the PMO and in UMAN.

- **Université de Lorraine (ULorraine)**

The Université de Lorraine (UL) is a large multidisciplinary university, open to international collaboration. With more than 3,700 teaching and research faculty and approximately 60,000 students, including nearly 8,000 foreign students, the Université de Lorraine (UL) is one of France's largest multidisciplinary universities. Its location in the heart of Europe, with borders on three European member states (Germany, Belgium and Luxembourg) offers to UL a privileged position for strong international partnerships. The scientific activity of UL is organized in 60 research laboratories located in 10 scientific centers and 6 research federations covering a wide range of disciplinary fields and topics. In addition, the university houses several technology platforms including large-scale facilities and large measurement instruments, providing research teams with the most efficient equipment. UL is committed to numerous European and international collaborations and exchanges, including multi-partnership projects and initiatives that, in many cases, go beyond European borders. UL is currently engaged in 15 European projects, including the Biomore, Lights, Newores, and EIT Knowledge and Innovation Community Raw Materials (Eurocore, TravelEx), more specifically in the scope of the NEXT program.

- The GeoRessources Laboratory is a Joint Research Unit which brings together Nancy's most important players in the field of Applied Geology having as supervising institutions the University of Lorraine and CNRS. GeoRessources employs a total of 190 personnel and orientates itself around three main research themes:

- "GeoModels" is a meeting-place for specialists in geometrical, geostatistical and physical-process modelling. The objectives are to forge strong collaborations between experts in digital and experimental simulation and to unite geometrical, inverse, hydrogeochemical and mechanical approaches.
- "Raw Materials" is a place for interaction and exchange between experts in the exploration, exploitation and treatment of carbon and mineral resources. Geologists, geochemists, metallogenists and mineralogists can interact freely with one another. The 'Raw Materials' mission is to develop models that explore upstream and downstream resource cycles.
- "GeoSystems" is a synergistic space that hosts experts in underground exploitation for the storage of waste and geothermal energy, as well as specialists in the hazards and risks associated with anthropogenic activity such as mining and excavation. Because the field of resource exploitation is developing like never before, it is essential that specialists from across the different research themes work together in finding new ways to minimize the environmental impact of resource exploitation.

The Geomodels and Geosystems themes conduct interdisciplinary research concerned with the use and management of the surface and sub-surface environment, with a strong focus on the safety of underground structures. Applications address local and national socio-economic issues, including geotechnics, environmental protection, and the surface and sub-surface storage of waste, CO₂ and H₂. The originality of the team's work lies in addressing these issues from the points of view of hydrodynamics and transfer mechanisms, as well as from poro-mechanics and geochemical perspectives.

Scientific goals of the Raw Materials theme concern a better understanding of: i) metals concentrations associated with crustal growth and evolution within the frame of plate

tectonics (multimethod approach combining field geology, structural analysis, petrology, geochemistry, geochronology), ii) the processes governing the extraction of metals from rock sources, their transport by fluid phases (speciation, especially through experimental studies, and spectroscopic monitoring, fluid origin), and iii) ore formation (PVTX reconstruction through integrated paleo-fluid studies (microthermometry, Raman, spectroscopy, LA-ICP-MS), thermodynamic and experimental modeling dating of ore stages), the overall data yielding to conceptual and numerical modelling of the genesis of ore deposits within their geologic and geodynamic contexts.

Link of the participant to the third party: The University of Lorraine is a co-partner together with CNRS and the research center CREGU of the GeoRessources laboratory.

Tasks to be performed by the third party:

It contributes in :

- WP2 ACED task 3, UL-GeoRessources, based on its strong experience on solid phase characterisation, proposes to use its platforms to rigorously and finely perform chemical and mineralogical analyses of solid phases coming from the dismantlement of experiments carried out by SCK/CEN on the Glass(SM359)/Steel/Cement. The goal is to highlight mineralogical transformations in the solid phases and at the different interfaces and to follow the chemical gradients along the materials and linked to the geochemical reactivity of the different phases in contact.
- WP6 GAS: UL-GeoRessources will conduct numerical simulations of multiphase fluid transport through deformable nanoporous geomaterials using a lattice-Boltzmann model applied to FIB-SEM images of actual material. Numerical results will be used to upscale effective properties (deformation-dependent saturation curve, relative permeability). Experiments will be also conducted to follow the evolution of damage and self-sealing processes in the argillaceous rock samples during gas injection and after shut-in using a high-resolution X-ray CT scanner.
- WP7 HITEC UL-Georessources will perform mechanical tests on different clay host rocks (Boom Clay, Opalinus Clay, Callovo-Oxfordian clay) to study the propagation of fractures at elevated temperatures (40 °C, 60°C, 80 °C, 100 °C), characterize fracture shape and size at different loading stages and self-sealing process. Tests will be conducted in a transparent triaxial cell under X-ray nano-tomography, on fractured samples (with two bedding orientations) mimicking the damage expected in the near field.

The short- and long-term thermo-mechanical behaviour of 2 claystones (Opalinus Clay, Callovo-Oxfordian claystone) will be investigated at elevated temperatures (40, 60, 80 and 100 °C). Short-term triaxial tests will allow characterising mechanical properties (failure criterion, elastic coefficients). Thermal profiles will be performed before and after TM tests with the optical scanning method to determine the evolution of thermal properties with damage. Long-term triaxial tests under 2 confining pressures (2 and 12 MPa) will allow characterising creep properties. For all tests, ultrasonic velocities and acoustic emissions will be measured to assess the evolution of elastic properties and then micro-cracking damage.

- **Université de Grenoble (UGrenoble)**

University Grenoble Alpes (UGA) is a public university created in January 2016 that aims to offer high-quality training and education leading to prestigious degrees, diplomas and courses. Regarding research and technology. The research group of ISterre laboratory has as a long experience on gas sorption (M. Didier PhD thesis (2012) – supervisor L. Charlet; IDEX innovation grant to L. Truche to study H₂ sorption on clay minerals applied to energy storage), clay minerals crystallography (BET, X-Ray, FIB-TEM, ATG-DTG, infer-red spectroscopy, neutron scattering at ILL), and hydrogen experiments (ATEX lab).

- UGA is a Linked Third Party of CNRS for the participation of its employees in the project within the unit ISterre. ISterre is a Joint Research Unit between UGA, CNRS, as well as USMB, IRD, and

IFFSTAR. ISTerre: 280 pers. including 108 researchers. Rank 18 in Earth Science (Shanghai). 3 main scientific priorities: 1) Understanding earthquakes, landslides, volcanic eruptions and Earth's Magnetic fields, 2) What is shaping the Earth? And 2) How rocks change as a function of natural and human constraints.

Link of the participant to the third party: The University of Grenoble is a co-partner together with the CNRS and the Grenoble INP of the 3SR laboratory and ISTerre.

Tasks to be performed by the third party: It contributes in :

- WP5 FUTURE: Measure hydrogen uptake by clay minerals (e.g. montmorillonite, illite, chlorite, Fe-serpentine) and clayrocks (bentonite, Callovo-Oxfordian claystone and Boom clays) as a function of H₂ partial pressure, temperature, water saturation (relative humidity), and presence of other gases competing for sorption (CO₂, CH₄, He). H₂ sorption isotherms will be measured over a wide range of pressure (typically from 1 mbar to 100 bar) to study the retention mechanisms and fundamental thermodynamic properties of the retention process (adsorption enthalpy, role of pore size distribution, crystallographic properties of the sorption sites).
- WP6 GAS: 2. Study the desorption processes to evaluate hydrogen mobility and retention mechanisms in clay-rich porous media.

Outcomes: 1) amount of hydrogen trapped in the disposal surroundings, 3) stability or reversibility of H₂ sorption with respect to near and far field perturbations (temperature, water resaturation, secondary minerals formation triggered by iron-clay interactions), and 3) positive and negative feedbacks of hydrogen sorption regarding: i) hydrogen overpressure and associated mechanical stress (in connection with tasks 2.1 and 3.1), ii) propagation of a redox front in the geological media, and iii) radionuclides mobility (in connection with WP FUTURE).

- **Université de Nice-Sophia Antipolis (UNice)**

Université Nice Sophia Antipolis is part of Université Côte d'Azur (UCA) which is a recently created cluster of higher education establishments on the French Riviera that brings together the major players in higher education and research on the Côte d'Azur. Université Côte d'Azur aims to develop a new, 21st-century model for French universities, based on new interactions between disciplines, a new form of coordination between research, teaching, and innovation, and strong partnerships with the private sector and local authorities. In January 2016, Université Côte d'Azur won a prestigious "IDEX" award from the French government for its UCAJEDI project, placing it among the top 10 world-class, comprehensive universities in France.

- The LJAD laboratory is a Joint Research Unit between the CNRS and Université Nice Sophia Antipolis (Laboratoire Dieudonné UMR 7351 CNRS), the mathematical laboratory of UCA, is structured around 6 research teams: Algebra, Topology and Geometry Geometry, Analysis and Dynamics, EDP and Numerical Analysis, Numerical Modeling and Fluid Dynamics, Probability and Statistics, Interfaces of Mathematics and Complex Systems. Bringing together 135 researchers and teacher-researchers, 16 administrative staff and research assistance engineers and 74 doctoral and post-doctoral students, the laboratory is also a partner of INRIA, of the CEA (CEA) under the LRC Fusion of the Doctoral School (EDSFA) and participates in many ANR projects. This project takes place in the LJAD team Partial Differential Equations and Numerical Analysis (around 40 permanent researchers and 20 PhD students) which has developed for a few years a group on geosciences applications including 2 permanent researchers, Konstantin Brenner and Roland Masson, and several doctoral and postdoctoral students. CNRS/INSMI/LJAD has specific roles in DONUT.

Link of the participant to the third party: The University of Nice-Sophia Antipolis is a co-partner together with the CNRS and INRIA of the LJAD laboratory.

Tasks to be performed by the third party:

- It contributes in WP4 DONUT to develop an efficient algorithm to couple a nonisothermal compositional liquid gas Darcy flow and a RANS nonisothermal compositional free gas flow. This type of coupled models plays a key role to study the mass and energy exchanges at the interface between the radioactive waste disposal and the ventilation galleries with two main objectives: to improve the modelling of the porous-medium desaturation and to model the variations of relative humidity and temperature in the galleries over a period of say one to two hundred years. A Domain Decomposition Method (DDM) has been developed during the postdoctoral position of Nabil Birgile ended in march 2018 in collaboration with Andra. It has been prototyped on 2D test cases with simple geometry and simple pipe flows with an algebraic turbulent model. The objective is to increase the complexity of the geometry and of the free flow using a code coupling strategy between the porous-medium code ComPASS co-developed by BRGM and LJAD-Inria and the free-flow code CimLib developed by the CFL team of CEMEF Mines ParisTech.

- **Université de Lille (ULille)**

Université de Lille is a public university created in January 2018 as a merging of 3 universities. It aims to offer high-quality training and education leading to prestigious degrees, diplomas and courses with wide disciplinary range.

Regarding research and technology. The research group on numerical analysis and partial differential equations of the Laboratoire Paul Painlevé (LPP, mathematic department) has built a strong expertise in numerical methods that remain accurate in the long time regim for dissipation driven systems, as well as on modeling based on variational principles. The team has a great experience in the certification of the numerical method it designs, thanks to mathematical proofs of stability, convergence and asymptotic behavior.

- LPP is a Joint Research Unit between Université de Lille and CNRS. LPP already experienced contractual collaborations with ANDRA and CEA on the numerical approximation of corrosion models. They particularly focused on the design of schemes implemented on the code CALIPSO which is the ANDRA and CEA reference code for the simulation of the Diffusion Poisson Coupled Model (DPCM) for corrosion.
- The LaMcube is a mixt research center of CNRS, University of Lille, and Centrale Lille, UMR9013. The actions proposed in this project will be realized by the team GEOM of the LaMcube. It is one of the most important research teams in the field of geomechanics in Europe, composed of 18 permanent staff members, more than 20 post-doctoral researchers and doctoral students.

The GEOM team has a high expertise on multiscale and multi-physical studies of cement-based and geological materials and structures on both experimental testing and modeling. In particular, we have developed a series of innovative multi-scale laboratory testing methods for the characterization of thermal-hydraulic and mechanical (THM) properties and of micro-structural evolutions of those materials under coupled THM and chemical actions. We have proposed different types of multiscale models for damage and plasticity description based on linear and nonlinear homogenization methods. Some of them are considered as reference models in related scientific community. We have also developed various advanced numerical methods and home-hold computer codes, in particular with the phase-field method, FFT-based method, and enriched finite element method (EFEM), for modeling cracking process in heterogeneous materials with thermal, hydraulic, mechanical and chemical actions. We have conducted and been involved in a number of French national research agency (ANR) funded and EC funded projects. We have also close scientific collaborations with leading industrial partners. Our team is publishing more than 30 papers per year in top international journals.

During the last decades, in the framework of scientific collaborations with Andra and other partners, LamCube have developed a series of multi-scale experimental studies and numerical modeling works for the description of short and long term thermos-hydromechanical (THM) behaviors of cement-based materials and structures. LamCube have in particular investigated effects of different chemical processes (carbonation, leaching and corrosion) on the THM behaviors in related with microstructural evolutions. LamCube have developed analytical and numerical homogenization methods for estimation of macroscopic THM properties of cement materials by considering materials heterogeneities (pores, aggregates, interfaces). LamCube have an efficient home computer code (THMPASA) being able to solve THM-chemical problems,

and also developed specific blocks in standard codes (Abaqus, COMSOL). LamCube have designed a series of testing devices for the realization of both macroscopic and microscopic laboratory tests on samples of different sizes and subjected to coupled THM-chemical processes. In particular, LamCube is familiar with the X-ray micro-tomography technique and digital volume correlation method for the characterization of 3D local strain fields during and post THM tests.

Link of the participant to the third party: The University of Lille is a co-partner together with the CNRS of the LPP Laboratory and the LamCube (Laboratoire de Mécanique, Multi-Physique Multi-échelle).

Tasks to be performed by the third party:

It contributes in WP4 DONUT: Even though the DPCM model is now a well established model for modeling the corrosion process in nuclear repositories, many fundamental questions still remain open. In particular, it is not clear if the model has an energy formulation of generalized gradient flow type as it would be expected in view of the large time scales. Such an energy formulation is key to guarantee the long-time behavior of the model. This motivates the following workplan.

- Task 1: Derivation of the energy, link with the DPCM model, mathematical results of existence of solutions and long-time behaviour of the DPCM model
- Task 2: Development of numerical methods based on the energetic formulation, validation of their energetic stability, study of the long time behavior
- Task 3: Implementation of the new methods in the electrochemical code CALIPSO, validation.
- Task 4: Investigation of the coupling with a reactive-transport model in porous media.

WP16- MAGIC: In this WP, the University of Lille is involved in three tasks. In task 2, they shall investigate the effects of chemical degradation (carbonation, microbial attack) on short and long term mechanical properties of OPC (CEM I) concrete, and the influences of initial mechanical damage (cracking) on carbonation process. A series of macroscopic compression and creep tests are performed on samples degraded by the chemical processes. The variations of elastic properties, compressive and tensile strength will be identified. In task 3, the University of Lille (via LamCube) shall perform micro-structural analyses and microscopic mechanical-chemical tests, in order to identify cracking patterns induced by mechanical loading and carbonation, micro-structural evolutions of interface zones around corroded armature, to determine 3D strain fields and local elastic properties variation in chemically degraded samples. A series of in situ micro-mechanical tests are performed by using x-ray micro-tomography imaging and digital volume correlation method. In task 4, the University of Lille shall develop a micromechanics-based constitutive model for OPC material by taking into account effects of microstructures (pores, aggregates, mineralogical compositions) by using analytical homogenization techniques. The local properties of constituents phases will be identified by using an artificial intelligence technique based method.

• **Université d'Orléans (UOrléans)**

University of Orleans, a public university, aims to offer high-quality training and education leading to prestigious degrees, diplomas and courses. In this university, the observatory of universe sciences (OSUC) is composed of two main laboratories. Among these, the “Institut des Sciences de la Terre d’Orléans” (ISTO). ISTO is a research laboratory in Earth Sciences, a Joint Research Unit (UMR) depending on three supervisory authorities (the Université d’Orléans, CNRS, BRGM). ISTO is leading two France-scale excellency projects (VOLTAIRE, 2012-2022; PLANEX, 2012-2019), two of the six platforms of one Région-scale excellency project (PIVOTS, Région Centre Val-de-Loire – Europe), the INSU national observatory “SO Tourbières”, and the “Val d’Orléans” site of the national observatory Karst. Our research reaches from Earth’s atmosphere and surface to the upper mantle with studies focusing on exchange processes at mantle-crust and crust-atmosphere interfaces. We are organized in five research teams. Among these, Continental Biogeosystem team has a long expertise in unraveling evolution of climates, ecosystems and human activities from organic matter and fossil molecules (biomarkers) preserved in lacustrine sedimentary archives. This team studies the stability of organic molecules, their sorption on clays and their transformation products under different environmental conditions. ISTO is involved, together with BRGM, in a partnership with ANDRA (CTEC and DRO project), to investigate the degradation of organic molecules in cementitious medias.

Link of the participant to the third party: The University of Orleans is a co-partner together with the CNRS of the CEMHTI laboratory (Extreme Conditions and Materials: High Temperature and Irradiation) located at Orleans and the ISTO laboratory.

Tasks to be performed by the third party:

- It contributes in WP3 CORI – Task 1 to study the effect of gamma irradiation on the degradation of superplasticizers and phthalate in cements and alkaline solutions in partnership with BRGM. The media considered would be alkaline (pH 12.5) in synthetic cement solutions. The various degradation media will be selected so as to form a consistent experience plan considering the following parameters: concentration of the molecule, redox conditions, nature of the alkaline/calc-alkaline cation and dose rate (1 kGy/h and 0.1 kGy/h). Degradation tests will be conducted on both irradiated and non-irradiated molecules and monitored as a function of time, up to 6 months. Analyses will be performed for the initial molecule and their degradation products. Degradation rates will be extracted from the experiments results, together with the production rates of the degradation products. ISTO beneficiaries from a cutting-edge organic geochemistry platform allowing bulk, molecular and isotopic characterization in a wide set of matrices and is able to develop detection and quantification methods adapted to a large range of organic molecules.

- **Université Jean Monnet - Laboratoire Hubert Curien (LHC) (UMR 5516)**

Université Jean Monnet Saint-Etienne is a multidisciplinary university (with health-sciences component) in a city of 450,000 inhabitants. Widely opened to its socio-economic environment, the University Jean Monnet welcomes 22,000 students and employs approximately 1,500 people. The Jean Monnet University is a founding member of the Center for Research and Higher Education (PRES) "University of Lyon" since July 2008. In the Rhône-Alpes region, it is the university that offers the widest range of courses. In line with its socio-economical surrounding, it promotes applied research in harmony with quality fundamental research, student training and a spirit of cooperation and partnership development. The research potential involves 34 research centers covering the main sectors and disciplines and it is based on a staff of 422 lecturers and researchers gathered in its research units. The development of contract research with companies and government agencies is a priority of the institution through the action of the Service Industrial and Commercial Activities (SAIC) that manages the valorisation of research activities of the University.

Université Jean Monnet Saint-Etienne is a multidisciplinary university widely opened to its socio-economic environment. The University Jean Monnet welcomes 15,000 students and offers a large range of courses. In line with its socio-economical surrounding, it promotes applied research in harmony with quality fundamental research, student training and a spirit of cooperation and partnership development. The research potential involves 34 research centers covering the main sectors and disciplines and it is based on a staff of 422 researchers

Created in 2006, the **Hubert Curien laboratory** is a joint research unit (UMR 5516) of the Jean Monnet University, Saint-Etienne, the National Research Centre "CNRS" and the Institut d'Optique Graduate School. It is composed of about 240 members who work on scientific topics related to optics, photonics and microwave, computer science, telecom and image.

The Hubert Curien Laboratory is a member of the LABEX (laboratory of excellence) MANUTECH-SISE and of the LABEX PRIMES and and the LABEX MILYON.

Based on its Knowledge, the Hubert Curien Lab will be responsible to explain and analyse optical fibre behaviour under radiation

Does the participant envisage the use of contributions in kind provided by third parties (Articles 11 and 12 of the General Model Grant Agreement)	N
Does the participant envisage that part of the work is performed by International Partners (Article 14a of the General Model Grant Agreement)?	N

9/ COVRA

Does the participant plan to subcontract certain tasks (please note that core tasks of the project should not be sub-contracted)	N
Does the participant envisage that part of its work is performed by linked third parties	Y
Delft University of Technology (TU Delft) With approximately 23,500 students and 5,200 staff, Delft University of Technology (TU Delft) is the largest university of technology in the Netherlands. The university covers virtually the entire spectrum of engineering sciences, divided across 40 departments in 8 faculties, and it offers an equally broad, high-quality array of degree programmes and unique facilities. The mission of the university is to contribute to solving global challenges by educating new generations of socially responsible engineers and expanding the frontiers of the engineering sciences. Description of the link between COVRA and TU Delft (including scientific and technical scope) COVRA have since 2012 sponsored the Faculty of Civil Engineering and Geosciences at TU Delft for work relating to research and education in the area of radioactive waste management. Several projects have been conducted within this scope of both national and international significance. A memorandum of understanding has been signed recently (between COVRA and TU Delft) to develop the relationship into a long term collaboration, with a focus on the following areas: • Investigation of technical feasibility of constructing a radioactive waste repository in the Netherlands. • Investigation of sub-surface layers (Boom Clay and other clay layers, and salt deposits). • Investigation of multi-physics processes occurring within a radioactive waste repository. • Education. Involvement of the TU-delft in GAS and the tasks to be performed (5-10 lines maximum) TU Delft is involved in three subtasks of the workpackage GAS, namely 2.2 (Advection), 3.3 (Model-based interpretation and synthesis of results) and 4.2 (Model assisted assessment of gas induced effects). In these subtasks, TU Delft will numerically investigate (using the FE code LAGAMINE) the effects of natural heterogeneities and induced discontinuities (able to self-seal) on the gas transfer mechanisms. TU Delft will back analyse laboratory experiments in order to feed in the development of a conceptual process model of gas-induced damage evolution and self-sealing processes for damaged or intact host rocks and EBS materials. Validation of this model will take place in a series of prediction-evaluation exercises, covering different loading paths in different geometric configurations. TU Delft will finally apply their numerical approach to a generic repository configuration with different sets of properties, conditions and scenarios. TU Delft will work with other partners in the EURAD project, who will also use the same computer code to harmonise the research efforts, and with partners inside and outside the project (where needed) to select appropriate experimental cases.	
Does the participant envisage the use of contributions in kind provided by third parties (Articles 11 and 12 of the General Model Grant Agreement)	N
Does the participant envisage that part of the work is performed by International Partners (Article 14a of the General Model Grant Agreement)?	N

10/ FTMC

Does the participant plan to subcontract certain tasks (please note that core tasks of the project should not be sub-contracted)	N
Does the participant envisage that part of its work is performed by linked third parties	N
Does the participant envisage the use of contributions in kind provided by third parties (Articles 11 and 12 of the General Model Grant Agreement)	N
Does the participant envisage that part of the work is performed by International Partners (Article 14a of the General Model Grant Agreement)?	N

11/ CV REZ

Does the participant plan to subcontract certain tasks (please note that core tasks of the project should not be sub-contracted)	N
Does the participant envisage that part of its work is performed by linked third parties	N
Does the participant envisage the use of contributions in kind provided by third parties (Articles 11 and 12 of the General Model Grant Agreement)	N
Does the participant envisage that part of the work is performed by International Partners (Article 14a of the General Model Grant Agreement)?	N

12/ DEKOM

Does the participant plan to subcontract certain tasks (please note that core tasks of the project should not be sub-contracted)	N
Does the participant envisage that part of its work is performed by linked third parties	N
Does the participant envisage the use of contributions in kind provided by third parties (Articles 11 and 12 of the General Model Grant Agreement)	N
Does the participant envisage that part of the work is performed by International Partners (Article 14a of the General Model Grant Agreement)?	N

13/ EEAE

Does the participant plan to subcontract certain tasks (please note that core tasks of the project should not be sub-contracted)	N
Does the participant envisage that part of its work is performed by linked third parties	N
Does the participant envisage the use of contributions in kind provided by third parties (Articles 11 and 12 of the General Model Grant Agreement)	N
Does the participant envisage that part of the work is performed by International Partners (Article 14a of the General Model Grant Agreement)?	N

14/ ENRESA

Does the participant plan to subcontract certain tasks (please note that core tasks of the project should not be sub-contracted)	Y
ENRESA plans to subcontract certain task to ENUSA and UDC. The subcontractors have been selected in accordance with the requirements of Article 13 of the grant agreement. Total budget of ENUSA: 208 750,00 € Total budget of UDC: 229 852,50 € <u>WP SFC</u> ENRESA will subcontract with ENUSA for Task 2: Fuel properties characterization / Develop, improve and demonstrate NDA methods/systems for SNF characterization. The contribution of Enusa to Task 2 will include the nuclide inventory by radiochemical analysis of a set of BWR SNF samples irradiated to an average burn-up of above 40 MWd/kgU, covering a range of initial enrichment and coolant void histories, as well as the modelling with SCALE and estimation of uncertainties. <u>WP ACED</u>:	

Task 1; State of the art. The contributions of UDC as subcontractor include: Task 1: 1) The compilation of previous modelling studies and 2) The identification of the remaining model uncertainties on the mineralogical alteration at the carbon steel/bentonite interface and 3) The proposal of a revised conceptual and mathematical model for the carbon steel/bentonite interactions which will be useful for other tasks of the WP

Task 2:

UDC as subcontractor will perform multicomponent geochemical reactive transport models (RTM) under saturated and unsaturated conditions of steel/bentonite laboratory experiments. The models will account for time-varying corrosion rates depending on ambient conditions (T, pH, Eh) and will be based on the revised conceptual and mathematical model of the steel/bentonite interactions identified in Task 1. The main outcomes include: 1) Improving the understanding of the dependence of the corrosion rate and the bentonite mineralogical alterations on thermal, hydrodynamic, solute transport and geochemical conditions; 2) Gaining confidence on RTM of the steel/bentonite interactions; and 3) Reducing the uncertainties of RTM. The outcomes of this task will be most useful for the modelling at the disposal cell scale (Task 4).

Task 4

UDC as subcontractor will perform multicomponent geochemical reactive transport models (RTM) of steel/bentonite, bentonite/concrete and concrete/clay interactions for a HLW repository in clay host rock and of steel/bentonite, bentonite/granite interactions for a HLW repository in granitic host rock. The model will be based on the revised conceptual and mathematical model of the steel/bentonite interactions identified in Task 1 and will incorporate the knowledge gained from the laboratory experiments of Task 2. The main outcomes include: 1) Improving the understanding of the geochemical evolution of the repository and the role of thermal, hydrodynamic, solute transport and geochemical conditions; 2) Gaining confidence on RTM; and 3) Reducing the uncertainties of RT

WP DONUT

Task 4:

UDC as subcontractor will contribute with innovative numerical methods for uncertainty and sensitivity analysis for coupled THC models (nonisothermal reactive transport models). The proposed methods include: 1) Adjoint-state methods and 2) Uncertainty quantification (UQ) methods. The main outcome of the UDC contribution is the development of innovative numerical methods for uncertainty and sensitivity analysis for coupled THC models.

Task 5:

UDC as subcontractor will contribute with benchmark test cases for the evaluation of the numerical tools and methods for coupled processes of relevance for the performance assessment of the engineered barrier of ILW and/or HLW repositories. The main outcomes of the UDC subcontractor contribution include: 1) Evaluation of the methods and tools derived in other tasks and 2) Evaluation of the efficiency of the numerical methods in terms of CPU time, ability to deal with large and complex problems at the disposal scale, comparison of multi-scale approaches and model uncertainties.

Does the participant envisage that part of its work is performed by linked third parties	N
Does the participant envisage the use of contributions in kind provided by third parties (Articles 11 and 12 of the General Model Grant Agreement)	N
Does the participant envisage that part of the work is performed by International Partners (Article 14a of the General Model Grant Agreement)?	N

15/ JUELICH

Does the participant plan to subcontract certain tasks (please note that core tasks of the project should not be sub-contracted)	N
Does the participant envisage that part of its work is performed by linked third parties	Y

Part of the work will be performed by linked third parties, namely: (1) Helmholtz Zentrum Dresden-Rossendorf, HZDR, (2) Helmholtz - Zentrum für Umweltforschung GmbH, UFZ. (3) The Helmholtz-Zentrum Potsdam Deutsches GeoForschungsZentrum, GFZ

The link of the participant to the above listed TLP is their **membership to the Helmholtz Association of German Research Centers**, which was founded in 1995 and is today one of the leading research organizations worldwide. The Helmholtz Association is a registered association of eighteen (18) legally independent research centers, funded by the German Federal Ministry of Education and Research (BMBF). The activities of the Helmholtz Association are governed by its statutes. With its programme-oriented funding (POF) system, in which cross-center research programs compete with one another for funding, the Helmholtz Association performs cutting-edge research in six research fields: Energy, Earth & Environment, Health, Aeronautics, Space and Transport, Matter, and Key Technologies. Further, the Helmholtz Associations enables research using their large-scale devices and infrastructure, cooperating closely with national and international partners.

Helmholtz Zentrum Dresden-Rossendorf, HZDR (PIC: 999470541) is a non-profit research organisation and a member of the Helmholtz Association of German Research Centers. It is funded by German Federal and Saxonian Authorities. HZDR is dealing with application-oriented basic research, focused on three major research fields: matter, energy, and health. It has been collaborating with JUELICH in various national and international projects. Within the national program HZDR and JUELICH are interlinked via the research program Nuclear Waste Management, Safety and Radiation Research (NUSAFE).

WP CORI: HZDR will study the influence of small- to middle-size organic molecules (EDTA, ISA and gluconate as reference) on the retention of radionuclides (U(IV, VI), Cm(III), Am(III)) by cementitious material (CSH, CASH) by the mean of complexation and batch sorption experiments. WP Spent Fuel: The local structure of the U oxides and of the FP secondary phases will be accurately determined by EXAFS and synchrotron XRD. WP DONUT: HZDR will deliver uncertainty quantifications and probability density functions for a variety on physico-chemical processes within THMC relevant et near and far field of a nuclear waste repository. This will be accompanied by the development of respective robust models. WP FUTURE: HZDR will carry out PET/ μ CT measurements using fractured samples with conservative and reactive tracers, interferometry/ confocal microscopy measurements of fracture surfaces, and petrographic analysis. In addition. The HZDR will perform sorption experiments, spectroscopy analyses, surface potential analyses, radiography analyses, and data reduction using the smart Kd concept. WP Strategic studies Uncertainties: HZDR will contribute to Subtask 2.2 by coordinating the work, organizing and participating in technical meetings, contributing to the compilation, assessment and improvement of approaches for the characterization and quantification of uncertainties associated with THMC models and leading the writing of the deliverable. KM WP - State-of-Knowledge: The HZDR together with the BGE are responsible for coordinating the EURAD Knowledge Management Platform, which is an Open-source knowledge sharing tool (IT system and associated management procedures) for organising and capturing key sources of knowledge on radioactive waste management.

WP ConCorD: HZDR consists of eight institutes, of which the Institute of Resource Ecology would like to participate in the ConCord proposal.

The Institute of Resource Ecology performs research to protect humans and the environment from hazards caused by pollutants resulting from technical processes that produce energy and raw materials. Among others the research of the Institute of Resource Ecology focuses on the ecological risks exerted by radioactive and non-radioactive metals in the context of nuclear waste disposal, the production of energy in nuclear power plants and in processes along the value chain of metalliferous raw materials.

Research and development focus on the assessment and reduction of risks related to the nuclear fuel cycle. The major goal is a better understanding of fundamental processes defining transport and accumulation of radiotoxic elements in the geo- and biosphere including the food chain. Our research advances the knowledge on the molecular scale in aqueous systems, in rocks and soils, and at the interface between geo- and biosystems. This covers the areas of spectroscopic identification and characterization of chemical species, the development and application of chemico-physical models from the molecular to the meter scale, and the determination and evaluation of thermodynamic, kinetic and transport parameters for such models.

Moreover, the influence of biota, ranging from bacteria to higher multicellular organisms, on the migration process is investigated.

Spectroscopic, microscopic, and microbiological methods are implemented in controlled areas allowing radiochemical studies that can be performed only at a few places in Europe. The Institute runs two stations at the Rossendorf Beamline, at the European Synchrotron Radiation Facility (ESRF) in Grenoble (France), dedicated to X-ray based absorption, emission and diffraction.

HZDR will contribute to the SotA report in Task 1. They will also contribute to Task 4 by performing experiments related to the bentonite dry density threshold for microbial activity and its impact on the corrosion of canister materials. Moreover, they will carry out experiments systematically investigating the role of bentonite dry density and particle size distribution on the viability of microorganisms in compacted bentonite. This work will be carried out in especially designed mini-reactors allowing the generation of statistically significant findings.

WP MAGIC: in Task 3 HZDR will study the microbial-chemo-mechanical-evolution of CEM I and low-pH hardened cement pastes exposed to calcareous solution or synthetic calcareous solution in lab experiments analogous to the in-situ experiments performed by IRSN. For this, flow-through and batch experiments will be carried out with and without (control experiment) microorganisms which are already present in the natural calcareous waters, monitoring the dissolution of the cementitious phases and the surface topography; complementary nanoindentation tests will be performed by IRSN. In collaboration with PSI, HZDR contributes to the development of a numerical model considering two interfaces and three geometries (fluid, biofilm, solid substrate) for simulating microbially-controlled cement alteration with a focus on surface reactivity. Parameters considered include redox behaviour, pH variability, and saturation (precipitation-dissolution); parametrization and validation is based on Task 3 experiments. Numerical treatment is performed by using an in-house Stokes-Brinkman transport code combined with parametrization of heterogeneous surface reactivity.

Helmholtz - Zentrum für Umweltforschung GmbH, UFZ (PIC: 999994632)

The UFZ is one of the world's leading research centres in the field of environmental research, enjoying high social recognition. It demonstrates ways in which a sustainable use of our natural resource base is possible for the benefit of both humankind and the environment. In the energy sector (resources and waste management), the spectrum of topics covered ranges from process modelling and simulation through the development of innovative monitoring strategies to the investigation of socio-economic aspects. The Department of Environmental Informatics (ENVINF) is developing numerical methods and software components for simulating coupled processes in porous media based on the finite element method. In addition, questions of the development of simulation platforms for the treatment of these problems as well as the benchmarking for model and software validation also take up wide space. An integral part of these platforms are workflows and system components for the 3D visualization of complex, heterogeneous data from different sources. In this context, the ENVINF acts as the lead developer and coordinator of OpenGeoSys, the international scientific open source software project. In addition to method and software development, there is a strong relationship to applications in hydrology, geotechnics and energy storage research.

WP DONUT (Task 3): The UFZ Team will develop numerical multi-scale scheme for coupled processes able to link different simulators as well as develop and test parallel execution capabilities. WP GAS (Task 3): UFZ together with BGE, BGR will employ and extend the open-source software OpenGeoSys, in which localization can be described using enriched approximation spaces, non-local elasto-plasticity or phase-field models of fracture. Together with existing multi-phase flow and swelling formulations, these models will be used in the modelling tasks described above. Random-field initialization will be used to trigger localization. WP ACED (Task 4): The UFZ team contributes to the methodology comparison and also inter-code benchmarking of reactive multiphase transport process relevant to the ILW at the scale of a waste repository. Together with PSI they will carry out simulations on the chemical evolution and gas/water mass balances in waste packages containing metallic and/or organic waste with the GEM-Selektor chemical modelling package and OpenGeoSys-MP-LT, a multi-component two-phase reactive code developed in cooperation with UFZ Leipzig.

WP ConCorD: UFZ will contribute to the SotA report in Task 1. They will also contribute to Task 6 by developing mechanistic corrosion models at the lab scale, which they will then simplify and apply at the disposal scale to facilitate performance assessment.

WP MAGIC: The work of **UFZ** is included in Task 4 which is divided into 3 steps (1) new chemo-mechanical numerical coupling development, 2) predictive modelling using the developed multi-scale framework, and 3) benchmarking with experimental data. In addition, UFZ is the Task leader of Task 4.

WP MODATS : Taking advantage that **UFZ** (Helmholtz) is partners in the Mon Terri project the work described here can be connected with monitoring activities being performed in two experiments where UFZ is contributing with modelling activities (a) the FE: Full Scale Emplacement experiment coordinated by NAGRA and the CD-A: Influence of humidity on cyclic and long-term deformations coordinated by BGR. However, the activities described here can also be related to other MODATS Reference Experiments which still needs to be defined.

The full workflow is divided in 4 steps and the software basis for the data and model integration is OpenGeoSys (www.opengeosys.org), an open-source code mainly developed by **UFZ** in collaboration with other research institutions.

Activities related to the FE experiment will be limited to the needs of NAGRA as in this experiment the FE information system (FEIS) is already existing and developed. Still there are possible extension of this system to virtual reality tools as the one described here that **UFZ** would be interested to further develop (see below):

Below the 4 different tasks, specifying to which subtask of MODATS WP are related:

- 1) **Subtask 2.2. Data management:** OpenGeoSys (OGS) contains already a large variety of standard interfaces to CAD, GIS, VTK, etc. which makes possible the integration of existing geological geotechnical data and sensor metadata (i.e. coordinates) in a data repository or database. Data obtained by monitoring (i.e sensors) or by the installation companies of the FE experiment will be collected and stored in OGS DataExplorer. Collected data in surfaces will be converted into VTK unstructured grids in order to facilitate the integration and comparison with models. Any nodal property contained in a file will be transferred into VTK scalar arrays which will be available for visualisation and further processing within OpenGeoSys models
- 2) **Subtask 2.3. Enhanced System Understanding:** Quality of the recorded measurements in the experiment will be controlled by means of statistical analysis and machine learning previously to analyse and model the data.
- 3) **Subtask 2.4. Integration of numerical tools and digital twins:** FE experiment will be modelled and calibrated according to measured and monitored data. Living digital models (digital twins) will integrate artificial intelligence, machine learning and software analytics with spatial network graphs that will change as their physical “real-life” counterpart evolve. At the present moment information related to a) claystone is obtained by electrical resistivity tomography, interval velocity measurements, b) climatic conditions (air humidity, temperature, atmospheric pressure, c) pore-pressure by a mini-piezometer, d) deformation by extensometer, laser-scan, convergence, tiltmeter and saturation by taupe measurements, NRM and evapometer is obtained.
- 4) **Subtask 2.4. Visualization** (work connected to the digital twins, see above): Study with 3D and interactive graphics elements in order to facilitate the decision-making

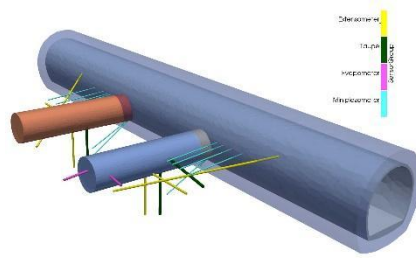


Figure 1. Example of data integration of monitored data (digital twins with Virtual Reality) using OpenGeoSys

Expected outcome: Further development of an integrated information system and numerical tool (OpenGeoSys), including: a) data management, b) enhancing system understanding and c) numerical tools, digital twin/simulation-assisted monitoring for understanding the performance of the engineering barriers and host rocks.

The Helmholtz-Zentrum Potsdam Deutsches GeoForschungsZentrum (GFZ)

The Helmholtz-Zentrum Potsdam Deutsches GeoForschungsZentrum GFZ (www.gfz-potsdam.de), founded in 1992, is the national research centre for Earth sciences of Germany. It is part of the Helmholtz Association of German Research Centres, the largest scientific organisation in Germany, and has collaborators from ~ 60 countries. The annual budget for 2020 is €108 million in total.

GFZ employs ~ 1300 scientists, across 28 highly collaborative sections that ranges across the full breadth of the Earth Sciences from the dynamics of Earth's deep interior to remote observation of its active surface. The core competence of GFZ is the sciences of the solid Earth encompassing the fields of geodesy, geophysics, geology, mineralogy, geochemistry, geochronology, geomorphology, physics, mathematics, biology and engineering. All work at the GFZ benefits from generous technical support and a uniquely comprehensive range of state-of-the-art equipment.

The GFZ is Germany's national research center for the solid Earth Sciences. Our mission is to deepen the knowledge of the dynamics of the solid Earth, and to develop solutions for grand challenges facing society. These challenges include anticipating the hazards arising from the Earth's dynamic systems and mitigating the associated risks to society; securing our habitat under the pressure of global change; and supplying energy and mineral resources for a rapidly growing population in a sustainable manner and without harming the environment.

These challenges are inextricably linked with the dynamics of planet Earth, not just the solid Earth and the surface on which we live, but also the hydrosphere, atmosphere, and biosphere, and the chemical, physical, and biological processes that connect them. Hence, we view our planet as a system with interacting components. We investigate the structure and history of the Earth, its properties, and the dynamics of its interior and surface, and we use our fundamental understanding to develop solutions needed to maintain planet Earth as a safe and supportive habitat.

WP 17- MODATS: the team involved in the workpackage includes researchers from several sections of the GFZ. This team includes experts with experience in monitoring in the clay environment but also geophysicists specialising in the location of microseisms or in the management of uncertainties and studies of risks to the safety of critical facilities.

Does the participant envisage the use of contributions in kind provided by third parties (Articles 11 and 12 of the General Model Grant Agreement)	N
Does the participant envisage that part of the work is performed by International Partners (Article 14a of the General Model Grant Agreement)?	N

16/ GRS

Does the participant plan to subcontract certain tasks (please note that core tasks of the project should not be sub-contracted)	N
Does the participant envisage that part of its work is performed by linked third parties	N
Does the participant envisage the use of contributions in kind provided by third parties (Articles 11 and 12 of the General Model Grant Agreement)	N
Does the participant envisage that part of the work is performed by International Partners (Article 14a of the General Model Grant Agreement)?	N

17/ INPP (IAE)

Does the participant plan to subcontract certain tasks (please note that core tasks of the project should not be sub-contracted)	N
Does the participant envisage that part of its work is performed by linked third parties	N
Does the participant envisage the use of contributions in kind provided by third parties (Articles 11 and 12 of the General Model Grant Agreement)	N
Does the participant envisage that part of the work is performed by International Partners (Article 14a of the General Model Grant Agreement)?	N

18/ ICHTJ

Does the participant plan to subcontract certain tasks (please note that core tasks of the project should not be sub-contracted)	N
Does the participant envisage that part of its work is performed by linked third parties	N
Does the participant envisage the use of contributions in kind provided by third parties (Articles 11 and 12 of the General Model Grant Agreement)	N
Does the participant envisage that part of the work is performed by International Partners (Article 14a of the General Model Grant Agreement)?	N

19/ IRSN

Does the participant plan to subcontract certain tasks (please note that core tasks of the project should not be sub-contracted)	N
Does the participant envisage that part of its work is performed by linked third parties	Y
IRSN envisage that part of its work will be performed by 3 linked third parties : Mutadis, NTW and MINES ParisTech Mutadis is an independent research organisation specialized in the area of the governance of activities entailing risks for people or the environment as well as in the field of ecological, economical & societal Transition. It operates for public and private organizations. Mutadis has a long-standing expertise and field experience regarding interaction between civil society and technological processes (in the context of decision-making, expertise processes and research) in the French, European and international context since	

1990. Mutadis had a role of methodological expert and facilitator of interactions with the Public in many research, surveys, and field projects. Mutadis has also developed projects and research regarding the adaptation and transformation of legal and institutional frameworks, in order to create the conditions for a permanent and influential participation of Civil Society Organisations and local communities in the governance of activities associated with risks and impacts on health and environment (notably on the ground of the Aarhus Convention - 1998). In France, Mutadis has been cooperating with IRSN in the field of health, food, environment and work hazards, in order to propose a vision and tools for the governance of expertise processes, and their approaches regarding stakeholders' involvement.

Link of the participant to the Third party: Since its creation, Mutadis has developed numerous research projects and partnerships with IRSN in the two last decades. Currently, a research partnership between Mutadis and IRSN, that began in September 2017, focuses in particular on structured dialogue tools facilitating interactions between experts and civil society on the field of Radioactive Waste Management. Mutadis also cooperated closely with IRSN in the context of the European projects SITEX (2012-2013) and SITEX-II (2015-2017) coordinated by IRSN, by providing its expertise, as Work Package leader, on governance and understanding of the socio-technical issues involved in the implementation of geological disposal, by developing a specific interaction model enabling meaningful engagement of civil society representatives in the context of RD&D on radioactive waste management and by developing a tool for pluralist dialogue on these issues. Together with IRSN, Mutadis was also partner of the European R&D project JOPRAD and contributed to the development of a participatory framework of governance for consideration by the future EURAD proposal. Mutadis, as a representative of the Civil Society function, is also member of the SITEX.network association that is chaired by IRSN.

Tasks to be performed by the LTP:

- 1- Mutadis will carry out the work in the task 5 of the Strategic Study WP – Uncertainty Management multi-Actor Network (UMAN). The work will consist in gathering views and contributions from a pluralistic stakeholder group on Uncertainty Management. The task will be organised through seminars gathering pluralistic stakeholder groups (task 5.1). Mutadis will also coordinate the contribution of stakeholders from the public and CS experts participating in specific subtasks of Tasks 2 to 4 (task 5.2).
- 2- Mutadis will also lead task 8 of the Programme Management Office (PMO), dedicated to the coordination of CS contribution within EURAD. It will ensure the finalisation of the composition of the CS group involved in EURAD. It will contribute to the organization of a yearly workshop as part of EURAD annual meeting (involving the participation of the CS group, the CS experts together with a panel of WMO, TSO and REs from the different WPs). Mutadis will also ensure the subtask “*Assessment of the experimental model of Interaction between EURAD participants and Civil Society*”.
- 3- In the UMAN workpackage, given its long experience of facilitator in fostering dialog between different profiles of actors in a large range of topics, Mutadis will coordinate the extension of task 5 on Interactions between all categories of actors, including Civil Society.
- 4- In the MODATS workpackage, MUTADIS will co-lead the sub-Subtask 2.5 (Dialogue Methodology) aiming at preparing a pluralistic dialogue during the 1st Workshop and also contribute with NTW to provide information to CS larger group on MODATS results during ICS Workshops. Mutadis will organise the key meetings of the sub-subtask 2, will contribute to the organisation and animation of the 2 workshops. Mutadis will also contribute to the final deliverable of subtask 2.5.

Nuclear Transparency Watch (NTW) is a European network that promotes a citizen watch on nuclear safety and transparency. The European network Nuclear Transparency Watch has been created in order to promote transparency and vigilance on nuclear safety issues and increase the contribution of civil society in the governance of nuclear activities, raise awareness among policy makers and European society about the need for transparency on nuclear decision-making processes at the local, national and European level. The network was launched in 2013 after a Public Call of Members of the European Parliament from different Political Parties. The action of Nuclear Transparency Watch is regarding most activities of the nuclear cycle:

nuclear safety, ageing of NPPs, life-time extension, new build, emergency preparedness and response, post-accident management (including liability issues), radioactive waste management, decommissioning, etc.

Link of the participant to the third party: NTW is member of the SITEX.network association chaired by IRSN, that results from SITEX and SITEX-II European projects, in which civil society experts, members of NTW, collaborated with IRSN as research partners of SITEX II, in order to develop experimental interactions between institutional experts (expertise function) and civil society (society function). Since 2013, NTW also coordinates, together with the DG-ENER of the European Commission, the second phase of the Aarhus Convention & Nuclear (ACN) process where IRSN is involved. The ACN process is regarding the concrete implementation of the Aarhus Convention Principles in the nuclear field in the European Union. It involves the organisation of pluralistic roundtables at European level, gathering concerned stakeholders of European countries (operators, regulators, institutional experts, civil society representatives).

Tasks to be performed by the LTP:

- 1- In the strategic study ROUTES, NTW will be Task 7 leader. It will provide CS experts involved as partners in WP activities, and will gather the contribution from CS larger group. The objectives of this task are NTW will also contribute to the UMAN WP, see MUTADIS task 1..
- 2- NTW will contribute to the task 8 of the Programme Management Office, dedicated to the coordination of CS interactions within EURAD. In order to organize the general session of a annual workshop in the frame of the EURAD Annual meetings, NTW will translate the results of the scientific/technical WPs to the CS group during the session and gather CS views on future EURAD activities. NTW will provide a small team of CS experts dedicated to this task and will work together with representatives from WMOs, TSOs and REs from the different WPs. NTW will also ensure the administrative work related to the invitation and reimbursement of the CS stakeholders.
- 3- In UMAN, NTW will provide CS experts involved as partners in WP activities and will organize the link with the CS larger group.
- 4- NTW is together with the linked third party EIMV working in Task 7 of the ROUTES project with activities related to interaction with civil society (ICS). NTW will contribute with similar work in a new subtask 7.4 in Task 7 specifically oriented to ICS in the ROUTES Extension.
- 5- In MODATS workpackage, will provide CS experts involved as partners in MODATS activities, and will organize the link with a CS larger group.
 - NTW will contribute to the sub-Subtask 2.5 (Dialogue Methodology) aiming at preparing a pluralistic dialogue.
 - NTW will provide information to CS larger group on MODATS results during ICS Workshops.
 - NTW will be in charge of the logistical aspects of the workshops (rooms, expenses) and external partners participation.

MINES ParisTech

The graduate school MINES ParisTech (www.mines-paristech.eu) is one of the oldest French higher education institutions in engineering. The Geosciences Department of MINES ParisTech is dedicated to all the research and teaching activities in the field of earth, geo-engineering and environmental sciences. In particular, the Geosciences Department has a great expertise in numerical modelling of hydrogeological and geochemical processes applied to the geological disposal of radioactive wastes.

Over the last two decades, IRSN and MINES ParisTech collaborated on the following projects:

- Clay/concrete interactions (3 joint publications, co-supervised Ph.D. of P. Lalan –collaboration agreement IRSN /LS 11862)
- Concrete carbonation modelling (Post Doc N. Seigneur 2013 – 2016 - collaboration agreement IRSN/ LS 20506)
- Iron/concrete interactions (2 joint publications, 1 co-supervised Ph.D.)
- Study of the oxidizing transient (1 joint publication)
- Numerical modelling of these interactions at long term (2 joint publications).

All these matters are highly relevant for the study proposed by IRSN (iron/concrete/clay interactions) as part of the WP chemical evolution. In ACED WP, the collaboration between IRSN and MINES ParisTech will be part of task 2 (reactivity at the interface scale) and task 4 (disposal cell scale). The core approach of MINES ParisTech will be reactive transport modelling (RTM) with the HYTEC code. This code is developed in MINES ParisTech in partnership with IRSN since 2000. In task 2, MINES ParisTech will do the RTM of the experiment on steel/concrete interface (IRSN) and of the experiment on steel/bentonite interface (Uni Bern); to discriminate the most relevant reactive pathways, develop a solid solution of Fe-solid phases and provide parameters for up-scaling the temperature and heterogeneity effects. One main outcome will be to provide the bases for up-scaling the RTM to waste package and near-field of HLW disposals. In task 4, MINES ParisTech will do the RTM to assess of sensitivity to heterogeneities and temperature gradient (evolving with time) of the long-term chemical evolution of a reference HLW disposal cell by two-phase reactive transport modelling, partly based on the up-scaling of the modelling of steel/bentonite and steel/cement experiments (task 2). These RTM results will be useful for the more abstracted models and performance assessment of TSO such as IRSN. WP MAGIC : As part of MAGIC WP, MINES ParisTech in collaboration with CEA will be in charge to model the impact of carbonation on cementitious materials with an approach based on a coupling between a reactive transport code Hytech and a classical Finite Element code Cast3M (cf. MINES ParisTech proposal) MINES ParisTech is in the Task 4 of MAGIC WP to develop a sequential iterative approach to describe the cracking which occurs during atmospheric carbonation of cementitious materials. This approach would couple the results of Hytec with Cast3m (mechanical code from CEA) to update mesh and hydrodynamic properties (diffusion permeability). Identification of relevant parameters (rate of porosity change, decalcification rate) to feed the mechanical algorithm would be performed in order to compute the internal stresses which may, in turn, lead to crack opening. Hence, the permeability and diffusion field would be update within the reactive transport simulation. Calibration of the simulation would be performed based on experimental results from CEA (Task 3). The numerical approach will be the result of a collaboration with CEA as well. This novel approach would consist in first step towards fully coupled THCM simulations.	
Does the participant envisage the use of contributions in kind provided by third parties (Articles 11 and 12 of the General Model Grant Agreement)	N
Does the participant envisage that part of the work is performed by International Partners (Article 14a of the General Model Grant Agreement)?	N

20/ IST-LPSR

Does the participant plan to subcontract certain tasks (please note that core tasks of the project should not be sub-contracted)	N
Does the participant envisage that part of its work is performed by linked third parties	N
Does the participant envisage the use of contributions in kind provided by third parties (Articles 11 and 12 of the General Model Grant Agreement)	N
Does the participant envisage that part of the work is performed by International Partners (Article 14a of the General Model Grant Agreement)?	N

21/ IST-ID

Does the participant plan to subcontract certain tasks (please note that core tasks of the project should not be sub-contracted)	N
Does the participant envisage that part of its work is performed by linked third parties	N

Does the participant envisage the use of contributions in kind provided by third parties (Articles 11 and 12 of the General Model Grant Agreement)	N
Does the participant envisage that part of the work is performed by International Partners (Article 14a of the General Model Grant Agreement)?	N

22/ JSI

Does the participant plan to subcontract certain tasks (please note that core tasks of the project should not be sub-contracted)	N
Does the participant envisage that part of its work is performed by linked third parties	Y

EIMV

The EIMV – Elektro inštitut Milan Vidmar is the leading Slovenian engineering and scientific research organisation acting in the area of electric power engineering. It has a long tradition in operation and, in 2018, it celebrates its 70th anniversary. The EIMV addresses the issues of generation, transmission and distribution of electricity from the technological, environmental and economic perspective. The experts at the institute prepare feasibility and implementation studies, expert reports, they implement technological, environmental and other analyses, inspect the quality and operation of electric power systems and facilities as required by electric power utilities, ministries and national as well as regional authorities. The staff of EIMV also performs research and analyses in relation to different aspect of ionizing radiation, work on use of nuclear energy, radioactive waste management, emergency preparedness and response, and different applications of nuclear technology. The institute also implements R&D projects in the EURATOM frame (Horizon 2020) and regional levels, which are developed from idea to their realisation.

The EIMV is also one of the Technical Support Organisations (TSOs) licensed by the Slovenian Nuclear Safety Administration (SNSA), the Nuclear Regulatory Authority (NRA) in Slovenia. EIMV provide opinions with regards to specific issues related to radiation and nuclear safety. The EIMV's license covers all related fields linked to nuclear safety and radiation protection of nuclear and radiation facilities and radioactive waste repositories. On the basis of extensive practical experience, the EIMV coordinates preparation of the expert opinion for refuelling and maintenance outage for the Krško NPP (NEK) where it organises the work of authorised institutions involved in the evaluation of implemented works during the outage. EIMV also provides, as the TSO, expert opinions for NEK in specific fields, such as maintenance and changes related to the main and emergency diesel generator, power and auxiliary transformers, cables, high voltage motors, control and protection systems and other equipment in the high voltage switchyard. EIMV likewise performs authorised expert opinions in collaboration with other institutions for activities which combine various topics (e.g. establishment of Emergency Control Room, Dry Storage for Spent Fuel, ...). Lately, EIMV has also been involved in the evaluation of licensing documentation for radioactive waste repository in Slovenia.

EIMV will contribute to several WPs in the EURAD:

In ROUTES the technical data on different radioactive waste types will be provided for Slovenia and all input information of different waste management routes will be collected and analysed. EIMV will be also involved in the interaction with civil society.

EIMV will contribute to the qualitative analysis of predisposal routes with analysis and assessment of existing predisposal routes for SIMS (in Sub-task 2.1) and linking those existing predisposal routes for SIMS with regard to disposal options (in Sub-task 2.2) in total of 1 pm. It will also participate in analysis and assessment of existing disposal options for SIMS (Sub-task 3.1) with experience from national context as one of the small inventory country, and add to the Subtask 3.2: Evaluation of waste routes resulting from subtask 3.1 on disposal options for SIMS subtask.

For Sub-task 3.3: Case studies, EIMV will participate in the development of selection criteria for the studies and preparation of the context. Total EIMV contributions in Task 3 will be 1 pm. As part of the Task 4 on the Interaction with Civil Society, EIMV will lead the scoping activities (Sub-Task 4.1), and will contribute to Sub-task 4.2 and 4.3 as described. In total the EIMV contributions are assessed for 1 pm.

In UMAN the contribution to common understanding among the different categories of actors on uncertainty management for RWM will be addressed by EIMV. EIMV will contribute to analyses and mitigation procedures on activities related to risk & safety.

In KM, EIMV will participate mainly in the WP on Guidance where it will contribute to identification of topics for early-stage of RWM programmes and development of guiding documents.

EIMV will also be an organisation, which will be involved in Interaction with Civil society activities, in the SFC WP and in ROUTES WP, but also in the coordination of CS group.

In MODATS workpackage, EIMV will be involved in Interaction with Civil society activities. EIMV will organize, animate and coordinate CSO workshop activities in subtask 2.5

ZAG

Slovenian National Building and Civil Engineering Institute (ZAG) is the leading research and testing institute of its kind in Slovenia. It is a state-owned, independent, impartial and non-profit organization, which fulfils all the requirements of the EEC Council Directive No. 89/106 regarding approval bodies, which carry out the testing and attestation of conformity of construction products. The main activities of ZAG are: research, quality assurance programs, and testing and assessment in the fields of building materials, structures (buildings and infrastructure) and geotechnics. For the last 20 years, ZAG has been involved in development of new highly efficient and sustainable construction materials and structures and infrastructure construction, including building energy efficiency, and has been the leading independent quality control and counselling organization. It has been developing and implementing tools for efficient inspections of structures and infrastructures' asset management, monitoring and safety assessments, evaluation of material degradation processes, and rehabilitation for many decades. ZAG performs comprehensive research of the waste material into the various possibilities for its use in the construction industry. ZAG employs 178 researchers, among them 40 PhD and it has approximately 10 million EUR of turnover. In the field of tasks deriving from the CPR (Construction Product Regulation) it has two independent services: the Certification Service and the Service for Technical Assessments, the latter including also system for issuing Environmental Products declaration. ZAG is involved in the international co-operation in science and technology with institutions from the EU, the USA and other countries. Over the last 10 years ZAG has participated in more than 60 projects funded by the EU (4th - 7th FP, H2020, LIFE, and EIT Raw Materials).

ZAG will contribute in ACED: in task 2 by an in-situ monitoring of corrosion of steels in their ongoing experiments and potentially in the new experiments proposed by IRSN (NE2-2/1) and to assist at the identification of corrosion type, rate and corrosion products. In task 3 ZAG will provide the test fields at three hydroelectric dams on Drava River in order to get reliable samples of concrete in different locations of saturated zone of the dams. Laboratory investigation of samples in terms of microstructure characteristics.

Does the participant envisage the use of contributions in kind provided by third parties (Articles 11 and 12 of the General Model Grant Agreement)	N
Does the participant envisage that part of the work is performed by International Partners (Article 14a of the General Model Grant Agreement)?	N

23/ JRC

Does the participant plan to subcontract certain tasks (please note that core tasks of the project should not be sub-contracted)	N
Does the participant envisage that part of its work is performed by linked third parties	N
Does the participant envisage the use of contributions in kind provided by third parties (Articles 11 and 12 of the General Model Grant Agreement)	N
Does the participant envisage that part of the work is performed by International Partners (Article 14a of the General Model Grant Agreement)?	N

24/ KIT

Does the participant plan to subcontract certain tasks (please note that core tasks of the project should not be sub-contracted)	N
Does the participant envisage that part of its work is performed by linked third parties	Y
The link of the participant to the listed LTPs is an: AGREEMENT FOR COLLABORATION ON THE FIELD OF MANAGEMENT AND DISPOSAL OF RADIOACTIVE WASTE Between Karlsruhe Institute of Technology (KIT) and: - University of Potsdam, Am Neuen Palais 10, 14469 Potsdam, represented by the President; Executing Unit: Institute for Chemistry, Apl. Prof. Dr. M. Kumke - Clausthal University of Technology, Adolph-Roemer-Straße 2a, 38678 Clausthal-Zellerfeld, represented by the president; Executing Unit: Institute for disposal research, represented by Prof. Dr. Klaus-Jürgen Röhlig - Johannes Gutenberg-University Mainz, represented by the President, Prof. Dr. Georg Krausch, Saarstr. 21, 55122 Mainz; Executing unit: Institute for Nuclear Chemistry, Contact: Prof. Dr. Tobias Reich - Federal Republic of Germany, represented by the Federal Minister of Economic Affairs and Energy, who in turn is represented by the President of the Bundesanstalt für Materialforschung und -prüfung (BAM), Unter den Eichen 87, 12205 Berlin - Federal Republic of Germany, represented by the Federal Minister of Economic Affairs and Energy, who in turn is represented by the President of the Bundesanstalt für Geowissenschaften und Rohstoffe (BGR), Stilleweg 2, 30655 Hannover - Amphos 21 Consulting S.L. Passeig de Garcia i Faria 49-51, 1-1. Barcelona E08019 Spain - PreussenElektra GmbH, Tresckowstrasse 5, 30457 Hannover, Germany University of Potsdam: WP CORI The research entity University of Potsdam (Physical Chemistry, UPPC) is a collaborator for more than a decade investigating the interaction of actinides (lanthanides) with key components of the near as well as the far field of a potential repository for nuclear waste. UPPC has its core competence in the development and application of high-end laser-based spectroscopy in the spectral and time domain. UPPC has (and is currently) been participating in national research projects on radioactive waste storage managed by the PTKA-WTE. Experiments performed at UPPC aim to improve the molecular understanding of organics-radionuclide complexes interplay with calcium-(aluminium)-silicium-hydrate phases (CSH, CASH) in order to strengthen the knowledge on the mobility of radionuclides under hyperalkaline conditions in cementitious environments under consideration of the redox state. The organics may be originating from the degradation of organic additives (cement components) or from polymers of waste components. The redox state +IV, +V as well as +VI will be investigated using novel (to be developed) spectro-electrochemistry techniques for speciation (time-resolved emission as well as absorption techniques). Additionally experiments on the redox state +III are performed as well. The cement phases considered are of CSH and CASH type. Investigations deal with the competition between organic ligands (e.g., ISA, phthalate etc.) in solution and sorption sites on cement phases (CSH, CASH) as well as the possible formation of ternary complexes with organics acting as partners. The influence of elevated calcium or sulphate concentrations (e.g., calcium as intrinsic cation contained in the system may act as a potential partner in the formation of mixed multicomplexes) will also be addressed. Investigation of the competition between organics and cementitious system for radionuclides (in different redox states) as well as the alteration of the cementitious system due to the presence of organics and the subsequent effect on the sorption/release of radionuclides are in the focus of the experiments performed at UPPC. University of Mainz: WP CORI, FUTURE The Johannes Gutenberg University Mainz (JGU) is one of the ten largest universities in Germany with about 31,500 students from about 120 nations. Teaching and research activities of JGU's Institute of Nuclear Chemistry (JGU-INC) cover the full range of nuclear chemistry and radiochemistry. In particular, JGU-INC	

has performed research activities in the field of management and disposal of radioactive waste for more than twenty years and is currently the coordinator of the joint national research project GRaZ (Geochemical retention of radionuclides on cement alteration phases) that has been funded by BMWi and managed by PTKA-WTE since 2015. About 50 bachelor, master, diploma, and graduate students are working in JGU-INC.

JGU-INC has the necessary infrastructure (controlled areas, inert gas glove boxes etc.) to work with all actinides, including Np and Pu. In addition to the standard radioanalytical techniques, the research reactor TRIGA Mainz and sophisticated equipment (XPS, TOF-SIMS, Laser-SNMS, ICP-MS, CE-ICP-MS, and RIMS) are available for investigations. JGU-INC has also vast experience in synchrotron-based X-ray techniques (XANES, EXAFS, μ -XRF, μ -XRD).

The contribution of JGU-INC to CORI aims at extending the knowledge about the effects of organics on the mobility of radionuclides in cement-based systems. In order to obtain a mechanistic understanding of the radionuclide interactions with cementitious phases, batch and diffusion experiments will be combined with speciation studies. The focus of these investigations will be on tri- and tetravalent plutonium (Pu). The cementitious phases will include pure cement preparations (HCP – CEM I) and cement phases (CSH). For investigating possible effects of organics on the Pu mobility, strong complexing organic agents as prioritized in Task 2 of CORI, i.e., isosaccharinic acid, phthalate, EDTA, and short-chained carboxylic acids, will be employed by JGU-INC.

Within FUTURE JGU-INC will address the role of the different mineral constituents of argillaceous rocks (Opalinus Clay) on the mobility of actinides (Np, Pu), which is governed by diffusion and sorption processes. There are open questions on whether redox transformations and sorption of actinides during their diffusion in intact clay rocks are decoupled, subsequent, and spatially separated processes involving several mineral phases or are related mostly to a particular mineral phase.

The combination of speciation calculations (Pourbaix diagrams based on Eh and pH measurements, thermodynamic database) with simultaneous speciation measurements both in solution (CE-ICP-MS) and on the solid surface (XPS, XANES, EXAFS) will provide the basis for developing a unified and complete model of the sorption of Np and Pu on mineral phases considered in FUTURE. Application of techniques with high spatial resolution to heterogeneous natural clay, the identification of most reactive mineral phases responsible for sorption and retardation of Pu and Np, and determination of diffusion parameters from nondestructive measurements are unique and beyond the state-of-the-art.

University of Clausthal: WP UMAN

Clausthal University of Technology – Institute of Disposal Research (TUC-IELF):

The Institute of Disposal Research (IELF) is the only university institute in Germany dealing with radioactive waste disposal in research and education in a comprehensive way.

Interdisciplinary research concerning site characterisation, site investigation, geotechnical barrier systems, and safety cases takes place in the departments of

- Geochemistry-Mineralogy-Salt Deposits,
- Geomechanics (co-opted department),
- Hydrogeology and Hydrogeochemistry,
- Mineral Resources,
- Repository Systems.

The planned research will be carried out by the Department of Repository Systems, which is active in the research areas of Safety Assessment Methodology, probabilistic methods and sensitivity analysis as well as of socio-technical issues related to radioactive waste disposal (co-ordinator of the interdisciplinary ENTRIA project s.o.).

TUC-IELF plans to contribute to the Uncertainty Management multi-Actor Network (UMAN):

- It will become the responsible organisation for Subtask 2.3 – Methodological approaches to uncertainty and sensitivity analysis: TUC-IELF will coordinate the work, organize and participate in technical meetings, share their experience with uncertainty and sensitivity methods and write the deliverable.

Since CEC's PAMINA project, TUC-IELF has taken a leading role in the field of sensitivity analysis (SA) methodology, contributed to deriving a holistic view of SA methods, and developing numerically efficient approaches. It is therefore excellently qualified for the task.

- Subtask 5.1 – Preparation, support and reporting of pluralistic analyses: TUC-IELF will be leader of Topic 1 and coordinate the development of materials to be discussed in seminar 1. TUC-IELF will lead the

development of deliverable D5.1. TUC-IELF will also take part to Topic 4, contributing to the development of proposals of methods for a pluralistic assessment of uncertainties.

Due to its co-ordination role in the interdisciplinary research project ENTRIA and its leading role in several OECD/NEA activities at the interface of social, natural and engineering sciences in the area of repository development and safety cases (jointly carried out by the working parties IGSC and FSC), TUC-IELF has excellent prerequisites for carrying out the aforementioned tasks.

Bundesanstalt für Materialforschung und -prüfung (BAM): WP Spent FUEL

The Bundesanstalt für Materialforschung und -prüfung (BAM) is a senior scientific and technical Federal institute with responsibility to the Federal Ministry for Economic Affairs and Energy. It tests, researches and advises to protect people, the environment and material goods. BAM sets and represents high standards for safety in technology and chemistry for Germany and for its global markets, to further develop the successful "Made in Germany" culture of quality. BAM fulfils this role through its dedicated employees. According to its founding decree, BAM is responsible for the

- further development of safety in technology and chemistry,
- implementation and evaluation of physical and chemical tests of materials and facilities, including the preparation of reference processes and reference materials,
- promotion of knowledge and technology transfer within the BAM's areas of work,
- cooperation in the development of statutory regulations, for example concerning the setting of safety standards and limits,
- advice to the Federal Government, industry, and national and international organisations in the fields of material technology and chemistry.

Five focus areas provide thematic platforms that structure the work. At the same time, they serve to make visible BAM's contribution to politically, socially and scientifically important topics. Within the focus area Energy the Radioactive waste Disposal is one specific area of expertise BAM is addresses for several decades. Major topics include safety evaluation and approval of all kinds of containments for transportation and storage of radioactive materials. Materials research and testing, component testing and up to full-scale container drop or fire testing are major competences as well as numerical simulation techniques to evaluate and demonstrate container safety.

The foreseen task BAM will contribute focuses on the integrity of spent nuclear fuel rods affected by thermo-mechanical conditions as well as fuel/cladding chemical interaction. BAM plans the numerical calculation of initiation fracture toughness for Zirlo in the initial elastic region or just shortly after passing this region in the ring compression test (RCT) on the basis of measured load-displacement curves, correlated observed distribution of hydrides, and postulated initial macroscopic cracks. As major outcome a fracture mechanics based failure criterion shall be developed. The gained knowledge base shall provide the basis for an extension to other and also irradiated cladding materials to evaluate fuel cladding integrity under mechanical loads during container operation and also under accidental loads.

Bundesanstalt für Geowissenschaften und Rohstoffe (BGR): WP HITEC, GAS, DONUT

The Bundesanstalt für Geowissenschaften und Rohstoffe (BGR) is the national geoscientific authority providing advice to the German Federal Government in all geo-relevant questions. It is subordinate to the Federal Ministry for Economic Affairs and Energy (BMWi). Since more than 30 years BGR significantly contributes to all geoscientific tasks and undertakings to realize an underground final repository for radioactive waste.

At a constantly high qualitative and quantitative level about 100 BGR experts to perform this research and consultancy tasks. BGR has been advising the national commission on "Storage of High-level Radioactive Waste" since 2014. Due to their comprehensive research activities in the field of radioactive waste disposal, BGR has made numerous expert contributions since the first meeting of the commission, including lectures, data sheets, review articles and data collections. Topics included geoscientific criteria for repository projects in other countries, and easily understandable facts on e.g. claystone research.

BGR is represented in well-established international working groups (OECD/NEA) on potential host rock formations, informally known as the [Salt Club](#), the [Clay Club](#) and the [Crystalline Club](#).

The internal structure of the depository research in BGR is optimized for the upcoming tasks related to the Site Selection Act in Germany (StandAG) and comprise of e.g. providing geological maps or catalogues on the distribution of potential host rock formations (salt structures, claystone, crystalline rock formations) in

Germany, geological-geotechnical exploration including the development of 3D-geological models, THM-rock and geotechnical barrier material characterization on laboratory and on in-situ scale, long-term safety (scenario development and analysis) and geotechnical safety analyses (THM numerical scenario studies).

The types of typical BGR research projects span from i) in-house-initiated, focused projects (e.g. updates/progress and synthesis reports of former studies), ii) initial research projects (methodological developments, feasibility studies, etc.), iii) projects assigned by federal institutions (BfS/BGE) related to explicit existing minesites (Asse II or Gorleben) or repositories (Konrad and Morsleben) in Germany or on international ground (Bure/FR, Aspö/SE, WIPP site/US, Beishan/CN, ect.), iv) mid- and long-term projects with relevant partners on a national level and v) international projects with high visibility (e.g. EU-project coordinator of PEBS (Performance of Engineered Barrier Systems), funding organization of DECOVALEX.org, Mont Terri consortium member since 1996). Stringent project and quality management systems with regular internal and external audits facilitate resource efficiency, strategic disposition and constrain the professional performance.

BGR will contribute to two work packages: a) The impact of elevated temperature ($> 100^{\circ}\text{C}$) on geochemical mineralogical properties of a suite of different bentonites (HITEC) and b) the impact and quantification of advective gas transport on the barrier integrity and barrier performance (GAS). In both these research areas BGR staff have significant share in the international knowledge development in the past decades (LOT, ABM1, ABM2, PEBS, ABM5 and DECOVALEX and Mont Terri Project).

In a third work package (DONUT) BGR aims at a guest status. The task focuses on the development and improvement of numerical methods and tools for the numerical modelling of coupled processes. Also here BGR staff has proven significant competence in numerous past and ongoing projects (PEBS, BEACON, DECOVALEX, etc.) and numerous publications.

Amphos 21 Consulting S.L. WP COR1

Amphos 21 (A21) is a private scientific and technical environmental consulting company with offices in Spain, Chile, Peru and France. Main activity fields are offered in the nuclear, mining, water resources and sustainability market sectors. The company was founded in 1994 and the nuclear services account for more than a 60% of the projects developed in Europe. The nuclear department gathers 30 professionals in the fields of chemistry, geochemistry, hydrology and IT development. A21 develop projects for most of the nuclear waste management organisations in Europe, focused on R&D activities in radioactive waste management, from the experimental and modelling studies of the behaviour of spent nuclear fuel and waste forms to the migration of radionuclides in the geosphere and performance assessment of deep and surface facilities for nuclear waste storage and deposition. A21 have worked in projects funded by the European Commission since 1994.

- **Link of the participant to the third party:** In 2018, KIT-INE and A21 signed a “Collaboration agreement on the field of management and disposal of Radioactive Waste”. The relationship between Amphos 21 and KIT-INE started in the 90’s and expands to different type of projects, EC and also private funded developments. The collaboration between KIT-INE and A21 has proven very successful and satisfactory for both parts. Last examples of close collaboration between both parties in EC projects have been CEBAMA, First-Nuclides, CROCK, Recosy and FUNMIG. Other types of collaborations have been through the Taslismán and Actinet instruments.

Examples of collaboration not funded by the EC have led to the development of several Ph.D thesis, such as:

- Tasi, A. (2018) “Solubility, redox and sorption behaviour of plutonium in the presence of α -D-isosaccharinic acid and cement under reducing conditions”. A21 subcontracted KIT-INE for the research project, which was funded by SKB (Sweden)
- Gonzalez-Siso, M.R. (2018). Determination of key master variables and radionuclide behaviour in the Swedish Final Repository environment
- Fernandes, T. (2017) Geochemical Behaviour of uranium and thorium in the waste of a uranium conversion facility.

Stages of personnel of A21 to KIT-INE and vice versa have been also accomplished through different collaboration and KIT-INE is part of the consortia for the development of the iCP tool and Image project managed by A21 (<https://image-modelling.net/project/view/1/iCP>)

An example of existing current collaboration contracts is the ThermAc3 (2017-2019) “Thermodynamics and speciation of actinides at elevated temperatures”, extension of the initial contract dated 2015.

- **Tasks to be performed by the third party in WP3 - CORI :**

1. A21 is co-subtask leader in CORI, Subtask 3.
2. Task 3. Interaction of pure cement phases (CASH or CSH) with adipate and phthalate (characteristic of PUR and PVC degradation, resp.) and isosaccharinate (ISA, characteristic of cellulose degradation) in the presence and/or in the absence of Fe. A scientific development is foreseen using pure cement systems (CASH or CSH with variable C/S ratio) The work will follow a bottom-up approach:
 - Uptake of single organic molecules (adipate, phthalate or ISA) with CASH or CSH
 - Uptake of one organic, selected based on previous results, with CASH or CSH in the presence of iron.
3. Task 4. Interaction of Radionuclides (e.g. Ni and/or U) with pure cement phases (CASH or CSH) and organic ligands (adipate, phthalate and isosaccharinate). The bottom-up approach of the study will similar to that detailed in Task 3 and includes:
 - Uptake of selected RN by cementitious phases (CASH or CSH) in the absence of organic ligands (batch experiments with solid samples dispersed in cement synthetic water).
 - Uptake of selected RN by cementitious phases (CASH or CSH) in the presence of organic ligands (batch experiments with solid samples dispersed in cement synthetic water).

- **Tasks to be performed by the third party in WP15-ConCorD :**

AMPHOS21 will contribute to Task 6 by improving the mechanistic understanding of the influence of irradiation, microbiology and transients corrosion process of metals by using laboratory-scale modelling to aid the interpretation of the results produced in Task 2 -5.

Third Party: PreussenElektra GmbH (PEL)

PreussenElektra is a wholly owned subsidiary of E.ON and has been operating Germany's largest fleet of commercial nuclear power stations. To its portfolio belong six nuclear power stations in the German states of Bavaria, Lower Saxony, and Schleswig-Holstein. Most of these plants were commissioned in the early 1980s. PEL owns minority shares in a further five plants. All of them will have been permanently shut down by 2022 and then await decommissioning. The safe operation of these facilities has been due to the continuous improvement and implementation of high safety standards, an extensive maintenance program and a highly-skilled workforce. One part of PEL's decommissioning activities is the qualification of suitable storage and transport casks for spent nuclear fuel and their subsequent loading and storage. PEL mainly uses the CASMO/SIMULATE toolset for reactor physics and source term calculations.

- ***Link of the participant to the third party:***

PEL and KIT have a long history of research collaboration in the field of nuclear reactor safety and in particular a framework agreement entitled “Agreement for collaboration on the field of management and disposal of radioactive waste” has been put into place since February 2019.

- ***Tasks to be performed by the third party:***

1. PEL contributes its industrial knowledge and experience about source term calculations for spent nuclear fuel and in particular its expertise regarding the requirements and techniques for nuclide vector determination for intermediate storage until final disposal.
2. PEL will be responsible for organizing the activities in subtask 2.4 of the main task “fuel properties characterization and related uncertainty analysis” and will be responsible for delivering the subtask's results. The objective is to standardize the analyses performed by the partners in order to obtain consistent results from a large dataset of samples. This complements the activities of earlier subtasks which focus on developing recommendations for state-of-the-art calculations and are based on a relatively small dataset. In subtask 2.4 calculations with an industry-standard and an improved code will be done, and the statistical significance of the preceding method development and improvements

will be demonstrated. PEL will develop with the partners a set of consistent input and calculation schemas to minimize modelling bias and merge results into a comprehensive report.	
Does the participant envisage the use of contributions in kind provided by third parties (Articles 11 and 12 of the General Model Grant Agreement)	N
Does the participant envisage that part of the work is performed by International Partners (Article 14a of the General Model Grant Agreement)?	N

25/ LEI

Does the participant plan to subcontract certain tasks (please note that core tasks of the project should not be sub-contracted)	N
Does the participant envisage that part of its work is performed by linked third parties	N
Does the participant envisage the use of contributions in kind provided by third parties (Articles 11 and 12 of the General Model Grant Agreement)	N
Does the participant envisage that part of the work is performed by International Partners (Article 14a of the General Model Grant Agreement)?	N

26/ MTA EK

Does the participant plan to subcontract certain tasks (please note that core tasks of the project should not be sub-contracted)	<u>N</u>
Does the participant envisage that part of its work is performed by linked third parties	<u>Y</u>
The Linked Third Party, Social Organization for Radioecological Cleanliness (SORC), is a non-governmental organization created in 1993, aims to promote modernization of higher education, enhance the quality and relevance of higher education in the region. According to the aims the SORC would like to give the public the valuable and reliable information about the hazard on the radiations. The most well-known problems of the nuclear accidents (Chernobyl, Fukushima, etc.) but nowadays the NORM materials are in the focus too. Environmental impact and harm resulting from present and past industrial past activities is very complex and diverse according to the type of industry, raw material extraction and exploitation process and waste processing and handling and factors such as site local geology and hydrogeology. Instruments of SORC are primarily capable of measuring environmental samples (laboratory equipment) and Physical process modelling and simulations (GPU-CPU Server). The last 10 years SORC has developed several software, especially an atmospheric modelling software for Hungarian NPP. SORC is in close co-operation with other research groups, therefore it is possible to involve/carry out further numerical simulation. Link of the participant to the third party: MTA EK and SORC have developed the Hungarian National Nuclear Forensics Library. This library (software) dedicated for a comparative assessment of several characteristics with existing information could be used to identify or exclude possible origins of the nuclear materials. In addition, MTA EK and SORC are members of SUSTAINABLE ATOMIC ENERGY TECHNOLOGY PLATFORM (FAETP) in Hungary, it is a nuclear platform for nuclear research where they collaborate on the definition and development of research projects on nuclear technologies including aspects of the nuclear waste management. Tasks to be performed by the third party: WP Development and improvement of numerical methods and tools for modelling coupled processes (DONUT) into the Task 2: Numerical methods for high performance computing of coupled processes work will be developed by SORC team. SORC will develop modules with numerical algorithms adapted to the resolution of multiphysic coupled problem on GPU-CPU Server platforms, how is: Models designed to represent the development of discrete gas pathways in clays are likely to be too restricted in application for full scale performance assessment calculations, and the development of continuum models that would satisfy the needs of the latter are considered a priority. A large problem can usually be divided	

into smaller tasks that operate together in order to create a solution. One possible, effective solution for increasing the computational time can be the parallelization of the source codes. The GPU got a heavy parallel architecture, making the effective for arithmetic operations and calculations. The main plan to compare different programming modules (CUDA, OpenCL, OpenMP, OpenACC) and optimize a module for a cost effective and reliable numerical method. Tibor Kovacs, is responsible for DONUT WP as LTP.	
Does the participant envisage the use of contributions in kind provided by third parties (Articles 11 and 12 of the General Model Grant Agreement)	<u>N</u>
Does the participant envisage that part of the work is performed by International Partners (Article 14a of the General Model Grant Agreement)?	<u>N</u>

27/ NAGRA

Does the participant plan to subcontract certain tasks (please note that core tasks of the project should not be sub-contracted)	Y
NAGRA plans to subcontract certain task to Better Data Systems and Swiss Company Marmota. The subcontractors have been selected in accordance with the requirements of Article 13 of the grant agreement. In Tasks 2 Nagra will be subcontracting BetterDataSystems to expand the capability of FEIS, the data acquisition, management & visualization platform used for the FE experiment. BetterDataSystems are the developers of FEIS and are optimally situated to carry out the feature expansion in collaboration with Nagra's experience with the experiment and the acquired data. We plan to continue the work with BetterDataSystems, who was contracted by Nagra since 2015, considering Nagra's tender and award procedures to ensure best practice and best value for money. A change of contractor would jeopardize the success of the planned research. Total budget of BetterData Systems: 70 000 euros In Task 3.2 the Swiss company Marmota will be subcontracted for the fibre-optic strain measurements in the framework of the TS-Experiment at the Mont Terri URL as well as for parts of the development of the advanced data processing and analysis techniques under the lead of Nagra. We plan to continue the work with Marmota, who was contracted by Nagra since 2018 for the work in the TS-Experiment taking into account Nagra's tender and award procedures to ensure best practice and best value for money. A change of contractor would jeopardize the success of the planned research. Total budget of Swiss Company Marmota: 35 000 euros	
Does the participant envisage that part of its work is performed by linked third parties	Y
- EPFL/LMS is a longtime research partner of Nagra in the field of THM coupled processes (laboratory, modelling). Collaboration has started in 2006; a multitude of PhD thesis have been accomplished, focussing on bentonite characterisation, gas transport in sand/bentonite and THM characterisation of indurated clays (Opalinus Clay and other Mesozoic clay formations). New experimental set-ups have been developed to characterise the suction behaviour of clay-rich material. The latest development is an advanced triaxial cell for gas permeability testing with highly accurate control of volumetric strains. The EPFL team has strong modelling capabilities; they have developed an elasto-plastic constitutive framework for modelling gas transport processes in clay-rich media. The modelling framework has been subjected to a comprehensive validation exercise in the context of SKB's EBS-Task Force (Task 7: "gas transport in bentonite"). - CIMNE and Nagra established comprehensive research collaborations 20 years ago. The collaboration started as part of an international project on gas transport in sand/bentonite mixtures at the Grimsel URL.	

Since then, Nagra has co-funded new experimental set-ups at CIMNE's geotechnical laboratories for investigating gas transport in bentonite and Opalinus Clay. Multiple publications in peer reviewed journals have been completed with emphasis on the deformation behaviour of clay-rich materials in response to gas pressures. On behalf of Nagra, CIMNE is currently performing a comprehensive laboratory programme on gas transport in bentonite in the context of SKB's EBS-Task Force. CIMNE participates in the validation exercise in the context of SKB's EBS-Task Force (Task 7: "gas transport in bentonite") with their own modelling framework.

- ZHAW/ICP collaborates with Nagra for more than 10 years in the field of microstructural imaging of clay-rich materials. This includes pioneering work on pore connectivity of bentonite and Opalinus Clay (FiB nano-tomography, TEM, BiB, micro-CT) which has been published in peer reviewed journals. The ZHAW team has developed advanced image processing tools for upscaling the microstructural information, aimed at linking the micro-scale to the scale of laboratory testing with core samples. The upscaling techniques have been validated in the context of the EBS-Task Force (Task 7: "gas transport in bentonite").
- INSTITUTE of GEOLOGICAL SCIENCES of the UNIVERSITY of BERNE has been collaborating with Nagra for more than thirty years. The Rock Water Interaction group (RWI) of the institute of Geological Sciences group has acquired expertise not only in the framework of Nagra's projects (e.g. Wellenberg, Projekt Opalinuston, Mont Terri and Grimsel URL's) but also contributed in various ways to international projects (EU-projects and for Nagra's sister organisations). The wide range of expertise by RWI includes but is not limited to: porewater analyses of clayrocks and bentonite materials, transport properties of clay rocks and bentonite materials, mineralogical and petrographical investigations and the evolution of interfaces of engineered and natural barriers. This also includes an in depth understanding of interface processes between steel and bentonite or cement and bentonite under repository conditions.
- The Radioactive Waste Corrosion Team at **JACOBS** has extensive experience in the understanding of corrosion and degradation processes of a variety of radioactive wastes and nuclear materials as well as of the materials used to treat and contain them. These include mild and carbon steel, cast iron, stainless steel, copper, titanium, aluminium, magnesium alloys and uranium, as well as cement/concrete, polymeric materials and nuclear glasses. Jacobs' clients include Nuclear Decommissioning Authority, Radioactive Waste Management Ltd, Nagra, SKB, Ondraf-Niras, Sellafield Ltd, and Magnox Ltd. On behalf of Nagra, for last 14 years, Jacobs has run several long term in-situ and laboratory based experimental programmes relating to behaviour of canister material exposed to Opalinus clay (Mont Terri programme) and granite (MaCoTe programme). Overall, their work focuses on developing and underpinning technical solutions able to withstand regulatory scrutiny, build robust safety cases and adopt solid industrial practices
- ETH Zurich is one of the leading international universities for technology and the natural sciences. It is well known for its excellent education, ground-breaking fundamental research and for implementing its results directly into practice. Founded in 1855, to researchers, it today offers an inspiring working environment, to students, a comprehensive education. ETH Zurich has more than 18,000 students from over 110 countries, including 3,900 doctoral students. About 500 professors currently teach and conduct research in engineering, architecture, mathematics, natural sciences, system-oriented sciences, and management and social sciences. ETH Zurich regularly appears at the top of international rankings as one of the best universities in the world. Twenty-one Nobel Laureates have studied, taught or conducted research at ETH Zurich, underlining the excellent reputation of the university. The Exploration and Engineering Geophysics (EEG) Group that is involved in the Modern2020 project, is embedded in the Institute of Geophysics and the Department of Earth Sciences of ETH Zurich. The EEG group comprises about 25 researchers that are involved in a large variety of projects devoted to characterization of the shallow subsurface (uppermost few hundred metres). Since more than 10 years, the EEG group is involved in projects related with radio waste disposal.
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Involvement of the Nagra LTPs in the EURAD :

- WP GAS: Laboratory experiments in support of Tasks 2.1 and 2.2 (gas-induced damage evolution/self-sealing) and modelling in support of Task 2.3 shall be performed through EPFL and CIMNE.
- WP GAS: Microstructural analyses of damage evolution and self-sealing processes using advanced 3-D imaging techniques in support of Tasks 2.1 and 2.2 (gas-induced damage evolution/self-sealing) shall be

performed through ZHAW. The intended activities include also the processing/upscaling of the microstructural data, which will feed in Task 2.3.

WP ACED: The University of Berne will contribute to the ACED work package, with an experimental part and a modelling part. The experiment investigates the interaction between a Fe(II) solution and smectite, by using chemical and isotope analysis on the solution and spectroscopic analysis for the solid phases. The modelling part will build on the former experiment and previous experiences. A reactive transport model will be developed to analyse the long-term evolution of Fe-bentonite interaction under repository relevant conditions.

WP ConCorD:

- EPFL will carry out experiments systematically investigating the role of bentonite dry density and particle size distribution on the viability of microorganisms in compacted bentonite. This work will be carried out in especially designed mini-reactors allowing the generation of statistically significant findings. Furthermore, the role of O₂ trapped into or adsorbed onto bentonite on the microbial community will be evaluated by deploying variably treated bentonite samples in a borehole at the Mt Terri URL. Metal coupons will be included within the compacted bentonite to evaluate the impact on corrosion.
- Jacobs maintains a unique dry walk-in Co-60 γ -irradiation facility, which will be used for experimental work in Task 3 to investigate the effect of radiation on the corrosion of copper and steel, with a focus on determining the relative importance of total radiation dose as compared to dose rate. Jacobs will also be the Task leader for Task 6, drawing on the experience of its in-house experts to contribute to the integration of the modelling work in the context of implications for current and future performance assessments.

WP MODATS :

- ETH will work on Task 3.1 of the WP: (i) algorithmic developments and tests with synthetic data and (ii) application of the new methodology to the Mont Terri full-scale emplacement (FE) experiment. .
- ETH will develop techniques for joint inversion of geophysical data in subtask 3.1

Does the participant envisage the use of contributions in kind provided by third parties (Articles 11 and 12 of the General Model Grant Agreement)	N
Does the participant envisage that part of the work is performed by International Partners (Article 14a of the General Model Grant Agreement)?	Y
Three International Partners will be involved through Nagra as WP leader of the WP ConCorD (WP15) : - Nuclear Waste Management Organisations (NWMO) – Canada - Commonwealth Scientific and Industrial Research Organisation (CSIRO) – Australia - Nuclear Waste Management of Japan (NUMO) – Japan - The Nuclear Waste Management Organization (NWMO) was established in 2002 in accordance with the Nuclear Fuel Waste Act to assume responsibility for long-term management of Canada's used nuclear fuel. The NWMO is implementing Adaptive Phased Management (APM), the approach selected by the Government of Canada in 2007 for long-term management of used nuclear fuel. The goal of APM is long-term containment and isolation of used nuclear fuel in a Deep Geological Repository (DGR) constructed in a suitable rock formation in either sedimentary or crystalline rock at a depth of approximately 500 m. In support of APM, NWMO has an active Research and Development (R&D) Program that is refining engineering designs, conducting safety assessments, and is developing plans and methods to assess the suitability of communities engaged	

in the site selection process. A significant aspect of the R&D program is to collaborate on a broad scale with the international waste management industry, to ensure that best practices are followed throughout the site selection, licensing, construction, operation and decommissioning processes.

Total in-kind contribution to ConCorD is approximately: 2,000,000 CAD

As Australia's national science agency, CSIRO solves the greatest challenges through innovative science and technology. With over 5,000 experts, state-of-the-art facilities, and a global collaborative research network we bring together the best and brightest minds to drive strategic growth and overcome unique business challenges. Our collaborative research turns science into solutions for food security and quality; clean energy and resources; health and wellbeing; resilient and valuable environments; innovative industries; and a secure Australia and region.

Total in kind contribution to ConCorD is approximately: 400,000 AUD.

Japan's Nuclear Waste Management Organization (NUMO) was established in October 2000 in accordance with the Designated Radioactive Waste Final Disposal Act, authorized by the Ministry of Economy, Trade and Industry (METI). NUMO is tasked with implementing final geological disposal of high-level radioactive waste (HLW) and low-level radioactive waste containing long-lived nuclides (TRU waste) from Japanese nuclear fuel cycle. NUMO has begun the initial stage of assessing two municipalities in Hokkaido Prefecture for their suitability to host a final disposal facility for high-level radioactive waste.

Total in-kind contribution to ConCorD is approximately: 600,000 EUR

They will be involved in the Experts Review Group (task 1.4).

NWMO and CSIRO will be also involved for the preparation of the State-of-the-Art reports.

CSIRO will participate in Subtask 6.2 ConCorD Perform integrated modelling of container performance under disposal conditions that are likely to be more extreme in terms of temperature, pressure and chemistry than boundary conditions for conventional geological disposal facilities using new knowledge on container performance from previous tasks. Knowledge gained from experimental work will be integrated within the model and applied to one or more relevant disposal concepts.

NWMO will be involved in Subtask 3.2: Irradiation under repository conditions

NWMO and NUMO will be involved in Subtask 4.2: Impact of bentonite dry density and particle size on microbial activity

NUMO will also provide their data on microbial activity in various bentonites, which may be leveraged in comparison to the work above.

28/ NCSR D

Does the participant plan to subcontract certain tasks (please note that core tasks of the project should not be sub-contracted)	Y
NCSR D plans to subcontract certain task to SRBATOM The subcontractor has been selected in accordance with the requirements of Article 13 of the grant agreement. Total budget of SRBATOM: 3 625 € Serbian Radiation and Nuclear Safety and Security Directorate (SRBATOM) is as an independent and separate Regulatory Authority in Republic of Serbia with regulatory, expert and associated executive functions in the area of radiation and nuclear safety and security. SRBATOM was established by the Law on Radiation and Nuclear Safety and Security (Official Gazette of Republic of Serbia 95/18 and 10/19), for the purpose of providing the environment for a professional and efficient regulatory control of practices regulated by the Law 2018. SRBATOM is a legal entity responsible to the Government of the Republic of Serbia. SRBATOM was established by the mean of transformation of Serbian Radiation Protection and Nuclear Safety Agency which performed regulatory tasks and duties. Main functions and responsibilities in relation to this project of SRBATOM are to prepare draft National Strategies and Action plans for their implementation; to prepare and/or adopt draft Regulations, Rulebooks and other guides; to prepare draft Response plan in case of nuclear and radiological emergency situation; to lay down protective measures for a member of the public, the public and the environment from the harmful effect of ionizing radiation; to bring decisions on issuing, suspending or revoking authorizations for practices, use of radiation sources, approvals to perform radiation protection, permits for trade in radiation sources and permits for the transport of dangerous goods class 7 ADR/RID/ADN (radioactive material), and for the exemption of duty to obtain authorization; to establish and keep registry of applications, issued authorization and certificates and persons responsible for the implementation of radiation protection measures, registry of radiation sources and their users, exposed workers, external workers and other data relevant for radiation protection and radiation and nuclear safety; to establish and keep records of facilities, radiation sources and radioactive waste, as well as other data relevant for radiation and nuclear safety and security; to establish a system of control over radiation sources and devices with such sources as their integral part to ensure their safe and secure management and protection during and at the end of their useful lives; to participate in defining design bases and design basis accidents for the purpose of implementing radiation and nuclear safety and security measures; to carry out regulatory control and inspection oversight of the implementation of radiation and nuclear safety and security measures; to control the fulfilment of conditions serving as the basis for the issuance of authorizations pursuant to the Law 2018; to review, observe and assess the practices to verify their compliance with the Law, applicable regulations and the requirements for obtaining authorizations; SRBATOM has over a decade of experience in regulation predisposal radioactive waste management activities as well as use of radiation sources in medical, industrial and research activities. Until now SRBATOM staff has successfully reviewed safety of and licensed trial run and operation of radioactive waste and sealed radioactive sources storage facilities and are currently reviewing application for licensing	

radioactive waste processing facility. Other relevant activities included licensing of decommissioning of two old storage facilities. SRBATOM staff is currently preparing National Radioactive Waste Management Strategy which will provide plans and actions for further steps in radioactive waste management such as disposal of radioactive waste or Extension of a lifetime of existing facilities. For such activities, additional knowledge shall be needed. SRBATOM will contribute to ROUTES Extension by • sharing their national experiences, • evaluating the applicability of the developed solutions to their challenges and by reviewing the reports.	
Does the participant envisage that part of its work is performed by linked third parties	Y
The linked third party is DMT GmbH & Co. KG, acronym DMT who is expert in mining, exploitation, radiation protection, waste management. DMT has approx. 700 employees. 65 are working in the field of disposal facilities for radioactive waste. NCSR D is linked to DMT by a MoU for cooperation on a cost-free basis, each party is only responsible for its own costs. The cooperation concerns the future planning of the disposal of the Greek radioactive waste and for planning the decommissioning and dismantling of components and systems of GRR-1 at the NCSR D on the one hand and for the planning of disposal options of radioactive waste in countries with small amounts of radioactive waste in general. Main tasks that will be performed by DMT are within WP9 ROUTES - Task 5 “RWM solutions for small amounts of waste” and Task 6 “Shared solutions in European countries in Waste Management Routes” of EURAD-1. DMT (LTP) will take over the management of Task5 and give information about disposal options appropriate for SIMS like the use of old mines, tunnels, bunkers, caverns, deep shafts and boreholes (some 100 m). Expertise in mining as well as treatment and disposal of radioactive waste are only present at DMT. Former investigations for general solutions for countries generating only small amounts of radioactive waste were already performed by DMT in cooperation with NCSR D. Furthermore, DMT will collect the necessary information for the work in Task5 from the other Tasks of the WP. In WP9 Task 6 DMT will contribute by describing examples of sharing facilities in Germany as well as by providing feedback. DMT will share the information from the work in this Task with NCSR D. DMT will make a major contribution to the qualitative assessment of the disposal options (Subtask 5.1) and, with its knowledge of predisposal waste treatment and packaging, can make a central knowledge contribution in Subtask 5.2. Based on the existing knowledge with regard to predisposal routes and disposal options, DMT will make the central contribution to the consolidation of the findings from the qualitative assessment of predisposal routes and disposal options. The elaboration of the mutual influence of predisposal routes and disposal options is also part of the DMT work. DMT supports the coordinator of ROUTES Extension and takes over task leadership for Task 5 and 8 for organisation and compilation of the contributor’s work.	
Does the participant envisage the use of contributions in kind provided by third parties (Articles 11 and 12 of the General Model Grant Agreement)	N

Does the participant envisage that part of the work is performed by International Partners (Article 14a of the General Model Grant Agreement)?	N

29/ NES

Does the participant plan to subcontract certain tasks (please note that core tasks of the project should not be sub-contracted)	N
Does the participant envisage that part of its work is performed by linked third parties	N
Does the participant envisage the use of contributions in kind provided by third parties (Articles 11 and 12 of the General Model Grant Agreement)	N
Does the participant envisage that part of the work is performed by International Partners (Article 14a of the General Model Grant Agreement)?	N

30/ NJF

Does the participant plan to subcontract certain tasks (please note that core tasks of the project should not be sub-contracted)	N
Does the participant envisage that part of its work is performed by linked third parties	N
Does the participant envisage the use of contributions in kind provided by third parties (Articles 11 and 12 of the General Model Grant Agreement)	N
Does the participant envisage that part of the work is performed by International Partners (Article 14a of the General Model Grant Agreement)?	N

31/ NRG

Does the participant plan to subcontract certain tasks (please note that core tasks of the project should not be sub-contracted)	N
Does the participant envisage that part of its work is performed by linked third parties	N
Does the participant envisage the use of contributions in kind provided by third parties (Articles 11 and 12 of the General Model Grant Agreement)	N
Does the participant envisage that part of the work is performed by International Partners (Article 14a of the General Model Grant Agreement)?	N

32/ ONDRAF

Does the participant plan to subcontract certain tasks (please note that core tasks of the project should not be sub-contracted)	N
Does the participant envisage that part of its work is performed by linked third parties	Y
ULiège The Civil Engineering Department of University of Liège (ULiège) is internationally recognized for its expertise in multi-physical and multi-scale modelling in geomechanics. It has participated to several EC projects in the field of geomechanics applied to the geological disposal of radioactive waste, such as TIMODAZ, FORGE and BEACON. Link to third-party: memorandum of understanding on collaboration and exchange of information on research in geomechanics, including but not limited to research related to the geological disposal of radioactive waste. Tasks: ULiège will model gas injections experiments performed on Boom Clay and CO_x in WP6 (GAS), to support the interpretation of these experiments and the identification of key parameters for gas transport in these natural materials. In that context, ULiège will develop innovative tools for multi-scale representation of gas – porous media interactions in clay materials and transport along interfaces. ULiège will also support WP7 (HITEC), participating in benchmark exercises on the modelling of in situ heater	

experiments in different clay rocks. In that context, the interface element approach developed by ULiège will be upgraded to make it possible to represent time-dependant sealing processes. Improving the understanding of the complex mechanisms involved in gas transport in clays (e.g. such as the development of discrete, unstable pathways controlled by the mechanical behaviour of the porous media) and the thermo-hydro-mechanical couplings, combined with sealing processes, is important to determine how the effects of these complex mechanisms can be bound and, in turn, to justify the use of simpler and robust descriptions for evaluation purposes. In addition, ULiège will co-organize the joint WP6-WP7 (GAS-HITEC) training activities on multi-physical couplings in geomechanics applied to geological waste disposal. EURIDICE Link to third-party: EURIDICE is an Economic Interest Grouping set by ONDRAF/NIRAS and SCK•CEN for the management and operation of The Belgian Underground Research Laboratory HADES. EURIDICE and/or its scientific staff have participated to several EC projects in the field of geomechanics applied to the geological disposal of radioactive waste, such as CLIPEX, SELFRAC (as coordinator), TIMODAZ (as coordinator) and FORGE. Tasks: As operator of the HADES URL, EURIDICE will provide experimental data to WP7 (HITEC) from the large scale in situ heater test PRACLAY. These experimental data will be used to support the benchmarking exercise. EURIDICE will also support EURAD by providing state-of-the-art knowledge on the geomechanical behaviour of Boom Clay.	
Does the participant envisage the use of contributions in kind provided by third parties (Articles 11 and 12 of the General Model Grant Agreement)	N
Does the participant envisage that part of the work is performed by International Partners (Article 14a of the General Model Grant Agreement)?	N

33/ POSIVA

Does the participant plan to subcontract certain tasks (please note that core tasks of the project should not be sub-contracted)	Y
POSIVA plans to subcontract with institute of Mine Seismology (IMS) to work on task 3.2 and with a subcontractor (not yet selected) for task 2.3 dedicated to .Software and visualization method based on existing technology The subcontractor IMS has been selected in accordance with the requirements of Article 13 of the grant agreement. Total budget of IMS: 40 000 €. The IMS will develop new methods for digital mapping of leakages <i>The subcontractor dedicated to “Software and visualisation method based on existing technology” will be select in the respect of the Posiva Rules and in accordance to the Article 13 of the grant agreement</i> Total budget of subcontracting for task 2.3: 10 000 €. The selected company will work on task 2.3 to update the visualisation system of Onkalo	
Does the participant envisage that part of its work is performed by linked third parties	Y
Envirocase Oy is a R&D consultancy company working with spent fuel disposal and safety case projects internationally. Envirocase do work for UMAN Subtask 3.1 – Types of uncertainties relevant to the safety analysis and the work is related to the safety case and description of knowledge quality assessment methodology. The person doing the work is former Posiva staff member having a good understanding of the safety case related tasks in spent fuel disposal.	
Does the participant envisage the use of contributions in kind provided by third parties (Articles 11 and 12 of the General Model Grant Agreement)	N

Does the participant envisage that part of the work is performed by International Partners (Article 14a of the General Model Grant Agreement)?	N

34/ PSI

Does the participant plan to subcontract certain tasks (please note that core tasks of the project should not be sub-contracted)	N
Does the participant envisage that part of its work is performed by linked third parties	Y
EMPA is the Swiss Federal Laboratories for Materials Science and Technology. EMPA and PSI belong are two Swiss biggest research institutes. The Concrete and Construction Chemistry Laboratory focuses on fundamental research, application-oriented research and production development within the field of cementitious materials, with the aim of improving their sustainability. By studying alternative binder systems, concrete of improved durability and high-performance concrete, we aim at reducing the consumption of energy and raw materials and the CO₂-emissions during the life cycle of concrete structures. Laboratory for waste management at PSI and the Concrete and Construction Chemistry Laboratory at EMPA have long standing collaborative research agreement in the area of cement degradation, cement-waste interaction and radionuclides retention by cement minerals. Concrete and Construction Chemistry Laboratory at EMPA is the leading expert in thermodynamic modelling and experimental studies of cement hydration and cement interaction with environment. EMPA participate in WP CORI. Within the Task 3 (Organics-Cement-Interactions) EMPA will investigate the sorption of low molecular weight organics on the main phases present in hydrated cements: C-S-H (high and low Ca/Si C-S-H), AFm-phases and ettringite. WP MAGIC: In Task 2 & Task 3, EMPA & PSI perform non-destructive ultrasonic studies of cement samples degraded in contact with OPA pore water in ongoing large-scale experiments and conventional mechanical testing of samples at saturated and partially saturated conditions. Nonlinear Elastic Wave Spectroscopies (NEWS) and Coda Wave Interferometry (CWI) offer state-of-the-art methods for non-destructively measuring linear (needed for computational models validation) and nonlinear (visco-) elastic moduli (proxy variables of microstructural features as micro-cracks, delaminations of interfaces and dissolution pores). They entail extremely higher sensitivity to microstructural changes compared with, e.g., traditional measurements of linear ultrasound pulse velocities (UPVs). Therefore, they are the most advanced techniques for, e.g., the identification of cracking initiation and for its tracking. These techniques allow detecting the appearance/evolution of cracks at sub-micrometer scale. Thus, they are complementary to the most advanced high resolution CT methods.	
Does the participant envisage the use of contributions in kind provided by third parties (Articles 11 and 12 of the General Model Grant Agreement)	N
Does the participant envisage that part of the work is performed by International Partners (Article 14a of the General Model Grant Agreement)?	N

35/ PURAM

Does the participant plan to subcontract certain tasks (please note that core tasks of the project should not be sub-contracted)	N
Does the participant envisage that part of its work is performed by linked third parties	N
Does the participant envisage the use of contributions in kind provided by third parties (Articles 11 and 12 of the General Model Grant Agreement)	N
Does the participant envisage that part of the work is performed by International Partners (Article 14a of the General Model Grant Agreement)?	N

36/ RATEN

Does the participant plan to subcontract certain tasks (please note that core tasks of the project should not be sub-contracted)	N
Does the participant envisage that part of its work is performed by linked third parties	N
Does the participant envisage the use of contributions in kind provided by third parties (Articles 11 and 12 of the General Model Grant Agreement)	N
Does the participant envisage that part of the work is performed by International Partners (Article 14a of the General Model Grant Agreement)?	N

37/ RWM

Does the participant plan to subcontract certain tasks (please note that core tasks of the project should not be sub-contracted)	N
Does the participant envisage that part of its work is performed by linked third parties	Y
WP 16 MAGIC: The UNIMAN work program addresses Task 3 WP priorities including “Chemo-mechanical evolution of Portland and low-pH cement and model materials (simplified materials); evolution of microstructure, in situ conditions and mechanical stability upon external perturbation.” We will rigorously assess “Systematic inclusion or exclusion of microorganisms to gauge their impact at nanoscale” using samples incubated with high pH microbial consortia and “non-destructive characterization of microstructure, porosity and saturation using X-Ray CT “. More specifically, UNIMAN will contribute to WP3 via a co-funded PhD (with associated supervisory and technical support) which will focus on assessing the impact of microbial metabolism on the structure and properties of low pH cement using high pH microbial inocula, and electron donors/acceptors representative of host porewaters. The student will use a cross-disciplinary approach to quantify microbial colonisation of low pH cement and identify the extent and impact of microbial metabolism. Full geochemical analysis (including pH, redox, anions and cations, organics) and microbial community analysis (planktonic and biofilms) by 16S and 18S rRNA sequencing, and functional gene analysis as required will be performed. Biofilm imaging using ESEM and fluorescence microscopy will be carried out. In addition, Structural analysis using x-ray diffraction (XRD) to assess & identify whether crystallographic phase changes have occurred (with/without microbial biomass), associated with microstructure degradation or biomineralization reactions. This will include the development and application of 3D X-ray CT to characterise, non-destructively, microstructure changes with spatial resolutions from mm to sub-micron length scales and 2D-3D image correlation techniques to monitor in situ changes. In addition, The UNIMAN project will generate data for modelling by other MAGIC partners e.g. the impact on microbial processes on local swelling or other changes in microstructure, and the impacts of these processes on material properties. UNIMAN has extensive experience of high pH microbiology, and has unique, well-characterised active cultures for these experiments. Engelberg is an expert in materials science and x-Ray CT. State of the art laboratories available to Lloyd and Engelberg have all the infrastructure required to conduct these experiments, including microbial culturing, genetic analysis, microscopy, mineralogical analysis, X-Ray CT etc. UNIMAN will contribute to the Task 3 via a co-funded PhD (with associated supervisory and technical support) which will focus on assessing the impact of microbial metabolism on the structure and properties of low pH cement using high pH microbial inocula, and electron donors/acceptors representative of host porewaters.	
Does the participant envisage the use of contributions in kind provided by third parties (Articles 11 and 12 of the General Model Grant Agreement)	N
Does the participant envisage that part of the work is performed by International Partners (Article 14a of the General Model Grant Agreement)?	N

38/ SCK•CEN

Does the participant plan to subcontract certain tasks (please note that core tasks of the project should not be sub-contracted)	N
Does the participant envisage that part of its work is performed by linked third parties	N
Does the participant envisage the use of contributions in kind provided by third parties (Articles 11 and 12 of the General Model Grant Agreement)	N
Does the participant envisage that part of the work is performed by International Partners (Article 14a of the General Model Grant Agreement)?	N

39/ SKB

Does the participant plan to subcontract certain tasks (please note that core tasks of the project should not be sub-contracted)	Y
SKB plans to subcontract task 2.3 to Clay technology and task 2.4 to PKI Konsult. Subcontractor has been selected in accordance with the requirements of Article 13 of the grant agreement. For Clay Technology the budget is 66 784, 00 euros. For PKi Konsult the budget is 4 648, 00 euros. In details CLAY TECHNOLOGY will extract, compile and analyse experimental data from prototype repository PKI KONSULT: will produce 3D-visualization to support and clarify the experimental data.	
Does the participant envisage that part of its work is performed by linked third parties	N
Does the participant envisage the use of contributions in kind provided by third parties (Articles 11 and 12 of the General Model Grant Agreement)	Y
Uppsala University, Department of Physics and Astronomy, will provide contributions to EURAD against payment, as third party to SKB. (according to Article 11 of the AMGA) Uppsala University (UU) is a public university founded in 1477. In WP8 for Spent Fuel characterization and evolution until disposal, Uppsala University Department of physics and astronomy, applied nuclear physics, are contributing to three tasks in the work package: 1) In subtask 1.1, UU will perform the scientific and technical coordination of the SFC work package. 2) In subtask 2.2, UU will contribute to the activities by developing improved analysis procedures for calorimetric measurements; analyse the data and describing the results together with detailed fuel histories, which are required for the validation of the theoretical calculations. 3) In subtask 2.4, The main contribution of UU is to choose regression techniques and perform a multivariate regression analysis between the fuel history parameters and the experimental observables. UU will also assist PEL in establishing well-founded uncertainties for the SNF source-terms. SKB and Uppsala University have a long research relationship. In this case with the Department of physics and astronomy, applied nuclear physics, the research is regarding nuclear fuel diagnostics. The contribution of UU will consist of 54,72 person.months, 341 041,75 € of personnel actual costs, 21 250 € of travels and 25 000 € for others goods and services. The in-kind contribution will not be used on the premises of the Beneficiary, so a flat rate of 25 % is already included in those costs.	
Does the participant envisage that part of the work is performed by International Partners (Article 14a of the General Model Grant Agreement)?	N

40/ SSTC NRS

Does the participant plan to subcontract certain tasks (please note that core tasks of the project should not be sub-contracted)	N

Does the participant envisage that part of its work is performed by linked third parties	N
Does the participant envisage the use of contributions in kind provided by third parties (Articles 11 and 12 of the General Model Grant Agreement)	N
Does the participant envisage that part of the work is performed by International Partners (Article 14a of the General Model Grant Agreement)?	N

41/ STUBA

Does the participant plan to subcontract certain tasks (please note that core tasks of the project should not be sub-contracted)	N
Does the participant envisage that part of its work is performed by linked third parties	N
Does the participant envisage the use of contributions in kind provided by third parties (Articles 11 and 12 of the General Model Grant Agreement)	N
Does the participant envisage that part of the work is performed by International Partners (Article 14a of the General Model Grant Agreement)?	N

42/ SÚRAO

Does the participant plan to subcontract certain tasks (please note that core tasks of the project should not be sub-contracted)	N
Does the participant envisage that part of its work is performed by linked third parties	Y

- **The Institute of Geonics AS CR, v.v.i. (IGN)**

The Institute of Geonics AS CR, v.v.i. (IGN) which is based in Ostrava, Czech Republic, is one of a number of public research institutions that operate under the umbrella of the Czech Academy of Sciences. The IGN was founded in 1982 with a major focus on engineering applications in the field of geosciences. The research team of the Department of Applied Mathematics and Computer Science has, for many years, been involved in the development and implementation of innovative numerical methods for the simulation of processes occurring within geomaterials and the geological environment. More recently, the Institute has been working intensively on the research of methods for the estimation of uncertainty in modelling. The team is a partner of the National Supercomputing Centre in Ostrava with which it is currently working on a project oriented towards developing high performance, massively parallelisable computing methods.

Linked third party (LTP) connection to the beneficiary:

Long-term cooperation with SÚRAO, which includes the participation of a team in the international DECOVALEX (Development of Coupled Models and their Validation against Experiments) project since 2008, is supported by a research cooperation agreement (SO2018-095) that was signed in 2018.

Tasks to be performed by the LTP:

WP DONUT - Development and Improvement of Numerical Methods and Tools for the Modelling of Coupled Processes. The IGN team will contribute to the development of robust and efficient, parallelizable numerical methods for the simulation of hydro-mechanical and thermo-hydro-mechanical (THM) processes in natural and bentonite DGR barriers. The newly-developed methods will be tested on suitable benchmark problems related to the performance-safety analysis of the future Czech DGR. The IGN team will also contribute to the Monte-Carlo methods via a suitable variance reduction technique (Multi-level Monte-Carlo methods for issues concerning poromechanics), a stochastic collocation method and response surface methods. Moreover, IGN research will also focus on sensitivity analysis and inverse identification problems, focusing specifically on the Bayesian inversion technique with the use of surrogate models. The developed uncertainty quantification/reduction methods will be tested on models for the analysis of coupled processes relevant to underground nuclear waste disposal.

- **ÚJV Řež, a.s.**

The principle mission of ÚJV Řež, a.s. (Nuclear Research Institute, NRI, hereinafter referred to as UJV) is to remain the pre-eminent technical-engineering company in terms of contributing to the development of a long-term sustainable power supply in the Czech Republic and to make up a significant player with respect

to European research in the field of nuclear energy. The Waste Disposal Department at UJV focuses primarily on supporting SÚRAO in the development of the long-term deep geological repository R&D programme. Its activities include the conducting of laboratory and field experiments for the quantification of migration and geochemical processes (sorption, diffusion) and laboratory experiments for the quantification of the degradation rates of spent fuel, waste forms and engineered barriers (disposal container materials, backfill and buffer materials). Moreover, the environmental safety performance and risk analysis of geological disposal systems (behaviour, spread of radionuclides and toxic substances in the near- and far-fields of disposal facilities and their environmental impacts) also make up important elements of the research programme of the department. The department is equipped with UV/Vis-spectroscopy, beta and gamma-spectroscopy and AAS etc. equipment and enjoys the support of the UJV's certified central laboratory (ICP-MS, DTA, alpha spectroscopy, DTA, HPLC etc.).

LTP connection to the beneficiary:

UJV and SÚRAO have enjoyed fruitful cooperation with concern to both national and international projects concerning radioactive waste management and the repository development programme since SÚRAO's establishment by the Atomic Act which was adopted in 1996. In 2017, UJV and SÚRAO signed cooperation agreement No. SO2017-105 focusing on various fields in the area of radioactive waste management and disposal.

Tasks to be performed by the LTP:

WP ACED – the Assessment of the Chemical Evolution of ILW and HLW Disposal Cells. The main contribution will be to study the effect of steel corrosion on bentonite at different temperatures – geochemical modelling of this interface will be carried out.

WP HITEC – the Influence of Temperature on Clay-based Material Behaviour. The study of changes in the properties of bentonite due to thermal loading (mineralogy with respect to changes of expandable structures of clay minerals, cation exchange capacity, specific surface, re-hydration - retention curves) and the provision of support for the CTU with respect particularly to analytical measurements.

WP GAS – the Mechanistic Understanding of Gas Transport in Clay-based Materials. The performance of laboratory experiments and the study of the migration (advection) of hydrogen through bentonite using experience obtained from previous projects (FORGE, Czech projects); the experiments are based on the detection of the lower pressure limit at which hydrogen breakthrough occurs in bentonite. The experiments will provide support for experiments conducted at the CTU.

WP CORI - Cement-Organics-Radionuclide-Interactions. The study of the degradation of concrete organic additives (superplasticisers) and ion-exchange resins via radiolysis (in an irradiation chamber) and hydrolysis in an alkaline environment and the consequent analytical evaluation of degradation products. Migration studies of the influence of degradation products of organics on cementitious materials – sorption, diffusion, leaching; the verification and description of the fixation of ion exchange resins in cement matrices; changes in the physical and mechanical properties of cement matrices due to the degradation of organics via irradiation and hydrolysis; studies of the migration of organics in cementitious materials influenced by iron corrosion products. The migration of selected tracers and their complexes with concrete additives and the degradation products of organics and the migration of selected tracers fixed on ion-exchange resins and their degradation products (e.g. Ni, U) in CEM I.

WP DONUT - Development/improvement of numerical methods and tools for the modelling of coupled processes. The UJV contributions will focus on the delivery of extensive pre-processed site-characterisation data, including the description and interpretation thereof in close connection with the FUTURE WP. A joint programme has been designed with concern to developments surrounding the mathematical representation of uncertain parameters applied for coupled processes involving cooperation between UJV, GRS, JUELICH and HZDR on the conducting of a complex uncertainty treatment and sensitivity analysis based on coordinated data collection, uncertainty quantification and the testing of sensitivity analysis methods applied in geochemical applications.

WP FUTURE - Fundamental Understanding of Radionuclide Mobility. The analysis of the connected pore network and surface topography of fractured crystalline rock samples and mineral infills followed by batch type and flow-through sorption experiments utilising the reference pore water of the specific host rock. UJV will focus on the preparation and characterisation of samples with respect to pore structure, batch sorption experiments (Eu, Ba, Sr, Se, I) and through-diffusion tests (HTO, I, Ba/Eu, U) with crystalline rock samples. The WP envisages extensive cooperation with HZDR and Helsinki university.

WP ConCorD :

The main goal of activities will be extending the understanding of coupled processes, integrating irradiation (Task 3, UJV), microbial effect on corrosion (Task 4, TUL+UJV) and thermal effect as one of the transients (Task 5, UJV), having effect on container performance under repository-relevant conditions. The experimental work represents a complex team (SURAO-UJV-TUL) approach which enables to couple both effects on the realistic system of bentonite – carbon steel under anaerobic conditions.

The main aim is to investigate the influence of irradiation on the compacted Ca-Mg bentonite – carbon steel system under anaerobic conditions, thermally affected up to 150°C and a focus on accelerated corrosion rates in comparison with non-irradiated system under anaerobic conditions. Complementary system heated up to 90 °C will also be available (Tasks 3, UJV, SURAO). Complementary samples with reference bentonite (e.g., MX80) will be added as well.

Moreover, the proposed experimental programme will allow the study of the survival of microorganisms in extreme transient conditions. The second goal is therefore to prove the assumption of limited microbially induced corrosion (MIC) under the high stress load and to assess the survivability of bacteria (regenerated from spores) that can be involved in MIC after transients are over. We propose a hypothesis that heat and radiation will have a more deleterious effect on survivability in water saturated (and dispersed) samples than in desiccated ones. Evaluation of microbial abundance and survivability in the carbon steel – bentonite system under irradiation and high thermal load at whole range of water saturation levels will be performed as a bridge to HITEC WP. The experimental design will enable the microorganisms to regenerate from dormant stages after long-term high stress load in more natural bentonite conditions that overcomes the main drawback (high selectivity) of cultivation-based approaches. All samples will contain carbon steel that will simulate the corrosive substrate to specifically target microorganisms potentially responsible for MIC Task 4 (TUL, UJV, SURAO).

Evaluation of development of interface carbon steel – Ca-Mg bentonite under higher thermal load in comparison with less temperature affected systems (already existing, being studied in ACED WP, Deliverable 2.6 and Table 1), directing toward potential DGR optimisation; however, have been evaluated only for bentonite performance so far (HITEC WP) – Task 5 (UJV, SURAO). Complementary samples with reference bentonite (e.g., MX80) will be added as well.

Contribution to SOTA in Task 1 is envisaged (UJV, TUL)

UJV will coordinate Task 5, therefore involvement in Task 1 Coordination is envisaged.

WP MAGIC: UJV as a research LTP will be responsible in Task 2 for:

- cooperation on sample preparation (cutting, grinding...)
- alternation on mechanical destructive tests - compressive strength (on smaller cylindrical samples)
- hydraulic conductivity measurement
- microstructure/pore space description by porosity measurement
- characterisation of solid phases - initial, during and after degradation/alteration process (bulk chemical analysis, XRF)

characterisation of surrounding environment (phys-chem properties, chemical composition)

• **Technical University of Liberec (TUL)**

The Technical University of Liberec (TUL), which was founded in 1953, is a regional public university offering an extensive range of technical and humanities subjects. Two departments are involved in the project: The Centre of Nano-materials, Advanced Technologies and Innovations (established as part of an EU regional operational programme) and the Faculty of Mechatronics and Interdisciplinary Engineering Studies. The specialised fields of the two teams include computer science research and numerical simulation in the field of geosciences. The teams have extensive experience of code comparison and benchmarking related to nuclear waste disposal (coordinated by SÚRAO) and the theory and implementation of numerical methods in the context of national research support programmes. The team also operates the “Charon” cluster of 400 cores in 20 nodes (introduced in 2017) as a part of the Czech MetaCentrum partnership.

LTP connection to the beneficiary:

The link between the participant and the third party is based on joint research work that has been underway via e.g. the DECOVALEX project (on the model development and testing of coupled processes and the processing of data on groundwater flow and the transport of tracers) since 2008 and the GEOSTAB project (on methodologies concerning the stability of underground constructions including SW for compiling 3D records of geological massifs) since 2011. An assessment of past cooperation with a view to subsequent cooperation was incorporated into research cooperation agreement No. SO 2018 – 091 of 9 November 2018.

Tasks to be performed by the LTP:

WP DONUT - Development and Improvement of Numerical Methods and Tools for the Modelling of Coupled Processes. As part of the project the TUL plans to develop and implement numerical approaches related to multi-dimensional domain modelling (fracture-continuum) comprising e.g. processes within intersections, coupling frameworks, the XFEM method and hybrid parallelism. The TUL will apply the multi-dimensional model concept in relation to data from different spatial scales using hydraulic/tracer field data. As part of the uncertainty analysis work, it is planned that the multilevel Monte-Carlo method will be applied to the various model problems, resulting to the effective approximation of generalised moments followed by the approximation of CDF from generalised moments. Finally, the TUL will contribute to benchmarking and the evaluation of the Flow123d simulation code including uncertainty analysis tools.

WP ConCorD :

The main goal of activities will be extending the understanding of microbial effect on corrosion (Task 4, TUL+UJV), having effect on container performance under repository-relevant conditions. The experimental work represents a complex team (SÚRAO-UJV-TUL) approach which enables to couple both effects on the realistic system of bentonite – carbon steel under anaerobic conditions.

Moreover, the proposed experimental programme will allow the study of the survival of microorganisms in extreme transient conditions. The second goal is therefore to prove the assumption of limited microbially induced corrosion (MIC) under the high stress load and to assess the survivability of bacteria (regenerated from spores) that can be involved in MIC after transients are over. We propose a hypothesis that heat and radiation will have a more deleterious effect on survivability in water saturated (and dispersed) samples than in desiccated ones. Evaluation of microbial abundance and survivability in the carbon steel – bentonite system under irradiation and high thermal load at whole range of water saturation levels will be performed as a bridge to HITEC WP. The experimental design will enable the microorganisms to regenerate from dormant stages after long-term high stress load in more natural bentonite conditions that overcomes the main drawback (high selectivity) of cultivation-based approaches. All samples will contain carbon steel that will simulate the corrosive substrate to specifically target microorganisms potentially responsible for MIC Task 4 (TUL, UJV, SÚRAO).

Contribution to SOTA in Task 1 is envisaged (UJV, TUL)

WP MAGIC : TUL as a research LTP will be responsible in Tasks 1, 2 and 3 for sample processing and microbiological analyses including:

- DNA extraction from biofilm swabs obtained from concrete surfaces
- DNA extraction from water, bentonite and concrete matrices
- NGS - 16S rDNA sequencing to detect and determine microbial abundance (metagenomics)
- real-time PCR for microbial quantification (different markers for different microbial groups)
- Epi-fluorescence microscopy to detect microbial presence and quantification and estimate living and dead cells

• Czech Technical University in Prague (CTU)

The Czech Technical University in Prague (CTU), a public university established in 1707, is one of the largest and oldest technical universities in Europe. The CTU currently has eight faculties (Civil Engineering, Mechanical Engineering, Electrical Engineering, Nuclear Science and Physical Engineering, Architecture, Transportation Sciences, Biomedical Engineering and Information Technology) and a student population of around 18,000. The university offers a wide variety of study programmes and hosts a number of leading research groups. Research groups from the Faculty of Nuclear Sciences and Civil Engineering will participate in the project.

LTP connection to the beneficiary:

The CTU enjoys long-standing cooperation with SÚRAO involving the conducting of a large number of joint research projects (e.g. DOPAS, BEACON, CEBAMA). Indeed, the CTU makes up one of SÚRAO's leading long-term research providers. The CTU and SÚRAO signed the latest framework research cooperation agreement (SO2018-096) on 2 February 2019, which establishes the will of the parties concerned to cooperate in research concerning the future Czech DGR.

Tasks to be performed by the LTP:

WP CORI - Cement-Organics-Radionuclide-Interactions. In close cooperation with UJV Řež, a. s., the CTU will study the degradation of cementitious materials, concrete organic additives and ion-exchange resins

with regard to their mutual interaction and transport/retention properties. The research will consist of an analysis of cementitious samples originating from radiolytic degradation and the hydrolysis of the materials, and will include the identification and quantification of organics, organics-cement and organics-iron species and the influence of organics-Fe/organics-cement species on RN transport and cement degradation. Long-term experience of the modelling of geochemistry and diffusion transport in the PHREEQC3 environment will facilitate the subsequent experimental data fitting process.

WP DONUT – the Development/improvement of Numerical Methods and Tools for the Modelling of Coupled Processes. Attention will be devoted to numerical modelling and simulation with concern to thermo-hydro-mechanics and will include modelling issues based on material constitutive laws (CU) as well as HPC issues related to parallelism based on domain decomposition.

WP GAS – the Mechanistic Understanding of Gas Transport in Clay-based materials. The CTU will perform laboratory experiments and study the migration (advection) of gases through bentonite using experience obtained from previous projects (FORGE, CZ projects). A long-term experiment involving slow gas injection and including a series of repeated fracturing (gas breakthrough) tests and the resealing of the bentonite barrier (re-saturation and a permeability check) is planned.

WP HITEC – the Influence of Temperature on Clay-based Material Behaviour. The main objective of the CTU is to characterise and model the thermo-mechanical behaviour of bentonite at temperatures in excess of 100°C. The CTU will perform the analysis of materials exposed to high temperatures, measure the various parameters at high temperatures and perform the laboratory experiments. The laboratory data will provide input material for the construction of a mathematical model as part of the work package. Along with its various research responsibilities, the CTU will coordinate Task 3 and provide assistance with the preparation of a training workshop.

WP SFC – Spent Fuel Characterisation. The CTU enjoys extensive experience with the determination of the radiation source term during fuel depletion and the consequent decay period. The CTU will study the sensitivity of this source term to realistic levels of impurities in the composition of materials and the importance of structural materials with respect to the overall SNF source term.

WP KM – Training/Mobility. The CTU will assist in the preparation and conducting of training courses. The CTU is able to offer courses involving the research reactor and other laboratories as well as the Josef Underground Laboratory.

WP MAGIC - Two departments of the Faculty of Civil Engineering of CTU in Prague are involved (Centre of Experimental Geotechnics and Dept. of Mechanics). CTU is responsible for mechanical analyses mainly. Work planned in Tasks 1, 2 and 3:

- samples preparation (drilling, cutting, grinding, polishing...)
- mechanical tests - non-destructive - nanoindentation, destructive - uniaxial strength (standard and punch test); potentially punch test on tension in bending
- microstructural analyses coupled with nanoindentation
- hydraulic conductivity tests, potentially gas conductivity

Both original (witness) samples and aged samples (delivered by the team partners) will be tested in several experimental campaigns.

• **Charles University (CU)**

The Charles University (CU) – is the oldest university in Central Europe. Established in 1348, and with 17 faculties, it is the largest and most respected university in the Czech Republic and also enjoys a high ranking internationally. SÚRAO is involved in the DONUT and HITEC WPs with the CU's College of Natural Sciences (Department of Engineering Geology). The university's main representative in the WPs, Dr. David Mašín, gained his professional experience at a number of leading universities in the field and has based his research at the University of Innsbruck; Imperial College, London; City University, London; Université Joseph Fourier, Grenoble; the University of Dresden; the University of Karlsruhe and the University of New South Wales, Sydney. The subject of the mechanical evolution of bentonite makes up the principal theme of the joint Horizon 2020 project commissioned in 2016 under the acronym BEACON and conducted in cooperation with SÚRAO.

LTP connection to the beneficiary:

Long-term cooperation with SÚRAO, which includes the participation of a team in the international BEACON project (Bentonite mechanical evolution, Horizon 2020, Proposal number: 745942) since 2015, is supported by an agreement on research cooperation signed on 5 April 2018 (SO 2018-094).

Tasks to be performed by the LTP: WP DONUT, Task 2 – particular attention will be devoted to numerical modelling and simulation with respect to Thermo-Hydro-Mechanics (THM) including modelling issues based on material constitutive laws. The HITEC WP, Task 3 - Subtask 3.1: the CU will focus on the post-mortem analysis of small-scale laboratory experiments performed by the CTU. The CU will investigate swelling under constant load test conditions and conduct oedometric load-unload tests and water retention tests on heat-treated BCV bentonite. Subtask 3.2: the CU will study the BCV material at 100 °C and 150 °C in specialised cells and conduct 2 swelling pressure tests with suction control, 2 swelling under constant load tests with suction control and 1 oedometric load-unload test. Subtask 3.3: the CU will further develop and validate a hypoplastic model for bentonite at high temperature and will conduct simulations of experiments conducted by the CTU.	
Does the participant envisage the use of contributions in kind provided by third parties (Articles 11 and 12 of the General Model Grant Agreement)	N
Does the participant envisage that part of the work is performed by International Partners (Article 14a of the General Model Grant Agreement)?	N

43/ SURO

Does the participant plan to subcontract certain tasks (please note that core tasks of the project should not be sub-contracted)	N
Does the participant envisage that part of its work is performed by linked third parties	N
Does the participant envisage the use of contributions in kind provided by third parties (Articles 11 and 12 of the General Model Grant Agreement)	N
Does the participant envisage that part of the work is performed by International Partners (Article 14a of the General Model Grant Agreement)?	N

44/ TNO

Does the participant plan to subcontract certain tasks (please note that core tasks of the project should not be sub-contracted)	N
Does the participant envisage that part of its work is performed by linked third parties	N
Does the participant envisage the use of contributions in kind provided by third parties (Articles 11 and 12 of the General Model Grant Agreement)	N
Does the participant envisage that part of the work is performed by International Partners (Article 14a of the General Model Grant Agreement)?	N

45/ TS Enercon

Does the participant plan to subcontract certain tasks (please note that core tasks of the project should not be sub-contracted)	Y
<u>TS ENERCON plans to subcontract certain tasks of DONUT Task 4 to Golder Associates Hungary Ltd. The subcontractor has been selected in accordance with the requirements of Article 13 of the grant agreement.</u> <u>Golder Associates Hungary Ltd will be involved in the following WP:</u> <u>DONUT Task 4: Supporting TS Enercon Ltd. with conceptual and mathematical modelling capabilities.</u> <u>Total budget of Golder Associates Hungary Ltd: 6 870 €</u>	
Does the participant envisage that part of its work is performed by linked third parties	N
Does the participant envisage the use of contributions in kind provided by third parties (Articles 11 and 12 of the General Model Grant Agreement)	N

Does the participant envisage that part of the work is performed by International Partners (Article 14a of the General Model Grant Agreement)?	N

46/ TUS

Does the participant plan to subcontract certain tasks (please note that core tasks of the project should not be sub-contracted)	N
Does the participant envisage that part of its work is performed by linked third parties	N
Does the participant envisage the use of contributions in kind provided by third parties (Articles 11 and 12 of the General Model Grant Agreement)	N
Does the participant envisage that part of the work is performed by International Partners (Article 14a of the General Model Grant Agreement)?	N

47/ UCY

Does the participant plan to subcontract certain tasks (please note that core tasks of the project should not be sub-contracted)	N
Does the participant envisage that part of its work is performed by linked third parties	N
Does the participant envisage the use of contributions in kind provided by third parties (Articles 11 and 12 of the General Model Grant Agreement)	N
Does the participant envisage that part of the work is performed by International Partners (Article 14a of the General Model Grant Agreement)?	N

48/ UH

Does the participant plan to subcontract certain tasks (please note that core tasks of the project should not be sub-contracted)	N
Does the participant envisage that part of its work is performed by linked third parties	Y
JyU (University of Jyväskylä), a linked third party to UH will utilize X-ray techniques to obtain detailed spatial and temporal information on wetting and hydromechanic behaviour of small-scale bentonite samples at elevated temperatures. The experiments will be carried out as a joint effort with GTK. The data obtained will be organized in an open database to support related modelling and model validation carried out in Task 3 (Subtask 3.2). The legal link between UH and JyU is based on Finnish Radiation Safety Research Program and Consortium (Cores). The Finnish Government Resolution on Comprehensive Reform of State Research Institutes and Research Funding took place in September 2013. GTK (Geological Survey of Finland), which is linked 3rd party (legal link) to UH, and GTK will be participating in Task 3, Subtask 3.2. for X-ray tomography. This is to be able to utilise the laboratory capacity and expertise at GTK for the project. The legal link between UH and GTK is based on the Cooperative agreement on shared laboratory facilities (The agreement from signed 2013). TUT (Tampere University of Technology), which is linked 3rd party to UH, will participate in Task 4 (Tools and methods to quantify/derive uncertainties induce by coupled processes) of WP DONUT (Development and Improvement Of NUMerical methods and Tools for modelling coupled processes). The role of TUT will be to develop metamodels for uncertainty quantification related to tools and models developed in DONUT. The legal link between UH and TUT is based on Finnish Radiation Safety Research Program and Consortium (Cores). The Finnish Government Resolution on Comprehensive Reform of State Research Institutes and Research Funding took place in September 2013.' Aalto University, which is linked 3rd party to UH, will participate in Task WP DONUT using the developed THMC coupled Finite Element Code (Abed & Sołowski 2017, 2018). In this project, the Aalto group intends to model the processes related to hydration of bentonite barrier in the nuclear waste storage. In Aalto they	

will simulate a repository scale problem (i.e. ‘generic repository’), as defined early in the subtask by the EURAD participants. The legal link between UH and Aalto is based on Finnish Radiation Safety Research Program and Consortium (Cores). The Finnish Government Resolution on Comprehensive Reform of State Research Institutes and Research Funding took place in September 2013.’	
Does the participant envisage the use of contributions in kind provided by third parties (Articles 11 and 12 of the General Model Grant Agreement)	N
Does the participant envisage that part of the work is performed by International Partners (Article 14a of the General Model Grant Agreement)?	N

49/ UKRI-BGS

Does the participant plan to subcontract certain tasks (please note that core tasks of the project should not be sub-contracted)	Y
UKRI-BGS plans to subcontract certain task of WP6 GAS (Task 2) and WP7 HITEC (Task 2). The subcontractor has been selected in accordance with the requirements of Article 13 of the grant agreement. Total budget of the subcontractor Elena Tamayo-Mas: 114 498 € distributed as follows: WP6 GAS: 76 332,00 € (Task 2) WP7 HITEC: 38 166,00 € (Task 2)	
Does the participant envisage that part of its work is performed by linked third parties	N
Does the participant envisage the use of contributions in kind provided by third parties (Articles 11 and 12 of the General Model Grant Agreement)	N
Does the participant envisage that part of the work is performed by International Partners (Article 14a of the General Model Grant Agreement)?	N

50/ VTT

Does the participant plan to subcontract certain tasks (please note that core tasks of the project should not be sub-contracted)	N
Does the participant envisage that part of its work is performed by linked third parties	Y
1. Short description of LTP Galson Sciences Ltd (GSL) is an international environmental safety and radioactive waste research and consultancy company, specialising in radioactive waste management and disposal, nuclear decommissioning and nuclear safety studies, risk and impact assessment, risk management and communication, and geoscience studies. GSL implements national R&D programmes on behalf of the national waste management organisation (WMO) and the waste producers responsible for radioactive waste management. For example, in the UK GSL holds framework contracts to implement national R&D with RWM and LLWR Ltd (waste disposal) and with the NDA for estate-wide R&D (decommissioning and predisposal waste management on behalf of all of the NDA’s Site Licence Companies). GSL also implements R&D directly for WMOs in other countries and for international organisations. 2. Description of link between VTT and GSL GSL has built up a close collaboration with VTT Technical Research Centre of Finland (amongst others) over many years via collaborative R&D in all of the above-noted areas, and this collaboration is documented in a series of legally binding Memoranda of Understanding (MoUs) and contracting agreements. The legal agreement under which work in EURAD would be carried out is the attached MoU signed September 2018, which covers the entire radioactive waste management field. VTT and GSL also have a working relation on earlier cooperative EC-funded projects, most recently Euratom projects DOPAS, Modern2020 and THERAMIN. Examples of recent collaboration outside of EURAD that illustrate the scope of recent collaboration include the following:	

- Project for RWM on durability of concrete containers for radioactive waste.
- Project for RWM on radionuclide migration parameter values and laboratory techniques.
- Project for RWM on approaches to backfilling, sealing and closure of geological disposal facilities.

An example of an existing public contracting arrangement is the consortium led by GSL with VTT participation, to support the UK's Nuclear Decommissioning Authority for "Integrated Waste Management and Site Decommissioning and Remediation." See <https://www.gov.uk/government/news/12-million-contracts-support-nuclear-decommissioning-research>.

3. Involvement of GSL per Work Package (WP)

GSL is involved in ROUTES and UMAN. The work to be done is as follows:

ROUTES – task2 - Contribute to identification and classification of challenging wastes and pre-disposal routes for these wastes; task4 - (co)Lead development of report on identification of waste acceptance criteria (WAC), and development of WAC where wastes exist, but disposal facilities do not; task6 – contribute to identification of shared predisposal waste management solutions across Europe, including identification of case studies and prospects.

As co-lead for ROUTES Task 4, GSL is well placed to help manage the interface and the flow of information between the existing work scope and proposed ROUTES Extension, in order to maximise the value of the Extension to the EC and its synergy with existing work. For example, we will be able to draw on the analysis conducted under Task 4.1 in relation to commonalities and differences in the use of WAC in different Member-States, and highlight WAC-related issues that are specific to SIMS. We are currently planning the workshop under sub-task 4.2 on the comparative analysis of situations where WAC are/are not available, and will be able to work with Task 5 leads to ensure discussion covers issues relevant to SIMS and is aligned to the scope of subsequent work to be done under the ROUTES Extension.

UMAN – WP2 - Lead review of general strategies, approaches and tools for managing uncertainties.

WP MODATS :

- In Task 2.1, GSL will co-ordinate a series of workshops to ensure R&D activities are focused on the specific challenges of repository monitoring.
- In Task 2.1, GSL will lead the survey of URL experiments. GSL will use its detailed knowledge of repository monitoring and experience of surveys in EC projects (e.g. DOPAS) to perform the work.
- In Task 2.1, GSL will co-ordinate the development of guidance on QAPPs, based on its experience in writing guidance documents across waste management practices (e.g. guidance on monitoring of radioactive waste stores in the UK).
- In Task 2.1, GSL will lead identification of the future R&D development needs for different programmes moving forward. GSL is particularly well placed to develop the data requirements aspect of this task based on ongoing work supporting the RWM programme focused on development of the RWM strategy, identification of monitoring parameters using an adapted version of the Modern2020 Screening Methodology, and development of a structured review of monitoring technologies.
- In Task 2.1, GSL lead the development of the Task 2 report that will integrate the outcomes from the work and relate the R&D outcomes to challenges with repository monitoring.
- In Task 3.3, GSL will support the FEP analysis which will form the basis for the research activities, in particular identifying a common set of technologies and sensors to be evaluated, a set of type engineered barriers systems under consideration across Europe, undertaking FEP analyses in collaboration with safety case experts, and preparing an integration report that draws conclusions on the interactions and that can be used as a reference document moving forward. GSL is particularly suited to this activity as it has safety case experts that have detailed understanding of post-closure safety functions and the application of FEP analysis methods to understanding of the interactions between equipment and the multi-barrier system.

Does the participant envisage the use of contributions in kind provided by third parties (Articles 11 and 12 of the General Model Grant Agreement)	N
Does the participant envisage that part of the work is performed by International Partners (Article 14a of the General Model Grant Agreement)?	N

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Does the participant plan to subcontract certain tasks (please note that core tasks of the project should not be sub-contracted)	N
Does the participant envisage that part of its work is performed by linked third parties	N
Does the participant envisage the use of contributions in kind provided by third parties (Articles 11 and 12 of the General Model Grant Agreement)	N
Does the participant envisage that part of the work is performed by International Partners (Article 14a of the General Model Grant Agreement)?	N

5. Ethics and Security

5.1.Ethics

Ethics issues are addressed in work package 14.

5.2.Security

Not applicable

ESTIMATED BUDGET FOR THE ACTION

	Estimated eligible ¹ costs (per budget category)										EU contribution			Additional information		
	A. Direct personnel costs				B. Direct costs of subcontracting	<i>[C. Direct costs of fin. support]</i>	D. Other direct costs		E. Indirect costs ²	Total costs	Reimbursement rate %	Maximum EU contribution ³	Maximum grant amount ⁴	Information for indirect costs	Information for auditors	Other information:
	A.1 Employees (or equivalent)		A.4 SME owners without salary				D.1 Travel	D.5 Costs of internally invoiced goods and services						Estimated costs of in-kind contributions not used on premises	Declaration of costs under Point D.4	Estimated costs of beneficiaries/ linked third parties not receiving funding/ international partners
Form of costs ⁶	Actual	Unit ⁷	Unit ⁸		Actual	Actual	Actual	Unit ⁹	Flat-rate ¹⁰							
		a	Total b	No hours	Total c	d	<i>[e]</i>	f	Total g	h = 0,25 x (a +b+c+f+g + <i>[i1]</i> ¹³ + <i>[i2]</i> ¹³ -n)	j = a+b+c+d + <i>[e]</i> +f+g+h + <i>[i1]</i> + <i>[i2]</i>	k	l	m	n	Yes/No
1. ANDRA	2 712 502.09	0.00	0.00	0.00	768 377.50	0.00	755 400.00	0.00	866 975.52	5 103 255.11	55.00	2 806 790.31	2 682 184.73	0.00	No	n/a
- BRGM	908 922.13	0.00	0.00	0.00	0.00	0.00	157 000.00	0.00	266 480.53	1 332 402.66	55.00	732 821.46	732 821.46	0.00	No	n/a
- UT3/LMDC	226 452.22	0.00	0.00	0.00	60 000.00	0.00	35 000.00	0.00	65 363.06	386 815.28	55.00	212 748.40	212 748.40	0.00	No	n/a
- IMT/EMSE	253 001.00	0.00	0.00	0.00	0.00	0.00	91 000.00	0.00	86 000.25	430 001.25	55.00	236 500.69	236 500.69	0.00	No	n/a
Total beneficiary	4 100 877.44	0.00			828 377.50	0.00	1 038 400.00	0.00	1 284 819.36	7 252 474.30		3 988 860.86	3 864 255.28	n/a	n/a	0.00
2. ARAO	5 103.07	0.00	0.00	0.00	0.00	0.00	5 000.00	0.00	2 525.77	12 628.84	55.00	6 945.86	6 945.86	0.00	No	n/a
3. BEL V	320 633.00	0.00	0.00	0.00	0.00	0.00	91 297.00	0.00	102 982.50	514 912.50	55.00	283 201.88	283 201.88	0.00	No	n/a
4. BGE	817 443.00	0.00	0.00	0.00	0.00	0.00	50 875.00	0.00	217 079.50	1 085 397.50	55.00	596 968.63	596 968.63	0.00	No	n/a
5. CEA	1 166 391.53	0.00	0.00	0.00	0.00	0.00	323 618.00	0.00	372 502.38	1 862 511.91	55.00	1 024 381.55	1 024 381.55	0.00	No	n/a
- EDF	446 300.00	0.00	0.00	0.00	0.00	0.00	53 700.00	0.00	125 000.00	625 000.00	55.00	343 750.00	343 750.00	0.00	No	n/a
- Orano	88 760.00	0.00	0.00	0.00	0.00	0.00	9 000.00	0.00	24 440.00	122 200.00	55.00	67 210.00	67 210.00	0.00	No	n/a
Total beneficiary	1 701 451.53	0.00			0.00	0.00	386 318.00	0.00	521 942.38	2 609 711.91		1 435 341.55	1 435 341.55	n/a	n/a	0.00
6. CIEMAT	1 714 897.49	0.00	0.00	0.00	0.00	0.00	294 651.00	0.00	502 387.12	2 511 935.61	55.00	1 381 564.59	1 381 564.59	0.00	No	n/a
- UPM	194 448.00	0.00	0.00	0.00	0.00	0.00	44 557.60	0.00	59 751.40	298 757.00	55.00	164 316.35	164 316.35	0.00	No	n/a
- UAM	115 000.00	0.00	0.00	0.00	0.00	0.00	43 200.00	0.00	39 550.00	197 750.00	55.00	108 762.50	108 762.50	0.00	No	n/a
- UPC	359 775.00	0.00	0.00	0.00	0.00	0.00	17 000.00	0.00	94 193.75	470 968.75	55.00	259 032.81	259 032.81	0.00	No	n/a
- CSIC	283 306.23	0.00	0.00	0.00	0.00	0.00	16 000.00	0.00	74 826.56	374 132.79	55.00	205 773.03	205 773.03	0.00	No	n/a
- IDOM	90 000.00	0.00	0.00	0.00	0.00	0.00	5 000.00	0.00	23 750.00	118 750.00	55.00	65 312.50	65 312.50	0.00	No	n/a
- UGR	102 500.00	0.00	0.00	0.00	0.00	0.00	68 500.00	0.00	42 750.00	213 750.00	55.00	117 562.50	117 562.50	0.00	No	n/a
Total beneficiary	2 859 926.72	0.00			0.00	0.00	488 908.60	0.00	837 208.83	4 186 044.15		2 302 324.28	2 302 324.28	n/a	n/a	0.00
7. ChRDI	9 000.00	0.00	0.00	0.00	0.00	0.00	5 000.00	0.00	3 500.00	17 500.00	55.00	9 625.00	9 625.00	0.00	No	n/a
- KIPT	98 200.00	0.00	0.00	0.00	0.00	0.00	16 000.00	0.00	28 550.00	142 750.00	55.00	78 512.50	78 512.50	0.00	No	n/a
- SHGNASU	34 000.00	0.00	0.00	0.00	0.00	0.00	6 000.00	0.00	10 000.00	50 000.00	55.00	27 500.00	27 500.00	0.00	No	n/a
Total beneficiary	141 200.00	0.00	0.00	0.00	0.00	0.00	27 000.00	0.00	42 050.00	210 250.00		115 637.50	115 637.50	n/a	n/a	0.00
8. CNRS	1 743 856.05	0.00	0.00	0.00	0.00	0.00	757 160.10	0.00	625 254.04	3 126 270.19	55.00	1 719 448.60	1 719 448.60	0.00	No	n/a
- IMT Atlantique	329 796.15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	82 449.04	412 245.19	55.00	226 734.85	226 734.85	0.00	No	n/a
- UGrenoble	281 900.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	70 475.00	352 375.00	55.00	193 806.25	193 806.25	0.00	No	n/a
- ULille	490 940.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	122 735.00	613 675.00	55.00	337 521.25	337 521.25	0.00	No	n/a
- ULorraine	342 999.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	85 749.85	428 749.25	55.00	235 812.09	235 812.09	0.00	No	n/a
- UMontpellier	68 970.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	17 242.60	86 213.00	55.00	47 417.15	47 417.15	0.00	No	n/a
- UNice	60 500.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	15 125.00	75 625.00	55.00	41 593.75	41 593.75	0.00	No	n/a
- UOrléans	79 000.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	19 750.00	98 750.00	55.00	54 312.50	54 312.50	0.00	No	n/a
- UPoitiers	249 868.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	62 467.00	312 335.00	55.00	171 784.25	171 784.25	0.00	No	n/a

ESTIMATED BUDGET FOR THE ACTION

	Estimated eligible ¹ costs (per budget category)										EU contribution			Additional information		
	A. Direct personnel costs				B. Direct costs of subcontracting	[C. Direct costs of fin. support]	D. Other direct costs		E. Indirect costs ²	Total costs	Reimbursement rate %	Maximum EU contribution ³	Maximum grant amount ⁴	Information for indirect costs	Information for auditors	Other information:
	A.1 Employees (or equivalent)		A.4 SME owners without salary				D.1 Travel	D.5 Costs of internally invoiced goods and services						Estimated costs of in-kind contributions not used on premises	Declaration of costs under Point D.4	Estimated costs of beneficiaries/ linked third parties not receiving funding/ international partners
Form of costs ⁶	Actual	Unit ⁷	Unit ⁸		Actual	Actual	Actual	Unit ⁹	Flat-rate ¹⁰							
									25%							
	a	Total b	No hours	Total c	d	[e]	f	Total g	h = 0,25 x (a +b+c+f+g +[i1] ¹³ + [i2] ¹³ -n)	j = a+b+c+d +[e]/+f+g+h +[i1]/+[i2]	k	l	m	n	Yes/No	
- UJean Monnet	65 949.80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	16 487.45	82 437.25	55.00	45 340.49	45 340.49	0.00	No	n/a
Total beneficiary	3 713 779.80	0.00			0.00	0.00	757 160.10	0.00	1 117 734.98	5 588 674.88		3 073 771.18	3 073 771.18	n/a	n/a	0.00
9. COVRA	303 500.75	0.00	0.00	0.00	0.00	0.00	70 800.00	0.00	93 575.19	467 875.94	55.00	257 331.77	257 331.77	0.00	No	n/a
- TU Delft	144 489.50	0.00	0.00	0.00	0.00	0.00	11 000.00	0.00	38 872.38	194 361.88	55.00	106 899.03	106 899.03	0.00	No	n/a
Total beneficiary	447 990.25	0.00			0.00	0.00	81 800.00	0.00	132 447.57	662 237.82		364 230.80	364 230.80	n/a	n/a	0.00
10. FTMC	83 032.00	0.00	0.00	0.00	0.00	0.00	33 000.00	0.00	29 008.00	145 040.00	55.00	79 772.00	79 772.00	0.00	No	n/a
11. CV REZ	175 850.00	0.00	0.00	0.00	0.00	0.00	52 000.00	0.00	56 962.50	284 812.50	55.00	156 646.88	156 646.88	0.00	No	n/a
12. Dekom	20 880.00	0.00	0.00	0.00	0.00	0.00	9 900.00	0.00	7 695.00	38 475.00	55.00	21 161.25	21 161.25	0.00	No	n/a
13. EEAE	13 960.00	0.00	0.00	0.00	0.00	0.00	9 400.00	0.00	5 840.00	29 200.00	55.00	16 060.00	16 060.00	0.00	No	n/a
14. ENRESA	97 628.50	0.00	0.00	0.00	438 602.50	0.00	42 500.00	0.00	35 032.13	613 763.13	55.00	337 569.72	337 569.72	0.00	No	n/a
15. JUELICH	687 477.34	0.00	0.00	0.00	0.00	0.00	101 242.60	0.00	197 179.99	985 899.93	55.00	542 244.96	542 244.96	0.00	No	n/a
- HZDR	1 239 967.00	0.00	0.00	0.00	0.00	0.00	96 238.00	0.00	334 051.25	1 670 256.25	55.00	918 640.94	918 640.94	0.00	No	n/a
- UFZ	1 132 880.80	0.00	0.00	0.00	0.00	0.00	73 500.00	0.00	301 595.20	1 507 976.00	55.00	829 386.80	829 386.80	0.00	No	n/a
- GFZ	177 702.12	0.00	0.00	0.00	0.00	0.00	7 000.00	0.00	46 175.53	230 877.65	55.00	126 982.71	126 982.71	0.00	No	n/a
Total beneficiary	3 238 027.26	0.00			0.00	0.00	277 980.60	0.00	879 001.97	4 395 009.83		2 417 255.41	2 417 255.41	n/a	n/a	0.00
16. GRS	663 669.18	0.00	0.00	0.00	0.00	0.00	73 400.00	0.00	184 267.30	921 336.48	55.00	506 735.06	506 735.06	0.00	No	n/a
17. IAE	4 840.00	0.00	0.00	0.00	0.00	0.00	5 500.00	0.00	2 585.00	12 925.00	55.00	7 108.75	7 108.75	0.00	No	n/a
18. INCT	18 120.00	0.00	0.00	0.00	0.00	0.00	9 400.00	0.00	6 880.00	34 400.00	55.00	18 920.00	18 920.00	0.00	No	n/a
19. IRSN	1 008 060.73	0.00	0.00	0.00	0.00	0.00	203 400.00	0.00	302 865.18	1 514 325.91	55.00	832 879.25	832 879.25	0.00	No	n/a
- MINES ParisTech	294 907.20	0.00	0.00	0.00	0.00	0.00	18 000.00	0.00	78 226.80	391 134.00	55.00	215 123.70	215 123.70	0.00	No	n/a
- MUTADIS	297 927.00	0.00	0.00	0.00	0.00	0.00	37 000.00	0.00	83 731.75	418 658.75	55.00	230 262.31	230 262.31	0.00	No	n/a
- NTW	211 660.00	0.00	0.00	0.00	0.00	0.00	124 400.00	0.00	84 015.00	420 075.00	55.00	231 041.25	231 041.25	0.00	No	n/a
Total beneficiary	1 812 554.93	0.00	0.00	0.00	0.00	0.00	382 800.00	0.00	548 838.73	2 744 193.66		1 509 306.51	1 509 306.51	n/a	n/a	0.00
20. IST	33 396.00	0.00	0.00	0.00	0.00	0.00	8 400.00	0.00	10 449.00	52 245.00	55.00	28 734.75	28 734.75	0.00	No	n/a
21. IST ID	26 249.30	0.00	0.00	0.00	0.00	0.00	14 060.00	0.00	10 077.33	50 386.63	55.00	27 712.65	27 712.65	0.00	No	n/a
22. JSI	293 990.00	0.00	0.00	0.00	0.00	0.00	85 900.00	0.00	94 972.50	474 862.50	55.00	261 174.38	261 174.38	0.00	No	n/a
- EIMV	282 328.00	0.00	0.00	0.00	0.00	0.00	76 300.00	0.00	89 657.00	448 285.00	55.00	246 556.75	246 556.75	0.00	No	n/a
- ZAG	160 000.00	0.00	0.00	0.00	0.00	0.00	16 500.00	0.00	44 125.00	220 625.00	55.00	121 343.75	121 343.75	0.00	No	n/a
Total beneficiary	736 318.00	0.00			0.00	0.00	178 700.00	0.00	228 754.50	1 143 772.50		629 074.88	629 074.88	n/a	n/a	0.00
23. JRC	0.00	811 711.29	0.00	0.00	0.00	0.00	278 630.93	0.00	272 585.56	1 362 927.78	55.00	749 610.28	483 422.21	0.00	No	n/a
24. KIT	745 150.00	0.00	0.00	0.00	0.00	0.00	78 575.00	0.00	205 931.25	1 029 656.25	55.00	566 310.94	566 310.94	0.00	No	n/a
- Uni Potsdam	80 000.00	0.00	0.00	0.00	0.00	0.00	5 000.00	0.00	21 250.00	106 250.00	55.00	58 437.50	58 437.50	0.00	No	n/a
- Uni Clausthal	33 000.00	0.00	0.00	0.00	0.00	0.00	5 500.00	0.00	9 625.00	48 125.00	55.00	26 468.75	26 468.75	0.00	No	n/a

ESTIMATED BUDGET FOR THE ACTION

	Estimated eligible ¹ costs (per budget category)									EU contribution			Additional information			
	A. Direct personnel costs			B. Direct costs of subcontracting	<i>[C. Direct costs of fin. support]</i>	D. Other direct costs		E. Indirect costs ²	Total costs	Reimbursement rate %	Maximum EU contribution ³	Maximum grant amount ⁴	Information for indirect costs	Information for auditors	Other information:	
	A.1 Employees (or equivalent)		A.4 SME owners without salary				D.1 Travel	D.5 Costs of internally invoiced goods and services						Estimated costs of in-kind contributions not used on premises	Declaration of costs under Point D.4	Estimated costs of beneficiaries/ linked third parties not receiving funding/ international partners
A.2 Natural persons under direct contract		A.5 Beneficiaries that are natural persons without salary				D.2 Equipment										
A.3 Seconded persons						D.3 Other goods and services										
<i>[A.6 Personnel for providing access to research infrastructure]</i>						<i>[D.4 Costs of large research infrastructure]</i>										
Form of costs ⁶	Actual	Unit ⁷	Unit ⁸		Actual	Actual	Actual	Unit ⁹	Flat-rate ¹⁰							
									25%							
	a	Total b	No hours	Total c	d	<i>[e]</i>	f	Total g	h = 0,25 x (a +b+c+f+g + <i>[i1]</i> ¹³ + <i>[i2]</i> ¹³ -n)	j = a+b+c+d + <i>[e]</i> +f+g+h + <i>[i1]</i> + <i>[i2]</i>	k	l	m	n	Yes/No	
- Uni Mainz	264 600.00	0.00	0.00	0.00	0.00	0.00	33 000.00	0.00	74 400.00	372 000.00	55.00	204 600.00	204 600.00	0.00	No	n/a
- BAM	173 190.00	0.00	0.00	0.00	0.00	0.00	5 000.00	0.00	44 547.50	222 737.50	55.00	122 505.63	122 505.63	0.00	No	n/a
- BGR	128 590.00	0.00	0.00	0.00	0.00	0.00	18 500.00	0.00	36 772.50	183 862.50	55.00	101 124.38	101 124.38	0.00	No	n/a
- AMPHOS 21	320 400.00	0.00	0.00	0.00	0.00	0.00	60 500.00	0.00	95 225.00	476 125.00	55.00	261 868.75	261 868.75	0.00	No	n/a
- PEL	27 000.00	0.00	0.00	0.00	0.00	0.00	5 000.00	0.00	8 000.00	40 000.00	55.00	22 000.00	22 000.00	0.00	No	n/a
Total beneficiary	1 771 930.00	0.00	0.00	0.00	0.00	0.00	211 075.00	0.00	495 751.25	2 478 756.25		1 363 315.95	1 363 315.95	n/a	n/a	0.00
25. LEI	267 850.00	0.00	0.00	0.00	0.00	0.00	45 525.00	0.00	78 343.75	391 718.75	55.00	215 445.31	215 445.31	0.00	No	n/a
26. MTA EK	194 000.00	0.00	0.00	0.00	0.00	0.00	51 000.00	0.00	61 250.00	306 250.00	55.00	168 437.50	168 437.50	0.00	No	n/a
- SORC	24 000.00	0.00	0.00	0.00	0.00	0.00	19 000.00	0.00	10 750.00	53 750.00	55.00	29 562.50	29 562.50	0.00	No	n/a
Total beneficiary	218 000.00	0.00			0.00	0.00	70 000.00	0.00	72 000.00	360 000.00		198 000.00	198 000.00	n/a	n/a	0.00
27. NAGRA	644 745.17	0.00	0.00	0.00	105 000.00	0.00	89 175.00	0.00	183 480.04	1 022 400.21	55.00	562 320.12	562 320.12	0.00	No	n/a
- CIMNE	153 000.00	0.00	0.00	0.00	0.00	0.00	26 000.00	0.00	44 750.00	223 750.00	55.00	123 062.50	123 062.50	0.00	No	n/a
- EPFL	407 700.40	0.00	0.00	0.00	0.00	0.00	87 500.00	0.00	123 800.10	619 000.50	55.00	340 450.28	340 450.28	0.00	No	n/a
- UBERN	299 600.00	0.00	0.00	0.00	0.00	0.00	24 700.00	0.00	81 075.00	405 375.00	55.00	222 956.25	222 956.25	0.00	No	n/a
- ZHAW	96 999.60	0.00	0.00	0.00	0.00	0.00	15 000.00	0.00	27 999.90	139 999.50	55.00	76 999.73	76 999.73	0.00	No	n/a
- ETH	273 000.00	0.00	0.00	0.00	0.00	0.00	20 000.00	0.00	73 250.00	366 250.00	55.00	201 437.50	201 437.50	0.00	No	n/a
- Jacobs	359 859.75	0.00	0.00	0.00	0.00	0.00	254 298.00	0.00	153 539.44	767 697.19	55.00	422 233.45	422 233.45	0.00	No	n/a
- CSIRO	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	260 000.00
- NWMO	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	1 350 000.00
- NUMO	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	600 000.00
Total beneficiary	2 234 904.92	0.00	0.00	0.00	105 000.00	0.00	516 673.00	0.00	687 894.48	3 544 472.40		1 949 459.83	1 949 459.83	n/a	n/a	2 210 000.00
28. NCSR	33 255.00	0.00	0.00	0.00	3 625.00	0.00	8 400.00	0.00	10 413.75	55 693.75	55.00	30 631.56	30 631.56	0.00	No	n/a
- DMT	120 550.00	0.00	0.00	0.00	0.00	0.00	14 400.00	0.00	33 737.50	168 687.50	55.00	92 778.13	92 778.13	0.00	No	n/a
Total beneficiary	153 805.00	0.00			3 625.00	0.00	22 800.00	0.00	44 151.25	224 381.25		123 409.69	123 409.69	n/a	n/a	0.00
29. NES	62 719.82	0.00	0.00	0.00	0.00	0.00	11 060.00	0.00	18 444.96	92 224.78	55.00	50 723.63	50 723.63	0.00	No	n/a
30. NJF	4 071.18	0.00	0.00	0.00	0.00	0.00	6 400.00	0.00	2 617.80	13 088.98	55.00	7 198.94	7 198.94	0.00	No	n/a
31. NRG	98 794.25	0.00	0.00	0.00	0.00	0.00	16 500.00	0.00	28 823.56	144 117.81	55.00	79 264.80	79 264.80	0.00	No	n/a
32. ONDRAF/ NIRAS	229 471.09	0.00	0.00	0.00	0.00	0.00	36 525.00	0.00	66 499.02	332 495.11	55.00	182 872.31	182 872.31	0.00	No	n/a
- ULiège	457 300.00	0.00	0.00	0.00	0.00	0.00	16 000.00	0.00	118 325.00	591 625.00	55.00	325 393.75	325 393.75	0.00	No	n/a
- EURIDICE	175 643.87	0.00	0.00	0.00	0.00	0.00	40 800.00	0.00	54 110.97	270 554.84	55.00	148 805.16	148 805.16	0.00	No	n/a
Total beneficiary	862 414.96	0.00			0.00	0.00	93 325.00	0.00	238 934.99	1 194 674.95		657 071.22	657 071.22	n/a	n/a	0.00
33. POSIVA	102 000.00	0.00	0.00	0.00	50 000.00	0.00	23 500.00	0.00	31 375.00	206 875.00	55.00	113 781.25	113 781.25	0.00	No	n/a
- Envirocas	15 888.00	0.00	0.00	0.00	0.00	0.00	5 500.00	0.00	5 347.00	26 735.00	55.00	14 704.25	14 704.25	0.00	No	n/a

ESTIMATED BUDGET FOR THE ACTION

	Estimated eligible ¹ costs (per budget category)										EU contribution			Additional information		
	A. Direct personnel costs				B. Direct costs of subcontracting	[C. Direct costs of fin. support]	D. Other direct costs		E. Indirect costs ²	Total costs	Reimbursement rate %	Maximum EU contribution ³	Maximum grant amount ⁴	Information for indirect costs	Information for auditors	Other information:
	A.1 Employees (or equivalent)		A.4 SME owners without salary				D.1 Travel	D.5 Costs of internally invoiced goods and services						Estimated costs of in-kind contributions not used on premises	Declaration of costs under Point D.4	Estimated costs of beneficiaries/ linked third parties not receiving funding/ international partners
A.2 Natural persons under direct contract		A.5 Beneficiaries that are natural persons without salary		D.2 Equipment												
A.3 Seconded persons				D.3 Other goods and services												
Form of costs ⁶	Actual	Unit ⁷	Unit ⁸		Actual	Actual	Actual	Unit ⁹	Flat-rate ¹⁰							
									25%							
	a	Total b	No hours	Total c	d	[e]	f	Total g	h = 0,25 x (a +b+c+f+g +[i1] ¹³ + [i2] ¹³ -n)	j = a+b+c+d +[e]/+f+g+h +[i1]/+[i2]	k	l	m	n	Yes/No	
Total beneficiary	117 888.00	0.00	0.00	0.00	50 000.00	0.00	29 000.00	0.00	36 722.00	233 610.00		128 485.50	128 485.50	n/a	n/a	0.00
34. PSI	0.00	2 120 075.56	0.00	0.00	0.00	0.00	210 891.50	0.00	582 741.77	2 913 708.83	55.00	1 602 539.86	1 602 539.86	0.00	No	n/a
- EMPA	212 360.84	0.00	0.00	0.00	0.00	0.00	46 000.00	0.00	64 590.21	322 951.05	55.00	177 623.08	177 623.08	0.00	No	n/a
Total beneficiary	212 360.84	2 120 075.56			0.00	0.00	256 891.50	0.00	647 331.98	3 236 659.88		1 780 162.94	1 780 162.94	n/a	n/a	0.00
35. PURAM	91 800.00	0.00	0.00	0.00	0.00	0.00	12 000.00	0.00	25 950.00	129 750.00	55.00	71 362.50	71 362.50	0.00	No	n/a
36. RATEN	112 948.00	0.00	0.00	0.00	0.00	0.00	61 900.00	0.00	43 712.00	218 560.00	55.00	120 208.00	120 208.00	0.00	No	n/a
37. RWM	286 794.70	0.00	0.00	0.00	0.00	0.00	52 500.00	0.00	84 823.68	424 118.38	55.00	233 265.11	233 265.11	0.00	No	n/a
- UNIMAN	149 687.65	0.00	0.00	0.00	0.00	0.00	50 595.20	0.00	50 070.71	250 353.56	55.00	137 694.46	137 694.46	0.00	No	n/a
Total beneficiary	436 482.35	0.00			0.00	0.00	103 095.20	0.00	134 894.39	674 471.94		370 959.57	370 959.57	n/a	n/a	0.00
38. SCK•CEN	2 093 846.21	0.00	0.00	0.00	0.00	0.00	672 102.84	0.00	691 487.26	3 457 436.31	55.00	1 901 589.97	1 901 589.97	0.00	No	n/a
39. SKB	553 366.75	0.00	0.00	0.00	71 432.00	0.00	76 250.00	0.00	60 581.25	761 630.00	55.00	418 896.50	418 896.50	387 291.75	No	n/a
- UU	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	55.00	0.00	0.00	0.00	No	n/a
Total beneficiary	553 366.75	0.00			71 432.00	0.00	76 250.00	0.00	60 581.25	761 630.00		418 896.50	418 896.50	n/a	n/a	0.00
40. SSTC NRS	256 975.00	0.00	0.00	0.00	0.00	0.00	60 025.00	0.00	79 250.00	396 250.00	55.00	217 937.50	217 937.50	0.00	No	n/a
41. STUBA	19 758.00	0.00	0.00	0.00	0.00	0.00	14 525.00	0.00	8 570.75	42 853.75	55.00	23 569.56	23 569.56	0.00	No	n/a
42. SÚRAO	245 905.00	0.00	0.00	0.00	0.00	0.00	87 000.00	0.00	83 226.25	416 131.25	55.00	228 872.19	228 872.19	0.00	No	n/a
- IGN	111 588.00	0.00	0.00	0.00	0.00	0.00	8 500.00	0.00	30 022.00	150 110.00	55.00	82 560.50	82 560.50	0.00	No	n/a
- CU	123 700.00	0.00	0.00	0.00	0.00	0.00	31 800.00	0.00	38 875.00	194 375.00	55.00	106 906.25	106 906.25	0.00	No	n/a
- CTU	607 852.75	0.00	0.00	0.00	0.00	0.00	139 075.00	0.00	186 731.94	933 659.69	55.00	513 512.83	513 512.83	0.00	No	n/a
- ÚJV	545 874.65	0.00	0.00	0.00	0.00	0.00	250 522.00	0.00	199 099.16	995 495.81	55.00	547 522.70	547 522.70	0.00	No	n/a
- TUL	203 370.00	0.00	0.00	0.00	0.00	0.00	77 801.10	0.00	70 292.78	351 463.88	55.00	193 305.13	193 305.13	0.00	No	n/a
Total beneficiary	1 838 290.40	0.00			0.00	0.00	594 698.10	0.00	608 247.13	3 041 235.63		1 672 679.60	1 672 679.60	n/a	n/a	0.00
43. SURO	186 960.00	0.00	0.00	0.00	0.00	0.00	40 400.00	0.00	56 840.00	284 200.00	55.00	156 310.00	156 310.00	0.00	No	n/a
44. TNO	89 600.00	0.00	0.00	0.00	0.00	0.00	22 800.00	0.00	28 100.00	140 500.00	55.00	77 275.00	77 275.00	0.00	No	n/a
45. TS Enercon	77 900.95	0.00	0.00	0.00	6 870.00	0.00	12 750.00	0.00	22 662.74	120 183.69	55.00	66 101.03	66 101.03	0.00	No	n/a
46. TUS	148 386.17	0.00	0.00	0.00	0.00	0.00	39 108.40	0.00	46 873.64	234 368.21	55.00	128 902.52	128 902.52	0.00	No	n/a
47. UCyprus	21 706.06	0.00	0.00	0.00	0.00	0.00	11 900.00	0.00	8 401.52	42 007.58	55.00	23 104.17	23 104.17	0.00	No	n/a
48. UHelsinki	0.00	226 150.00	0.00	0.00	0.00	0.00	25 100.00	0.00	62 812.50	314 062.50	55.00	172 734.38	172 734.38	0.00	No	n/a
- Aalto	32 850.00	0.00	0.00	0.00	0.00	0.00	5 000.00	0.00	9 462.50	47 312.50	55.00	26 021.88	26 021.88	0.00	No	n/a
- TUT	116 000.00	0.00	0.00	0.00	0.00	0.00	8 000.00	0.00	31 000.00	155 000.00	55.00	85 250.00	85 250.00	0.00	No	n/a
- JYU	122 200.00	0.00	0.00	0.00	0.00	0.00	25 000.00	0.00	36 800.00	184 000.00	55.00	101 200.00	101 200.00	0.00	No	n/a
- GTK	42 500.00	0.00	0.00	0.00	0.00	0.00	39 000.00	0.00	20 375.00	101 875.00	55.00	56 031.25	56 031.25	0.00	No	n/a
Total beneficiary	313 550.00	226 150.00			0.00	0.00	102 100.00	0.00	160 450.00	802 250.00		441 237.51	441 237.51	n/a	n/a	0.00
49. UKRI	968 716.07	0.00	0.00	0.00	114 498.00	0.00	260 884.08	0.00	307 400.04	1 651 498.19	55.00	908 324.00	908 324.00	0.00	No	n/a

ESTIMATED BUDGET FOR THE ACTION

	Estimated eligible ¹ costs (per budget category)									EU contribution			Additional information							
	A. Direct personnel costs				B. Direct costs of subcontracting	<i>[C. Direct costs of fin. support]</i>	D. Other direct costs		E. Indirect costs ²	Total costs	Reimbursement rate %	Maximum EU contribution ³	Maximum grant amount ⁴	Information for indirect costs	Information for auditors	Other information:				
	A.1 Employees (or equivalent)		A.4 SME owners without salary				D.1 Travel	D.5 Costs of internally invoiced goods and services						Estimated costs of in-kind contributions not used on premises	Declaration of costs under Point D.4	Estimated costs of beneficiaries/ linked third parties not receiving funding/ international partners				
A.2 Natural persons under direct contract		A.5 Beneficiaries that are natural persons without salary		D.2 Equipment																
A.3 Seconded persons				D.3 Other goods and services																
<i>[A.6 Personnel for providing access to research infrastructure]</i>				<i>[D.4 Costs of large research infrastructure]</i>																
Form of costs ⁶	Actual	Unit ⁷	Unit ⁸				Actual										Actual	Actual	Unit ⁹	Flat-rate ¹⁰
																				25%
	a	Total b	No hours	Total c	d	<i>[e]</i>	f	Total g	h = 0,25 x (a +b+c+f+g + <i>[i1]</i> ¹³ + <i>[i2]</i> ¹³ -n)	j = a+b+c+d + <i>[e]</i> +f+g+h + <i>[i1]</i> + <i>[i2]</i>	k	l	m	n	Yes/No					
50. VTT	0.00	787 740.49	0.00	0.00	0.00	0.00	275 208.01	0.00	265 737.13	1 328 685.63	55.00	730 777.10	730 777.10	0.00	Yes	n/a				
- GSL	454 230.00	0.00	0.00	0.00	0.00	0.00	22 900.00	0.00	119 282.50	596 412.50	55.00	328 026.88	328 026.88	0.00	No	n/a				
Total beneficiary	454 230.00	787 740.49	0.00	0.00	0.00	0.00	298 108.01	0.00	385 019.63	1 925 098.13		1 058 803.98	1 058 803.98	n/a	n/a	0.00				
51. VUJE	6 700.00	0.00	0.00	0.00	0.00	0.00	5 000.00	0.00	2 925.00	14 625.00	55.00	8 043.75	8 043.75	0.00	No	n/a				
Total consortium	34 708 884.91	3 945 677.34		0.00	1 618 405.00	0.00	7 969 326.36	0.00	11 559 149.28	59 801 442.89		32 890 793.65	32 500 000.00			2 210 000.00				

¹ See Article 6 for the eligibility conditions.

² Indirect costs already covered by an operating grant (received under any EU or Euratom funding programme; see Article 6.5.(b)) are ineligible under the GA. Therefore, a beneficiary/linked third party that receives an operating grant during the action's duration cannot declare indirect costs for the year(s)/reporting period(s) covered by the operating grant, unless it can demonstrate that the operating grant does not cover any costs of the action (see Article 6.2.E).

³ This is the theoretical amount of EU contribution that the system calculates automatically (by multiplying all the budgeted costs by the reimbursement rate). This theoretical amount is capped by the 'maximum grant amount' (that the Commission decided to grant for the action) (see Article 5.1).

⁴ The 'maximum grant amount' is the maximum grant amount decided by the Commission. It normally corresponds to the requested grant, but may be lower.

⁵ Depending on its type, this specific cost category will or will not cover indirect costs. Specific unit costs that include indirect costs are: costs for energy efficiency measures in buildings, access costs for providing trans-national access to research infrastructure and costs for clinical studies.

⁶ See Article 5 for the forms of costs.

⁷ Unit : hours worked on the action; costs per unit (hourly rate) : calculated according to the beneficiary's usual accounting practice.

⁸ See Annex 2a 'Additional information on the estimated budget' for the details (costs per hour (hourly rate)).

⁹ Unit and costs per unit : calculated according to the beneficiary's usual accounting practices.

¹⁰ Flat rate : 25% of eligible direct costs, from which are excluded: direct costs of subcontracting, costs of in-kind contributions not used on premises, direct costs of financial support, and unit costs declared under budget category F if they include indirect costs (see Article 6.2.E).

¹¹ See Annex 2a 'Additional information on the estimated budget' for the details (units, costs per unit).

¹² See Annex 2a 'Additional information on the estimated budget' for the details (units, costs per unit, estimated number of units, etc).

¹³ Only specific unit costs that do not include indirect costs.

¹⁴ See Article 9 for beneficiaries not receiving funding.

¹⁵ Only for linked third parties that receive funding.



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