EUROPEAN COMMISSION
Innovation and Networks Executive Agency
Director

AMENDMENT Reference No AMD-653718-19

Grant Agreement number: 653718 — ENabling Onshore CO2 Storage in Europe (ENOS)

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

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

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

2 . Changes of Annex 2 (estimated budget of the action)

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

3. Change of bank account for payments

The bank account for payments is changed.

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

- The bank account is replaced in **Article 21.8**:

  "Name of bank: TRESOR PUBLIC
  Address of branch: 4 PL DU MARTROI ORLEANS CEDEX 1, France
  Full name of the account holder: B R G M
  Full account number (including bank codes):
  IBAN code: FR7610071450000000100003492"

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

Pierre TOULHOAT with ECAS id ntoupier signed in the Participant Portal on 21/02/2018 at 21:02:25 (transaction id SigId-271-0CoV1Ajq6fWPli3Xi6hwT1lJyiJVjWY3Pzu7ezzrwEJGVDywdklauMheunzdnOpPRt4ljwZGqAvgRe3QPFv8Fji-Jj71zxYb8yrpvnlRw59Bae-5gebnZkMQtHgHvF7hNNdJIBGWacDEyJhxzHgA8DQ1zeG). Timestamp by third party at Wed Feb 21 21:02:59 CET 2018

For the Agency

Signed by Alan HAIGH with ECAS id haigala as an authorised representative on 27-02-2018 17:54:30 (transaction id SigId-52608-6MYrKDi3P6zw86rDv1vlt8lROg8nYj9SGCk2VV7DHQixZ6H7GaQ1BOeWpxYsvDYqfOfRiCmQGMqW2fydVODRx4-PHslUMVSXYCYEG8dniZwzt-kARuIgUjN93KMfvqHAmOZ3fQKoJP24DLO23Y9oX2RA8) Tue Feb 27 17:54:35 CET 2018

Enclosures:

Annex 1
Annex 2

EUROPEAN COMMISSION
Innovation and Networks Executive Agency
ENERGY RESEARCH

ANNEX 1 (part A)

Research and Innovation action

NUMBER — 653718 — ENOS

Table of Contents

1.1. The project summary

Project Number [1]	653718	Project Acronym [2]	ENOS

One form per project

General information	
Project title [3]	ENabling Onshore CO2 Storage in Europe
Starting date [4]	01/09/2016
Duration in months [5]	48
Call (part) identifier [6]	H2020-LCE-2015-1-two-stage
Topic	LCE-15-2015 Enabling decarbonisation of the fossil fuel-based power sector and energy intensive industry through CCS
Fixed EC Keywords	Carbon capture and sequestration
Free keywords	CO2 geological storage, onshore Europe, safe storage, storage sites, pilots, field experiments

Abstract [7]

To meet the ambitious EC target of an 80% reduction in greenhouse gas emissions by 2050, CO2 Capture and Storage (CCS) needs to move rapidly towards full scale implementation with geological storage solutions both on and offshore. Onshore storage offers increased flexibility and reduced infrastructure and monitoring costs. Enabling onshore storage will support management of decarbonisation strategies at territory level while enhancing security of energy supply and local economic activities, and securing jobs across Europe. However, successful onshore storage also requires some unique technical and societal challenges to be overcome. ENOS will provide crucial advances to help foster onshore CO2 storage across Europe through: 1) Developing, testing and demonstrating in the field, under “real-life conditions”, key technologies specifically adapted to onshore storage. 2) Contributing to the creation of a favourable environment for onshore storage across Europe.The ENOS site portfolio will provide a great opportunity for demonstration of technologies for safe and environmentally sound storage at relevant scale. Best practices will be developed using experience gained from the field experiments with the participation of local stakeholders and the lay public. This will produce improved integrated research outcomes and increase stakeholder understanding and confidence in CO2 storage. In this improved framework, ENOS will catalyse new onshore pilot and demonstration projects in new locations and geological settings across Europe, taking into account the site-specific and local socio-economic context.By developing technologies from TRL4/5 to TRL6 across the storage lifecycle, feeding the resultant knowledge and experience into training and education and cooperating at the pan-European and global level, ENOS will have a decisive impact on innovation and build the confidence needed for enabling onshore CO2 storage in Europe.

1.2. List of Beneficiaries

Project Number [1]	653718	Project Acronym [2]	ENOS

List of Beneficiaries

No	Name	Short name	Country	Project entry date[8]	Project exit date
1	BUREAU DE RECHERCHES GEOLOGIQUES ET MINIERES	BRGM	France		
2	BUNDESANSTALT FUER GEOWISSENSCHAFTEN UND ROHSTOFFE	BGR	Germany		
3	NATURAL ENVIRONMENT RESEARCH COUNCIL	BGS	United Kingdom		
4	CESKA GEOLOGICKA SLUZBA	CGS	Czech Republic		
5	CENTRO DE INVESTIGACIONES ENERGETICAS, MEDIOAMBIENTALES Y TECNOLOGICAS-CIEMAT	CIEMAT	Spain		
6	FUNDACION CIUDAD DE LA ENERGIA	CIUDEN	Spain		
7	FLODIM SARL	flodim	France		
8	GEOGREEN	GGR	France		
9	I.D.I.L. SAS (INGENIERIE-DEVELOPPEMENT-INSTRUMENTATION-LASER)	IDIL	France		
10	INTERNATIONAL RESEARCH INSTITUTE OFSTAVANGER AS	IRIS	Norway		
11	NHAZCA SRL	NHAZCA	Italy		
12	ISTITUTO NAZIONALE DI OCEANOGRAFIA E DI GEOFISICA SPERIMENTALE	OGS	Italy		
14	STATNY GEOLOGICKY USTAV DIONYZA STURA	SGIDS	Slovakia		
15	SILIXA LTD	SILIXA	United Kingdom		
16	SOTACARBO - SOCIETA TECNOLOGIE AVANZATE CARBONE SPA.	SOTACARBO	Italy		
17	NEDERLANDSE ORGANISATIE VOOR TOEGEPAST NATUURWETENSCHAPPELIJK ONDERZOEK TNO	TNO	Netherlands		
18	UNIVERSITA DEGLI STUDI DI ROMA LA SAPIENZA	UNIROMA1	Italy		
19	THE UNIVERSITY OF NOTTINGHAM	UNOTT	United Kingdom		
20	CO2GEONET - RESEAU D'EXCELLENCE EUROPEEN SUR	CO2GeoNet	France		

1.2. List of Beneficiaries

No	Name	Short name	Country	Project entry date[8]	Project exit date
	LE STOCKAGE GEOLOGIQUE DE CO2				

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	Ensuring safe storage operations	6 - CIUDEN	278.70	1	48
WP2	Ensuring storage capacities and cost-effective site characterisation	1 - BRGM	88.10	1	48
WP3	Managing leakage risks for protection of the environment and groundwater	3 - BGS	242.60	1	48
WP4	Integration of CO2 storage with local economic activities	17 - TNO	85.50	1	48
WP5	Coordination with local communities	18 - UNIROMA1	119.30	1	48
WP6	International Cooperation & seeding pilots and demos in Europe	4 - CGS	105.10	1	48
WP7	Spreading innovation	10 - IRIS	123.10	1	48
WP8	Promoting CCS through Training and education	20 - CO2GeoNet	50.80	1	48
WP9	Management	1 - BRGM	83.90	1	48
		Total	1,177.10		

1.3.2. WT2 list of deliverables

Deliverable Number[14]	Deliverable Title	WP number[9]	Lead beneficiary	Type[15]	Dissemination level[16]	Due Date (in months)[17]
D1.1	Design of CO2 injection tests	WP1	6 - CIUDEN	Report	Confidential, only for members of the consortium (including the Commission Services)	6
D1.2	Report on installation, with constantly updated data and threshold assessments	WP1	2 - BGR	Report	Public	14
D1.3	Dynamic ranking of the impact of heterogeneities on plume movement	WP1	19 - UNOTT	Report	Confidential, only for members of the consortium (including the Commission Services)	25
D1.4	Benchmarking studies on deep sampling	WP1	1 - BRGM	Report	Public	25
D1.5	Design & optimization of seismic monitoring network for induced seismicity management	WP1	17 - TNO	Report	Public	25
D1.6	Report on fault activity	WP1	20 - CO2GeoNet	Report	Confidential, only for members of the consortium (including the Commission Services)	32
D1.7	Interpretation and history matching on CO2 injection activities	WP1	8 - GGR	Report	Confidential, only for members of the consortium (including the Commission Services)	37
D1.8	Risk model updated	WP1	5 - CIEMAT	Report	Confidential, only for members of the consortium (including the Commission Services)	37
D1.9	Benchmarking on different geophysical techniques	WP1	12 - OGS	Report	Public	37
D1.10	Assessment of KPI from measurements	WP1	12 - OGS	Report	Confidential, only for members of the consortium (including the	38

Deliverable Number[14]	Deliverable Title	WP number[9]	Lead beneficiary	Type[15]	Dissemination level[16]	Due Date (in months)[17]
					Commission Services)	
D1.11	Specifications for future integrated and automated system	WP1	6 - CIUDEN	Report	Public	39
D1.12	Lessons learned on Geochemical modelling and sampling activities	WP1	1 - BRGM	Report	Public	39
D1.13	Results of induced seismic risk control activities	WP1	1 - BRGM	Report	Public	42
D1.14	integrated workflow for operational risk management	WP1	1 - BRGM	Report	Public	44
D2.1	Report on FEED study on light drilling	WP2	6 - CIUDEN	Demonstrator	Confidential, only for members of the consortium (including the Commission Services)	21
D2.2	Uncertainty Quantification of capacity estimates: coherent framework & applications	WP2	1 - BRGM	Report	Public	22
D2.3	High resolution simulation to determine heterogeneity effects on storage estimates in fractured reservoirs	WP2	19 - UNOTT	Report	Public	25
D2.4	Smart Characterization	WP2	20 - CO2GeoNet	Report	Public	28
D2.5	Drilling activities study for extension to other sites	WP2	6 - CIUDEN	Report	Confidential, only for members of the consortium (including the Commission Services)	44
D2.6	Technical Guidelines on storage capacities estimates and cost-effective site characterisation	WP2	1 - BRGM	Report	Public	42
D3.1	Report on leakage through faults (T3.2.1 & 3.2.2)	WP3	18 - UNIROMA1	Report	Public	37
D3.2	Assessment of leakage risk presented by old boreholes at onshore	WP3	10 - IRIS	Report	Public	26

Deliverable Number[14]	Deliverable Title	WP number[9]	Lead beneficiary	Type[15]	Dissemination level[16]	Due Date (in months)[17]
	site (case study report) (T3.2.4)					
D3.3	BGS optic fibre tool (T3.1.1)	WP3	3 - BGS	Demonstrator	Confidential, only for members of the consortium (including the Commission Services)	35
D3.4	BRGM-IDIL optic fibre tool (T3.1.1)	WP3	1 - BRGM	Demonstrator	Confidential, only for members of the consortium (including the Commission Services)	35
D3.5	UNIROMA1 probes (T3.1.1)	WP3	18 - UNIROMA1	Demonstrator	Confidential, only for members of the consortium (including the Commission Services)	32
D3.6	Silixa hybrid cable (T3.1.1)	WP3	15 - SILIXA	Demonstrator	Confidential, only for members of the consortium (including the Commission Services)	32
D3.7	IRIS biosensors (T3.1.1)	WP3	10 - IRIS	Report	Confidential, only for members of the consortium (including the Commission Services)	35
D3.8	OGS UAV drone (T3.3.1)	WP3	12 - OGS	Demonstrator	Confidential, only for members of the consortium (including the Commission Services)	35
D3.9	Report on field tests and modelling of impact of CO2 leakage on freshwater aquifers (T3.1.1)	WP3	1 - BRGM	Report	Public	37
D3.10	Report on Improvement in advanced soil gas monitoring techniques and assessment of CO2 source (T3.3.2)	WP3	2 - BGR	Report	Public	37

Deliverable Number[14]	Deliverable Title	WP number[9]	Lead beneficiary	Type[15]	Dissemination level[16]	Due Date (in months)[17]
D3.11	UNIROMA1 GasPro system (3.3.2)	WP3	18 - UNIROMA1	Demonstrator	Confidential, only for members of the consortium (including the Commission Services)	33
D3.12	UNIROMA1 ground mapper robot (T3.3.1)	WP3	18 - UNIROMA1	Demonstrator	Confidential, only for members of the consortium (including the Commission Services)	33
D3.13	Report on leakage detection and quantification tools (T3.3.3)	WP3	3 - BGS	Report	Confidential, only for members of the consortium (including the Commission Services)	37
D3.14	Report on the development of wide-area surface coverage tools and their efficacy) (T3.3.1)	WP3	18 - UNIROMA1	Report	Public	37
D3.15	Report on monitoring techniques which can detect CO2 migrating through fault planes (T3.2.2)	WP3	12 - OGS	Report	Public	37
D3.16	Technical guidelines for CO2 leakage detection and quantification:integration of monitoring tools developed through ENOS with existing state of the art tools in the context of full scale storage site operation (T3.4)	WP3	3 - BGS	Report	Public	40
D4.1	Novel Concepts for EOR with permanent storage of CO2	WP4	10 - IRIS	Report	Confidential, only for members of the consortium (including the Commission Services)	13
D4.2	Progress report on the economic evaluation on the project value of the geo-technical uncertainties related	WP4	20 - CO2GeoNet	Report	Confidential, only for members of the consortium (including the	20

Deliverable Number[14]	Deliverable Title	WP number[9]	Lead beneficiary	Type[15]	Dissemination level[16]	Due Date (in months)[17]
	to CO2 buffering and re-production for greenhouse horticulture, and to onshore CO2 storage and oil production				Commission Services)	
D4.3	Progress report on identified key chemical processes	WP4	17 - TNO	Report	Confidential, only for members of the consortium (including the Commission Services)	22
D4.4	Summary report with gas stream scenarios and user specifications	WP4	17 - TNO	Report	Confidential, only for members of the consortium (including the Commission Services)	25
D4.5	Reservoir models of novel CO2-EOR concepts at LBr-1	WP4	10 - IRIS	Report	Confidential, only for members of the consortium (including the Commission Services)	30
D4.6	Assessment of transboundary effects at LBr-1 and regulatory solutions	WP4	4 - CGS	Report	Public	37
D4.7	Approaches to regulating CO2 with EHR in selected Member States	WP4	17 - TNO	Report	Public	37
D4.8	Economic evaluation on the project value of the geo-technical uncertainties related to CO2 buffering and re-production for greenhouse horticulture, and to onshore CO2 storage and oil production	WP4	20 - CO2GeoNet	Report	Public	37
D4.9	Report on separation technology options and recommendation for the gas stream scenarios	WP4	17 - TNO	Report	Confidential, only for members of the consortium (including the Commission Services)	38
D4.10	Design of a CO2-EOR pilot	WP4	10 - IRIS	Report	Confidential, only for members	38

Deliverable Number[14]	Deliverable Title	WP number[9]	Lead beneficiary	Type[15]	Dissemination level[16]	Due Date (in months)[17]
					of the consortium (including the Commission Services)	
D4.11	Monitoring system for an integrated CO2 buffer and permanent CO2 storage project	WP4	17 - TNO	Report	Public	39
D4.12	Final report on gas phase quality assessment during CO2-EHR, buffering and storage	WP4	17 - TNO	Report	Confidential, only for members of the consortium (including the Commission Services)	40
D5.1	Presentation of the project's technical content in lay terms	WP5	18 - UNIROMA1	Report	Public	13
D5.2	Public Information Tool upgraded and ready for application to other CO2 storage sites	WP5	6 - CIUDEN	Other	Public	34
D5.3	CO2 Storage Best practice indications from the Hontomin site community	WP5	6 - CIUDEN	Report	Public	35
D5.4	CO2 Storage Best practice indications from Rotterdam area community	WP5	17 - TNO	Report	Public	37
D5.5	CO2 Storage Best practice indications from the GeoEnergy TestBed site community	WP5	19 - UNOTT	Report	Public	38
D5.6	CO2 Storage Best practice indications from the Sulcis site community	WP5	18 - UNIROMA1	Report	Public	40
D5.7	Guidelines for coordinating the developmentof of CO2 storage projects with local communities	WP5	18 - UNIROMA1	Report	Public	44
D5.8	Report on feed-back from citizens on ENOS activities	WP5	17 - TNO	Report	Public	45
D5.9	Report on the process of integration of indications coming	WP5	18 - UNIROMA1	Report	Public	46

Deliverable Number[14]	Deliverable Title	WP number[9]	Lead beneficiary	Type[15]	Dissemination level[16]	Due Date (in months)[17]
	from site communities in ENOS research and CO2 storage Best Practices					
D6.1	Detailed plan of international collaboration activities	WP6	1 - BRGM	Report	Confidential, only for members of the consortium (including the Commission Services)	3
D6.2	1st report on Twinning Programme	WP6	1 - BRGM	Report	Confidential, only for members of the consortium (including the Commission Services)	25
D6.3	1st report on European links, liaison and knowledge exchange	WP6	20 - CO2GeoNet	Report	Public	25
D6.4	State-of-the-art report identifying current lessons learned and future research priorities for EERA	WP6	3 - BGS	Report	Public	40
D6.5	Summary report on activities of the Leakage simulation alliance	WP6	3 - BGS	Report	Public	42
D6.6	Roadmap for CO2-Buffering in the Dutch greenhouse sector to 2030	WP6	17 - TNO	Report	Public	42
D6.7	Towards a strategic development plan for CO2 EOR in the Vienna Basin	WP6	17 - TNO	Report	Public	42
D6.8	Study on new pilot and demonstration project opportunities in Europe	WP6	20 - CO2GeoNet	Report	Public	42
D6.9	Report on the focus group activities and recommendations	WP6	1 - BRGM	Report	Public	46
D6.10	Follow-up plan for continuation of ENOS pilot projects	WP6	4 - CGS	Report	Confidential, only for members of the consortium (including the Commission Services)	46

Deliverable Number[14]	Deliverable Title	WP number[9]	Lead beneficiary	Type[15]	Dissemination level[16]	Due Date (in months)[17]
D6.11	2nd report on Twinning Programme	WP6	1 - BRGM	Report	Confidential, only for members of the consortium (including the Commission Services)	48
D6.12	2nd report on European links, liaison and knowledge exchange	WP6	20 - CO2GeoNet	Report	Public	48
D7.1	Plan for dissemination and exploitation of results	WP7	17 - TNO	Report	Confidential, only for members of the consortium (including the Commission Services)	6
D7.2	Web-platform	WP7	12 - OGS	Websites, patents filling, etc.	Public	7
D7.3	Results of OpenForum n°1	WP7	12 - OGS	Websites, patents filling, etc.	Public	10
D7.4	Newsletter 1	WP7	20 - CO2GeoNet	Websites, patents filling, etc.	Public	10
D7.5	Annual publication summary report n°1	WP7	10 - IRIS	Report	Public	13
D7.6	Results of OpenForum n°2	WP7	12 - OGS	Websites, patents filling, etc.	Public	22
D7.7	Short note summarizing knowledge integration workshop n°1	WP7	10 - IRIS	Report	Public	22
D7.8	Newsletter 2	WP7	20 - CO2GeoNet	Websites, patents filling, etc.	Public	22
D7.9	Updated plan for dissemination and exploitation of results	WP7	17 - TNO	Report	Confidential, only for members of the consortium (including the Commission Services)	25
D7.10	Annual publication summary report n°2	WP7	10 - IRIS	Report	Public	25
D7.11	Results of OpenForum n°3	WP7	12 - OGS	Websites, patents filling, etc.	Public	34

Deliverable Number[14]	Deliverable Title	WP number[9]	Lead beneficiary	Type[15]	Dissemination level[16]	Due Date (in months)[17]
D7.12	Short note summarizing knowledge integration workshop n°2	WP7	10 - IRIS	Report	Public	34
D7.13	Newsletter 3	WP7	20 - CO2GeoNet	Websites, patents filling, etc.	Public	34
D7.14	Best practice documents	WP7	20 - CO2GeoNet	Report	Public	46
D7.15	Annual publication summary report n°3	WP7	10 - IRIS	Report	Public	40
D7.16	Short note summarizing knowledge integration workshop n°3	WP7	10 - IRIS	Report	Public	45
D7.17	Newsletter 4	WP7	20 - CO2GeoNet	Websites, patents filling, etc.	Public	43
D7.18	Final plan for exploitation of results	WP7	17 - TNO	Report	Public	45
D8.1	E-book: Climate change and importance of CCS technology for decarbonisation of energy and industry	WP8	2 - BGR	Websites, patents filling, etc.	Public	10
D8.2	Joint education activities – Report 1, including outcome of internal workshop for the development of the joint curriculum	WP8	18 - UNIROMA1	Report	Confidential, only for members of the consortium (including the Commission Services)	10
D8.3	Report on awareness raising course for journalists workshop and interactions with media – months 1-12	WP8	20 - CO2GeoNet	Report	Public	13
D8.4	E-book: Geoscience applied to geological storage of CO2	WP8	2 - BGR	Websites, patents filling, etc.	Public	14
D8.5	ENOS Spring School 1 on CO2 storage	WP8	20 - CO2GeoNet	Websites, patents filling, etc.	Public	21
D8.6	E-book: Regulatory and social aspects of CCS technology	WP8	2 - BGR	Websites, patents filling, etc.	Public	22
D8.7	Report on awareness raising course for journalists workshop	WP8	20 - CO2GeoNet	Report	Public	25

Deliverable Number[14]	Deliverable Title	WP number[9]	Lead beneficiary	Type[15]	Dissemination level[16]	Due Date (in months)[17]
	and interactions with media – months 13-24					
D8.8	ENOS Spring School 2 on CO2 storage	WP8	20 - CO2GeoNet	Websites, patents filling, etc.	Public	33
D8.9	Report on awareness raising course for journalists workshop and interactions with media – months 25-36	WP8	20 - CO2GeoNet	Report	Public	37
D8.10	Evaluation of joint Master and post-graduate Master educational programme based on first experience	WP8	18 - UNIROMA1	Report	Public	37
D8.11	Outcome of building and providing an e-learning course	WP8	2 - BGR	Report	Public	38
D8.12	Outcome of WP8 - Promoting CCS through Training and education	WP8	20 - CO2GeoNet	Report	Public	45
D8.13	ENOS Spring School 3 on CO2 storage	WP8	20 - CO2GeoNet	Websites, patents filling, etc.	Public	45
D8.14	Report on interactions with media and journalist final report 37-45	WP8	20 - CO2GeoNet	Report	Public	45
D9.1	Plan for site activities	WP9	6 - CIUDEN	Report	Confidential, only for members of the consortium (including the Commission Services)	4
D9.2	Minutes of Management Board and General Assembly meetings for Year 1	WP9	1 - BRGM	Report	Confidential, only for members of the consortium (including the Commission Services)	13
D9.3	Updates to site activity plans 1	WP9	6 - CIUDEN	Report	Confidential, only for members of the consortium (including the Commission Services)	16

Deliverable Number[14]	Deliverable Title	WP number[9]	Lead beneficiary	Type[15]	Dissemination level[16]	Due Date (in months)[17]
D9.4	Minutes of Management Board and General Assembly meetings for Year 2	WP9	1 - BRGM	Report	Confidential, only for members of the consortium (including the Commission Services)	25
D9.5	Updates to site activity plans 2	WP9	6 - CIUDEN	Report	Confidential, only for members of the consortium (including the Commission Services)	28
D9.6	Minutes of Management Board and General Assembly meetings for Year 3	WP9	1 - BRGM	Report	Confidential, only for members of the consortium (including the Commission Services)	37
D9.7	Updates to site activity plans 3	WP9	6 - CIUDEN	Report	Confidential, only for members of the consortium (including the Commission Services)	40
D9.8	Minutes of Management Board and General Assembly meetings for Year 4	WP9	1 - BRGM	Report	Confidential, only for members of the consortium (including the Commission Services)	48
D9.9	detailed Project Management Plan	WP9	1 - BRGM	Report	Confidential, only for members of the consortium (including the Commission Services)	3
D9.10	Update of detailed Project Management Plan 1	WP9	1 - BRGM	Report	Confidential, only for members of the consortium (including the Commission Services)	16
D9.11	Update of detailed Project Management Plan 2	WP9	1 - BRGM	Report	Confidential, only for members of the consortium (including the Commission Services)	28

Deliverable Number[14]	Deliverable Title	WP number[9]	Lead beneficiary	Type[15]	Dissemination level[16]	Due Date (in months)[17]
D9.12	Update of detailed Project Management Plan 3	WP9	1 - BRGM	Report	Confidential, only for members of the consortium (including the Commission Services)	40

1.3.3. WT3 Work package descriptions

Work package number [9]	WP1	Lead beneficiary [10]	6 - CIUDEN
Work package title	Ensuring safe storage operations		
Start month	1	End month	48

Objectives

To demonstrate safe and environmentally sound onshore storage is essential for later development of CCS. Issues arising from the operational phase will be tackled in this WP, using real-life experience from running the Hontomin pilot site. Increased understanding on CO2 injection and operational procedures will be acquired in ENOS at this far from ideal site, with settings far from ideal, but give an outstanding opportunity to demonstrate operational procedures, monitoring techniques and integrated risk management pproaches taking advantage of the huge capabilities of an already existing facility.
The objectives of WP1 are the following:
- to demonstrate innovative injection strategies and history matching approaches for increased confidence of operators in managing sites safely
- to validate methodologies using microseismic monitoring network data to manage induced seismicity risk.
- to validate tools and methodologies for monitoring the CO2 plume in the reservoir and for acquiring data on reservoir properties for improved understanding on reservoir behaviour.
- to develop the smart integration of the different monitoring data acquired during operation.
- to develop an integrated risk management workflow leading to reliable and safe CO2 storage operation, fulfilling the requirements of the European Directive for CO2 Storage, in order to meet the needs of regulators, local population and operators; encompassing monitoring activities, update of risk assessment and potential risk mitigation and corrective measures.
- to perform an integrated approach for the definition of technical guidelines for CO2 storage operation, through cooperation in R&I of research institutions, industry and service providers.

Work in WP1 therefore aims at generating a TRL progress, where tools will be validated at Hontomin, i.e. at pilot scale, for a wide range of technologies and methodologies related to injection operations and associated monitoring.

Description of work and role of partners

WP1 - Ensuring safe storage operations [Months: 1-48]
CIUDEN , BRGM, BGR, CIEMAT, flodim, GGR, OGS, SILIXA, SOTACARBO, TNO, UNIROMA1, UNOTT, CO2GeoNet
Task 1.1 Reliable CO2 injection procedures in carbonates (CIUDEN, GGR, UNOTT, CO2GeoNet-HWU)
State of the art
Extensive experience of CO2 injection exists for enhanced hydrocarbon recovery (e.g. Weyburn, Canada), where reservoir history is typically available to help inform injection management. Injection into saline aquifers was only recently developed at the industrial scale (e.g. Sleipner, Snøvhit, In-Salah) but mainly within sandstone formations. Experience in carbonate reservoirs for permanent storage of CO2 is limited, such as the Michigan Basin site within the US DOE RCSP validation phase (finished in 2009), the Cholla site in Arizona, USA, during which CO2 injection was not performed due to the lower permeabilities found during well drilling (WESTCARB, 2009), and the Williston Basin field demonstration (PCOR, 2009) in North Dakota, USA, in which up to 400t CO2 were injected into the Mission Canyon carbonate formation at more than 2400m depth. This site demonstrated the importance of fracture networks on migration of the injected CO2 plume given that the matrix permeability is typically lower than 0.5 mD and the same well was used for injection and oil production both before and after the test (with increasing values due to CO2 injection). Field scale experiments complemented by well validated next-generation reservoir models are therefore urgently needed to better understand CO2 injection into fractured carbonate saline formations and to demonstrate our ability to safely inject and store CO2 at relevant scale.

Progress beyond the state of the art
The results from this task will increase the confidence of future storage operators in injecting CO2 in deep saline formations, especially carbonate formations, providing a higher understanding on the risks and cost-effectiveness.

Task 1.1.1 Design and execution of CO2 injection strategies at Hontomin (CIUDEN, GGR)

The operation of Hontomin TDP represents a core part of the efforts developed in ENOS. It will be linked with many activities within the project, including injection tests and pressure management. It involves the operation of the Hontomin facility for a period of two years during which up to 10 kton of CO2 will be injected in addition to the 3 kton currently injected. Innovation in the design, performance and interpretation of the different injection operations will be ensured by learning from the recommendations from twinned sites (see WP6) and from T.1.2 on induced seismicity risk management.
Partners will build on existing experiences in fractured carbonates, analyse the reservoir dynamic model, and define injection strategies with a special view on maintaining geomechanical integrity. Most of the past experiences were based on a continuous flow of CO2, but in view of future storage operations at commercial scale different injection schemes are needed in order to face unexpected reservoir behaviour or intermittent supply during CO2 capture. Detailed analysis will be done throughout this task in order to define the best approach for such injection strategies, i.e.:
- Discontinuous strategies: focusing on improving hydrodynamic stability in the fractured reservoir
- Continuous strategies: managing operational parameters (temperature, pressure and flow rates) to control storage integrity
- Alternative strategies: cold injection or co-injection of CO2 and brine will be designed and tested, with the aim of finding the most efficient operation parameters
Geogreen will update and integrate existing data and models from Hontomin TDP within an advanced earth model using PETREL 2014™. The earth model will serve as a repository for ENOS project tasks and as a basis for numerical investigation of the different injection strategies. The dynamic model, using GEM™ shall be tuned to match the already performed tests on Hontomin TDP.
The injection scenarios will then be modelled, considering different options of injection protocols (mainly pressure, temperature, flow rate and duration) and parameters of the geological static model (permeabilities of the rock matrix and the fracture network of the reservoir and the overlaying formation from caprock to surface, including faults). The injection scenarios will then be performed and this task will allow the acquisition of operational data by CIUDEN associated with CO2 injection in ENOS.

Task 1.1.2 Interpretation of CO2 injection tests and history matching (GGR, CIUDEN, UNOTT, CO2GeoNet-HWU)
Based upon the models developed in T 1.1.1, Geogreen will perform an advanced history matching and uncertainty assessment tool for investigating and history matching the different scenarios to represent the injection test performed on site. Beyond the pressure and flow response from the storage and its immediate overburden, a particular focus shall be on defining the stress regime and pressure conditions prior and during CO2 injection tests with their geomechanical consequences. Given the compartmentalized reservoir settings, modeling of impacts heterogeneities such as faults or fractures will be undertaken by UNOTT and CO2GeoNet-HWU. UNOTT will use INTERSECT™ next-generation reservoir simulator software, using unstructuring meshing, partitioned within a multi-million cell high resolution model of the overall reservoir. This activity will allow dynamic ranking of the different realizations, leading to improved understanding of the impact of heterogeneities and movement (with potential redirection) of the injected plume. It will be enabled by parallel processing using UNOTT´s High Power Computing facility. CO2GeoNet-HWU will work on a fault upscaling approach, testing different physical representations of the faults and implementing various scenarios from the geological model developed in T.1.1.1. This will allow Geogreen to update the geological model with detailed knowledge on fault behavior.

Outcomes
Design and execution of cost-effective and innovative CO2 injection strategies (pulse, cold, ...), associated modelling and history matching activities, linked with Pressure management and site conformance, under real-life conditions.
Demonstration of safe and environmentally sound CO2 storage

Task 1.2 Induced seismicity: monitoring, control and hazard mitigation (TNO, CIUDEN, BRGM, CO2GeoNet-IGME)
State of the art
Induced seismicity risk in connection with subsurface fluid injection and production has recently become an increasingly important concern. For instance, observations of induced seismicity related to conventional gas production, gas storage, shale gas production, waste water injection, and geothermal activities have demonstrated that there is a need to improve our ability to reduce the uncertainty in seismic hazard assessment and investigate mitigation options. For onshore CO2 storage in populated areas, induced seismicity is a major public concern and therefore a critical project and safety risk. Until now, CO2 storage operations have resulted in very few recordings of induced earthquakes (IEAGHG report 2013/09, 2013). However, detailed monitoring studies of induced seismicity are scarce and cannot be generalized into a standard practice approach. In induced seismicity risk management so-called traffic-light systems are common in geothermal and O&G. However, these approaches, that prescribe measures to be taken if the seismicity observed exceeds a threshold, are highly qualitative and have not been tested widely under a wide variety of conditions. At present, the

protocol that has been developed in the context of geothermal energy production in the EU FP7 Geiser project is the most advanced and detailed and no such protocol exists for CO2 storage.

Progress beyond the state of the art
The objective of the work proposed in Task 1.2. is to develop and validate methods for generating input for risk management and control systems. This includes improvements on the physical modelling of seismic wave propagation to optimize monitoring systems and development of innovative approaches that combine physical modelling and statistical data to update the seismicity risk model as more observations and operational data become available.
The activities in Task 1.2 are grouped into three subtasks that are strongly linked but each focus on a different aspect of induced seismicity risk management.

Task 1.2.1. Baseline and background of the fault activity (CO2GeoNet-IGME, CIUDEN)
The aim of this sub-task is to determine the recent seismic activity around Hontomín site and its possible change caused by the injection. This will establish the Hontomín seismological baseline, which is needed to provide the initial risk assessment and interpretation of seismicity observed at the site. The seismic behaviour of a fault depends on the stress and strength fields. Existing characterization activities provided by CIUDEN will be extended by CO2GeoNet-IGME for the Hontomín site with a detailed analysis of the following aspects:
- Structural Analysis. Fault population analysis defines stress and strength trajectories.
- Analysis of natural seismicity into the area. Palaeoseismic recognition of active faulting, tectonic geomorphology and archaeoseismology.
- Analysis of induced seismicity: time-series analysis of trigged earthquakes. Estimation of short-term and long-term behavior.
These activities will be performed in different level of detail for three zones of interest: the storage complex, an intermediate area (25km range from the injection site) and on a regional scale (100 km).

Task 1.2.2 Demonstration of (Passive) Seismic Monitoring Network reliability (TNO, CIUDEN)
The aim of this task is to test the reliability of the existing seismic monitoring network at Hontomin and optimize it, in terms of reliability, accuracy, and sensitivity. This will lead to increased safety during operation, thus promoting confidence in CO2 storage.
Part of the activities will be devoted to execute a detailed performance assessment methodology for the existing micro-seismic monitoring network at Hontomin. This activity will be done in two phases, first conducting a conventional calibration analysis of the seismic instruments, using correlation analysis of recorded micro-seismic events to improve the sensitivity and using progressive propagation model updates to improve localisation of the events. A parallel simulation process using detailed 3D finite element with SPECFEM3D will be done, which will provide the simulated data that can be compared with actual observations using advanced Full Waveform Inversion techniques, providing improved understanding and ultimately better predictive capabilities of the seismic response to the injection. Once a detailed model for the seismic response is available, a Value of Information (VOI) analysis will be performed. This analysis will not only provide an evaluation of the performance of the existing monitoring network but also considers alternative monitoring layouts, focusing on the trade-offs between initial and operational costs and reliability, accuracy and sensitivity of the network and instruments. The results of this analysis will be used to develop effective and validated monitoring strategies for induced seismicity risk management in onshore CO2 storage projects.

Task 1.2.3. Implementation of risk control activities (BRGM, CIUDEN)
Approaches for time-dependent seismic hazard estimates will be developed, using an advanced traffic light system, aiming to mitigate seismicity through real-time adaptation of injection strategy. Traffic light risk management systems require (near)-real time detection, localization, and (preferably) characterization of induced seismic events. The Hontomin site fulfils the needs with the monitoring network and characterization and monitoring data, providing a unique opportunity to develop the workflows to generate the information needed to execute a seismicity risk management protocol.
Existing guidelines have been formulated in the context of geothermal energy development. In this task this protocol will be evaluated and adapted for application in a CO2 context. In particular, a mitigation strategy will be developed that is based on control of injection rates to keep seismic hazard below a pre-defined level; thus linked with T.1.1 on operation aspects of CO2 injection.
This task will include a validation of each step of the methodology against observations from Hontomin operations. In particular, the simulated seismicity catalogues will be compared to observations and a calibration of free parameters in the approach to be developed. Specifically, the ground-motion models proposed for geothermally-induced seismicity will be compared with available ground-motion records. Potentially, simulations will be conducted for validation using the spectral-element codes (EFISPEC3D by Florent De Martin), where possible building on the spectral element simulations performed in Task 1.2.

Outcomes
Methods for reducing uncertainty and producing reliable and transparent induced seismicity hazard estimates under real-life conditions, using experiences and observations from Hontomín to validate the methods developed.
Demonstration of best practices for effective monitoring and risk assessment related to induced seismicity control allowing optimising the safe operation of storage sites.
Demonstration of mitigation techniques, to keep induced seismicity risks below an acceptable threshold
Providing input for a sustained engagement of local communities by a dedicated explanation of the risk management activities, in close collaboration with WP5 effort.

References:
IEAGHG (2013) Induced Seismicity and its Implication for CO2 Storage Risk, 2013/09, June 2013.

Task 1.3 Monitoring safe underground storage behaviour (CIUDEN, BRGM, BGR, OGS, Silixa, UNIROMA1, Flodim)
State of the art
Monitoring technologies are expected to be improved for reliable control of CO2 storage. Many of the tools and techniques in use at the existing sites, such as Sleipner, come from Oil&Gas sector. The costs for deploying such techniques however need to be optimized and other techniques coming from other sectors still need to be adapted and demonstrated for CO2 storage purposes. Geochemical monitoring through deep sampling is mainly performed with permanently installed U-tube system, which has been tested in key onshore CO2 storage sites such as Frio Brine (US), Otway (AUS), Ketzin (GER) and Hontomin (ES).
Some tools as the Distributed Acoustic Sensor (iDAS) already installed at Hontomin in well H-I has been utilised for VSP surveys (this tool was developed through deployment at Hontomin, Otway (AUS), Ketzin (GER), or AQUISTORE (CAN))
Regarding soil gas monitoring stations, both BGR and UNIROMA1 stations were tested at different pilot and naturally leaking sites.
The aim of this task is to test different technologies under real-life conditions, each measuring different useful parameters that, when integrated, will contribute to understand what is occurring in the reservoir and the overburden, which is key for the demonstration of safe and environmentally sound CO2 storage and for providing the needed information in T.1.4 for risk management.

Progress beyond the state of the art
Monitoring techniques for demonstrating site conformance using different monitoring techniques will be validated. For geochemical monitoring, a deep sampler will be tested at larger depths in the observation well (H-A) under harsh saline environments, supported by the knowledge acquired from the U-tube system at the injection well, H-I. Sampling fluids that are representative of in-situ conditions is still a challenge in particular for removable tools that can resist downhole pressure temperature and salinity. Improvement of active and passive seismic methods will be done, taking advantage of the existing settings in Hontomin (see. T.1.3.2) , this will include testing the use of the Silixa IDAS cable for monitoring purposes other than VSP.. This will allow acquiring precise data from the storage complex while validating monitoring techniques that can represent a cost effective solution when compared to well-known geophysical techniques common for Oil&Gas. In addition, different soil gas monitoring stations will be installed in Hontomin, pursuing a continuous control of the values in surface that will allow a TRL progress and a more complete monitoring plan at Hontomin. The combination of continuously measured soil gas composition data with CO2 flux surveys will allow interpreting thresholds representing an irregularity.

Task 1.3.1 Alternative deep geochemical monitoring solutions (BRGM, CIUDEN, Flodim)
The overall aim of this task is to demonstrate tools for reservoir water and/or gas sampling and to validate the contribution geochemical monitoring can provide to the monitoring and management of CO2 Storage.
BRGM will work on further developments of its deep sampler (patent FR-1259214), which will allow getting representative samples of water and/or gases existing at depth. The proposed monitoring strategy is oriented towards a system that is both retrievable and can be left in place in monitoring boreholes to get samples. Until now, the device has only been deployed at shallower depth and in freshwater environment (1035 m in the Aquitaine basin in France). This will allow evaluating potential adverse effects linked to saline environments, such as corrosion. Three sampling campaigns are budgeted in the proposal (2016, 2017 and 2018). Flodim will test its new Bottom Hole Sampling system, where the sampling chamber is also a transport container and a PVT cell and its High Temperature Geochemical instrument (P, T, GR, CCL, pH, Redox potential, Conductivity and dissolved O2).
Gas and water samples will be acquired at Hontomin and processed at a subcontracting laboratory in order to get major and trace element analyses. This will bring information on the remobilization of trace metal elements in water, and hence understanding processes that may lead to such remobilization in a carbonated aquifer.

Using the initial composition of the formation water from Hontomin characterization phase, from the existing U-tube sampler located at the Injection well and from flodim probe, the geochemical evolution of the reservoir will be evaluated. A reactive transport model will be developed that will be based on calibration laboratory experiments. Because of the relatively high salinity in the Hontomín reservoir, geochemical modeling will be made using the Pitzer formalism, suitable for high salinity solutions and enabling to test it on real case. Such a modeling will also give the opportunity to implement the Pitzer approach for the Fe(II)/Fe(III) redox couple and to validate it versus natural brines at the reservoir scale.

Task 1.3.2 Innovative geophysical monitoring (OGS, Silixa, BRGM, CIUDEN)
The scope of this activity is to provide geophysical data in relevant time (i.e. useful to take decisions) for the integrated risk management approach in T.1.4.There are techniques that offer opportunities in terms of integration, usability and cost reduction, which are going to be demonstrated under real conditions in ENOS.
OGS and Silixa will perform 2 surveys (2016, 2018) using a surface seismic vibrator source, and recording data at the existing iDAS in H-I (injection well) and hydrophones in H-A (observation well). Results will be confronted by OGS with already existing 3D seismic information for improving the subsurface imaging, and the definition of the fractured blocks within the reservoir and for CO2 plume tracking. The iDAS dense spatial sampling offers the opportunity to extensively apply to 3D VSP the innovative dual-field separation method, without need of detailed signal picking. Associated numerical modeling including attenuation and ray tracing, using existing information of the subsurface and near-surface Hontomin 3D seismic model, will verify downhole illumination zone, estimate resolution, and provide sensitivity analysis (see also Task 1.4.1).
Moreover, OGS will use a slim sparker borehole source to acquire crosswell and single-well acoustic signals with higher frequency and without the overburden effects, immediately after the 3D VSP surveys in 2016 and 2018, to improve the resolution and sensitivity of the seismic results to be used for the subsequent integration with downhole resistivity (ERT) data from permanent borehole electrodes installed in H-I and H-A that will be acquired by CIUDEN, and local calibration of the areal 3D VSPs from surface sources.
The application of seismic interferometry (SI) techniques to borehole data with active (seismic vibrator) and passive sources (injection noise) will make possible to obtain signals redatumed at depth without the overburden effects, and to remove the source effects in the time lapse applications. This approach will create signals from virtual sources, which will be compared with the sparker crosswell acoustic results. SI will be based on cross-correlation and, thanks to dense iDAS sampling, multidimensional deconvolution method to remove the virtual source´s point spread function. To extend the stationary coverage condition with partial illumination OGS will use the tangent-phase method proposed by Poletto et al. (2013, and see Bibliography for OGS in Section 4).
From operational point of view, crosswell acoustic and SI by active surface sources represent quick methods, with respect to 3D VSP, to monitor the local CO2 plume evolution between virtual source and receivers in the borehole.
Another approach from BRGM relates to seismic noise correlation. This method for CO2 storage monitoring has undergone a first test on the Ketzin injection site. This test showed that this method offers room for improvement to get a better insight at the reservoir level and thus offers a competitive and continuous alternative to the current 4D time lapse seismic surveys. BRGM will reprocess the data from the surface seismological network and transpose new developed algorithms, to extract speed variations at the reservoir level and thus highlight changes in the reservoir induced by CO2 presence or fracturation.

Task 1.3.3 Determination of action levels by soil gas monitoring (BGR, CIUDEN, UNIROMA1)
The aim of this activity is to progress the TRL of permanently acquired soil gas concentration data from monitoring stations developed by BGR and UNIROMA1. These will be located at key sites at Hontomin, close to the injection area and near existing faults. Both monitoring stations will provide accurate data during the operation of the facility. These data will be permanently cross-referenced to a “reference site” station, which is mandatory to acquire accurate natural background (annual, inter-annual or daily variations) and threshold data. This subtask will take advantage of the existing baseline CO2 fluxes and data from the existing meteorological station acquired by CIUDEN, and further CO2 fluxes surveys are also expected in order to correlate them with the data acquired by the soil gas monitoring stations equipped with a commercial flux measurement device. By combining continuously measured data and spatial data threshold can be defined that could represent an irregularity. These thresholds will be inputs to the risk management procedure developed in T1.4. This activity will complement the BGR soil gas monitoring activities in Task 3.3.2 where leakage will occur for sure.

Outcomes
Extension of the deep sampling capacities for CO2 storage, key for improving knowledge on reservoir behaviour, geochemical response, and a better understanding on the processes in the reservoir.
Benchmarcking of different samplers (Utube, BGRM’s and Flodim’s)

Demonstration of best practices for monitoring of CO2 storage, providing accurate data on the behaviour of the storage complex during the operation of a CO2 storage site. Progress TRL monitoring tools validated at real-life conditions. Building public awareness by facilitating data and "visible in surface" monitoring stations.

References:
Poletto F., B. Farina, and G. Böhm, 2013. Tangent-Phase Interferometry, Time Lapse Application and Sensitivity Analysis: 75th EAGE Conference & Exhibition incorporating SPE EUROPEC, Extended Abstract.

Task 1.4 Demonstrating operational risk management (BRGM, CIUDEN, CIEMAT, GGR, OGS, SOTACARBO, TNO)
State of the art
Some form of operational risk management were already performed in previous injection sites but in most of them used an ad hoc methodology. In some cases, no clear workflow or procedure is apparent (Sleipner, Chadwick et al. 2008; In Salah, Ringrose et al. 2012; Ketzin, Wurdemann et al. 2011, Martens et al. 2014). Those references often mention updates of either the main models or the risk assessments but not in a clearly defined way, such as what is required from the EU directive and the accompanying guidance documents. In North America, more robust risk management methods were used (at Weyburn, Bowden et al. 2013, or at Decatur, Hnottavange-Telleen, 2014) but how monitoring is used to update the risk assessment is less clear. An operational automated system for monitoring was developed for the Decatur site (Picard et al. 2011) but again, the link with risk assessment is not clear.
The ROAD project in the Netherlands, developed risk management plans in accordance with the requirements of the EU directive but is still in the pre-injection phase (Steeghs et al. 2014).
There also exist various published (but still untested on real sites) methods regarding links between the risk management plans and how to set thresholds: Setting up a Monitoring plan: Bourne et al. 2014; Having probabilistic thresholds in the monitoring plan: Jenkins, 2013; Using a traffic light system for dealing with the offset between models and measurements: Kronimus et al. 2013; Using Key Performance indicators for linking observation and risk assessments: Pearce et al. (2013).

Progress beyond the state of the art
The task will seek to make progress on the following points:
- Integration of different monitoring techniques in order to derive more meaningful indicators
- Robust link between risk assessment updates and observations through the use of clearly defined thresholds
- Use of probabilistic risk models
- Integrated workflow for operational risk management including monitoring, modelling and risk communication.

The activities in Task 1.4 are grouped into three subtasks: the first two are demonstration of best practices at the Hontomin site, while the third will deal with more general aspects:
- In Task 1.4.1 the measurements from different monitoring techniques (geophysical and geochemical) are integrated in order to obtain more meaningful information related to the actual risk;
- Task 1.4.2 will update of the risk models following the observations made during operations;
- Task 1.4.3 will be dedicated to the methodological aspects and to the extrapolation of results for future storage sites.

Task 1.4.1. Integration of monitoring data (OGS, BRGM, CIUDEN)
Integration of monitoring data is needed as part of an operational risk management procedure for several reasons: 1/ some monitoring techniques such as geophysical techniques can reduce the uncertainty on their measurements when combined with other, complementary measurements; and 2/ reasoning on risks is more practical with meaningful indicators (such as localisation of CO2 front) rather than on raw measurements, but such indicators can be computed using different information sources.
OGS will coordinate the integration and evaluation of the geophysical data, including correlation of the recorded microseismicity (including waveforms) with CO2 injection activities, seismic and electromagnetic sensitivity analysis, poro-visco-elastic modeling and data inversion (including multi-phase fluid geophysical characterization). BRGM will contribute by integrating the geochemical data and surface measurements of gases. CIUDEN, as operator of the site, will gather all possible data, including data from the shallow hydrogeological monitoring network. During a previous baseline campaign at Hontomin, BRGM acquired a spatially dense CSEM dataset with an innovative/efficient source type, the surface LEMAM setup combining surface electrodes and one borehole casing. Integrated with the previously mentioned monitoring techniques, these data can bring complementary information at storage complex scale, thus reducing uncertainties on measurements and facilitating interpretation. In order to do this, a 3D resistivity map will be inverted from the baseline data (i.e. apparent resistivity maps) using a modular parallel frequency-domain CSEM inversion code.

Task 1.4.2 Update of risk assessment (CIEMAT, CIUDEN)
A key issue in CO2 storage activities is that the knowledge on the risks is evolving along the life of the project as new information is derived from the monitoring system, and thus requiring a regular update of the risk assessment. As

an objective of the task is to progress on the development of a risk management procedure for a potential automated alert system (subtask 1.4.3), a key aspect in this subtask will be to develop a clear, robust and repeatable workflow for updating the risk models.
In the current collaboration between CIUDEN and CIEMAT, a methodology for estimating the probability of risk of leakage has been developed for the Hontomin Technology Development Plant site and an ad hoc model has been implemented on a probabilistic simulation object-oriented framework. This model yields quantitative risk probability functions of the total CO2 storage system and of each one of their subsystems as well as the stochastic time evolution of the CO2 plume during the injection period, the stochastic time evolution of the drying front, the probabilistic evolution of the pressure front, and the leakage probability functions through major leakage risk elements (fractures / faults and wells / deep boreholes (Hurtado et al. 2014)).
In Task 1.4.2, CIEMAT proposes to validate that risk model using as input data those variables from the monitoring process related to the temporal evolution of the CO2 plume and the drying front. As a result of the validation process, the probabilistic model will be modified as to reflect the singularities of the Hontomin site.

Task 1.4.3. Technical Guidelines for operational risk management (BRGM, CIEMAT, CIUDEN, GGR, OGS, SOTACARBO, TNO)
This subtask will have two main purposes: the first is to guide the methodological developments needed in the other subtasks. The other is to extract the lessons learned in the whole task and to extrapolate them for future storage sites.
Using the existing Risk Assessment and the latest data produced by the monitoring infrastructure at Hontomin, a list of the Key Performance Indicators (KPI) of the site will be defined, as well as how they will be computed in subtask 1.4.1, and used in task 1.4.2.
Then thresholds based on those KPI will be set in coherency with the traffic-light system developed by TNO in the FP7 CO2CARE project. Thresholds on the KPI will allow triggering additional monitoring or corrective measures. There is also a need for a threshold related to the offset between models and observations that, when overpassed, would require the model to be modified.
Those developments will allow having a full operating workflow, linking risk assessment, the monitoring system and corrective measures. The partners will provide a first version of the workflow in the beginning of the project and will then improve it as more data and experience are gathered during the project. One goal of this task is to draft the specifications for a future integrated and automated alert system. The integration of the storage component in the whole CCS system, and the potential effect on operations in the whole chain (incl. capture and transport) will also be assessed.
BRGM will lead the task. All partners will contribute to the methodological developments through dedicated meetings. CIUDEN, with SOTACARBO, and likely other industrial actors, will work on the specifications of the alert system for its integration on an industrial full chain project.

Outcomes
Demonstration of an integrated workflow of risk management, providing a strong basis for communication of risks with various stakeholders, including authorities and the general public.
Initial design stage of an integrated alert system, providing provide a strong methodological framework for future operators and regulators of storage sites and will be consistent with the guidance of the EU directive.

References:
Chadwick, A., Arts, R., Bernstone, C., May, F., Thibeau, S., & Zweigel, P. (2008). Best practice for the storage of CO2 in saline aquifers. British Geological Survey Occasional Publication, 14, 267.
Ringrose, P. S., Mathieson, A. S., Wright, I. W., Selama, F., Hansen, O., Bissell, R., & Midgley, J. (2013). The In Salah CO2 storage project: Lessons learned and knowledge transfer. Energy Procedia, 37, 6226-6236.
Würdemann, H., Möller, F., Kühn, M., Heidug, W., Christensen, N. P., Borm, G.,. & CO2SINK Group. (2010). CO2 SINK—from site characterisation and risk assessment to monitoring and verification: one year of operational experience with the field laboratory for CO2 storage at Ketzin, Germany. IJGGC, 4(6), 938-951.
Martens, S., Möller, F., Streibel, M., Liebscher, A., & Group, T. K. (2014). Completion of Five Years of Safe CO2 Injection and Transition to the Post-closure Phase at the Ketzin Pilot Site. Energy Procedia, 59, 190-197.
Bowden, A. R., Pershke, D. F., & Chalaturnyk, R. (2013). Geosphere risk assessment conducted for the IEAGHG Weyburn-Midale CO2 Monitoring and Storage Project, IJGGC, 16, S276-S290.
Hnottavange#Telleen, K. (2014). Risk management at the Illinois Basin–Decatur Project: A FEPs#based approach. Greenhouse Gases: Science and Technology, 4(5), 604-616.
Picard, G., Bérard, T., Chabora, E., Marsteller, S., Greenberg, S., Finley, R. J., & Davard, J. (2011). Real-time monitoring of CO2 storage sites: Application to Illinois Basin–Decatur Project. Energy Procedia, 4, 5594-5598.
Steeghs, P., Neele, F., Gittins, C., & Ros, M. (2014). Drafting a monitoring plan for the ROAD project under the EU CCS Directive. Energy Procedia, 63, 6680-6687.

Bourne, S., Crouch, S., & Smith, M. (2014). A risk-based framework for measurement, monitoring and verification of the Quest CCS Project, Alberta, Canada. IJGGC, 26, 109-126.
Jenkins, C. (2013). Statistical aspects of monitoring and verification. IJGGC, 13, 215-229.
Kronimus A., de Bruin G., Wollenweber J. et al. (2013) Criteria for decision making in site abandonment. FP7 CO2CARE project, Deliverable D4.22. DOI: 10.2312/GFZ.CO2CARE_2013.002
Pearce J.M., Hannis S.J., Kirby G.A., et al. Interaction with other WPS - (2013) How to Submit a CO2 Storage Permit: Identifying Appropriate Geological Site Characterisation to Meet European Regulatory Requirements. Energy Procedia. Volume 37, 2013, Pages 7783-7792.
Hurtado, A.; Eguilior, S.; and Recreo, F. (2014). "Methodological development of a probabilistic model for CO2 geological storage safety assessment". Journal of Energy and Environmental Engineering 5, 2-3. SpringerOpen.

Interaction with other WPS
A strong interaction with other WP in the project is assured, especially with WP3 on demonstration that there is no leakage. WP1 will focus on monitoring to verify deep processes which control the security of storage and technologies used to demonstrate that the CO2 is contained within the storage complex. WP3 will focus on verifying the effectiveness of selected shallow and surface monitoring technologies and techniques advanced through the ENOS project that will be utilised alongside improved understanding of major leakage pathways (faults and boreholes) and the outcomes of WP1 to advance monitoring protocols.
With WP5 where coordination with local population includes the explanation of the activities at Hontomin.
In WP7, the development and dissemination of best practices will use conclusions from WP1. Knowledge sharing and international cooperation in WP6 will be based on WP1 activities for Hontomin site twining with site projects outside Europe, as Otway (AUS), and Battelle (US) ones.

Participation per Partner

Partner number and short name	WP1 effort
1 - BRGM	45.00
2 - BGR	10.00
5 - CIEMAT	6.00
6 - CIUDEN	103.00
7 - flodim	4.00
8 - GGR	11.40
12 - OGS	40.00
15 - SILIXA	4.50
16 - SOTACARBO	5.60
17 - TNO	16.00
18 - UNIROMA1	1.00
19 - UNOTT	8.00
20 - CO2GeoNet	0.00
HWU	4.00
IGME	20.20
Total	278.70

List of deliverables

Deliverable Number[14]	Deliverable Title	Lead beneficiary	Type[15]	Dissemination level[16]	Due Date (in months)[17]
D1.1	Design of CO2 injection tests	6 - CIUDEN	Report	Confidential, only for members of the consortium (including the Commission Services)	6
D1.2	Report on installation, with constantly updated data and threshold assessments	2 - BGR	Report	Public	14
D1.3	Dynamic ranking of the impact of heterogeneities on plume movement	19 - UNOTT	Report	Confidential, only for members of the consortium (including the Commission Services)	25
D1.4	Benchmarking studies on deep sampling	1 - BRGM	Report	Public	25
D1.5	Design & optimization of seismic monitoring network for induced seismicity management	17 - TNO	Report	Public	25
D1.6	Report on fault activity	20 - CO2GeoNet	Report	Confidential, only for members of the consortium (including the Commission Services)	32
D1.7	Interpretation and history matching on CO2 injection activities	8 - GGR	Report	Confidential, only for members of the consortium (including the Commission Services)	37
D1.8	Risk model updated	5 - CIEMAT	Report	Confidential, only for members of the consortium (including the Commission Services)	37
D1.9	Benchmarking on different geophysical techniques	12 - OGS	Report	Public	37
D1.10	Assessment of KPI from measurements	12 - OGS	Report	Confidential, only for members of the consortium (including the Commission Services)	38
D1.11	Specifications for future integrated and automated system	6 - CIUDEN	Report	Public	39

List of deliverables

Deliverable Number[14]	Deliverable Title	Lead beneficiary	Type[15]	Dissemination level[16]	Due Date (in months)[17]
D1.12	Lessons learned on Geochemical modelling and sampling activities	1 - BRGM	Report	Public	39
D1.13	Results of induced seismic risk control activities	1 - BRGM	Report	Public	42
D1.14	integrated workflow for operational risk management	1 - BRGM	Report	Public	44

Description of deliverables

Task 1.1
D1.1 Design of CO2 injection tests. M6. CIUDEN (GGR)
D1.3 Dynamic ranking of the impact of heterogeneities on plume movement, M25, UNOTT (CO2GeoNet-HWU)
D1.7 Interpretation and history matching on CO2 injection activities, M37, GGR, (CIUDEN, UNOTT, CO2GeoNet-HWU)

Task 1.2
D1.6 Report on fault activity, M32, CO2GeoNet-IGME (CIUDEN)
D1.5 Design & optimization of seismic monitoring network for induced seismicity management, M25, TNO (CIUDEN)
D1.13 Results of induced seismic risk control activities, M42. BRGM (CIUDEN)

Task 1.3
D1.4 Benchmarking studies on deep sampling, M25, BRGM (CIUDEN,Flodim)
D1.12 Lessons learned on Geochemical modelling and sampling activities, M39, BRGM (CIUDEN,Flodim)
D1.9 Benchmarking on different geophysical techniques, M37. OGS (CIUDEN, SILIXA, BRGM).
D.1.2 Report on installation, with constantly updated data and threshold assessments, M8, BGR (CIUDEN)

Task 1.4
D1.8 Risk model updated M37. CIEMAT (CIUDEN)
D1.10 Assessment of KPI from measurements, M 38. OGS (BRGM, CIUDEN)
D1.14 Integrated workflow for operational risk management, M44. BRGM (TNO, Sotacarbo, CIUDEN)
D1.11 Specifications for future integrated and automated system, M39. CIUDEN (BRGM, TNO, Sotacarbo)

D1.1 : Design of CO2 injection tests [6]

The aim of this deliverable is to define a methology involving field tests and operation procedures for its development at Hontomín Technology Development Plant, according planned activitivities to be performed in the project scope. Following tasks are related with D1.1: Tasks 1.1, 1.2, 1.3 and 1.4

D1.2 : Report on installation, with constantly updated data and threshold assessments [14]

Two monitoring stations will be installed at key sites in Hontomin (close to observation wells), a third as reference site. Data will be cross-referenced against each other. Based on the detected annual/diurnal/other natural variations at the reference site, site specific threshold values of soil gas concentration changes will defined and reported.

D1.3 : Dynamic ranking of the impact of heterogeneities on plume movement [25]

Task 1.1 The impact of heterogeneities (e.g. faults) on plume behaviour will be determined using INTERSECT high resolution reservoir tool. The resulting impact will be dynamically ranked according to fault characteristics.

D1.4 : Benchmarking studies on deep sampling [25]

Task 1.3 - A report presenting the different geochemical monitoring techniques implemented at Hontomin to control the safety of CO2 storage

D1.5 : Design & optimization of seismic monitoring network for induced seismicity management [25]

The report describes the reliability, accuracy and sensitivity of the existing seismic monitoring network at Hontomin based on a detailed performance assessment, which will be performed in Task 1.2.2 of WP1 (TNO and CIUDEN). The assessment consists of two stages: conventional calibration using the recorded microseimic events and a detailed finite element data simulation enabling comparsion with the actual data. A subsequent Value-of-Information analysis will provide the comparison of different monitoring layouts and recommendations for future monitoring strategies.

D1.6 : Report on fault activity [32]

Task 1.2 Report will include fault population, natural seismicity and induced seismicity analysis in the Hontomín area in order to estimate short-term and long-term behavior

D1.7 : Interpretation and history matching on CO2 injection activities [37]

Task 1.1.2: Report presenting the Performed history matching of injection tests.It will present the conclusions on: Assessing the geomechanical impacts, and the influecne of heterogenities and uncertainties on the CO2 plume development. It will propose alternative fault models into the geological model, if adequate.

D1.8 : Risk model updated [37]

Task 1.4 Global quantitative risk probability function at Hontomin TDP site after up to 10 kton of CO2 injection tests, based on monitoring observations during the operation.Leakage probability functions through major leakage risk elements such as fractures / faults and wells / deep boreholes.

D1.9 : Benchmarking on different geophysical techniques [37]

This deliverable is related to task T 1.3.2 and consists of reporting on innovative geophysical monitoring of safe underground storage behaviour. This activity will perform a benchmarking on geophysucal techniques, by evaluating their effectiveness for the integrated risk management approach of task T 1.4.

D1.10 : Assessment of KPI from measurements [38]

This deliverable is related to tasks T 1.4.1 and also T 1.4.3, and consists of reporting on integration and evaluation of monitoring data, which are needed as part of an operational risk management procedure. This activity will provide information useful to determine the Key Performance Indicators (KPI) for the purposes of the operational risk management of task T 1.4.3.

D1.11 : Specifications for future integrated and automated system [39]

Task 1.4 The deliverable will present the sepcifications on the specifications of the alert system for its integration on an industrial full chain project. It will reflect the needs from operators for the full chain.

D1.12 : Lessons learned on Geochemical modelling and sampling activities [39]

Task 1.3 - A report presenting the results of the deep sampling campains, the analysis of the gas and water sampled at underground conditions and the evaluation of the geochemical evolution of the reservoir by numerical simulations

D1.13 : Results of induced seismic risk control activities [42]

Task 1.2 - A report presenting the result for the seismic risk control activities as tested on the Hontomin site. The chosen approach consists in adapting advanced mitigation protocols developed for geothermal energy projects, and will combine the observations with short term predictions (combining physical and statistical models) of the seismicity.

D1.14 : integrated workflow for operational risk management [44]

Task 1.4 - A report describing the risk management workflow as created in the project, tested on the Hontomin site and further refined. The aim of the workflow is to provide consistent links between risk assessment update, monitoring, and corrective measures. An important aspect is to extrapolate the main lessons from the application in order to be useful for other sites.

Schedule of relevant Milestones

Milestone number[18]	Milestone title	Lead beneficiary	Due Date (in months)	Means of verification
MS3	Hontomin 3D Geological model	6 - CIUDEN	3	Data available

Schedule of relevant Milestones

Milestone number[18]	Milestone title	Lead beneficiary	Due Date (in months)	Means of verification
MS4	International collaboration input to Work programme planned	1 - BRGM	3	D6.1
MS7	Hontomin 3D dynamic model	6 - CIUDEN	6	Data available
MS8	first geochemical investigation in Hontomin	1 - BRGM	6	Samples acquired
MS9	Soil Gas Monitoring installed in Hontomin	2 - BGR	6	Data acquired
MS11	Start of injection in Hontomin	6 - CIUDEN	7	First tonnes injected
MS13	Input from End-User Committee 1	10 - IRIS	11	Key outcomes from meeting
MS15	Definition of KPI and preliminary thresholds	1 - BRGM	12	Validation by partners
MS18	second geochemical investigation on site	1 - BRGM	18	Samples acquired
MS22	Feedback to CO2 injection operations in Hontomin	6 - CIUDEN	21	Data available
MS23	Input from End-User Committee 2	10 - IRIS	23	Key outcomes from meeting
MS28	Last geochemical investigation at hontomin	1 - BRGM	30	Samples acquired
MS29	End of injection in Hontomin	6 - CIUDEN	31	Injection stopped
MS32	Input from End-User Committee 3	10 - IRIS	35	Key outcomes from meeting
MS33	Update of thresholds	1 - BRGM	36	Validation by Partners
MS34	Advisory board input 2	1 - BRGM	36	report and note on impact on ENOS
MS35	End of all field activity	1 - BRGM	36	End of CO2 injection and ENOS data acquisition
MS36	Input from End-User Committee 4	10 - IRIS	47	Key outcomes from meeting

Work package number [9]	WP2	Lead beneficiary [10]	1 - BRGM
Work package title	Ensuring storage capacities and cost-effective site characterisation		
Start month	1	End month	48

Objectives

While offshore storage in Europe will certainly occur underneath the North Sea in large CO2 storage units collecting CO2 through long distance transport infrastructure, onshore CO2 storage in Europe will probably be distributed in many low to medium storage capacity sites close to CO2 emitters. Unless uncertainty on storage capacities onshore is significantly decreased, the cost for site selection reduced and early characterization improved, onshore CCS will not happen. Operators can only engage minimum funds in site investigation before FID (Final Investment Decision) is taken. However as for all underground related activities, perceived uncertainties are high and the way to reduce them is often expensive: e.g. drilling and seismic acquisition. For new storage projects to be developed and therefore for CCS to be deployed widely, the future site operators need to be able to assess the financial and operational risk taken and therefore need to be able to streamline procedures and reduce the cost whilst improving the reliability of the capacity estimates and the potential cost for reducing uncertainties (exploration). More research is needed to de-risk site characterisation in order to provide bankable capacity
assessments that can satisfy stakeholders and investors. To reach this goal, working on datasets from real sites is essential.

This work package aims to:
- Further investigate potentialities of next-generation 'high resolution' reservoir modelling to assess
impact of heterogeneities on CO2 storage capacities;
- Quantify the reliability of storage capacities estimates;
- Lower characterisation costs through (i) the validation of methodology to optimize exploration program, and (ii) the development of front-end engineering study for low cost drilling.

Description of work and role of partners

WP2 - Ensuring storage capacities and cost-effective site characterisation [Months: 1-48]
BRGM, BGS, CIUDEN , SOTACARBO, UNOTT, CO2GeoNet
Task 2.1 Quantify reliability of storage capacities estimates (BRGM, CO2GeoNet-HWU, BGS, UNOTT, CIUDEN)
A more realistic estimate of storage capacities implies: (1) to optimize computing performance for dynamic modelling of heterogeneous and complex reservoirs and (2) to account for the multiple sources of uncertainty (geological heterogeneities, model parameters, choice in the physical laws, etc.). By doing so, quantification of the reliability of capacity volumes can be provided.
State of the art
Dynamic capacity assessment relies strongly on modelling capabilities. Schlumberger ECLIPSE has been a benchmark reservoir simulation tool for the past 25 years to deal with increased complexities in oil fields, as well as alternative hydrocarbons and CO2 geological storage. Then next-generation reservoir models (e.g. INTERSECT, simulation code developed by Schlumberger), which will also be applied to study injectivity in T1.1, include scalable parallel processing capability for dramatic decrease in run-times on multi-million segment grids, advanced gridding techniques for accurate representation of heterogeneities (DeBaun et al., 2005; Dogru et al., 2009). INTERSECT was used in a recent case study, for the Australian Gorgon Project, taking advantage of its high performance with parallel processing (Edwards et al., 2012). However, these capabilities have not been used to assess the impact of heterogeneities such as permeable faults and (low permeability) granulation seams on plume migration and 'bankable' storage capacity estimates in faulted and complex reservoirs targeted for CO2 storage.
Within the flow modelling workflow for dynamic capacity estimates, uncertainties are introduced from a range of sources, for example uncertainties in geological characteristics and limitations of modeling input and software. Uncertainty can take several forms. A first category referred to as parametric stems from difficulty in estimating the input parameters (in a broad sense) of models/analysis due to the limited number, poor representativeness (caused by time, space and financial limitations), and imprecision of observations/data. Examples are model spatially homogeneous parameters like multiphase flow properties of a given rock formation and geological heterogeneities related to spatial variability (e.g., heterogeneous reservoir permeability field). A second category referred to as modelling uncertainty is related to the assumptions underlying the construction of the model. Examples in the domain of CO2 storage modeling are the inclusion of the capillary processes, the size of the grid mesh and the choices of boundary conditions. This last

category also includes modelling errors, which can be defined by the discrepancy between the simulation code and the actual physical system (e.g., Kennedy & O'Hagan, 2001).
Any efficient management of storage site (e.g., site selection, injection operations, etc.) should then rely on a "good picture" of what is unknown: this is the purpose of Uncertainty Quantification (UQ). Standards for reliability of reserves in the domain of O&G typically rely on quantiles P10, P50, P90 to do so (Px is a statistical confidence level for an estimate, when probabilistic Monte Carlo type evaluations are adopted. Px is defined as x% of estimates exceed the Px estimate. P90 and P10 are low and high estimates respectively).

Progress beyond the state of the art
INTERSECT will be used to investigate the impact of fracture networks and granulation seams on capacity evaluation. Detailed analysis of these features, using down-hole characterisation data from the GeoEnergy Test Bed. Also, follow-on activities from the INTERSECT simulations of injectivity in T1.1 (Hontomin test site) will investigate the role of fractures on capacity evaluation in fractured carbonate reservoirs. These studies will improve our understanding of storage capacity estimates in complex reservoirs.
UQ of storage capacities can rely on several approaches. Meta-Models (i.e., response surface based on Design of Experiments as traditionally used in O&G) have proved to be powerful since they allow reducing the required computational costs to perform a full UQ study into manageable level (Manceau and Rohmer, 2014, Petvipusit et al., 2014). Yet, several deficiencies still require to be addressed for direct use for UQ of capacity estimates:
Def.1. meta-modelling can be severely hindered by the large number of uncertain parameters (>10);
Def.2. modelling uncertainty related to the necessary assumptions on flow modelling (e.g., boundary conditions) are rarely placed on the same footing for comparison with parametric uncertainties;
Def.3. UQ based on meta-models should also include the influence of complex geological heterogeneities (spatial uncertainty) together with model and parametric uncertainties;
Def.4. current implementation of these techniques rarely accounts for modelling errors which can be significant.

Task 2.1.1 High resolution Dynamic modelling of heterogeneous Reservoirs
UNOTT will provide high-resolution scalable reservoir simulation for representative modeling of geology and wells, along with field management and planning for the CO2 injection. This will involve using the 'INTERSECT' High-Resolution Reservoir Simulator. This tool will enable detailed reservoir characterization of the GeoEnergy Test Bed and Hontomin sites by taking into account the heterogeneous lithologies and well network coupling with minimal or no upscaling. For this purpose the extensive data generated by down-hole imaging at the GeoEnergy Test Bed will be made available for use in this project, and will allow the inclusion of accurate and detailed modeling of the faults and other features. Large field simulations of up to billion grid blocks are possible in conjunction with UNOTT's High Performance Computing (HPC) facility. Efficient solver technology delivers results in a fraction of the time required by existing simulators. This will be used to simulate the impact of heterogeneities (at reservoir scale) on the storage of CO2 and the potential redirection of the injected plume. This will be modelled in a single, unified simulation incorporating dual and single porosity and permeability.

Task 2.1.2 Uncertainty quantification and sensitivity analysis
Step 1: "Developments"
BRGM and CO2GeoNet-HWU will lead on assessing the impact of uncertainty on modeling parameters. The first step will focus on addressing each deficiency in turn and on developing appropriate tools using synthetic but realistic cases. Combining response surfaces with global sensitivity analysis can be a powerful approach even for a high number of uncertain parameters (>20; Def.1). This can for instance be tackled within the formal setting of High Dimensional Model Representation (HDMR) (e.g., Petvipusit et al., 2014). This setting is generic enough to include different types of uncertainties. Regarding parametric uncertainty (like uncertainty in the value of permeability, porosity, etc.), continuous variables can classically be used. BGS will provide realistic ranges for key geological parameters (e.g. permeability, injectivity) where site data are not available using the state-of-the-art CO2Stored database for input into the models being built by CO2GeoNet-HWU and BRGM. The CO2Stored database contains a wealth of data compiled for potential geological storage sites for the UK. Regarding modelling uncertainties (Def.2), discrete (categorical) variables can be defined to point to each plausible scenario (for instance each plausible model assumption like the choice for a physical law, mesh grid size, boundary conditions, etc.). This was recently tested by Manceau and Rohmer (2014) using ACOSSO-type meta-models. Treating spatial uncertainty (Def.3) can be envisaged in a similar manner in the HMDR setting using ACOSSO-type response surfaces as shown by Rohmer (2014): BRGM will propose an approach for treating simultaneously modelling and spatial uncertainties. This could be combined with advanced techniques like adaptive sparse grid methods (Elsheikh et al., 2014) to improve and optimise computation time cost, which will be set-up by CO2GeoNet-HWU.
In parallel, CO2GeoNet-HWU will develop an approach to make use of any sources of modelling information. Capacity estimates can typically rely on a large variety of models with different levels of details. A multi-model (i.e. hierarchy of

models) approach can then be proposed to combine information from static models, dynamic models with full physics and reduced order dynamic models (i.e. Vertical Equilibrium). Given this toolbox of different models (static, full physics and VE), an optimal combination of model runs (number and input parameters for each run) can be sought to efficiently estimate the capacity of a specific site. Finally, modelling errors (Def.4) can be addressed making use of any observed data using Gaussian process (kriging) meta-models in the Bayesian calibration framework proposed by Kennedy & O'Hagan (2001). Recently, Josset et al. (2015) built an error model using a mapping between a detailed physic model (multi-phase flow) and an approximate physic model (single phase flow model) for immiscible two phase flow problem. The purpose of that work was to accelerate model calibration using MCMC (i.e. history matching). The same approach will be used for uncertainty quantification and modelling error estimation.
Step 2: "Unified framework and application on real cases"
Based on step 1, a coherent framework will be defined by CO2GeoNet-HWU and BRGM supported by other partners incorporating the best of the developed approaches. This will be conducted via working sessions among partners based on cross-comparison and benchmarking using shared dataset of simulations. More specifically, the question of meta-model errors (the uncertainty related to use of meta-models instead of the "true" flow simulators) will be carefully tackled through validation on independent dataset of simulations (i.e. set of simulations not used for constructing the response surfaces). Once validated, the applicability and extrapolation of the proposed UQ framework will be tested with the geological characteristics from the different ENOS sites with the view which will enable consideration of a wide range of different geological settings.
The a priori selected sites for sub-tasks 2.1.1 and 2.1.2 are the same as those studied in task 2.2: Hontomin, Spain (fractured carbonate aquifer), and GeoEnergy Test Bed, UK (faulted Permo-Triassic sandstone aquifer). For this benchmark, base data from the sites could include geological facies, basic core data, geophysical well log data, seismic data, geological samples, water samples, published maps and papers. Use of existing models will be made where appropriate. For the Hontomin site, CIUDEN will develop a model using a free code and provide with dynamic simulations based on different input data sets defined by BRGM and its expertise on geology and properties of target formations. Final decisions on sites to be worked on will be taken at the beginning of the project after detailed assessment of the available data in the different cases (Milestone 2.1)

Outcomes
Modelling techniques for high resolution simulation of fractured reservoirs and an understanding of the effect of fractures on storage estimates
Methods and a modelling strategy (framework) for tackling the different uncertainty sources (parametric, modelling, spatial uncertainty, and model errors) for capacity estimates.
P10, P50, P90 estimates (similar to the widely used reserve estimation techniques in the O&G) of the expected capacities of at least two sites of ENOS project fields.

References
DeBaun D, Byer T, Childs P, Chen J, Saaf F, Wells M, Liu J, Cao H, Pianele L, Tilakraj V, Crumpton P, Walsh D, Yardumian H, Zorzynski R, Lim K-T, Schrader M, Zapata V, Nolen J, Tchelepi H. An extensible architecture for next generation scalable parallel reservoir simulation. SPE Reservoir Simulation Symposium, Houston TX (2005)
Dogru AH, Fung LSK, Middya U, Al-Shaalan TM, Pita JA, HemanthKumar K, Su HJ, Tan JCT, Hoy H, Dreiman WT, Hahn WA, Al-Harbi R, Al-Youbi A, Al-Zamel NM, Mezghani M, Al-Mani T. A next generation parallel reservoir simulator for giant reservoirs. SPE Reservoir Simulation Symposium, The Woodlands TX, Feb 2009
Edwards DA, Gunasekera D, Morris J, Shaw G, Shaw K, Walsh D, Fjerstad PA, Kikani J, Franco J, Hoang V, Quettier L. Reservoir simulation: keeping pace with oilfield complexity. Oilfield Review 23 4 4-15 (2012)
Elsheikh A H, Hoteit I, Wheeler, M F, 2014, "Efficient Bayesian inference of subsurface flow models using nested sampling and sparse polynomial chaos surrogates", Computer Methods in Applied Mechanics and Engineering,
Josset L, Demyanov V., Elsheikh A.H., Lunati I., "Accelerating Monte Carlo Markov chains with proxy and error models", accepted for publication in Computers & Geosciences, 2015
Kennedy, M. C., & O'Hagan, A. (2001). Bayesian calibration of computer models. Journal of the Royal Statistical Society: Series B (Statistical Methodology), 63(3), 425-464.
Manceau, JC., Rohmer, J., (2014). Ranking importance of uncertainties for the assessment of residual and dissolution trapping of CO2 on a large-scale storage site. Energy Procedia, 63, 3658–3664.
Petvipusit K , Elsheikh A , Laforce T , King P , Blunt M , 2014"Robust optimisation of CO2 sequestration strategies under geological uncertainty using adaptive sparse grid surrogates", Computational Geosciences, Volume 18-5.
Rohmer, J. (2014). Combining meta-modeling and categorical indicators for global sensitivity analysis of long-running flow simulators with spatially dependent inputs. Computational Geosciences, 18(2), 171-183.

Task 2.2 Smart Characterization (CO2GeoNet-HWU, BGS)

State of the art
Studies have been performed to address site characterization for geological CO2 storage (CO2CRC, 2008; DNV, 2009; NETL, 2010; SiteChar, 2013; Bachu, 2015; Heidug, 2013). This is a data, cost and time intensive process. The initial steps is to collect all available data followed by screening, and detailed modeling using both static and dynamic models. For a depleted hydrocarbon site, large amount of data is usually available to the field owner including well logs, seismic surveys and historical production data. On the contrary, deep saline storage sites characterization will involve active data collection by drilling wells or performing new seismic surveys. Site characterisation heavily relies on building a static model describing the structural and stratigraphic geology of the reservoir and the cap rock as well as populating this model with properties from available data. Decision on actual project development is based on assessing storage site uncertainties and reducing these uncertainties corresponds to active collection of new data.

Progress beyond the state of the art
This task will develop methodologies to optimise the data gathering and interpretation process to balance the acquisition costs with the insights this data provides. Statistical experimental design provides rules for resource allocation for information gathering. An experimental design approach for agile site characterization, where the process is continuously assessed and revised as the data being collected will be tested. For the highly nonlinear process of CO2 injection, optimal designs generally depend on the true values of the model parameters and since the data has not been collected yet, the model parameter values are not known. Bayesian methodologies for optimal experimental design (Huan & Marzouk, 2013) provide an elegant solution to this problem where prior distributions of the unknown parameters are postulated during the formulation of the experimental design problem. Solving the Bayesian optimal design involved maximizing the expected utility function over the different options of data collection with respect to the future observed data and model parameters. Two approaches are proposed:
1. Nested Sampling algorithm (Skilling 2006, Elsheikh et al. 2014) for performing the high dimensional integration of the expected utility function for solving the optimal experimental design problem.
2. meta-modeling techniques (Elsheikh et al. 2014, Petvipusit et al. 2014, Rohmer, 2014) for efficient solution of the optimal experimental design problem.

Description of work
Step 1: “Methodology Developments”
CO2GeoNet-HWU will investigate the application of Bayesian experimental design techniques on synthetic but realistic cases mimicking the Hontomin CO2 storage site. Various algorithms for evaluating the high-dimensional integral of the expected utility function (i.e. Monte-Carlo, Nested Sampling and Important Sampling) will be evaluated. Additionally, meta-modeling techniques developed in Task 2.1.2 will be used to replace the full dynamic simulator with approximate proxy functions for rapid solution of the optimal experimental design problem. BGS will contribute to new frameworks for streamlined smart characterization. BGS will also provide feedback on sensitivity of geological parameters relevant to CO2 storage based on the CO2Stored database (where the most sensitive parameters affecting storage capacity were indicated to be permeability, pressure response and injectivity).
Step 2: “Application to real cases”
Based on the developed methodologies in Step 1, a framework for optimal data gathering will be developed. This task will be led by CO2GeoNet-HWU. This framework will be systematically streamlined to evaluate the impacts of data variability and applied to two onshore CO2 injection sites, anticipated to be the Hontomin site (carbonate aquifer) and the GeoEnergy test bed in the UK (sandstone shallow aquifer). The sites to be included will be confirmed at the beginning of the project after detailed assessment of the available data in the different cases (Milestone 2.1). The available data will be divided into base-case data which is needed to build a base case model for each site. Each additional data that is not included in the base-case data set will be plugged into the Bayesian experimental design to obtain the optimal data gathering schedule. BGS will provide at least one geological model (depending on work carried outside of ENOS) and data relating to the GeoEnergy Test Bed and will provide feedback on the geological models generated by CO2GeoNet-HWU which have been built using the ENOS smart data gathering workflow to assess the optimal solution balancing the requirements of low cost and producing a reliable geological model.

Outcomes
Methods and a modelling strategy (framework) on how to prioritize data collection, summarized in a report detailing the general procedure for smart site characterization and accompanied by a set of computer script (i.e. wrappers) utilizing commercial simulation tool. The streamlining framework of data use and acquisition will contribute to cost efficient characterization.

References:
Bachu, S. 2015. Review of CO2 storage efficiency in deep saline aquifers, International Journal of Greenhouse Gas Control, Available online 1 February 2015, ISSN 1750-5836

CO2CRC, 2008, Storage capacity estimation, site selection and characterisation for CO2 storage projects, CO2CRC report RPT08-1001.
DNV, 2009, CO2Qualstore – Guideline for selection and qualification of sites and projects for geological storage of CO2, DNV report 2009-1425.
Elsheikh, A H; Hoteit, I, Wheeler, M F, 2014, "Efficient Bayesian inference of subsurface flow models using nested sampling and sparse polynomial chaos surrogates", Computer Methods in Applied Mechanics and Engineering,
Heidug, W 2013 IEA Workshop 2013 Methods to assess geologic CO2 storage capacity: status & best practice.
Huan, X. and Marzouk, Y. M., 2013, "Simulation-Based Optimal Bayesian Experimental Design for Nonlinear Systems," Journal of Computational Physics, 232(1):288-317.
NETL, 2010, Site screening, selection and initial characterization for storage of CO2 in deep geological formations, DOE report DOE/NETL-401/090808.
Petvipusit K. R., Elsheikh A. H., Laforce T. C., King P. R., Blunt M. J., 2014 "Robust optimisation of CO2 sequestration strategies under geological uncertainty using adaptive sparse grid surrogates", Computational Geosciences, Volume 18, Issue 5.
Rohmer, J., 2014"Combining meta-modeling and categorical indicators for global sensitivity analysis of long-running flow simulators with spatially dependent inputs". Computational Geosciences, 18(2), 171-183
SiteChar, 2013, Characterisation of storage sites: Best practices and Guidelines developed from the SiteChar project. SiteChar Report D2.4. 85 pages.
Skilling, J., 2006, "Nested sampling for general Bayesian computation," Bayesian Analysis, 1(4), 833–859,

Task 2.3 Low Cost Drilling (CIUDEN, SOTACARBO)

State of the art

Drilling boreholes using O&G industry standard rigs is expensive, which reduces the number of wells drilled during exploration and therefore reduce the amount of data available for reservoir characterization. Drilling using light equipment technology (adapted from the mining industry) presents a distinct advantage in offering the ability to obtain fully cored wells that cost less than wells drilled with hydrocarbon rigs. This is of high interest for CO2 storage and site characterization. The technology however has only been tested at depths of up to 1500m at Hontomin Technology Development Plant. The original plan at Hontomin was to use conventional O&G drilling techniques but finally light drilling was selected and saved up to 60% of the original planned budget. The resulting well has a smaller diameter than O&G standards. The implications of this for CO2 storage site operation need to be studied and consideration of how drilling techniques can be optimized need to be investigated through discussion between the drill rig operators and geoscientists who will use the core for experimentations to characterise reservoir and seal.
Although there are experiences in the light drilling for other activities such as mining and shale gas exploration especially in the USA, experiences at CO2 storage are limited to the Hontomin case. Deeper reservoirs are usually reached using oil and gas machinery, with higher cost and low flexibility.

Progress beyond the state of the art

A study will be carried out on developing the drilling rig and its associated equipment in order to reach depths of up to 2,500 m and to integrate different services, namely drilling, well completion and well logging, leading to cost savings and reducing the contracts for well services for the execution of exploratory, injection or monitoring wells.

Description of work

CIUDEN will work with SOTACARBO, and likely with other sites, for acquiring the required data that support the basic design of a rig machinery and all the associated engineering studies in order to provide a cost effective solution to support the development for drilling activities within the SULCIS characterization process, which will be deployed after the ENOS timeframe, using the solution provided by the project. It is therefore expected that the FEED (Front-End Engineering Design) study developed will likely be tested after the ENOS timeframe as part of the committed tasks of the exploratory permit of SOTACARBO, using funds outside of ENOS. Implication of the diameter of the drilled well for its use as future monitoring or injection well will be studied with input from BRGM.

Outcomes

Development of cost effective solutions to execute key characterization activities such as the drilling of wells to have a precise description of the reservoir and caprock. The light drilling activities will provide significant cost savings in the characterization phase of this demo site and other future sites onshore in Europe.

Task 2.4 Technical guidelines on storage capacities estimates and cost-effective site characterisation (BRGM, BGS, CIUDEN, CO2GeoNet-HWU,SOTACARBO, UNOTT)

This task aims at synthetizing all the results of WP2 into technical guidelines regarding:
- the impact of heterogeneities (faults and granulation seams) on storage capacities

- the quantification of reliability of dynamic capacities including the large variety of different uncertainty sources (geological, model, parametric, etc.
- smart characterization
- light-equipment and low-cost drilling
BRGM will lead the task. Partners contributing to the tasks 2.1 to 2.3 will provide the description of technical or numerical tools, methodologies or workflow developed during the WP, highlighting their novelty compared to the state of the art. These results will be assessed by Sotacarbo considering their use and applicability in their own workflow at the Sulcis site. These guidelines will be presented into a comprehensive approach so that they could be useful for industrials or investors and be applied for future storage sites.
Interaction with other WPS
Results from WP2 will feed WP7 for the development and dissemination of best practices. It is also closely linked to WP5 that will link the technical WPs 1 to 4 with the societal context.
Knowledge sharing between partners will be assured through integration of results and with external stakeholders through input to WP6, 7 and 8.

Participation per Partner

Partner number and short name	WP2 effort
1 - BRGM	15.00
3 - BGS	6.20
6 - CIUDEN	18.50
16 - SOTACARBO	10.40
19 - UNOTT	12.00
20 - CO2GeoNet	0.00
HWU	26.00
Total	88.10

List of deliverables

Deliverable Number[14]	Deliverable Title	Lead beneficiary	Type[15]	Dissemination level[16]	Due Date (in months)[17]
D2.1	Report on FEED study on light drilling	6 - CIUDEN	Demonstrator	Confidential, only for members of the consortium (including the Commission Services)	21
D2.2	Uncertainty Quantification of capacity estimates: coherent framework & applications	1 - BRGM	Report	Public	22
D2.3	High resolution simulation to determine heterogeneity effects on storage estimates in fractured reservoirs	19 - UNOTT	Report	Public	25
D2.4	Smart Characterization	20 - CO2GeoNet	Report	Public	28

List of deliverables

Deliverable Number[14]	Deliverable Title	Lead beneficiary	Type[15]	Dissemination level[16]	Due Date (in months)[17]
D2.5	Drilling activities study for extension to other sites	6 - CIUDEN	Report	Confidential, only for members of the consortium (including the Commission Services)	44
D2.6	Technical Guidelines on storage capacities estimates and cost-effective site characterisation	1 - BRGM	Report	Public	42

Description of deliverables

Task 2.1
D 2.2 : Report on Uncertainty Quantification of capacity estimates: coherent framework & applications – M22 – BRGM, CO2GeoNet-HWU, BGS
D 2.3: Report on High resolution simulation to determine heterogeneity effects on storage estimates in fractured reservoirs – M25 – UNOTT

Task 2.2
D 2.4: Report on Smart Characterisation and computer scripts developed – M28 – CO2GeoNet-HWU, BGS

Task 2.3
D 2.1: Report on FEED study for light drilling – M15 – CIUDEN, Sotacarbo
D 2.5: Drilling activities study for extension to other sites – M44 – CIUDEN, Sotacarbo

Task 2.4
D 2.6: Technical Guidelines on storage capacities estimates and cost-effective site characterisation – M42 – BRGM, BGS, CIUDEN,SOTACARBO,UNOTT,CO2GEONET-HWU

D2.1 : Report on FEED study on light drilling [21]

Regarding CIUDEN experiences from well drilling works at Hontomín site, required data and engineering studies for the basic design of a light drilling rig will be performed, in order to provide a cost effective solution for the exploration phase of other sites. Following tasks are related with D2.1: Tasks 2.3 and 2.4

D2.2 : Uncertainty Quantification of capacity estimates: coherent framework & applications [22]

Task 2.1 - Description of methods and a modelling strategy (framework) for uncertainty characterization (ranking of the different uncertainty sources (parametric, modelling, spatial uncertainty, and model errors) and quantification regarding capacity estimates. This will be supported by application on reservoir cases.

D2.3 : High resolution simulation to determine heterogeneity effects on storage estimates in fractured reservoirs [25]

Task 2.1 The impact of permeable faults and (impermeable) granulation seams on reliable CO2 storage capacity estimates in faulted and complex reservoirs will be determined using INTERSECT high resolution reservoir tool.

D2.4 : Smart Characterization [28]

Task 2.2 Summary of efficient techniques for optimal data gathering for site characterisation with links to open source repository of computer scripts demonstrating the methodology

D2.5 : Drilling activities study for extension to other sites [44]

Light drilling equipment FEED will be performed under boundary conditions determined by the singularities from different sites, particularly, geological and geo-mechanical characteristics. A study analyzing the drilling rig applicability to different sites will be performed, identifying the achievable improvements. Following tasks are related with D2.5: Tasks 2.3 and 2.4.

D2.6 : Technical Guidelines on storage capacities estimates and cost-effective site characterisation [42]

Technical guidelines for integrating theresults of ENOS with existing state of the art tools in the context of full scale storage (uses inputs from all tasks in WP2)

Schedule of relevant Milestones

Milestone number[18]	Milestone title	Lead beneficiary	Due Date (in months)	Means of verification
MS1	Decision on sites and modelled to be used in task 2.1 and 2.2	1 - BRGM	3	Minutes of data evaluation meeting
MS4	International collaboration input to Work programme planned	1 - BRGM	3	D6.1
MS13	Input from End-User Committee 1	10 - IRIS	11	Key outcomes from meeting
MS23	Input from End-User Committee 2	10 - IRIS	23	Key outcomes from meeting
MS25	Specific conditions from other sites to determine drilling rig applicability	6 - CIUDEN	28	Report
MS32	Input from End-User Committee 3	10 - IRIS	35	Key outcomes from meeting
MS34	Advisory board input 2	1 - BRGM	36	report and note on impact on ENOS
MS35	End of all field activity	1 - BRGM	36	End of CO2 injection and ENOS data acquisition
MS36	Input from End-User Committee 4	10 - IRIS	47	Key outcomes from meeting

Work package number [9]	WP3	Lead beneficiary [10]	3 - BGS
Work package title	Managing leakage risks for protection of the environment and groundwater		
Start month	1	End month	48

Objectives

WP3 will focus on monitoring leakage risks for protection of the environment and groundwater, including identifying and quantifying any CO2 emissions into the atmosphere, using practical experience from real-life sites. Injection tests will be performed at a range of sites, each offering unique geological characteristics adapted to address specific issues: Sulcis Fault Lab for injection near faults; GeoEnergy Test Bed (GTB) for groundwater impact and LBr-1 field site for risks relating to boreholes and faults. The resulting understanding of leakage and its potential impact will be used to enhance development of monitoring technologies.
Targeted monitoring technologies for leakage detection and quantification will be advanced at real-life sites progressing them from TRL 4-5 to TRL 6 or 7. The tools developed in WP3 will meet the monitoring requirements of the EU Directives and supporting documents and be applicable over the full storage lifecycle. Furthermore, the different tools will be integrated into a comprehensive monitoring solution with consideration of other state-of-the-art tools available outside of the project and in the context of full scale storage site operation.
WP3 will use innovative CO2 injection tests, experiments carried out under realistic storage site conditions and advanced modeling techniques to develop technical guidelines and feed into WP7 Best Practices.

Description of work and role of partners

WP3 - Managing leakage risks for protection of the environment and groundwater [Months: 1-48]
BGS, BRGM, BGR, CGS, CIUDEN , IDIL, IRIS , NHAZCA, OGS, SILIXA, SOTACARBO, TNO, UNIROMA1, UNOTT, CO2GeoNet
Task 3.1 Groundwater protection: Geochemical and geophysical monitoring and potential impact of leakage on potable aquifers (BRGM, BGS, IDIL, IRIS, UNOTT, UNIROMA1, Silixa)
State of the art:
In the FP7 RISCS project, and other recent reviews, the potential geochemical risks to drinking water aquifers related to CO2 leakage out of the storage complex were identified. Geochemical surveying at Hontomin demonstrates current commercially available tools for geochemical monitoring of groundwater quality in an extensive network of monitoring wells. Shallow groundwater monitoring in a few <100 m deep well near the injection site at Otway in Australia highlighted the importance of baseline measurements to remove seasonal and local effects. There remains scope for improvement through further technological development and validation for monitoring potable groundwater.
Progress beyond the state of the art:
The aim is to build on previous groundwater modelling and monitoring work on the impact of CO2 on underground drinking water so as to demonstrate the efficacy and increase the TRL of these techniques and technologies. There are geochemical and geophysical based numerous tools for detecting the first arrival of CO2, the TRL of tools suitable for use in potable water supply areas will be advanced in this task. The work in ENOS will advance beyond state of the art as the tests at the GTB and Sulcis Fault Lab will be carried out at greater depths than previous groundwater assessments. Effective monitoring deployment strategies to locate leakage will be developed, the most sensitive parameters highlighted, sensitivity of tools improved and low cost solutions capable of long term deployment developed.

3.1.1 Understanding potential leakage impacts and developing a groundwater monitoring strategy
The impact of CO2 on groundwater will be tested at controlled leakage sites. Baseline data will be obtained and early warning signs for CO2 intrusion will be detected through tests at two field sites; Sulcis Fault Lab and the GTB where CO2 will be injected at 100-300m depth over the time-scale of months to 1-2 years. Basic mineralogical testing and groundwater baseline data will be obtained from Sulcis (by UNIROMA1) and the GTB (by BGS and UNOTT) to inform the modelling work and provided. In order to be able to develop a monitoring strategy, a good understanding of the impact of CO2 arrival in the aquifer and of the fate of the CO2 must be developed. A tool-box, based on water-gas-rock interaction on the potential reactivity of CO2 within a potable aquifer, will be tested by BRGM on these sites. The effectiveness of this tool will be validated in the field. It will identify the geochemical changes to be expected and therefore steer the definition of the groundwater geochemical monitoring strategy by highlighting the most sensitive parameters to monitor and appropriate deployment of monitoring tools. The modelling will be verified (history matched) using the field site data.

3.1.2 Increasing the TRL of groundwater quality monitoring tools in boreholes

Innovative monitoring tools suitable for deployment in boreholes in potable aquifers will be tested during ENOS. These tools have been selected to fill gaps identified in the currently available suite of tools for CO2 site monitoring. The effectiveness of the tools developed through ENOS will be compared to commercial probes at the Sulcis Fault Lab to assess the sensitivity, accuracy and reliability of each technique and technology, thereby increasing the TRL level of these novel technologies to at least TRL6:

• An optical fibre tool for dissolved CO2 detection through changes in pH is developed by BGS. This tool requires field testing (and further laboratory based calibration) to move the tool from TRL 4 to TRL6. The aim is to develop a low cost, almost 'disposable' monitoring technique that can be deployed in many boreholes. This tool will be deployed at the GeoEnergy Test Bed and/or the Sulcis Fault Lab.

• An innovative optical fibre tool, transparent in the mid-infrared, detecting gaseous CO2, has been developed by BRGM and IDIL. This tool will be calibrated in the laboratory then field tested and the results compared with the BGS optic fibre tool at the Sulcis Fault Lab and/or GeoEnergy Test Bed sites. This will move the tool from TRL 5-6 to TRL 7. The sensitivity, reproducibility and detection limits of the tool will be compared with the results of standard CO2 detection sensors.

• Cost-effective tools developed by UNIROMA1 (that measure CO2, CH4, pH, P, T) will be deployed at the Sulcis Fault Lab site. The probe has been tested to a limited extent in groundwater wells, but will be demonstrated more extensively here. UNIROMA1 will improve the response time of the pCO2 tool. In addition, other sensors will be added to the system, such as Eh and conductivity, to give a more complete and detailed assessment of water quality and breakthrough times of leakage related parameters. The tool will hereby be brought to TRL7.

• A hybrid cable with more sensitive acoustic detection thresholds than currently commercially available seismic sensors and with temperature change detection capability is being developed by Silixa and will be tested at the Sulcis Fault Lab for application to leakage detection and groundwater monitoring and will be compared with other commercially available tools (which will be installed at the site through the national programme). The seismic survey will provide a better characterization of the faults. Moreover Distributed Temperature Sensor measurements during the injection phase will contribute to the leak detection and characterization. TRL of this application will be brought to 7 through testing in wells in the freshwater zone.

• IRIS will further develop and test a biosensor technology based on DNA recognition to monitor changes in microbial communities in groundwater caused by CO2 leakage. Key advantage of specific microbial changes is that it allows the leakage detection a posteriori, even after chemicals may no longer be detectable. The method may also detect low-level leaks at, or below, rates detectable by chemical methods developed in parallel, possibly enhancing sensitivity and greatly increasing overall detection reliability by combining methods with different detection principles. This biotechnology will be field tested at the GeoEnergy Test Bed and Sulcis Fault Lab sites to move this technology to TRL6.

Outcomes

- Tool-box to assess the geochemical reactivity of CO2 leakage within groundwater and define key parameters to monitor for early leakage detection.
- Five Monitoring tools demonstrated at pilot scale with sensitivity and cost optimised so that they are ready for use at demonstration/flagship sites (at least TRL6). These tools will be included in the integrated monitoring solution to be prepared under Task 3.4

Task 3.2 Understanding risk of CO2 migration through faults and boreholes for effective monitoring (UNIROMA1, IRIS, CGS, BRGM, OGS, SILIXA, BGS, NHAZCA, CO2GeoNet-HWU, CO2GeoNet-GeoEcoMar)

State of the art:

Faults and boreholes are the most likely major potential leakage pathways at storage sites. The possible expression and rates of leakage along these pathways during and post-injection need to be understood to feed into risk-led site characterisation (e.g. as described in the SiteChar project) and inform monitoring strategies throughout the site lifecycle. Few field data are available on CO2 migration through faults in sedimentary basin regions or on borehole leakage other than from major blowout events. Studies of leakage at natural analogue sites were undertaken in the FP7 RISCS project and indicated that further study on the expression of leakage at the surface (vent or diffuse, continuous or sporadic) were required. Borehole leakage through cement and/or casing defects is mainly limited to model studies with virtually no direct field experience. Damaged cement can increase the risk of leakage.

It is known that injection of fluids in the subsurface can induce surface deformation, however few studies have addressed the correlation between gas leakage through faults and boreholes and the resulting surface displacement patterns. Satellite Interferometry is presently used to quantify and map surface ground deformation, nevertheless there are still limitations for its application to small scale storage fields with vegetative cover.

Progress beyond the state of the art:

The Sulcis Fault Lab, where CO2 will be injected near a fault, offers a rare opportunity to advance understanding of technologies for monitoring CO2 leakage through faults beyond the state of the art. The activities carried out through

ENOS will complement the Sulcis Fault Lab programme funded by the Sardinia Region and Ministry of Economic Development which includes high resolution seismic surveys, soil gas surveys, seismic monitoring, acquisition of core samples and fracture modeling of the seal. If faults are present at the GTB, this may also allow insights to be gained should they provide pathways for fluid migration. A key milestone for WP3 will be establishing early in the project if CO2 is migrating through faults at the test injection sites to surface and if not, alternative sites to carry out field activities will be selected. This sub-task will generate valuable information for development of the most effective surface monitoring strategy for sites where faults are identified.

Task 3.2.1: Assessing what makes a fault likely to leak
The geochemical (including mineralogy) and physical properties increasing the risk of fault leakage will be assessed using the Sulcis Fault Lab site, GTB and knowledge from natural analogue(s) where leakage of CO2 and other substances is occurring. These sites will be assessed by BGS and UNIROMA1 to understand what characteristics of these faults permit leakage and what characteristics prevent leakage of CO2 and other fluids by taking a number of samples along the faults.
The geomechanical aspects of leakage from a fault need to be considered as highly dense CO2 is being injected under pressure and will induce stresses, potentially re-opening fault planes and opening new fractures. Based on real-life data from the Sulcis Fault Lab and the fault stability analysis at LBr-1 from the REPP-CO2 project in the Czech Republic, provided by CGS, IRIS will perform a transient analysis of the expected pressure changes if the faults were to leak. Transient analysis requires fewer data than full numerical simulation and can therefore be implemented at early site characterisation stage. The results of this analytical modelling will be useful as a benchmark for later numerical modelling (to be completed outside of the ENOS project).
Using data from Sulcis Fault Lab, UNIROMA1 will model the gas migration pathway though and along a fault using appropriate software to reconstruct the geometry of the fault and the potential stress pattern produced during injection. This will be compared with real-life data to establish the effectiveness of the modeling technique, taking advantage of the opportunity to utilise primary data at the Sulcis Fault Lab.
Both work will link with WP1, where appropriate, to consider the risk of induced seismicity (note that the stress regime will be different at the field sites utilised by WP3 compared to WP1 as the zone of investigation is shallower).
Upscaling of the fault zone will be undertaken in order to reduce complexity and save on computational cost and increases efficiency for subsequent risk analysis/uncertainty runs. CO2GeoNet-HWU will consider how to apply analytical upscaling techniques for fault zones to be imbedded in CO2 simulators to account for sub-grid features. These upscaling techniques will be calibrated using real data from the Sulcis Fault Lab and if appropriate the GTB and results from the other teams in the task.

Task 3.2.2: Monitoring CO2 migration through fault planes in the sub-surface
At the Sulcis Fault Lab, OGS will undertake geophysical measurements using downhole tools and surface techniques, to examine if the migration of CO2 along the fault and its proximity can be tracked. Seismic techniques will include borehole measurements using wireline and SILIXA DAS-VSPTM, cross well applications and seismic interferometry (in surface-borehole and cross-well geometry). These will be integrated and compared with other geophysical and well results, such as electric and electromagnetic logs and surveys to demonstrate the most effective integrated geophysical approaches for monitoring migration of CO2 in the near sub-surface in and around faults. Sensitivity analyses will be performed for both the seismic and electric methods based on detailed investigation of the area including comparison against time lapse surface and well geochemical data to determine if the signal is absent or below the geophysical detection threshold. The time-lapse data will use accurate modelling and sensitivity analysis for CO2 injection in the area of investigation, to obtain the best acquisition parameters, and support interpretation of the results. The numerical modelling will also make use of existing geological and geophysical data acquired with national funding. The results of Task 3.3.3 will be incorporated into the integrated monitoring solution to be prepared in Task 3.4.
An innovative technique, based on state of the art remote sensing techniques will be adopted by NHAZCA to monitor the surface deformation pattern on a range of time scales (from baseline through injection phase to a few months after the injection phase) and geometric scales (from local to regional scale). The collected data will be used to derive detailed information about CO2 leakage at Sulcis Fault Lab on the basis of the induced surface ground deformation. The technique combines corner reflectors installed on a regular grid, a photogrammetric RPAS used to refine the interferometric analysis and continuous topographic monitoring of targets to validate data collected by both RPAS and Satellite InSAR.

Task 3.2.3: Characterising expression of leakage through faults at/near the surface to improve monitoring strategies
Leakage through faults will be characterized (discrete vents vs. diffuse leakage at the surface, continuous vs. intermittent). In particular, the expression of CO2 leakage through faults at the surface will be assessed with general conclusions drawn for application at storage sites (BGS and UNIROMA1) Geochemical survey data at the Sulcis Fault Lab site (and possibly GTB) will be used. These data will be supplemented by investigation at natural analogue site

in San Vittorino, Italy where leakage has been occurring for an extended time. This sub-task will generate valuable information for development of the most effective surface monitoring strategy for sites where faults are identified.

Task 3.2.4: Assessing risks presented by boreholes
At the LBr-1 site, there are a number of abandoned wells which are now being recompleted to mitigate the risk of leakage of hydrocarbons and CO2. Using the site as a case study, CGS and IRIS will assess potential pathways, extent and impacts of leakage through boreholes on shallow groundwater using innovative dynamic modelling of leakage scenarios – the aim will be full 3D coupled flow, geochemical modelling and detailed representation of well and annuli flow. This will build on the results of the FP7 RISCS and CO2 CARE projects. CGS will provide static geological models (horizon topography) and field data from the site. IRIS will perform flow-path simulations and model a range of borehole conditions including detailed modelling on tubular and annuli conditions appropriate for the LBr-1 site to quantify (temporally and spatially) the potential leakage through abandoned wells. This modelling will assess the short-term risk presented by boreholes during the operational lifetime of the storage site.
Boreholes can represent a leakage risk if improperly completed or if the CO2 affects the sealing ability of the borehole materials. A risk assessment of leakage from abandoned wells & recompletion procedures using LBr-1 as a case study will be performed to feed technical guidelines and the best practice recommendations of WP7. CGS and IRIS will perform a risk-based assessment of old abandoned wells on the site (led by IRIS) to identify the main risks and to generate a best-practice report with recommendations for safely assessing and mitigating the risks presented by old boreholes for future storage sites. State of the art data from the Getica site on the risk assessment of existing wells (carried out for a completed feasibility study) will be provided by CO2GeoNet-GeoEcoMar who will thus support the assessment of leakage risk through boreholes at LBr-1. BGS will provide data from laboratory experiments carried out for previous projects on cement carbonation as an in-kind contribution

Outcomes
- Improved understanding of the risk posed by faults utilising unique new field data to understand what geochemical and geomechanical properties make faults more likely to leak and how this leakage will present at surface/in the shallow fault plane to improve the effectiveness of the monitoring programme. Technical guidelines for mitigating risk of leakage through based on data from real-life case studies.
- Data to feed into technical guidelines on mitigation of risks through intelligent site design and monitoring strategies based on risk assessment of boreholes and faults

Task 3.3: Development of surface monitoring tools towards quantification of CO2 emissions from a leaking CO2 storage site (BGR, BGS, UNIROMA1, UNOTT, OGS, CGS, TNO, CO2GeoNet-HWU and CO2GeoNet-GeoEcoMar)
State of the art:
One of the recognised challenges of surface monitoring is finding potentially small leaks (metres to tens of metres across) over the comparatively large storage footprint (100 km2 +). The aim of wide-area coverage technologies is to survey a large area rapidly to locate possible leakage that would then be verified by detailed ground investigation. Techniques have been trialed at natural CO2 leakage and storage sites. However, they all have drawbacks in terms of sensitivity, false positives and areal coverage. This has highlighted the need for additional development. Continuous monitoring generating point data has also been tested at a small number of sites but still has scope for technology development and more widespread deployment. Soil gas monitoring is a well-recognised technique that is often the first technique applied when leakage is suspected, however, experience at industrial CCS sites has shown there can be challenges in discriminating between background biogenic and injected CO2. Earlier work at the CO2FieldLab and for RISCS indicated diffuse leakage of injected CO2 can occur when concentrations and fluxes are within baseline values but the extent and importance of this for overall emissions has yet to be established. There has been little progress in practical demonstration of quantification of CO2 emissions from storage.

Progress beyond the state of the art:
Partners are developing a range of tools to address the above issues that will be advanced during ENOS. Wide-area coverage tools for leakage detection, continuous monitoring and emission quantification tools/techniques will be advanced. Technologies applicable to onshore storage will be taken to at least TRL6 during ENOS. These tools have been developed in previous projects and specific field demonstration is required to improve them. The importance of diffuse leakage (often below the detection threshold for standard tools) will be assessed to determine if this should be considered in all storage site monitoring plans.

Task 3.3.1: Wide-area coverage tools for leakage detection
The trade-offs between wide areal coverage, cost and the need for more sensitive sensors will be examined. All techniques will be benchmarked against established tools with more limited areal capability. These techniques will be used to demonstrate the effectiveness of monitoring for CO2 leakage at various heights above the ground.

UNIROMA1 will improve the sensitivity and response time of the ground CO2 mapper and integrate it with an autonomous robot to continuously map CO2 concentrations over a specified area. This unit detects CO2 close to the ground and will be tested both at natural CO2 leakage sites and during CO2 injection tests at the Sulcis Fault Lab.
The possibility of using an Unmanned Aerial Vehicle (UAV) as a mobile platform for leakage detection using direct absorption spectra and temperature difference techniques will be investigated using repeated surveys at one or more site. This low cost OGS drone can carry a selection of tools including CO2 probe, a thermal camera and/or a HD video camera. The UAV can record CO2 concentrations both along transects and vertical profiles (hovering mode) to map and study CO2 dispersion rates in the air.
BGS will test a new more sensitive multispectral thermal sensor detector for its ability to detect leakage in the thermal region of the electromagnetic spectrum using pre-dawn flights at the GTB using a plane available to NERC.

Task 3.3.2: Advanced soil gas monitoring
Soil gas monitoring is one of the main techniques used for leakage detection. However, uncertainties in identifying leakage remain due to the high variation of natural background levels. Therefore a better understanding of these variations will improve the operator's ability to demonstrate that the soil gas measurements indicate no leakage without frequent recourse to additional analyses to prove this to be the case. These new soil gas tools will be compared against each other and commercially available tools and will be used to examine the efficacy of the wide-area coverage tools in T3.3.1.
The newly developed BGR monitoring devices for measuring CO2 concentrations at the internal boundary layer (constant flux layer) will be enhanced. Preliminary tests during a controlled CO2 release at the Ketzin Pilot Site have shown promising results. Further developments will move this approach from TRL 4 to 6. This new probe will examine the migration of CO2 from the shallow sub-surface into the atmosphere immediately above the ground to evaluate CO2 migration into the atmosphere at selected points at the GeoEnergy Test Bed. Water table changes occurring in the vadose zone affect soil gas readings and better understanding of this will increase confidence in soil gas results. Metre-scale test bed experiments and modelling studies by BGR will assess migration effectiveness of CO2 and CH4 gas (potentially resulting from bio reduction of CO2) at the saturated/vadose zone interface. Comparative measurements of CO2 in the vadose zone and in the groundwater simultaneously will validate the applied models and increase the TRL to 6.
The UNIROMA1 GasPro system, able to continuously measure CO2 concentration, P and T in the unsaturated soil horizon has been tested in small numbers at several natural and experimental sites. UNIROMA1 will extend the capability of the system by further reducing production costs and by conducting a "mass" deployment of 50 probes at the Sulcis Fault Lab, bringing the technology to TRL7. It will show how multiple unit deployment improves the chances of detecting spatially localized leakage and the definition of variability in time and different controlling conditions (e.g., soil type, topography, water content, seasonal changes etc.) at a given site.
Diffuse leakage detection presents severe monitoring challenges for storage sites: detection threshold and differentiation from naturally produced CO2 in the shallow environment. BGS will investigate if significant low concentration diffuse leakage of CO2 occurs in injection tests and at natural analogue sites, well characterized in previous projects (e.g. S Vittorino), using the stable C isotopic signature of leaking CO2 compared to shallow biogenic CO2. This activity will move this monitoring technique for diffuse leakage forward to TRL6. The identification of the CO2 source (shallow natural production vs. injected CO2) in soil gas will benefit from a new combination of techniques that focuses on the processes of CO2 formation. The formation temperature of CO2 determines the abundance of rare CO2 isotopologues (abundance of 13C and 18O bonds in CO2). TNO will undertake measurements for a number of selected samples at San Vittorino where CO2 is leaking from depth to test the method. Soil gas samples will further be analysed for CO2, N, O, CH4 and C2-C5 hydrocarbon concentrations and isotopes to evaluate the new method against previous approaches to define the source of CO2 and to further evaluate the significance of diffuse low-level leakage.

Task 3.3.3: Emission quantification
A new open path laser CO2 detection tool is under development in a separate project by Rutherford Appleton Laboratory, working with BGS and Shell, performing laboratory and prototype field testing. A reflector array is used to detect and quantify leakage in the atmosphere using tomographic reconstruction. The applicability to onshore storage will be tested at one of the field sites. This will advance the technique towards the market through field demonstration.
In addition, UNIROMA1 will establish an empirical relationship between the ground CO2 mapper results from subtask 3.3.1 and direct soil gas flux measurements to extend the mapper's capability to emission quantification.

Outcomes
- Demonstration of techniques for effective surface monitoring which will fill identified gaps in current techniques including wide-area coverage tools for rapid location of potential leakage sites (e.g. UAV, autonomous ground mapper robot) and complementary advanced ground truthing techniques (e.g. soil gas).
- Improved detection threshold and origin discrimination for CO2 in soil gas monitoring tools, and related increase in TRL.

- Tested CO2 leakage/emission quantification techniques

Task 3.4: Integrated monitoring solution for leakage detection and quantification (BGS, all WP partners)
Established tools are not sufficient to ensure efficient leakage monitoring of a storage site. Their different capabilities must be considered in light of the site risk assessment and this should be integrated into a monitoring strategy. The innovative tools advanced through ENOS need to be integrated into a comprehensive monitoring solution alongside current state of the art tools to provide technical guidelines on appropriate monitoring solutions for onshore site operators. The technical guidelines developed here will feed into best practice recommendations made by WP7.
BGS will lead this task with strong support by BGR, a partner in the MONACO project, which developed an integrative hierarchical assurance monitoring concept, and all ENOS WP3 partners. In particular, CIUDEN, UNIROMA1,Sotacarbo and end user committee (in WP7) will provide expertise based on their real-life experience at fault lab, large storage and industrial sites. This will ensure that the technical guidelines from WP3 are practicable. The report will include an assessment of the upscaling of techniques to large scale demonstration, as undertaken by Sotacarbo with support from CIUDEN and other partners. Sotacarbo with support from all partners will consider how technologies and techniques tested in WP3 could be integrated into a monitoring plan for the Sulcis pilot site. This will provide a real-life assessment of their potential benefits and will include a cost estimation of their deployment. The outcome will be a site monitoring plan improved with the technologies and monitoring tools developed through WP3. This task will also receive input from WP5 on societal requirements based on specific sites in ENOS and consider how these views fit into technical guidelines for storage site operation.

Outcomes
Technical Guidelines for an integrated onshore monitoring solution, including ENOS and other cutting edge tools to detect and quantify CO2 leakage.
Interaction with other WPs
Data from tools in T3.2.1 and 3.3.2 and from integration inT3.4 will be shared with WP1 as required, in particular the recommendations will also be fed into the Task 1.4 on integration of deep monitoring data. Through WP7, the leakage monitoring technical guidelines will be assessed to ensure it is fit for a wide range of technical stakeholders with particular focus on (potential) site operators and technical guidelines from WP3 will feed into best practice documents. Knowledge sharing between partners will be assured through integration of results and with external stakeholders through input to WP6, 7 and 8. In particular, activities in WP3 will be the basis for international cooperation in the leakage simulation alliance in WP6. Societal requirements highlighted by WP5 will feed into WP3 where practicable. Information will be provided to WP5 for presentation to the local population near pilot injection sites in Spain, the Czech republic and Italy.

Participation per Partner

Partner number and short name	WP3 effort
1 - BRGM	12.00
2 - BGR	32.00
3 - BGS	31.00
4 - CGS	10.00
6 - CIUDEN	1.00
9 - IDIL	4.00
10 - IRIS	8.00
11 - NHAZCA	6.00
12 - OGS	40.00
15 - SILIXA	3.00
16 - SOTACARBO	10.60
17 - TNO	5.00

Partner number and short name	WP3 effort
18 - UNIROMA1	57.00
19 - UNOTT	4.50
20 - CO2GeoNet	0.00
HWU	16.00
GEOECOMAR	2.50
Total	242.60

List of deliverables

Deliverable Number[14]	Deliverable Title	Lead beneficiary	Type[15]	Dissemination level[16]	Due Date (in months)[17]
D3.1	Report on leakage through faults (T3.2.1 & 3.2.2)	18 - UNIROMA1	Report	Public	37
D3.2	Assessment of leakage risk presented by old boreholes at onshore site (case study report) (T3.2.4)	10 - IRIS	Report	Public	26
D3.3	BGS optic fibre tool (T3.1.1)	3 - BGS	Demonstrator	Confidential, only for members of the consortium (including the Commission Services)	35
D3.4	BRGM-IDIL optic fibre tool (T3.1.1)	1 - BRGM	Demonstrator	Confidential, only for members of the consortium (including the Commission Services)	35
D3.5	UNIROMA1 probes (T3.1.1)	18 - UNIROMA1	Demonstrator	Confidential, only for members of the consortium (including the Commission Services)	32
D3.6	Silixa hybrid cable (T3.1.1)	15 - SILIXA	Demonstrator	Confidential, only for members of the consortium (including the Commission Services)	32
D3.7	IRIS biosensors (T3.1.1)	10 - IRIS	Report	Confidential, only for members of the consortium (including the Commission Services)	35
D3.8	OGS UAV drone (T3.3.1)	12 - OGS	Demonstrator	Confidential, only for members of the	35

List of deliverables

Deliverable Number[14]	Deliverable Title	Lead beneficiary	Type[15]	Dissemination level[16]	Due Date (in months)[17]
				consortium (including the Commission Services)	
D3.9	Report on field tests and modelling of impact of CO2 leakage on freshwater aquifers (T3.1.1)	1 - BRGM	Report	Public	37
D3.10	Report on Improvement in advanced soil gas monitoring techniques and assessment of CO2 source (T3.3.2)	2 - BGR	Report	Public	37
D3.11	UNIROMA1 GasPro system (3.3.2)	18 - UNIROMA1	Demonstrator	Confidential, only for members of the consortium (including the Commission Services)	33
D3.12	UNIROMA1 ground mapper robot (T3.3.1)	18 - UNIROMA1	Demonstrator	Confidential, only for members of the consortium (including the Commission Services)	33
D3.13	Report on leakage detection and quantification tools (T3.3.3)	3 - BGS	Report	Confidential, only for members of the consortium (including the Commission Services)	37
D3.14	Report on the development of wide-area surface coverage tools and their efficacy) (T3.3.1)	18 - UNIROMA1	Report	Public	37
D3.15	Report on monitoring techniques which can detect CO2 migrating through fault planes (T3.2.2)	12 - OGS	Report	Public	37
D3.16	Technical guidelines for CO2 leakage detection and quantification:integration of monitoring tools developed through ENOS with existing state of the art tools in the context of full scale storage site operation (T3.4)	3 - BGS	Report	Public	40

Description of deliverables

Task 3.1
D3.9 Report on field tests and modelling of impact of CO2 leakage on freshwater aquifers (T3.1.1), M 33, BRGM (BGS, UNIROMA1, UNOTT, Silixa, IRIS) [including tools applicable to potable groundwater sites tested]
D3.3 BGS optic fibre tool (T3.1.1) M32
D3.4 BRGM-IDIL optic fibre tool (T3.1.1) M32
D3.5 UNIROMA1 probe (T3.1.1) M32
D3.6 Silixa hybrid cable (T3.1.1) M32
D3.7 IRIS biosensors (T3.1.1) M32

Task 3.2
D3.1 Report on leakage through faults and tools tested in T3.2, M23, UNIROMA1 (BGS, CGS, IRIS,NHAZCA)
D3.15 Report on monitoring techniques which can detect CO2 migrating along fault planes, (T3.2.2) M 37,OGS
D3.2 Assessment of leakage risk presented by old boreholes at onshore site (case study report), (T3.2.4) M26, CO2GeoNet-HWU (CGS, BRGM, CO2GeoNet-GeoEcoMar)

Task 3.3
D3.14 Report on the development of wide-area surface coverage tools and their efficacy, M35, UNIROMA1 (OGS, BGS)
D3. 12 UNIROMA1 ground mapper robot (T3.3.1) M33 [including tools tested in T3.3.1]
D3.8 OGS UAV drone (T3.3.1) M33
D3.10 Report on Improvement in advanced soil gas monitoring techniques and assessment of CO2 source, M37, BGR (UNIROMA1, TNO, BGS) [including tools tested in T3.3.2]
D3.11 UNIROMA1 GasPro system (3.3.2) M33
D3.13 Report on leakage detection and quantification tools, (T3.3.3) M35, BGS (UNIROMA1)

Task 3.4
D3.16 Technical guidelines for CO2 leakage detection and quantification: integration of monitoring tools developed through ENOS with existing state of the art tools in the context of full scale storage site operation, M40 BGS (all WP partners)

D3.1 : Report on leakage through faults (T3.2.1 & 3.2.2) [37]

Task 3.2 This report will describe the results obtained by the numerical modelling of leakage mechanisms and pressures throught a fault. It will Summarise of what makes a fault likely to leak and what form the leakage is likely to take based on ENOS field studies and outcomes of testing tools for effective monitoring around faults It will include data from Uniroma1 and Iris work.

D3.2 : Assessment of leakage risk presented by old boreholes at onshore site (case study report) (T3.2.4) [26]

Task 3.2.4 Summary of what risks old boreholes present for unwanted CO2 migration/leakage through integration of modelling and field data for two sites

D3.3 : BGS optic fibre tool (T3.1.1) [35]

Task 3.1 - A cost effective downhole optical fibre tool for detecting dissolved CO2 by testing for changes in pH tested in the field

D3.4 : BRGM-IDIL optic fibre tool (T3.1.1) [35]

Task 3.1 - Calibrated optic fibre tool for detecting gaseous CO2 demonstrated in the field

D3.5 : UNIROMA1 probes (T3.1.1) [32]

Task 3.1 - validated UNIROMA1 pCO2 probe, describing the results of the experiments and the deployments that moved the technology from TRL5 to TRL7.

D3.6 : Silixa hybrid cable (T3.1.1) [32]

Task 3.1 - Field demonstration of hybrid cable with more sensitive acoustic detection thresholds than currently commercially available with temperature change detection capability

D3.7 : IRIS biosensors (T3.1.1) [35]

Task 3.1 - report on potential bacterials strains that could be used as markers to detect and identify CO2 leakage into groundwater. Special focus should be on detecting low level concentrations.

D3.8 : OGS UAV drone (T3.3.1) [35]

Task 3.3.1 Tested UAV drone to monitor CO2 leakages. Innovative instruments and methodologies will be described.

D3.9 : Report on field tests and modelling of impact of CO2 leakage on freshwater aquifers (T3.1.1) [37]

Task 3.1.1 Summary of findings on the impact of CO2 on potable groundwater and the tools tested in the field (uses outputs from T3.1.1, 3.1.2)

D3.10 : Report on Improvement in advanced soil gas monitoring techniques and assessment of CO2 source (T3.3.2) [37]

Task 3.3 - Different techniques for effective surface monitoring will be tested against each hother and gaps in current techniques will be identified. Included are results of wide-area coverage tools for location of potential leakage sites (e.g. UAV, autonomous ground mapper robot) and complementary advanced ground truthing techniques (e.g. soil gas) and techniques for origin discrimination for CO2.

D3.11 : UNIROMA1 GasPro system (3.3.2) [33]

Task 3.3 - Technical development and testing of the UNIROMA1 GasPro system, describing the integration of additional sensors (like conductivity) into the existing prototype and the results of experiments.

D3.12 : UNIROMA1 ground mapper robot (T3.3.1) [33]

Task 3.3 - Technical development and testing of the ground mapper robot, results of experiments and possible deployments.

D3.13 : Report on leakage detection and quantification tools (T3.3.3) [37]

Report on Field tests of new tool for CO2 leakage quantification in the air above a leakage zone

D3.14 : Report on the development of wide-area surface coverage tools and their efficacy) (T3.3.1) [37]

Task 3.3 - This report will detail the technical solution adopted, the deployments and the results obtained during the monitoring activities and experiments performed at the Sulcis fault Lab.

D3.15 : Report on monitoring techniques which can detect CO2 migrating through fault planes (T3.2.2) [37]

This deliverable is related to task T 3.2.2. and reports the monitoring of of CO2 Migration through fault plane in the sub-surface at the Sulcis Fault Lab by geophysical measurements using downhole tools, surface and also satellite techniques. The results will be incorporated in the integrated monitoring solution of Task 3.4.

D3.16 : Technical guidelines for CO2 leakage detection and quantification:integration of monitoring tools developed through ENOS with existing state of the art tools in the context of full scale storage site operation (T3.4) [40]

Technical guidelines for integrating the tools advanced through ENOS with existing state of the art tools in the context of full scale storage (uses inputs from all tasks in WP3)

Schedule of relevant Milestones

Milestone number[18]	Milestone title	Lead beneficiary	Due Date (in months)	Means of verification
MS4	International collaboration input to Work programme planned	1 - BRGM	3	D6.1
MS5	Start of field activities in Sulcis Fault lab	16 - SOTACARBO	5	Staff at field
MS13	Input from End-User Committee 1	10 - IRIS	11	Key outcomes from meeting
MS17	Start of field activities in GeoEnergy test bed	3 - BGS	17	Staff at field
MS23	Input from End-User Committee 2	10 - IRIS	23	Key outcomes from meeting
MS30	End of field activities in GeoEnergy test bed	3 - BGS	37	no more staff at field

Schedule of relevant Milestones

Milestone number[18]	Milestone title	Lead beneficiary	Due Date (in months)	Means of verification
MS31	End of field activities in Sulcis Fault lab	16 - SOTACARBO	37	no more staff at field
MS32	Input from End-User Committee 3	10 - IRIS	35	Key outcomes from meeting
MS34	Advisory board input 2	1 - BRGM	36	report and note on impact on ENOS
MS35	End of all field activity	1 - BRGM	36	End of CO2 injection and ENOS data acquisition
MS36	Input from End-User Committee 4	10 - IRIS	47	Key outcomes from meeting

Work package number [9]	WP4	Lead beneficiary [10]	17 - TNO
Work package title	Integration of CO2 storage with local economic activities		
Start month	1	End month	48

Objectives

CO2 storage, especially onshore is facing resistance as its added value is not easily recognized by the general public and local communities. At the same time early movers find great difficulties in financing their CCS projects. Integration of CO2 storage combined with other (economic) activities, will increase societal and political acceptance and improve the business case for CCS projects.
The objective of WP4 is to evaluate and develop demonstration of CO2 storage integrated in other economic activities, e.g. enhanced hydrocarbon production, CO2 buffering for different types of utilization and CO2 buffering as part of a CO2 (shipping) terminal, prior to transport and large-scale storage. Work will be done at 2 sites:
- LBr-1: an oil field in the Czech Republic to demonstrate integration of safe and permanent CO2 storage in combination with Enhanced Hydrocarbon Recovery (EHR);
- Q16-Maas: a gas-condensate field in The Netherlands to demonstrate safe and permanent CO2 storage in combination with CO2 buffering and delivery for different types of utilization. Furthermore the Q16-Maas field can be integrated as a buffer location for a CO2 shipping terminal in the Port of Rotterdam. The data from a different gasfield offshore the Netherlands ,K12 B, will be used as an analogue to provide information on the composition of the back produced CO2.

The evaluation and development will focus on technical, economic and regulatory aspects. Developing these projects will contribute to the higher goal of accelerating the development and deployment of CCS in Europe and will improve the competitiveness and growth of companies in the energy and food sectors and will positively impact employment and decrease the carbon footprint (see also WP6).

Description of work and role of partners

WP4 - Integration of CO2 storage with local economic activities [Months: 1-48]
TNO, CGS, GGR, IRIS , SGIDS, CO2GeoNet
Task 4.1 CO2 buffering and re-production for greenhouse horticulture (TNO, GGR)
State of the art
A wealth of experience is already available on the storage and production of natural CO2, natural gas and other hydrocarbons, as well as on CO2 storage. In contrast, studies on integrated gas production and seasonal and permanent CO2 storage activities are rare. In general just 25% of CO2 used for EHR is permanently stored (North America). Main reason for this is that the CO2 EOR project is not designed for permanent storage. The Q16-Maas field will be designed in order to store > 80% of the CO2 injected. This means a closed loop system needs to be designed and monitored. Furthermore the short- and long-term geochemical impact of CO2 injection and storage has been assessed for depleted natural gas fields in different geological contexts (Chiquet et al., 2013; Girard et al., 2013; Snippe et al., 2012). However, most projects were focusing on CO2 storage procedures and prediction of fluid flow (Tambach et al., 2015) or on chemical effects (Waldmann et al., 2014), rather than on modeling the approach for a combined project on CO2 buffering and permanent storage. Different forms of CO2 utilization (CCU) are developing rapidly and can accelerate the development of CCS by adding value to the business case of individual projects. In practice there can be a mismatch between demand and supply. Temporal oversupply or shortage can be compensated for by buffer storage. From a legal perspective CO2 storage or buffering can be permitted, however it is not yet possible to gain EU-ETS credits for the CO2 stored for a combined operation.

References:
Chiquet P, Thibeau S, Lescanne M, Prinet C.(2013) Geochemical Assessment of the Injection of CO2 into Rousse Depleted Gas Reservoir Part II: Geochemical Impact of the CO2 Injection. Energy Procedia, 37, 6383-6394.
Girard, J. P., Chiquet, P., Thibeau, S., Lescanne, M., & Prinet, C. (2013). Geochemical Assessment of the Injection of CO2 into Rousse Depleted Gas Reservoir. Part I: Initial Mineralogical and Geochemical Conditions in the Mano Reservoir. Energy Procedia, 37, 6395-6401.
Snippe, J., Wei, L., Lovelock, C., et al. (2012). Reactive Transport Modeling for CO2 Storage in a Depleted North Sea Gas Field. In: Third EAGE CO2 Geological Storage Workshop.
Tambach, T. J., Koenen, M., Wasch, L. J., & van Bergen, F. (2015). Geochemical evaluation of CO2 injection and containment in a depleted gas field. International Journal of Greenhouse Gas Control, 32, 61-80.

Waldmann, S., Busch, A., van Ojik, K., Gaupp, R. (2014). Importance of mineral surface areas in Rotliegend sandstones for modeling CO2-water-rock interactions. Chemical Geology, 378-379, 89-109.

Progress beyond the state of the art
The ENOS project will advance the understanding of integrating CO2 seasonal storage with back-production and permanent storage of CO2. The mass balance of the whole system will be a key issue: what and how much CO2 comes in, goes out, or stays in the system and how can the CO2 be monitored in order to meet legal requirements and gain ETS credits for the CO2 stored. The regulatory requirements on CO2 for these integrated activities will be investigated. This task will demonstrate if CO2 from industrial sources can be buffered and reproduced in sufficient quantities, with the proper gas composition specifications for different uses including the greenhouse horticulture. Understanding of the gas purity is crucial for different forms of use. The composition of the produced gas and requirements for gas treatment before it can be delivered to customers like the greenhouses will be investigated in detail. A novel approach in developing the integration of spatial irreducible formation water and minerals in geochemical models will be developed.

The overall technical feasibility of combined CO2 buffering and permanent storage in the Q16-Maas gas field, will be evaluated: Quantification of mass balance, quality of the required and delivered end-products and embedding in regulation. Furthermore an adequate monitoring system, meeting the regulatory requirements will be designed.

Task 4.1.1 Modelling of CO2 quality during temporary buffering and permanent storage in Q16-Maas (TNO)
In terms of CO2 injection and storage, geochemical fluid-rock interactions are important site-specific issues playing a role in the short- and long term during the buffer and storage phases. These processes will be assessed with geochemical modeling tools to identify the most significant chemical reactions. For these purposes, kinetic mineral dissolution and precipitation reactions will be taken into account, using data from a real-life gas field Q16-Maas. The relatively low water saturation, compared to aquifers, of the porous medium has a major influence on the accurate prediction of fluid-rock interactions. The spatial distribution of and local equilibria between water and mineral(s) will be evaluated, included in geochemical models and compared to an average whole rock compositions generally used for such models. Whole rock mineralogy and chemistry as well as the type and chemical composition of the clay fraction will be analyzed (e.g. X ray diffraction, X ray fluorescence, and electron microprobe analysis) to define input parameters. The spatial distribution of minerals will be assessed on thin-section scale (e.g. Qemscan). Additional data and parameters, like reservoir temperature, as well as gas and water composition, will be provided by the Q16-Maas site operator.
An integrated geological model will be built based upon existing models The injection/production stream composition will be evaluated using a 3-D coupled compositional multiphase flow - geochemistry model of the storage. The key geochemical interactions and parameters will be identified by geochemical models and used in the 3-D storage model to compute the evolution of CO2 inventory throughout the commercial life of the gas field and beyond for permanent storage.

Task 4.1.2 Integrating and optimizing suitable separation methods to meet requirements for end users (TNO)
Different forms of CO2 utilization are under development in the larger Rotterdam area. In order to meet the requirements or CO2 specifications for the different forms of use, the CO2 must be purified, using technologies designed to capture CO2 from flue gasses (CO2 concentrations typically from 5 – 15%). The CO2 concentrations of the re-produced gas / CO2 are much higher (40% K12B, > 90% in Q16-Maas). The cost of CO2 separation can be an economical showstopper to developing a buffer project. Therefore existing separation technologies need to be optimized in order to meet the requirements in a cost effective way. This task will focus on a review of existing separation technologies and how these can be optimized for this purpose. The results of task 4.1.1. will be used. Depending on the gas composition produced from the Q16-Maas field, it may or may not be viable to extract methane for sale. Different technology options can be deployed to obtain sales gas. Significant amounts of condensates and/or heavies can represent an important revenue stream. Recommendation will be made on how these components can be extracted and/or whether an existing gas separating unit can be used directly or after modifications.
Furthermore, significant amounts of components such as propane and butane may occur. Alternatively, the gas stream may contain impurities such as benzene, toluene, and xylene (BTX) that need to be removed from the stream. Recommendation will be made on how the gas should be treated to obtain or remove these components.

Task 4.1.3 Removing regulatory barriers
The injection of anthropogenic CO2 into the Dutch subsurface either for enhanced hydrocarbon recovery, buffering (temporary storage), or permanent storage, has yet to take place. The current legal framework for CO2 storage in the EU, specifically the EU Directive on the geological storage of CO2, and the amendments allowing CO2 storage as a permitted mitigation activity under the EU ETS, does not prohibit the combination of CO2 storage with enhanced hydrocarbon recovery and/or buffering of CO2. Despite this, certain Member States, for instance the Netherlands, have enacted legislation that prevents operators holding a license for both permanent CO2 storage and CO2 EHR or buffering. In addition, the permitting process for regulating a CO2 storage site, where a small percentage of the storage volume

may act as a CO2 buffer, has yet to be approached by any European Member State. In the current regulatory system it is not possible to gain credits for CO2 storage during hydrocarbon production and/or buffering.
This task will primarily be focused on the Dutch legislative and regulatory framework, however brief comparative assessments of the regulation of combined CO2/EHR activities in the Member States of the United Kingdom and Denmark will be completed. The deliverables of Task 4.1.3 will be completed through specific legal/regulations research in combination with interviews with regulators and industry stakeholders.
The purpose of Task 4.1.3 is to describe the legality of combining the activities of CO2 buffering, permanent CO2 storage, and enhanced hydrocarbon recovery. A legal assessment, including permitting steps, will be conducted for three different scenarios:
1. CO2 injection, buffering and permanent storage
2. CO2 injection for the purposes of EHR
3. CO2 buffering with simultaneous EHR

Task 4.1.4 Monitoring
An accurate knowledge of the volume of CO2 in the reservoir and of the total volumes injected and produced is a first priority in regulations that would accept combined buffering and storage activities. This activity prepares for such future regulations by designing a monitoring system for accounting purposes in a scenario in which part of the CO2 is to remain permanently in storage. The approach in this activity will be to combine existing techniques to design a system that produces the necessary information. While the focus will be on designing a system for the Q16-Maas field, more generally applicable guidelines will be defined on the design of a monitoring system for combined projects. A key part of this evaluation will be an investigation of the role monitoring and associated requirements on monitoring as part of the regulatory framework. In particular, considerations with regard to monitoring and measurement for accounting purposes will be taken into account in a scenario in which part of the CO2 is to remain permanently in storage.

Outcomes
• Technical feasibility of combined CO2 buffering and permanent storage activity.
• Quantification of mass balance and quality of the delivered end-products (back-produced CO2), including a description of additional separation methods.
• Potential solution for adapting current regulatory regime to accept the combination of buffering and enhanced production activities.
• Detailed description of an adequate monitoring system that suits the regulatory requirements.

Task 4.2 CO2 storage and oil production (IRIS, CGS, CO2GeoNet-METU-PAL& TNO)
State of the art
CO2 EOR has been applied extensively for over 3 decades, predominately in the USA and Canada but also in Hungary, Croatia and Turkey. Most of the CO2 used in these operations is from natural sources: it is produced from CO2 reservoir and transported to the oil fields, where it is sold to operators. As the CO2 is rather an expensive commodity, the amount used for the EOR process is minimized, while the oil production is maximized. This is done by alternating CO2 injection with as much water as possible (Water Alternating Gas process). Furthermore, a final water flood is often conducted at the end of the oil production to sweep and reproduce as much CO2 as possible for reuse in adjacent oil fields. The US CO2 EOR situation is described in a number of papers, e.g. Mungan (1981) and ARI Inc. (2005). The Weyburn field in Canada is a prime example of CO2 EOR.

References:
Mungan N. (1981) CO2 flooding - fundamentals-The journal of Canadian Petroleum Technology 81-01-03:87-92.
ARI Inc. (2005) Basin oriented strategies for CO2 Enhanced oil recovery: California. DOE report.

Progress beyond the state of the art
For the European CCUS (Carbon Capture Utilisation and Storage) projects, the ambition is two-fold: maximizing total oil production and making optimal use of the gradually depleting reservoir for storing CO2. In terms of volumes of CO2 injected such projects have opposite objectives to American analogues. Together with boosting oil production, opportunities for reduction of CO2 back production and increase in volumes of CO2 injected towards the end of field lifetime will be screened. Physical forces controlling both EOR, (e.g. miscibility with oil), and storage (e.g. solubility in water or mineralogical reactions) will be screened, evaluated and accounted for. The simulation work will be based on both available data (static geological model, samples crude oil, cores etc.) and the lab tests results obtained in this project (miscibility, impact of CO2 on crude etc.). The optimization will be based not only on the volumes of CO2 stored and oil produced, but also on economical screening of different scenarios. An economic assessment tool will optimize the objective function with costs/benefits values of the injected fluids (CO2 and water) and the produced crude oil. This means that these assigned costs will have an impact on the way the injection process is designed. Recent studies have shown that this combined approach is capable of increasing the net use of CO2 by 25 and 40% for immiscible

and miscible CO2, respectively, without compromising crude oil production. These optimized simulations will result in recommendations for a future pilot test in the oil field or a similar field nearby. The Czech LBr-1 site, will be used as an example for developing technical-economical evaluations of the CCUS concept in Task 4.3. LBr-1 is close to the Czech-Slovakian border and future injection of CO2 may lead to trans-boundary issues. Those will be tackled with support of the Slovak partner SGIDS, and possible regulatory solutions will be proposed.
A CCUS solution (combining CO2-EOR with CCS) is one of the best ways to mitigate reservoir pressure and, at the same time, recover hydrocarbons in order to generate revenue to cover some of the storage expenses. CCUS projects, however, have their own peculiarities and challenges, that would be addressed in this task. Task leader will be IRIS, with CGS, TNO, CO2GeoNet-METU-PAL and SGIDS contribution. International collaboration on novel EOR concepts will be developed with the Kansas Geological Survey, through WP6 twining with LBr-1.

Task 4.2.1 Design of novel EOR-concept
The CCUS concept has key differences from both pure utilization and pure storage projects that require significant design and planning changes. The aim is to increase oil recovery and at the same time increase volume of CO2 stored during the process and after field-end-of-life. Both subsurface reservoir conditions and required infrastructure for increasing oil production and CO2 injection during the different phases of the project lifetime will be taken into account. Different options for the design of wells will be considered: cheap and flexible ones that could easily be converted from hydrocarbon production to CO2 injectors and monitoring wells in the CO2 storage phase. The development of novel concepts for EOR will start from a thorough review of the literature in the US, Canada and Europe.

Task 4.2.2 Reservoir modelling of designed concepts
Based on the available geological architecture and properties, and a history matched dynamic model of the LBr-1 field a number of production and storage scenarios will be screened. Reservoir simulation coupled with screening of risk, uncertainties and costs would provide a reasonable evaluation of several design concepts. An assessment of the volatility in demand and supply of CO2 will be performed. The simulation work will be backed up with lab test work (slim tube and contact tests) on the basis of analogue reservoir core material.

Task 4.2.3 Study on trans-boundary storage site issues and regulation
The national transpositions of the EU CCS Directive doesn't fully tackle trans-boundary issues, which creates hurdles for utilization of promising storage sites situated on or near Member States boundaries. LBr-1, situated close to the Czech-Slovak border, will be studied from the trans-boundary point of view, including items such as national legislations, definition of the storage complex, assessment of CO2 storage pressure footprint, risk management and proposals for possible regulatory solutions. CGS, SGIDS and IRIS will perform a practical study based on the LBr-1 site case. Regulatory solutions of the trans-boundary storage issues will be provided and recommendations for EU regulation will be defined.

Task 4.2.4 Design of CO2-EOR pilot
Based on the proposed designs and simulations carried out a detailed plan for the field-scale CCUS pilot at LBr-1 field will be prepared. The plan will include subsurface configuration, injection/production schedule and a required infrastructure. The design will be fitted to local condition and a draft of local community involvement will be prepared, taking into account WP5 outcomes.

Outcomes
A developed approach combining EOR and storage aspects based on both technical economical and regulatory factors for the LBr-1 field. While the end-result would be field specific, the developed approach will lay a basis for the roadmap to be developed in Taksk6.5 and for a guidance document (best practice) in Task 7.3.

Task 4.3 Building the socio-economic case (CO2GeoNet-GSB-RBINS, IRIS, TNO)
State of the art
The economic evaluation of projects in which CO2 geological storage forms an important element, is currently based on relatively straightforward, often even generic schemes. In a generic scheme, such a system can be pictured as a single chain, with generally CO2 being passed on from source to geological reservoir. Economic evaluations calculate costs and benefits of capturing, transporting and storing based on realistic average values for the different techniques (e.g. van den Broek, 2010). Such an approach ignores essential uncertainties regarding geological context, problems of project flexibility due to high upfront investment costs, or uncertain socio-economic outlooks including forecasted CO2-ETS costs and economic boundary conditions. An example of such difference between theory and practice are the economic evaluations of CO2-EOR in the North-Sea Basin (e.g. Klokk et al., 2010). These unanimously indicate an important increase in return compared to primary oil production, but in reality such projects appear much less evident to realize (none have been realized yet).
With the exception of the work in the recent years of the CO2GeoNet-GSB-RBINS (Piessens et al., 2012; Welkenhuysen et al., 2013), this is the end-point for CCS related assessments. Analogue problems arise wherever geological data is

an important factor in calculating the value of a project, e.g. in determining the price of licenses for natural resources (hydrocarbons, ores, e.g. Moel & Tufano, 2000), or when comparing the costs of remediation technologies (Compernolle et al., 2014). The central methodology proposed for such situations is Real Option Analysis (ROA; Dixit & Pindyck, 1994), able to meaningfully deal with very large uncertainties, including those of geological nature. Although the first public studies proposing ROA as the proper methodology date back to 1985 (Brennan & Schwartz, 1985), it is not commonly applied (e.g. also not for assessing CCS projects). Reasons seem to be mainly practical: combination in one team of geological, economic and mathematical expertise, the potential complexity of ROA decision criteria, and potential long calculation times of stochastic results.

References:

Brennan MJ & Schwartz ES 1985 Evaluating Natural Resource Investments. Journal of Business, 58(2),135-157.
Compernolle, T., Van Passel, S. Huisman, K. & Kort, P. 2014. The option to abandon: Stimulating innovative groundwater remediation technologies characterized by technological uncertainty. Science of The Total Environment 07/2014, p. 63-74.
Dixit A, Pindyck R (1994). Investment under Uncertainty. In: Princeton University Press.
Klokk, Ø., Schreiner, P. F., Pagès-Bernaus, A., & Tomasgard, A. (2010). Optimizing a CO2 value chain for the Norwegian Continental Shelf. Energy Policy, 38(11), p.6604–6614.
Moel, A. & Tufano, P. 2000. Bidding for the Antamina Mine. In: Brennan, M.J., Trigeorgis (Eds.), Project Flexibility, Agency, and Competition: New developments in the Theory and Application of Real Options. Oxford University Press, New York, 357p.
Piessens K, Welkenhuysen K, Laenen B, Ferket H, Nijs W, Duerinck J, Cochez E, Mathieu Ph, Valentiny D, Baele J-M, Dupont N & Hendriks Ch, 2012. Policy Support System for Carbon Capture and Storage and Collaboration between Belgium-the Netherlands "PSS-CCS", Final report. Belgian Science Policy Office, Research Programme Science for a Sustainable Development contracts SD/CP/04a,b& SD/CP/803, 335p
Van den Broek, M., Brederode, E., Ramirez, A., Kramers, L., van der Kuip, M., Wildenborg, T., Turkenburg, W. & Faaij, A., 2010. Designing a cost-effective CO2 storage infrastructure using a GIS based linear optimization energy model. Environmental Modelling & Software, 25, p.1754-1768.
Welkenhuysen, K., Ramírez, A., Swennen, R., Piessens, K., 2013. Strategy for ranking potential CO2 storage reservoirs: a case study for Belgium. International Journal of Greenhouse Gas Control, 17, p.431-449.

Progress beyond the state of the art

The major challenge is to include essential additional factors that come into play in real world projects, which may importantly improve or weaken the economic case: geological uncertainty and infrastructure costs. Uncertainty usually affects project decisions, because higher uncertainty on return requires a higher expected return. Positive FIDs are therefore less likely to be taken. Geologic uncertainty is distinct from technological or economic uncertainties. Estimating the level of this uncertainty often requires in-depth regional (per country or basin) expertise. It will not resolve gradually over time, as is the case for most technical or socio-economic parameters, but requires a significant upfront investment for additional exploration. Reservoirs are also complex natural systems, and the residual uncertainty after exploration and pilot testing may remain relatively large. The other essential factor to be captured is project flexibility: the capacity to adjust to some extent a project as uncertainty is increasingly resolved in the course of an actual project with a positive or negative impact on the project.

When uncertainties are taken into account, project outlooks will generally be less favourable. When project flexibility is not taken into account, then the rigid theoretical outlooks will be pessimistic compared to projects in the real world. ROA meets those needs but has only rarely been used for assessing projects involving CO2 geological storage, and, not to the topic of temporary storage of CO2 or onshore EOR. Previous studies on offshore EOR were performed at a much more generic level than this proposed task.

One of the intentions of putting projects in a realistic socio-economic context is to demonstrate how CCS and CCUS can be a positive and non-intrusive element in sustainable economic and industrial development. A transparent economic case will facilitate valuating the importance of innovative (CO2 based) industry, as well as make CO2 geological storage more acceptable and appealing to a local population.

For the two storage schemes that will be scrutinized, comparable subtasks are required, each however taking into account the peculiarities of the specific project. Results will be used directly for evaluating the economic viability of a proposed project, to pinpoint weaknesses and strengths from the investors point of view, and to evaluate the required context for these specific CCS projects, which will allow ENOS to assess how generally they can be applied in Europe. Since CCS is being placed as accurately as possible in a regional context in WP6, the results are particularly relevant also to policy makers when rolling out socio-economic policy in a climate and resource constraint Europe.

Task 4.3.1 Outlining the optional project development scheme

Integrating flexibility in the simulation of the project execution, starts with a tree-like mapping out of the different evaluations and decisions that can be taken in function of the outcome of a project from start to end (Real Options Scheme). A straightforward example is the outcome of exploration activities, after which the Final Investment Decision for the full scale project may be taken. Only decision points that have an important impact, also referred to as 'Option Value', on the overall NPV calculation will be integrated and these will be different for a temporary gas storage or EOR project.

Task 4.3.2 Assessing the stochastic ranges/distributions of the input data
In the stochastic calculations, different decisions at option points will be taken because of the stochastic nature of input values. Particular focus will be on the realistic translation of geological uncertainty, but also on techno-economic parameters. In order to obtain meaningful results, the number of stochastic parameters is best limited to 4 or 5. Close collaboration is needed between the reservoir modelers of the gas storage and EOR projects, in order to realistically represent the uncertainty and variability of the geological and simulation input data to the economic evaluations.
Assessing the general economic or policy related parameters, such as CO2-ETS price, will be discussed within WP4, based on the background assumptions proposed in Tasks 4.1 and 4.2, and on proposed ranges by the techno-economic sub-task group (4.3). These uncertainties will be caught at the scenario level. A minimum number of scenarios will be used, mainly to address the issue of the highly volatile energy and CO2 ETS prices.

Task 4.3.3 Determination of the project value
The actual value of the two projects will be calculated by using the PSS (Policy Support System) simulator directly or indirectly with the help of a spreadsheet environment. The ROA schemes will be calculated using a Monte-Carlo approach, and the outcome will be evaluated both in terms of the average and variance of the project value, the different options, and the sensitivity to each of the stochastic parameters.

Outcomes
The market potential, economic viability, physical planning with synergies and conflicts, and legal and regulatory aspects specific to the identified integrated chains including CO2 storage will be evaluated (see also Task 6.3). The business cases for the identified chains will be elaborated so that they can be used as a basis for investment decision making. Relevant stakeholders will be engaged in this process; participation of the local inhabitants will be enabled via WP5.
Interaction with other WPs Results from WP4 will feed the work in task 6.5 Roadmap for upscaling identified synergies of CO2 storage with CO2 utilisation. WP4 and 5 will cooperate on the definition of the work with the local community. Furthermore WP4 will deliver building blocks for best practice documents in WP7 and will contribute to the curriculum of the training sessions in WP8.

Participation per Partner

Partner number and short name	WP4 effort
4 - CGS	9.00
8 - GGR	3.50
10 - IRIS	10.00
14 - SGIDS	3.00
17 - TNO	30.00
20 - CO2GeoNet	0.00
GSB-RBINS	24.00
METU	6.00
Total	85.50

List of deliverables

Deliverable Number[14]	Deliverable Title	Lead beneficiary	Type[15]	Dissemination level[16]	Due Date (in months)[17]
D4.1	Novel Concepts for EOR with permanent storage of CO2	10 - IRIS	Report	Confidential, only for members of the consortium (including the Commission Services)	13
D4.2	Progress report on the economic evaluation on the project value of the geo-technical uncertainties related to CO2 buffering and re-production for greenhouse horticulture, and to onshore CO2 storage and oil production	20 - CO2GeoNet	Report	Confidential, only for members of the consortium (including the Commission Services)	20
D4.3	Progress report on identified key chemical processes	17 - TNO	Report	Confidential, only for members of the consortium (including the Commission Services)	22
D4.4	Summary report with gas stream scenarios and user specifications	17 - TNO	Report	Confidential, only for members of the consortium (including the Commission Services)	25
D4.5	Reservoir models of novel CO2-EOR concepts at LBr-1	10 - IRIS	Report	Confidential, only for members of the consortium (including the Commission Services)	30
D4.6	Assessment of transboundary effects at LBr-1 and regulatory solutions	4 - CGS	Report	Public	37
D4.7	Approaches to regulating CO2 with EHR in selected Member States	17 - TNO	Report	Public	37
D4.8	Economic evaluation on the project value of the geo-technical uncertainties related to CO2 buffering and re-production for greenhouse horticulture, and to onshore CO2 storage and oil production	20 - CO2GeoNet	Report	Public	37

List of deliverables

Deliverable Number[14]	Deliverable Title	Lead beneficiary	Type[15]	Dissemination level[16]	Due Date (in months)[17]
D4.9	Report on separation technology options and recommendation for the gas stream scenarios	17 - TNO	Report	Confidential, only for members of the consortium (including the Commission Services)	38
D4.10	Design of a CO2-EOR pilot	10 - IRIS	Report	Confidential, only for members of the consortium (including the Commission Services)	38
D4.11	Monitoring system for an integrated CO2 buffer and permanent CO2 storage project	17 - TNO	Report	Public	39
D4.12	Final report on gas phase quality assessment during CO2-EHR, buffering and storage	17 - TNO	Report	Confidential, only for members of the consortium (including the Commission Services)	40

Description of deliverables

Task 4.1
D4.3 Progress report on identified key chemical processes (M 22; TNO)
D4.4 Summary report with gas stream scenarios and user specifications (M 25; TNO)
D4.7 Approaches to regulating CO2 with EHR in selected Member States (M 37; TNO)
D4.9 Report on separation technology options and recommendation for the gas stream scenarios (M 38; TNO)
D4.11 Monitoring system for an integrated CO2 buffer and permanent CO2 storage project (M 39; TNO)
D4.12 Final report on gas phase quality assessment during CO2-EHR, buffering and storage (M 40; TNO)

Task 4.2
D4.1 Novel Concepts for EOR with permanent storage of CO2 (M 13; IRIS)
D4.5 Reservoir models of novel CO2-EOR concepts at LBr-1 (M 30; IRIS)
D4.6 Assessment of trans-boundary effects at LBr-1 and regulatory solutions (M 37; CGS)
D4.10 Design of CO2-EOR pilot (M38; IRIS)

Task4.3
D4.2 Progress report on the economic evaluation on the project value of the geo-technical uncertainties related to CO2 buffering and re-production for greenhouse horticulture, and to onshore CO2 storage and oil production (M20; CO2GeoNet-RBINS-GSB)
D4.8 Economic evaluation on the project value of the geo-technical uncertainties related to CO2 buffering and re-production for greenhouse horticulture, and to onshore CO2 storage and oil production (M 37; CO2GeoNet-RBINS-GSB)

D4.1 : Novel Concepts for EOR with permanent storage of CO2 [13]

Task 4.2 - Report on Novel Concepts for EOR with permanent storage. The report should describe differences from "conventional" storage and EOR projects in a form of maximising both hydrocarbon production and volumes of CO2 stored on site. An optimisation methodology would be developed and concept suggested based on LBr-1 site.

D4.2 : Progress report on the economic evaluation on the project value of the geo-technical uncertainties related to CO2 buffering and re-production for greenhouse horticulture, and to onshore CO2 storage and oil production [20]

This intermediary WP4.3 report will outline the geo-techno-economic methodology and implementation that has been developed, including first test results based either on preliminary actual input or dummy data, depending on the progress in the largely parallel tasks WP4.1 and WP4.2. Additional topics at this stage will likely include a stochastic sensitivity analysis, important for understanding the importance of the uncertainty on key-parameters.

D4.3 : Progress report on identified key chemical processes [22]

The progress report describes the first results of Task 4.1.1 in WP4. The chemical interaction processes, which are key to the understanding of the chemical composition of the gas stream produced from the Q16-Maas field will be elucidated.

D4.4 : Summary report with gas stream scenarios and user specifications [25]

The second interim report in Task 4.1.1 describes various scenarios of the composition of the gas stream produced during subsequent stages of gas production and CO2 injection at the Q16-Maas field, and specifications of the gas stream composition required by different users.

D4.5 : Reservoir models of novel CO2-EOR concepts at LBr-1 [30]

Task 4.2 - A reservoir model showing optimised scenario of maximising recovery and storage volumes (based on concept from delivery 4.1) would be prepared and delivered. The model would optimise for well location and injection rates

D4.6 : Assessment of transboundary effects at LBr-1 and regulatory solutions [37]

Task 4.2 Study on trans-boundary issues of the LBr-1 site, which is situated close to the Czech-Slovak border. It will include items such as national legislations, definition of the storage complex, assessment of CO2 storage pressure footprint, risk management and proposals for possible regulatory solutions. Regulatory solutions of the trans-boundary storage issues will be provided and recommendations for EU regulation will be defined.

D4.7 : Approaches to regulating CO2 with EHR in selected Member States [37]

The report includes the results of Task 4.1.3 in WP4 and is directed to the regulatory assessment of several combinations of injection, buffering and HC production for the Netherlands, the UK and Denmark. The report will conclude with recommentdations for removing existing regulatory barriers.

D4.8 : Economic evaluation on the project value of the geo-technical uncertainties related to CO2 buffering and re-production for greenhouse horticulture, and to onshore CO2 storage and oil production [37]

This WP4.3 report will detail how the schemes and data from WP 4.1 and WP4.2 were translated in a geo-techno-economic model, and how the economic, technical and geological maturation outlooks are for the respective CO2 utilization cases. This report is scheduled near the end of the project to allow for maximum adoption of data and proposed operational schemes from WP4.1 and WP4.2, and is as such dependend on the (expected) pre-reporting availability of final views from these tasks (e.g. the design of the CO2-EOR project).

D4.9 : Report on separation technology options and recommendation for the gas stream scenarios [38]

The report deals with available separation options to purify the produced gas stream according to existing specifications for the users of hydrocarbons or CO2 (Task 4.1.2 in WP4). Recommendations for the most cost-effective solutions will be made.

D4.10 : Design of a CO2-EOR pilot [38]

Task 4.2 - A report with the design of the CO2-EOR pilot for LBr-1 (number and position of wells, operational conditions) based on the simulation results in delivery 4.5.

D4.11 : Monitoring system for an integrated CO2 buffer and permanent CO2 storage project [39]

The report describes the results of Task 4.1.4 in WP4 on the design of a monitoring system for the mass balance of injected and produced CO2 streams, and permanently stored CO2 according to regulation for CO2 accounting.

D4.12 : Final report on gas phase quality assessment during CO2-EHR, buffering and storage [40]

The final report of Task 4.1.1 (TNO & GGR) provides a full account of the assessment of the gas quality during the stages of EHR, CO2 buffering and storage at the Q16-Maas field. The assessment is based on results of geochemical modelling of fluid-rock interactions, lab analysis of the chemical composition and spatial distribution of minerals and 3-D coupled compositional multiphase flow - geochemistry simulations.

Schedule of relevant Milestones

Milestone number[18]	Milestone title	Lead beneficiary	Due Date (in months)	Means of verification
MS4	International collaboration input to Work programme planned	1 - BRGM	3	D6.1
MS13	Input from End-User Committee 1	10 - IRIS	11	Key outcomes from meeting
MS14	Draft Real Option Schemes for CO2 buffer and CO2-EOR	20 - CO2GeoNet	12	Discussed and validated schemes by partners of Tasks 4.1, 4.2 and 4.3
MS16	Identification of main geochemical processes	17 - TNO	14	Geochemical model outcome supplied to partner in Task 4.1.1
MS21	Decision on designs for considered separation processes	17 - TNO	18	Approved list of process designs by partners in Tasks 4.1.1 and 4.1.2
MS23	Input from End-User Committee 2	10 - IRIS	23	Key outcomes from meeting
MS24	Selection of production scenario(s)	17 - TNO	24	Definition of scenario supplied to partner in Task 4.1.2
MS27	Transfer of data, pending potential updates, of Tasks 4.1 and 4.2 to Task 4.3	17 - TNO	30	Notes with data from Tasks 4.1 and 4.2 in agreement with needs in 4.3
MS32	Input from End-User Committee 3	10 - IRIS	35	Key outcomes from meeting
MS34	Advisory board input 2	1 - BRGM	36	report and note on impact on ENOS
MS35	End of all field activity	1 - BRGM	36	End of CO2 injection and ENOS data acquisition
MS36	Input from End-User Committee 4	10 - IRIS	47	Key outcomes from meeting

Work package number [9]	WP5	Lead beneficiary [10]	18 - UNIROMA1
Work package title	Coordination with local communities		
Start month	1	End month	48

Objectives

By linking the work of the technical WPs to the perspective of the local population, ENOS will develop a unique body of knowledge about how technical aspects of CO2 storage can be synchronized with societal needs. Evaluation of the technology's societal implications and identification of possible solutions together with local populations will be the focus of the WP5. The main objectives will be:
- To gain the involvement of the local population in the development of best practices by organizing collaborative research processes between lay citizens and experts
- To support the ENOS project in developing best practices which are proven for societal aspects, in particular with regard to safety and potential impacts
- To provide a methodology to link the scientific and technical development of the best practices with societal concerns and implementation issues at local level
- To develop an online public information tool based on input and feed-back from the local population
- To verify how the integration of societal input in CO2 storage research and implementation can increase awareness about storage processes and confidence in how they are being developed and implemented

Description of work and role of partners

WP5 - Coordination with local communities [Months: 1-48]
UNIROMA1, BRGM, BGR, CGS, CIUDEN , OGS, SOTACARBO, TNO, UNOTT, CO2GeoNet
Storage projects will need to be implemented in such a way that is felt to be safe by the local population. This will not only require the projects to be compliant with technical best practices but also to ensure that what they do is recognized by the population as following safe state of the art practices. In other words, it is not sufficient that the site obeys regulations, it is also necessary that it is perceived as such. WP5 will undertake activities with the goal of developing knowledge and tools that can fill the gap between the technical and the societal level of perception on CCS. To achieve this, WP5 will create conditions for the establishment of a long term relationship with a group of public's representatives, within which research and technological issues will be discussed with two main objectives: (i)to gain input from the population to make sure that the best practices developed by the ENOS project don't neglect reasonable societal concerns and integrate the point of view of the population; (ii) to produce a public information tool specific for CO2 storage sites that enables people to understand and follow site development and operation. The two objectives are closely related, through the relationship with the population, ENOS will coordinate the scientific and technological aspects with the social and societal ones. The outcomes will be directed to satisfy the authorities and the operators, through the contribution to ENOS final best practice documents and to engage the general public and other societal stakeholders, through the production of a dedicated public information tool.

Task 5.1 – Knowledge development and integration in a societal perspective (UniRoma1, all WP partners)
State of the art
Discussion at societal level on technical topics requires support of the technical community and suitable supporting material. There are existing examples of researchers working together to integrate their knowledge from different disciplines related to storage and making the effort of expressing it in lay terms, which have produced a variety of materials for communication with the public. The most notable one is CO2GeoNet brochure "What does the geological storage of CO2 really mean?", now available in 27 languages, which some of the ENOS partners have contributed to. However these are one way communication materials, produced for general engagement purposes, without direct input or verification by the population.

Progress beyond the state of the art
To allow participation and discussion with civil society on technical topics and integration of public concerns in research and implementation projects a common language, terminology and understanding of concepts is required. ENOS will work with researchers and the population alike to find satisfactory formulations that facilitate reciprocal input and pave the way for correct but accessible communication between the technical researchers and the local community.

Activities: Work will be performed in interaction with WPs1-4 to define the key steps of the technological development being undertaken in easy-to-understand, communication-prone materials which will provide the basis for exchange

on technical issues with the local community. Task 5.1 will be performed by means of desktop work, email and teleconference exchange plus six two-day workshops with WPs1-5 researchers. During the later stages of ENOS WP5 will provide input to WP7 research integration activities. During the first part of the project the materials for exchange will be prepared (Task 5.1); subsequently the work with the researchers will focus on the discussion of the input coming from the population and how it can be taken into account in the development of the research work (Task 5.2).

Task 5.1.1 Description and definition of technical themes and technologies that ENOS aims to develop, through exchange among researchers and agreement on lay formulations, including provisional description of the topics' relevance for the local community (developed with the community itself in task 5.2). Main areas of work following the technological challenges tackled in WP1 to 4:
Advanced methods for risk management, injection strategies and monitoring at injection site (WP1)
Risk and mitigation techniques (WP1&3)
Understanding of capacity issues (WP2)
Protection of water resources (WP3)
Monitoring plans (WP1&3)
Synergies of CO2 geological storage with CO2 utilisation (WP4)
The materials produced will be translated (in the languages of the communities involved, by site partners) and used for the group work with the local population and once verified and updated also for general communication purposes.

Task 5.1.2 Integration of the population's input in the research process, in implementation process of pilots and in the development of the best practice manuals at the end of the project.
The work with the population will highlight what is regarded as most important in public perception terms; based on this, researchers will discuss how to integrate public input in the ENOS research to addresses public values. Wherever possible researchers will look for technically and socially sound solutions. The interplay between researchers' analysis and the input gained through the representatives of the public involved, will help finding appropriate formulations of the final best practice report to ensure both technical and societal relevance and comprehensibility.

Outcomes:
WP5 provide input into best practice documents (in WP7) that take into account and integrate the perspective of the population, these will be an important tool to help operators and the authorities develop storage projects with greater awareness of what needs to be considered, not only in a technical perspective but also in a societal perspective. Another important outcome relates to the influence that the process established in this task will have on research development: Researchers that will be more aware of societal requirements will develop tools, models and techniques that better serve both industrial and societal demands.

Task 5.2 – Work with the local communities (UniRoma1, SOTACARBO, TNO, CIUDEN, UNOTT)
State of the art
Interaction with the population on technical issues and the establishment of a collaborative research process is not new in other sectors. For instance the application of methodologies that seek to include social and societal aspects into what is commonly referred to as 'technical' challenges has largely taken place in formerly technical issues such as water and soil management. This approach is only just starting in the field of CCS. An example is a German study on participative modelling for CO2 storage characterization by Class et al. However, these studies usually involve technical stakeholders or civil society organisations, rather than the local population living near an existing or potential storage site - the stakeholder most affected by technical choices made by scientists and operators.
Progress beyond state of the art
ENOS will expand work for participative research and operation processes, by covering a range of storage topics, which are of direct interest for the population and by involving and prioritizing lay citizens living near the storage pilot areas. This will be an important step towards a methodology for a community centred exchange between scientists, operators, local authorities and the local population. Progress will also be made on how to facilitate successful societal exchange on storage themes and on the advantages of an organized and long term joint effort, which could be replicated by future storage operators, with respect to more focused and short term activities. Additionally this task will progress our knowledge on the potential for integration of different methodologies to work with the population. The project will therefore advance state of the art knowledge providing insight on how researchers, the population and local authorities can work together to build safety conditions and best practice protocols.

Activities:
Task 5.2 focuses on the interaction with the local communities on the thematic areas covered by the technical WPs. Four sites/areas will be covered presenting different kinds and stages of storage plans: Sulcis, Hontomin, GeoEnergy TestBed, Rotterdam area.

Task 5.2.1: Coordination and elaboration of the work with the local communities (UniRoma1, SOTACARBO, TNO, CIUDEN, UNOTT):
The partners will define together the approach to the work with the local community, by sharing methodologies and experience and, building a common understanding about the development of the relationship with the local communities. Different methodologies for establishing a collaborative relationship with the population will be used by the partners, ranging from psychoanalytic based (Vercelli et al., 2014) to political science based approaches (Duijn, M., Laws D.W., 2005; Ehrmann, J.R., Stinson B.L., 1999).

Task 5.2.2: Joint work with citizens and stakeholders (UniRoma1, SOTACARBO, TNO, CIUDEN, UNOTT)
The activities in this task will be carried on at the level of the individual sites.
Preparatory phase: The partners will further develop existing contacts with the local authorities and relevant stakeholders in order to establish the framework conditions for working with citizens living in the area, including making public presentations of the project, its aims and objectives and launching social media activities or other forms of involvement of the community to communicate about the work being done and its outcomes. This preliminary phase to collect and apply knowledge on the appropriate conditions for the research work with the citizens will pave the way for the collaborative research process at the selected locations.
Group work: Groups of 12-15 citizens (reflecting proportions of gender, age, education etc.) and stakeholders will be formed for interaction on the different thematic areas identified in task 5.1 and exploration of the different perspectives on the technological issues under study. The groups will meet for a cycle of regular meetings of 2-3 hours to address the need of dedicated space and sufficient time for people to understand, reflect, formulate requests and look together for solutions (Vercelli et al. 2015). The group work with the participants will focus on three distinct areas and phases of work:
1) introduction and understanding of the technological aspects;
2) discussion and evaluation of societal implications, critical aspects, etc.;
3) development of solutions or improvements that are acceptable from a research/industrial/societal point of view

The four sites represent different social, geographical, economic and industrial realities and different stages of development of the pilot/ projects; they will bring a variety of perspectives which will make the final best practice guidelines more reliable.

The Hontomin site (CIUDEN): the pilot is in operation and the relationship with the population is already well advanced; the perspectives brought in the group work by citizens will reflect their experience with having an operating site in their area. After the preliminary organizing and communication activities, a group of citizens will be established for 15 meetings. The group work will have a focus on operational issues, so it will be shaped in order to improve communication activities with local society on safe storage operation and promote transparency of the activities ongoing in the area. This exchange will provide the base for the public information tool to be developed in task 5.3.

The Sulcis site (UNIROMA1, SOTACARBO): the pilot project is in the stage of completing the characterization phase, a limited number of public communication activities has taken place up to now and the community is in a phase of increasing interest for the project. Activities will be performed at the Sulcis pilot site to encompass all the main sectors of the local society and explore the advantages of a full coverage and more articulated work with the community. After the preparatory phase three long term groups (for a minimum of 15 meetings) will be established involving 1) a random sample of lay citizens; 2) local industrial, commercial and civil society stakeholders; 3) regional and local policy makers. The group work will focus on understanding how the topics defined in task 5.1 are relevant for the local context and how research can better be directed in synergy with other contextual elements and societal requirements. To this end collaboration with Regional authorities will be enhanced and collaboration with civil society organisations present in the areas will be established.

The GeoEnergy TestBed (UNOTT): This is a test injection site on University owned land and the local population are accustomed to research activities. Starting with the preparatory phase, the established GERC website will be updated to inform the public about ENOS activities. Relationships with the local authority, the British Army Royal Engineers (UK armed forces national borehole capability located in Nottingham), the national regulators (Environment Agency), and the local population (Parish Councils) already exist. Within this framework the ENOS project will provide the opportunity for a more technical and long term exchange with a group of citizens which will meet for 15 meetings In addition UNOTT will facilitate links with the UNOTT China campus (Ningbo), and gain input to the collaborative research process through colleagues at the Ningbo campus and UNOTT's partnership with CO2 storage site owners at the China University of Mining and Technology.

The Rotterdam area (TNO): the Rotterdam area has an interesting potential for both capture and storage of CO2, due to the presence of intensive industrial activities, gas fields and geological formations suitable for storage. This region has also previously been involved in proposed CO2 storage projects that have raised controversial discussions, as was the

case for Barendrecht. The ENOS project will undertake activities with a group of representatives of the lay public to share and explore the potential for storage and the conditions that would make its implementation of interest for the local population. Results of this consultation will be brought to the attention of different stakeholder groups in the area, such as industry/entrepreneurs, local citizens, NGOs and politicians and policy professionals. First, a panel group formed by a random sample of citizens will meet for about 15 meetings. This exploration will deliver insights into the key factors that characterize the disposition of citizens towards these types of project. Second, the input from the citizens will be shared in 3 workshops with representatives of all stakeholder groups in the area facilitating a dialogue approach to explore new possibilities for CO2 storage. This will create a better understanding of the potential synergies of temporary CO2 storage with economic activities like greenhouse horticulture and energy storage, which can bring additional benefits to the local population. The different technological challenges tackled in WP1-4 will be explored with a focus on the design of a participatory monitoring system for the different phases of project development; decision-making, construction and operation (e.g. what items should be monitored? From what perspectives? Which data is needed? Which data is already available, from whom? Which data needs to be collected, by whom? Etc.).

Task 5.2.3 – Verification and feed-back from the population (TNO, UniRoma1, SOTACARBO, CIUDEN, UNOTT)
During the last phase of ENOS, verification will be performed through interviews and a questionnaire on the level of satisfaction of involved citizens and stakeholders, about the process of exchange and the way the input has been taken into account by the researchers. This will also contribute to collecting feed-back on the innovative process for integrating the community input into best practices for technology implementation.

Outcomes: The experience of a collaborative research process for producing indications for guidelines, best practices and a public information tool for storage sites, tested by societal stakeholders and lay citizens, will contribute in creating an important reference on the possibility of working together with the population to solve storage implementation challenges. Onshore storage needs to be well understood in its potential impacts and benefits by society as a whole; by enabling technical discussions with the population, ENOS will set an example of collaboration across stakeholders and will increase trust in guidelines appropriate for the population.

Task 5.3 – Development of a Public Information Tool for CO2 storage sites (CIUDEN, UNIROMA1, SOTACARBO, TNO, UNOTT)
In this task the partners will apply the knowledge gained through the relationship with the local communities to develop a dynamic and interactive online Public Information Tool of an active CO2 storage site (Hontomin). The work in this task builds on the recognition that people living near a storage site have the right to access information about site operations and that trust and feelings of safety will be positively influenced by facilities that enable people to follow the work. The challenge is to structure the information tool so that people can quickly and easily understand how to use it. Close collaboration will be necessary with members of the public to ensure the ENOS tool answers these requirements. The application will be developed during the first two years of the project and will be tested during the third year. A smartphone enabled application will be developed to explain key project data and interesting facts for all stakeholders. It will be a web-based application that can follow the progress of the implementation process of an active CO2 storage site. It will be developed for Hontomin and the platform will offer the option for addition of other sites. In this way in the future the end user will be able to connect and get information from one or more storage sites. Content will be defined by the interaction with the local population and other stakeholders like journalists, local and regional politicians and regulators conducted as part of Task 5.2.2. It will be updated at regular intervals with information such as the amount of CO2 injected,, results from recent surveys performed at the site, news from the project and CCS in general The contents would be updated in two languages, English and Spanish (for ease of reading for the local population).

Outcomes: The Public Information Tool which will give access to storage sites development in a manner comprehensible to all, supporting further interaction between the technical and the local communities.

Interactions with other WPs
WP5 work will proceed in close collaboration with the technical WPs 1 to 4 (Task 5.1), will provide input to WP7 for the inclusion of societal aspects in Best Practice documents and WP8 for e-learning and educational activities and for collaborating to media events. Concerning WP6 it will contribute to Experience sharing focus groups and defining storage sites' follow up activities.
References:
Class, H. et al., (2015), Combined Natural and Social Science Approach for Regional-Scale Characterisation of CO2 Storage Formations and Brine Migration Risks (CO2BRIM) in Liebscher, A., Münch, U., Geological Storage of CO2 – Long Term Security Aspects Advanced Technologies in Earth Sciences, Springer.
Duijn, M., D.W. Laws (2005). Facilitating network (inter-organizational) learning: a relativist - pragmatist perspective on participatory policy analysis, Proceedings of the OLKC-conference, Cambridge/MA.

Ehrmann, J.R., B.L. Stinson (1999). Joint Fact-Finding and the Use of Technical Experts, in: The Consensus Buidling Handbook, L.E. Susskind, S. McKearnan, J. Thomas-Larmer, (eds.), SAGE Publications.
Vercelli et.al., (2014), Dialogue and Mutual Learning towards a Low Carbon Society – Experiences from 10 Countries Across Europe, Energy Procedia, Volume 58, Pages 30-35.
Vercelli et al. (2015), The Geological Storage of CO2: and what do you think? – Findings from the ECO2 project about the public perception of CO2 geological storage. Lay report D6.4, April 2015, 24 pages.

Participation per Partner

Partner number and short name	WP5 effort
1 - BRGM	4.00
2 - BGR	2.00
4 - CGS	4.00
6 - CIUDEN	21.00
12 - OGS	2.00
16 - SOTACARBO	8.00
17 - TNO	14.00
18 - UNIROMA1	40.00
19 - UNOTT	9.00
20 - CO2GeoNet	0.00
TTUGI	2.30
HWU	3.00
IGME	2.00
GEOECOMAR	4.00
GBA	4.00
Total	119.30

List of deliverables

Deliverable Number[14]	Deliverable Title	Lead beneficiary	Type[15]	Dissemination level[16]	Due Date (in months)[17]
D5.1	Presentation of the project's technical content in lay terms	18 - UNIROMA1	Report	Public	13
D5.2	Public Information Tool upgraded and ready for application to other CO2 storage sites	6 - CIUDEN	Other	Public	34
D5.3	CO2 Storage Best practice indications from the Hontomin site community	6 - CIUDEN	Report	Public	35

List of deliverables

Deliverable Number[14]	Deliverable Title	Lead beneficiary	Type[15]	Dissemination level[16]	Due Date (in months)[17]
D5.4	CO2 Storage Best practice indications from Rotterdam area community	17 - TNO	Report	Public	37
D5.5	CO2 Storage Best practice indications from the GeoEnergy TestBed site community	19 - UNOTT	Report	Public	38
D5.6	CO2 Storage Best practice indications from the Sulcis site community	18 - UNIROMA1	Report	Public	40
D5.7	Guidelines for coordinating the developmentof of CO2 storage projects with local communities	18 - UNIROMA1	Report	Public	44
D5.8	Report on feed-back from citizens on ENOS activities	17 - TNO	Report	Public	45
D5.9	Report on the process of integration of indications coming from site communities in ENOS research and CO2 storage Best Practices	18 - UNIROMA1	Report	Public	46

Description of deliverables

Task 5.1
D5.1 Presentation of the project's technical content in lay terms (Collection of lay terms text and ppt presentations for each of the technologies or set of technologies being developed) (M 13)(UNIROMA1)

Task 5.2
D5.3 CO2 Storage Best practice indications from the Hontomin site community (M 35)(CIUDEN)
D5.4 CO2 Storage Best practice indications from the Rotterdam area community (M 37) (TNO)
D5.5 CO2 Storage Best practice indications from the GeoEnergy TestBed site community (M 38) (UNOTT)
D5.6 CO2 Storage Best practice indications from the Sulcis site community (M 40) (UNIRMA1)
D5.7 Guidelines for coordinating the development of CO2 storage projects with local communities (M 44)
D5.8 Report on feed-back from citizens on ENOS activities (M 45)
D5.9 Report on the process of integration of indications coming from site communities in ENOS research and CO2 storage Best Practices (M 46) (UNIROMA1)

Task5.3
D5.2 Public Information Tool upgraded and ready for application to other CO2 storage sites (M 34) (CIUDEN)

D5.1 : Presentation of the project's technical content in lay terms [13]

This deliverable relates to task 5.1.1. It will consist of a report or alternatively of another suitable instrument (for instance fact sheets, posters or a video) that allows facilitated communication of the scientific content of the project. It will illustrate the technical themes and technologies that ENOS aims to develop in terms as much as possible understandable for local population participants and in a form that is functional for the activities to be undertaken with them in task 2.

D5.2 : Public Information Tool upgraded and ready for application to other CO2 storage sites [34]

The aim of this deliverable is to develop a dynamic and interactive on line tool for public information in Hontomín as operation site. Partners will apply the knowledge gained through relationship with local populatios. The platform will offer the option for addition of other sites. Following tasks are related with D5.2: Tasks 5.1, 5.2 and 5.3

D5.3 : CO2 Storage Best practice indications from the Hontomin site community [35]

Experiences and lessons learned corresponding to the works performed with Hontomín local community will produce indications for development of best practise guidelines, in order to solve onshore storage implementation challanges. Following tasks are related with D5.3: Tasks 5.1, 5.2 and 5.3

D5.4 : CO2 Storage Best practice indications from Rotterdam area community [37]

The report describes the results of the interaction with stakeholders in the Rotterdam area in Task 5.2.2 of WP5. The interaction follows two stages: in the first stage a panel of citizens will interact on the type of projects considered and in the 2nd stage stakeholders will repond to the input from the citizens. The possibilities for participatory monitoring will be explored.

D5.5 : CO2 Storage Best practice indications from the GeoEnergy TestBed site community [38]

This report will illustrate the outcomes of the group work undertaken with local stakeholders and citizens of the GeoEnergy TestBed site. It will highlight their meaning for the development of CO2 Storage best practices (task 5.2.2)

D5.6 : CO2 Storage Best practice indications from the Sulcis site community [40]

This report will illustrate the outcomes of the group work undertaken with local stakeholders and citizens of the Sulcis site. It will highlight their meaning for the development of CO2 Storage best practices (task 5.2.2)

D5.7 : Guidelines for coordinating the developmentof of CO2 storage projects with local communities [44]

This report will draw conclusions from the overall experience conducted with the four site communities. It will further develop the indications coming from deliverables 5.3 to 5.6, to formulate general guidelines for the stakeholders on how, based on the project's experience, the development of CO2 storage sites can be coordinated with the local communities (task 5.2.1)

D5.8 : Report on feed-back from citizens on ENOS activities [45]

The report entails the feedback from citizens on the process followed in ENOS and on the way the results have been used. The reported work inlcudes all activities of Task 5.2.3 in WP5.

D5.9 : Report on the process of integration of indications coming from site communities in ENOS research and CO2 storage Best Practices [46]

This report will illustrate the process followed in the project for integrating the input received from local communities in ENOS research and in the final ENOS CO2 storage guidelines. It will explain if and how the observations and suggestions coming from the population have informed the research activities and the formulation of the guidelines (task 5.1.2)

Schedule of relevant Milestones

Milestone number[18]	Milestone title	Lead beneficiary	Due Date (in months)	Means of verification
MS4	International collaboration input to Work programme planned	1 - BRGM	3	D6.1
MS13	Input from End-User Committee 1	10 - IRIS	11	Key outcomes from meeting
MS20	Start of group meetings with citizens	18 - UNIROMA1	18	First meeting documents
MS23	Input from End-User Committee 2	10 - IRIS	23	Key outcomes from meeting

Schedule of relevant Milestones

Milestone number[18]	Milestone title	Lead beneficiary	Due Date (in months)	Means of verification
MS26	Launch of the Public Information tool	6 - CIUDEN	24	First version available online
MS32	Input from End-User Committee 3	10 - IRIS	35	Key outcomes from meeting
MS34	Advisory board input 2	1 - BRGM	36	report and note on impact on ENOS
MS35	End of all field activity	1 - BRGM	36	End of CO2 injection and ENOS data acquisition
MS36	Input from End-User Committee 4	10 - IRIS	47	Key outcomes from meeting

Work package number [9]	WP6	Lead beneficiary [10]	4 - CGS
Work package title	International Cooperation & seeding pilots and demos in Europe		
Start month	1	End month	48

Objectives

In order to successfully deploy commercial CCS with onshore storage across Europe, a series of pilot projects needs to be developed and realized, preferably in a variety of geographical and geological settings across the continent, followed by larger-scope demonstration projects. Additionally, the experience gained from existing pilots needs to be maximised through knowledge sharing and identifying analogous sites where the lessons learned can be most effectively applied to catalyse the next generation of successful onshore storage projects.
The objective of WP6 is to facilitate such development by:
• Establishing partnerships and sharing experience and knowledge with groups and entities executing CO2 storage pilots, demonstration projects and leakage simulation tests worldwide;
• Liaising and exchanging knowledge with other pilot and demonstration projects in Europe across the full pilot/ demonstration lifecycle (planned-operational-closed);
• Identifying success criteria that can be applied to create a catalogue of potential situations where new storage sites might be successful;
• Paving the way for pilot sites in the ENOS project portfolio to further develop beyond the end of the project through planning of follow-up stages of their development and/or upscaling to a larger amount of stored CO2;
• Preparing a Roadmap for upscaling identified synergies of CO2 storage with CO2 utilisation

Description of work and role of partners

WP6 - International Cooperation & seeding pilots and demos in Europe [Months: 1-48]
CGS, BRGM, BGR, BGS, CIUDEN , IRIS , OGS, SGIDS, SOTACARBO, TNO, UNIROMA1, UNOTT, CO2GeoNet
Task 6.1 International cooperation (BRGM, CGS, CIUDEN, BGS, UNOTT, UNIROMA1, OGS, IRIS, CO2GeoNet-GeoEcoMar, Sotacarbo)
Context
Europe is lagging behind North America and other parts of the world in deployment of CO2 storage onshore. The European experience is limited to a few pilot sites (e.g.Ketzin, Lacq-Rousse, Hontomin), which makes sharing experience and knowledge with other onshore storage sites outside Europe (e.g.., in U.S.A., Canada or Australia) imperative. ENOS can learn the most from sites which represent similar types of storage to those in the ENOS project, with respect to geological setting, reservoir type, storage strategy. The proposed work in this task will provide a framework for sharing and mutual learning with international sites, who provided letter of intent to participate in this task see Section 4.

Activity
Task 6.1.1 Storage Site twinning programme
A twinning programme, aimed at creating a durable close working relationship between onshore site owners, will be set up. It will consist of mutual visits, regular exchanges of information and data, discussions on real-life issues encountered by the twinned sites operations and where possible l identification of collaborative actions to address those issues through research alignment and cooperation. Activities will take advantage of modern communication and data sharing tools to maximize collaboration opportunities.
The proposed twinnings are: Sulcis–Janggi (Korea)–South Africa Pilot CO2 Storage Project /
Hontomin– Batelle site in Michigan Basin (USA)-Otway(Australia) / LBr1–Kansas Wellington Field.
A detailed plan of international collaboration activities will be drafted within the first 3 months of the project (D6.1). Two joint reports with international site owners will be produced at the end of Year 2 (D6.2) and Year 4 (D6.11), describing results of the Twinning Programme, including common issues identified and mutual learning.
BRGM will be responsible for this sub-task and will facilitate exchanges in the twinning groups.

Task 6.1.2 Leakage simulation alliance
Worldwide there are several sites planning to study CO2 leakage in different environments and conditions through real-life field injection experiments. The alliance will foster cooperation and allow comparison and generalization of results. The sites proposed for the alliance are the GeoEnergy Test Bed (UK) and the Sulcis fault (Italy) sites from ENOS, as

well as the Carbon Management Canada (CMC), South Korean K-COSEM and South African Bongwana Fault (natural analogue) site. If possible other sites will be added during the course of the project.
Activities will consist of site visits, workshops, data exchange and joint reports/publications. It is proposed that one workshop will be held in Canada in conjunction with the annual CMC workshop to allow attendance at both events and a visit to the CMC Field Research Station.
Visits will explore the possibility of collaborative working across the sites through separate funding mechanisms. This sub-task will build on an existing project funded by the UK CCS Research Centre project involving visits by BGS and UNOTT to forge collaborative links between the GeoEnergy Test Bed and the sites in South Korea, South Africa and Canada.
The activities of the alliance led by BGS and will be summarised in a report (D6.5)

Task 6.1.3 Experience sharing Focus groups
ENOS will create a small number of experience sharing groups, which will each target a specific issue that is relevant to all sites.. The work will rely on each participant's own research activities with the aim of sharing experience (both successes and failures), exchanging datasets where relevant, and identifying the necessary developments of technologies and methodologies. In contrast to the activities of the twinning program, the focus groups will be open to many sites and research teams and focused on a single issue. European sites approached in task 6.2 will be invited to join.
Anticipated topics for the focus groups are: site characterisation, CO2 injection management, site monitoring strategy or relation with the local population. The final decision on the topics will be taken at the beginning of the project in accordance with the site owners'/operators' updated needs.
Activities will consist of webinars (no less than 8 webinars are planned during the project duration), preferably in cooperation with the European CCS Demonstration Project Network, and two workshops aligned with the CO2GeoNet Open Forums. These activities will be organised in close cooperation with Task 6.2 that will link ENOS to further European projects and activities).
BRGM will be responsible for this task and will facilitate exchanges in the groups as well as producing reports on the meetings and workshops. BGS will be responsible for sub-task 6.1.2. Representatives of the individual sites in the ENOS portfolio will be involved in this task. OGS will (with the external support of the Global CCS Institute, currently running the Secretariat of the European CCS Demonstration Project) organise of the webinars.
The activities of the Focus groups will be described in a report that will also include recommendations resulting from experience sharing (D6.9).

Impact
Enhancing experience sharing amongst pilot sites and field experiments worldwide and providing opportunities for research alignment will leverage research investments made at each of the different sites as well as in previous and current research projects. The activity will also increase the visibility of activities performed as part of ENOS and of the sites within the ENOS portfolio.

Task 6.2 European liaison and knowledge exchange (CO2GeoNet-GeoEcoMar, CGS, CO2GeoNet-TTUGI, CIUDEN, CO2GeoNet-IGME, BRGM, BGS, UNOTT, CO2GeoNet-UNIZG-RGNF)
Context
In addition to the international cooperation and exchange identified in Task 6.1, it is also important to establish and strengthen links between the ENOS sites and the European activities in the area of onshore storage. These include both the existing pilot storage sites and the association and networks active within this field.

Activity
Discussion and experience exchange with other onshore pilot and demonstration projects in Europe that are in various project lifecycle stages (planned, ongoing and completed – e.g., Ketzin, Lacq-Rousse, Heletz, CarbFix, Longyearbyen, GETICA CCS) will be strengthened or newly established in order to include these projects in the international cooperation organised by ENOS. In addition, ENOS will actively cooperate with the European CCS Demonstration Project Network, using the support of GCCSI. Hontomin TDP, the BGS Hydrothermal Laboratory, BGS Near Surface Gas Monitoring Facility and the Sulcis Fault Lab and OGS aircraft are all part of the European Carbon Dioxide Capture and Storage Laboratory Infrastructure (ECCSEL) and these links will be exploited by the partners of ENOS.
Cooperation with ECCSEL on support and development of CO2 storage pilots will be ensured through those partners (BGS, BRGM, CIUDEN, OGS, Sotacarbo, TNO) already active in ECCSEL and working in ENOS. Support for ETP ZEP on demonstrations will be fostered through active participation of ENOS project partners in ZEP activities, building on the success of the ZEP/CGS Europe 'State of play' report. ENOS will liaise with the EURELECTRIC CCS taskforce and with national CO2 Clubs existing in several countries across Europe.
ENOS partners will use the knowledge obtained through ENOS to contribute directly to the development of the EERA CCS JP research activities. This will be achieved through partner s' attendance at an EERA research workshop which

will review the state of the art and identify future European research priorities. In addition ENOS partners will produce a report for EERA summarising the conclusions of the discussions (D6.4).
ENOS will liaise with the Baltic Sea Region CCS network recently established by BASREC (Baltic Sea Region Energy Cooperation) to support cooperation and exchange of knowledge between ENOS project and regional CCS activities in the Baltic Sea Region as well as possible newly organised onshore pilots and some ongoing onshore EOR-CCS activities in the EU countries not participating in ENOS (Poland, Sweden, Latvia, Lithuania). A joint workshop will be organised in Tallinn.
All activities performed in Task 6.2 will be summarised in two periodic reports at the mid-term (D6.3) and at the end (D6.12) of the project.

Impact
Liaising with European projects and other activities is necessary in order to strengthen the position of ENOS-supported sites in the European CCS context, to share knowledge and experience within the European CCS community and to exchange achievements with other onshore storage sites in Europe. These outputs will inform European research priorities, via direct support to ECCSEL and the EERA CCS JP.

Task 6.3 Supporting new pilot and demonstration opportunities (CO2GeoNet-UNIZG-RGNF, BGS, CGS, CO2GeoNet-IGME, CO2GeoNet-TTUGI, CO2GeoNet-GeoEcoMar)
Context
Existing pilot and demonstration sites enhance confidence in the ability of geological formations to safely store CO2 on a regional basis and local demonstration of CCS technology will encourage further project development. So far, onshore storage has been tested and demonstrated only at a few pilot sites in Europe (i.e. Ketzin, Lacq-Rousse, and recently Hontomín), which is deemed insufficient. A ZEP/CGS Europe study identified several promising opportunities for possible onshore storage pilots across Europe, based on proposals by partners with 19 potential onshore locations for pilot projects. There was a limited assessment of the probability of these pilot sites moving forward and as the CCS landscape changes rapidly. This could now be updated and the assessment of the likelihood of these storage pilots moving forward enhanced by considering a wider range of factors including regional circumstances and potential impact, variability of geological settings, comparison with successful projects etc.

Activity
A study focusing on onshore pilot/demonstration project opportunities across Europe (D6.8) will be prepared, delivering on a diverse portfolio of geological settings (covered / not covered so far) and regions with little CCS activity to date. The study will identify factors that have helped lead to a successful pilot or demonstration site and look for other sites where there is a good chance that success could be replicated. The aim is to seek out areas where the geological setting and other technical factors (e.g. CO2 sources, infrastructures etc.) are similar to existing successful pilot projects in order to identify regions likely to be favourable for future pilot projects or regions with potential to scale up to demonstration scale. This task will use data from existing pilot sites, key recommendations from other research projects (inter alia EU GeoCapacity, SiteChar, RISCS, CO2CARE, etc.) and build on the CGS Europe 'State of Play of CCS' report and the CGS Europe/ZEP report on potential pilot projects in Europe. A catalogue of the most prospective candidates for second generation pilots will be developed for a few regions that offer the greatest potential. These regions will be selected to provide representative and concise case studies to illustrate the possibilities. Direct links will be established with the ECCSEL Research Infrastructure, to whom ENOS will provide a written recommendation on future opportunities for second generation pilots.

Impact
Task 6.3 will provide recommendations regarding future developments of onshore CO2 storage in Europe, including promising opportunities for future pilot/demo sites, and the identification of unused or underused geological settings in Europe with significant storage potential.

Task 6.4 Preparation of follow-up stages for ENOS pilot sites (CGS, UNOTT, BGS, CIUDEN, OGS, UNIROMA1, TNO, IRIS, CO2GeoNet-TTUGI, CO2GeoNet-UNIZG-RGNF, BGR, CO2GeoNet-GEOINZ, Sotacarbo, CO2GeoNet-GBA, SGIDS)
Context
Real-life experimental sites, even if of different scale all require high up-front investment. The value obtained for such investment should be maximised in time by ensuring that the sites will continue to operate and provide benefit to the scientific community and other CCS stakeholders after ENOS. To support the continuation of activities at the sites and maximize the value of their contribution to the development of onshore CO2 storage in Europe, ENOS will prepare internally reviewed plans for further development of the sites and their utilization.

Activity

An action plan for continuation of storage pilot projects and injection test sites in the ENOS portfolio will be prepared (D6.10). For sites that achieve more advanced stages of development during the project (Hontomín, Sulcis fault injection, GeoEnergy Test Bed), plans will be prepared to increase the value of the sites and the knowledge gained. Challenges, remaining after ENOS, will be identified and a set of recommendations will be established for future activities. For example, it is intended to expand the scope of the GeoEnergy Test Bed site to act as a research hub to draw CO2 storage researchers and industrial stakeholders together as a component of ECCSEL. Future planning to expand the scope of the site to satisfy these stakeholders will need to build on the knowledge gained during ENOS with input from the project stakeholder workshops. UNOTT and BGS will host an ENOS scoping workshop and monitoring technology demonstration at the GeoEnergy Test Bed site inviting consortium members to explore future opportunities for expanding and enhancing the site and its capabilities as a collaborative research facility.
For projects in early stage of development (e.g., LBr-1), items such as preparatory work for the storage permit (including the definition of lacking pieces of information and data), drilling plans, CO2 delivery, injection strategy etc. will be included.
For the Sulcis Fault Lab, after the deliberate CO2 injection and drilling of the deeper characterisation well (with national funding), supported by ENOS, the injection test area and infrastructure (injection and monitoring wells) will constitute a permanent Field Experimental Lab, able to host researchers after the end of ENOS, to test and calibrate monitoring systems (geochemical and geophysical), to verify models and to plan new injection test experiments.
The site development plans will also be reviewed by partners not directly involved in site activities to ensure an independent view and that the European dimension, complementarity and research potential of the pilot sites development is taken into account.
Impact The plans for further development of storage and injection test sites of the ENOS portfolio will be important for sustaining the impetus derived from ENOS. This will pave the way for further development of the sites and help the site owners to adjust their site-related plans according to the needs of the European and international context.

Task 6.5 Roadmap for upscaling identified synergies of CO2 storage with CO2 utilisation (TNO, CGS, IRIS, CO2GeoNet-GBA, SGIDS)
Context
To move CO2 storage and utilisation projects beyond the research and demonstration phase, business cases have to be identified and developed, which involve the exploration of additional factors beyond technical feasibility alone. Roadmaps can be used to identify individual engineering, economic, environmental, regulatory and societal factors that must be addressed to allow projects to move forward.

Activity
Roadmaps will be developed for both the CO2 EOR and CO2 Buffering concepts, which will include the technical, economic and regulatory outputs from WP4.
CO2-Buffering in the Dutch greenhouse sector to 2030
Sufficient warmth, light and enhanced CO2 levels in a greenhouse are essential for creating the optimal growing conditions for all commercial crops. The combustion of natural gas in combined heat and power (CHP) installations is the most common route to create such an environment. The majority of growers use purified exhaust streams from such installations as the primary source of CO2, which is also the primary source of CO2 emissions from the sector. Many stakeholders are looking to reduce the reliance on CHP installations, looking towards more sustainable sources of heat from geothermal installations and industrial waste heat. However, without access to secure and affordable CO2, CHP installations will continue to be used.
A Roadmap for CO2 re-use will cover the expected demand by greenhouses in the south-western part of the Netherlands to 2030. The roadmap (D6.7) will clearly outline the necessary technical and organisational milestones, expected duration, potential challenges and solutions associated with realising the CO2 buffering concept.
Towards a strategic development plan for CO2 EOR in the Vienna Basin
Leading from the exploratory work completed for the Czech LBr-1 CO2 EOR pilot site, an assessment will be made of the EOR potential in the oil fields of the Vienna Basin. Initial studies have been completed on using various techniques to maximise the production of individual mature oil fields of the Vienna Basin spread across Austria, the Czech Republic, and Slovakia, information has been published within European projects (Sliaupa 2013, EU Geocapacity 2008), and by commercial parties (Potsch 2004). From this information it is clear that potential exists for enhancing oil recovery in the region through CO2 injection, however commercial projects have yet to take place. A strategic, regional dialogue, involving both emitters, potential storage operators and governing bodies, on the potential for CO2 EOR and storage synergies can have considerable value for understanding the barriers and drivers for moving this concept forward.
The objective of this task is to explore the potential drivers and barriers to the development of CO2 EOR in the region of Austria, the Czech Republic, and Slovakia. Based on existing data, estimates will be made on both the economic and environmental benefits the developing a regional plan for accelerated deployment of CO2 EOR projects. Existing CO2 sources and transportation routes to specific EOR fields will be identified. Potential operators will be approached to

build an initial representation of the conditions necessary to realise a business case for a project in the region. This task will result in a report (D6.8) providing the foundations for a strategic development plan for CO2 EOR in the region.

References:
Šliaupa, S et al., 2013. CO2 storage potential of sedimentary basins of Slovakia, the Czech Republic, Poland and the Baltic States. Geological Quarterly, 2013, 57 (2): 219–232
EU GeoCapacity, 2008. Economic uses of CO2. WP3 Report, D22.
Potsch, K. 2004. Enhanced oil recovery of OMV in the Vienna Basin.

Impact
Both the Roadmap for the CO2 buffering project in the Netherlands, and the report on CO2 EOR potential in the Vienna Basin, are intended to raise awareness, stimulate dialogue and aid decision making both by businesses and policy makers, regarding the potential synergies of combining CO2 storage with other economic activities, both to the benefit of society and the environment. The reports will include consistent approaches to stakeholder and economic analysis, and the identification of engineering milestones for CO2 storage projects, which may be transferable to similar concepts in other regions.

Participation per Partner

Partner number and short name	WP6 effort
1 - BRGM	5.00
2 - BGR	1.00
3 - BGS	7.20
4 - CGS	17.00
6 - CIUDEN	8.00
10 - IRIS	3.50
12 - OGS	6.00
14 - SGIDS	5.00
16 - SOTACARBO	5.00
17 - TNO	8.00
18 - UNIROMA1	4.00
19 - UNOTT	6.00
20 - CO2GeoNet	0.00
TTUGI	5.90
UNIZG-RGNF	7.30
IGME	2.00
GEOINZ	1.00
GEOECOMAR	6.20
GBA	7.00
Total	105.10

List of deliverables

Deliverable Number[14]	Deliverable Title	Lead beneficiary	Type[15]	Dissemination level[16]	Due Date (in months)[17]
D6.1	Detailed plan of international collaboration activities	1 - BRGM	Report	Confidential, only for members of the consortium (including the Commission Services)	3
D6.2	1st report on Twinning Programme	1 - BRGM	Report	Confidential, only for members of the consortium (including the Commission Services)	25
D6.3	1st report on European links, liaison and knowledge exchange	20 - CO2GeoNet	Report	Public	25
D6.4	State-of-the-art report identifying current lessons learned and future research priorities for EERA	3 - BGS	Report	Public	40
D6.5	Summary report on activities of the Leakage simulation alliance	3 - BGS	Report	Public	42
D6.6	Roadmap for CO2-Buffering in the Dutch greenhouse sector to 2030	17 - TNO	Report	Public	42
D6.7	Towards a strategic development plan for CO2 EOR in the Vienna Basin	17 - TNO	Report	Public	42
D6.8	Study on new pilot and demonstration project opportunities in Europe	20 - CO2GeoNet	Report	Public	42
D6.9	Report on the focus group activities and recommendations	1 - BRGM	Report	Public	46
D6.10	Follow-up plan for continuation of ENOS pilot projects	4 - CGS	Report	Confidential, only for members of the consortium (including the Commission Services)	46
D6.11	2nd report on Twinning Programme	1 - BRGM	Report	Confidential, only for members of the consortium (including the Commission Services)	48

List of deliverables

Deliverable Number[14]	Deliverable Title	Lead beneficiary	Type[15]	Dissemination level[16]	Due Date (in months)[17]
D6.12	2nd report on European links, liaison and knowledge exchange	20 - CO2GeoNet	Report	Public	48

Description of deliverables

Task6.1
D6.1 Detailed plan of international collaboration activities (BRGM, M3)
D6.2 1st report on Twinning Programme (BRGM, M25)
D6.5 Summary report on activities of the Leakage simulation alliance (BGS, M42)
D6.9 Report on the focus group activities and recommendations (BRGM, M46)
D6.11 2nd report on Twinning Programme (BRGM, M48)

Task 6.2
D6.3 1st report on European links, liaison and knowledge exchange (CO2GeoNet-GeoEcoMar, M25)
D6.4 State-of-the-art report on current lessons learned and future research priorities for EERA (BGS, M40)
D6.12 2nd report on European links, liaison and knowledge exchange (CO2GeoNet-GeoEcoMar, M48)

Task 6.3
D6.8 Study on new pilot and demonstration project opportunities in Europe (CO2GeoNet-UNIZG-RGNF, M42)

Task 6.4
D6.10 Follow-up plan for continuation of ENOS pilot projects (CGS, M46)

Task 6.5
D6.6 Roadmap for CO2-Buffering in the Dutch greenhouse sector to 2030 (TNO, M42)
D6.7 Report: Towards a strategic development plan for CO2 EOR in the Vienna Basin (TNO, M42)

D6.1 : Detailed plan of international collaboration activities [3]

Task 6.1 Plans for international collaboration, with confirmed partners for the three sub tasks 6.1.1, 6.1.2, 6.1.3. It will include planned activities, travels, data exchanges.

D6.2 : 1st report on Twinning Programme [25]

Task 6.1.1 Report presenting the site twinning activities taken place in the first half of the project

D6.3 : 1st report on European links, liaison and knowledge exchange [25]

Task 5.2 - The report will present the international cooperation and knowledge exchange activities undertaken within the ENOS project during the first project period (months 0-24).

D6.4 : State-of-the-art report identifying current lessons learned and future research priorities for EERA [40]

Task 6.2 - ENOS partners will attend an EERA research workshop to review the state of the art and identify future European research priorities. ENOS partners will produce a report (coordinated by BGS) for EERA summarising the conclusions of the discussions (D6.4).

D6.5 : Summary report on activities of the Leakage simulation alliance [42]

Task 6.1.2 The activities of the leakage simulation alliance will be summarised in a report (D6.5). This report will describe activities such as site visits, workshops, data exchange and joint reports/publications to highlight new and strengthened collaboration achieved through ENOS

D6.6 : Roadmap for CO2-Buffering in the Dutch greenhouse sector to 2030 [42]

The report describes a roadmap for developing CO2 buffering in the Dutch greenhouse sector up to 2030 (part of Task 6.5 in WP6). The roadmap will clearly outline the necessary technical and organisational milestones, expected duration, potential challenges and solutions associated with realising the CO2 buffering concept.

D6.7 : Towards a strategic development plan for CO2 EOR in the Vienna Basin [42]

The report describes a strategic implementation plan for CO2 EOR in the Vienna Basin (part of Task 6.5 in WP6). The potential drivers and barriers to the development of CO2 EOR in the region of Austria, the Czech Republic, and

Slovakia will be evaluated. Based on existing data, estimates will be made on both the economic and environmental benefits for the region.

D6.8 : Study on new pilot and demonstration project opportunities in Europe [42]

Task 6.3 - The study will contain description of a diverse portfolio of geological settings and EU regions with little CCS activity to date. Emphasis will be given to factors that have lead to a successful pilot or demonstration sites elsewhere, trying to explain why and where that success could be replicated. The most important factors are the geological setting and surface conditions such as vicinity/properties of CO2 sources, infrastructure etc.

D6.9 : Report on the focus group activities and recommendations [46]

Task 6.1.3 Report presenting the outcomes of the different focus groups and the resulting recommendations for the future. The report will include the presentation of the different activities conducted during the project. A general conclusion of task 6.1.3 will also be included.

D6.10 : Follow-up plan for continuation of ENOS pilot projects [46]

Task 6.4 Plans for further development of storage and injection test sites of the ENOS portfolio - they will be important for sustaining the impetus derived from ENOS, paving the way for further development of the sites and helping the site owners to adjust their site-related plans according to the needs of the European and international context.

D6.11 : 2nd report on Twinning Programme [48]

Task 6.1.1 Report presenting the site twinning activities taken place in the second half of the project

D6.12 : 2nd report on European links, liaison and knowledge exchange [48]

Task 5.2 The report will present the international cooperation and knowledge exchange activities undertaken within the ENOS project during the second project period (months 24 - 48).

Schedule of relevant Milestones

Milestone number[18]	Milestone title	Lead beneficiary	Due Date (in months)	Means of verification
MS4	International collaboration input to Work programme planned	1 - BRGM	3	D6.1
MS13	Input from End-User Committee 1	10 - IRIS	11	Key outcomes from meeting
MS23	Input from End-User Committee 2	10 - IRIS	23	Key outcomes from meeting
MS32	Input from End-User Committee 3	10 - IRIS	35	Key outcomes from meeting
MS34	Advisory board input 2	1 - BRGM	36	report and note on impact on ENOS
MS35	End of all field activity	1 - BRGM	36	End of CO2 injection and ENOS data acquisition
MS36	Input from End-User Committee 4	10 - IRIS	47	Key outcomes from meeting

Work package number [9]	WP7	Lead beneficiary [10]	10 - IRIS
Work package title	Spreading innovation		
Start month	1	End month	48

Objectives

WP7 will communicate R&D results between work packages, present the ENOS project results and deliver TRL improvements externally to the R&D, engineering, business, operational industrial and regulatory communities. This WP will enhance the results of the project and maximize its impact by bringing the technology towards the market through publications, best practices and patents, as appropriate. Furthermore, WP7 will help deliver cross-disciplinary integration of the research and researchers. The core group of WP7 will be the Scientific Editor Committee that will gather, analyse, and steward the knowledge developed in WPs 1-5 by promoting collaboration, encouraging and supervising publication, aiding in organising workshops and knowledge exchange with research industrial and policy making communities. One of the key instruments will be a plan for dissemination and exploitation of the innovative ENOS results (task 7.3.1). The Scientific Editor committee will be also responsible for contents of the ENOS newsletter (task 7.3.2) and website. The Scientific Editors will work in close cooperation with WP leaders and will also be responsible for bringing attention to important breakthroughs and updates from WPs 1-5 to WP 6 and -8.

Key objectives are:
• To facilitate research integration and dissemination across the WPs
• To author best practice guidance documents specifically aimed at industrial sector and policy makers to favour market uptake of the research results
• To promote exploitation of project results among the research community

Description of work and role of partners

WP7 - Spreading innovation [Months: 1-48]
IRIS , BRGM, BGR, BGS, CGS, CIEMAT, CIUDEN , flodim, GGR, IDIL, NHAZCA, OGS, SGIDS, SILIXA, SOTACARBO, TNO, UNIROMA1, UNOTT, CO2GeoNet
Task 7.1 Research integration (IRIS, all partners)
The task objective is to facilitate and boost cross-disciplinary collaboration and integration of results between WPs 1-5, by establishing board of Scientific Editors and providing a reliable and convenient web platform.

7.1.1 Knowledge integration workshops (IRIS, all partners)
ENOS will tackle different field of science covering a broad spectrum of geosciences metrology, economics and social sciences. Outcomes from each field need to be seen in light of each other. Only through such integration can CO2 storage gain the required level of confidence from all stakeholders and progress to implementation at large scale. Integration of the ENOS research will be achieved through Knowledge Integration Workshops, that will address cross cutting issues and leave ample time for discussion and group work. The key goal of the workshops is to allow participating ENOS researchers to reflect on the implications of their results for storage as a whole, which will support the development of best practice documents and other communications outputs. The Workshops will be organized at least annually in conjunction with other events. The work in this task will serve as a bridge between WPs 1-5 and provide ground material for WP 6 and WP 8 by defining cross-cutting and common issues in the storage lifecycle, e.g. risk management, economics. These will be defined during the first year of the project and will contribute both to the identification of the dissemination materials and to the creation of fit-for-purpose best practice documents.

7.1.2 Web site and Knowledge-Sharing Platform (OGS)
The web site and knowledge-sharing platform will be established within the first 6 months. The key goals for the website are to provide i) a collaborative internal area open only to project partners and ii) a public area . The website will be based on the technologies developed by OGS and used for the establishedCO2GeoNet website. Easy-to-use technology for tracking the project status, exchanging draft documents and for publishing results will facilitate information sharing and collaboration across the whole ENOS team. The open access area of the website will provide information for interested parties outside the project, such as industry, decision makers and regulators. The ENOS website will be easy to navigate and be useful for both scientifically-literate people as well as the interested general public.
Sub task 7.1.2 will persist for the whole ENOS project duration and comprises technical support and maintenance as well as technology updates of the website.

Impact

This task should provide facilities in the form of website and workshops in order to facilitate, information flow and co-operation between the ENOS partners across WPs 1-5. The impact should be in increased knowledge building, aligned research efforts and better handling of project and R&D bottlenecks.

Task 7.2 Best practices (CO2GeoNet-GEOINZ, all partners)
Objective:
A significant amount of data and knowledge has been produced across the CC(U)S community in different countries. This knowledge covers most of the CC(U)S value chain, however, rather limited efforts to optimize, connect and standardise the data and approaches have been made so far. The key objective of this task is to create a set of best practices- and guidance documents based on the research findings in WPs 1-5. The best practices and guidelines should form a set of short, down to the point documents aimed at particular target groups, such as decision makers, risk managers, financial officers and regulators in order to streamline the development of storage projects as well as to reduce costs associated with planning and design.
Planned activities: The Scientific Editors together with WP leaders shall identify technologies reaching TRL 6 and summarize the essential results ready to be included in the best practice documents. The best practices would be created based on the detailed technical guidance documents from WPs 1-5. The four best practices to be produced are short and focused documents aimed at Research and Development, Business and Industry, Government and Regulators and NGOs and General Public communities. The aim is to design and develop a useful and informative document for each target group that would boost market uptake and brief each of the target groups in best available solutions and practices through the whole CCUS value chain. Representatives from target groups will be invited to form an End-User Committee to provide input and feed-back to these guidance documents. The End-User Committee meetings will be held at least on an annual basis and will provide a platform for open cooperation and integration between research, industrial and regulatory actors.

Impact:
The current state-of-the-art data and the advancements achieved in WPs 1-5 will be collated and analysed and the increase in the TRL-level will be evaluated. A set of best practices will be created. The resulting document package will help to reduce the costs, to confine uncertainties and to streamline the development of CCS projects. Collaboration with the end-user committee which includes representatives from industry actors and regulators shall draw together the research and industry sectors to ensure WP7 outputs are suitable for targeted end users.

Task 7.3 Promoting exploitation of ENOS results (TNO, CO2GeoNet-TTUGI, CGS, IRIS, CO2GeoNet-GeoEcoMar, CO2GeoNet-GEOINZ, CIUDEN)
Objectives:
The task objective is to develop and update an innovation management strategy with plans for dissemination, exploitation and communication of ENOS results and actions, the first drafts of which have been outlined in Section 2.2. The planning will include goals and criteria for publications and patents and identification of target groups and their primary interests. Coordination of workshops and forums spanning across ENOS organised for outside communities will also be part of the task 7.3. Moreover, preparation, publication and distribution of ENOS newsletters are planned. Task 7.3 comprises the following sub-tasks.
ENOS will contribute, upon invitation by the INEA, to common information and dissemination activities to increase the visibility and synergies between H2020 supported actions.

Task 7.3.1 Plans for dissemination and exploitation of results
This subtask will coordinate, update and follow-up the dissemination and exploitation of the project results, presented in Section 2.2. The Scientific Editors together with the work package leaders will be responsible for identifying and facilitating the opportunities for bringing to the market the main outcomes and messages of the project, through publications and communications, contacts with end users and patents where relevant. The plan for dissemination and exploitation of results will include an end user communication plan with events and conferences to be organised, strategic external events to be attended, a publication strategy and IPR management for near market results. The plan will be regularly updated during the project, i.e. at the start of the project, mid-term and in the final stage of the project.

Task 7.3.2 Scientific dissemination
Every publication and conference-participation related to ENOS activities will be coordinated and supported by the scientific editors and WP leaders through WP7. Scientific editors will also bring attention to material that is ready for publication and encourage dissemination of results. Participation in large strategic events will be coordinated and partially financed through WP7. The key event organised by ENOS for presenting its results will be the Open Forum annually hosted by CO2GeoNet in Venice. Workshops and/or training sessions spanning across WPs would be organized at least annually in conjunction with the Open Forum, to meet the dissemination, engagement and education aims of ENOS.

Task 7.3.3 Promoting utilisation of ENOS results
An annual newsletter will promote ENOS' progress among the technical community but also to policy makers, regulators and the public. The newsletter will be made available in both an electronic format on ENOS website and in printed form to be distributed at special events. All ENOS members participating in scientific and general meetings as well as professional and social media will be asked to advertise, promote and distribute the project newsletter. Newsletters editor CO2GeoNet-TTUGI will have the editorial responsibility for the newsletter and the publishing commitment. The contents, structure and format of the newsletter will be developed jointly with the Scientific Editors.
Starting from the plans built in Subtask 7.3.1, this subtask will generate and provide information to the ENOS partners in order to facilitate knowledge transfer to local target groups. A seminar format (including a platform for webinars) will be designed in order to address industry, regulators and operators and allow to follow up on their response.
The webinars should also allow engagement of a broader audience by providing a simple and cost-free (no travels, no participation fee) platform for knowledge sharing across Europe (including SMEs) and to the rest of the world.
CO2GeoNet-TTUGI is responsible for the Task 7.3.3

Impact
Aligned dissemination of results and tighter interaction with target groups should allow the development of stronger and consistent messages and, boost market uptake and utilisation of ENOS results beyond the involved ENOS partners.
Interaction with other WPs: WP7 will be very strongly linked with all other WPs as it will gather and integrate results from WP1-5 and help define the content of the activities in WP6 and 8.

Participation per Partner

Partner number and short name	WP7 effort
1 - BRGM	6.00
2 - BGR	3.00
3 - BGS	5.40
4 - CGS	15.00
5 - CIEMAT	1.00
6 - CIUDEN	3.00
7 - flodim	1.00
8 - GGR	0.50
9 - IDIL	1.00
10 - IRIS	15.20
11 - NHAZCA	1.00
12 - OGS	14.00
14 - SGIDS	1.00
15 - SILIXA	1.00
16 - SOTACARBO	1.00
17 - TNO	10.00
18 - UNIROMA1	4.00
19 - UNOTT	1.00
20 - CO2GeoNet	0.00
GSB-RBINS	1.00
TTUGI	11.30
UNIZG-RGNF	1.00

Partner number and short name	WP7 effort
HWU	1.00
IGME	3.40
GEUS	3.00
GEOINZ	7.00
GEOECOMAR	7.30
METU	1.00
GBA	3.00
Total	123.10

List of deliverables

Deliverable Number[14]	Deliverable Title	Lead beneficiary	Type[15]	Dissemination level[16]	Due Date (in months)[17]
D7.1	Plan for dissemination and exploitation of results	17 - TNO	Report	Confidential, only for members of the consortium (including the Commission Services)	6
D7.2	Web-platform	12 - OGS	Websites, patents filling, etc.	Public	7
D7.3	Results of OpenForum n °1	12 - OGS	Websites, patents filling, etc.	Public	10
D7.4	Newsletter 1	20 - CO2GeoNet	Websites, patents filling, etc.	Public	10
D7.5	Annual publication summary report n°1	10 - IRIS	Report	Public	13
D7.6	Results of OpenForum n °2	12 - OGS	Websites, patents filling, etc.	Public	22
D7.7	Short note summarizing knowledge integration workshop n°1	10 - IRIS	Report	Public	22
D7.8	Newsletter 2	20 - CO2GeoNet	Websites, patents filling, etc.	Public	22
D7.9	Updated plan for dissemination and exploitation of results	17 - TNO	Report	Confidential, only for members of the consortium (including the Commission Services)	25

List of deliverables

Deliverable Number[14]	Deliverable Title	Lead beneficiary	Type[15]	Dissemination level[16]	Due Date (in months)[17]
D7.10	Annual publication summary report n°2	10 - IRIS	Report	Public	25
D7.11	Results of OpenForum n °3	12 - OGS	Websites, patents filling, etc.	Public	34
D7.12	Short note summarizing knowledge integration workshop n°2	10 - IRIS	Report	Public	34
D7.13	Newsletter 3	20 - CO2GeoNet	Websites, patents filling, etc.	Public	34
D7.14	Best practice documents	20 - CO2GeoNet	Report	Public	46
D7.15	Annual publication summary report n°3	10 - IRIS	Report	Public	40
D7.16	Short note summarizing knowledge integration workshop n°3	10 - IRIS	Report	Public	45
D7.17	Newsletter 4	20 - CO2GeoNet	Websites, patents filling, etc.	Public	43
D7.18	Final plan for exploitation of results	17 - TNO	Report	Public	45

Description of deliverables

Task 7.1
D7.2 Web-platform (OGS, Month 7)
D7.7,D7.12, D7.16 Short notes summarizing knowledge integration workshop (Month22,34, 45)

Task 7.2
D7.14 Best practice documents (CO2GeoNet- GEOINZ, Month 46)

Task 7.3
D7.1 Plan for dissemination and exploitation of results (TNO, Month 6)
D7.9 Updated plan for dissemination and exploitation of results (TNO, Month 25)
D7.4, D7.8, D7.13 Newsletters (CO2geoNet-TTUGI, Month 10, 22, 34)
D7.5, D7.10, D7.15 Annual publication summary report (IRIS, Month 13, 25, 40)
D7.3, D7.6, D7.11 Results of Open Forum (OGS, Month 10, 22, 34)
D7.17 Final plan for exploitation of results (TNO, Month 45)

D7.1 : Plan for dissemination and exploitation of results [6]

The plan for dissemination and exploitation of results describes the actions to bring to the market the main outcomes and messages of the project, through publications and communications, contacts with end users and patents where relevant. The plan will include an end user communication plan with events and conferences to be organised, strategic external events to be attended, a publication strategy and IPR management for near market results (Task 7.3.1 in WP7)

D7.2 : Web-platform [7]

The web platform including both internal (aimed at data and knowledge exchange for project partners) and external (aimed at dessimination and general public) should be established and filled in with general project information

D7.3 : Results of OpenForum n°1 [10]

The report from the 2016 open forum would be made available on specialised and ENOS web site as soon as the web platform is establishes.

D7.4 : Newsletter 1 [10]

An annual newsletter will promote ENOS' progress (task 7.3.3) among the technical community, policy makers, regulators and the public. The newsletter will be made available in both an electronic format on ENOS website and in printed form to be distributed at special events. The contents, structure and format of the newsletter will be developed by the newsletters editor CO2GeoNet-TTUGI jointly with the Scientific Editors.

D7.5 : Annual publication summary report n°1 [13]

Task 7.3 A report summarising all publications by the project partners would be prepared and delivered every 12 months starting from the project start up date. The report should include references and a short summary of all publications. The report would be publically available on the ENOS project web site.

D7.6 : Results of OpenForum n°2 [22]

This deliverable is related to task T 7.3.2. The most important results of the annual Open Forum will be reported, distributed as a pdf file to all the Open Forum attendees and made available through the project website in the form of an interactive e-brochure.

D7.7 : Short note summarizing knowledge integration workshop n°1 [22]

Each knowledge integration workshop would be summirised with a short note presenting main theme, workshop participants and key outcomes. The workshops summary notes would be made available on the project website.

D7.8 : Newsletter 2 [22]

An annual newsletter will promote ENOS' progress (task 7.3.3) among the technical community, policy makers, regulators and the public. The newsletter will be made available in both an electronic format on ENOS website and in printed form to be distributed at special events. The contents, structure and format of the newsletter will be developed by the newsletters editor CO2GeoNet-TTUGI jointly with the Scientific Editors.

D7.9 : Updated plan for dissemination and exploitation of results [25]

The plan for dissemination and exploitation of results will be updated on the basis of feedback from project partners and external stakeholders (Task 7.3.1 in WP7).

D7.10 : Annual publication summary report n°2 [25]

Task 7.3 A report summarising all publications by the project partners would be prepared and delivered every 12 months starting from the project start up date. The report should include references and a short summary of all publications. The report would be publically available on the ENOS project web site.

D7.11 : Results of OpenForum n°3 [34]

Task 8.3 - Report on the preparation for university cooperation to set the basis for a coordinated Master and post-graduate Master programmes on CO2 storage (development of a network of institutions and laboratories, and educational modules/lectures)

D7.12 : Short note summarizing knowledge integration workshop n°2 [34]

Each knowledge integration workshop would be summirised with a short note presenting main theme, workshop participants and key outcomes. The workshops summary notes would be made available on the project website.

D7.13 : Newsletter 3 [34]

An annual newsletter will promote ENOS' progress (task 7.3.3) among the technical community, policy makers, regulators and the public. The newsletter will be made available in both an electronic format on ENOS website and in printed form to be distributed at special events. The contents, structure and format of the newsletter will be developed by the newsletters editor CO2GeoNet-TTUGI jointly with the Scientific Editors.

D7.14 : Best practice documents [46]

Task 7.2 Integration of research outcomes from WPs1-5 and set-up of short, down to the point documents aimed at particular target groups in order to streamline the developments of the project

D7.15 : Annual publication summary report n°3 [40]

Task 7.3 A report summarising all publications by the project partners would be prepared and delivered every 12 months starting from the project start up date. The report should include references and a short summary of all publications. The report would be publically available on the ENOS project web site.

D7.16 : Short note summarizing knowledge integration workshop n°3 [45]

Each knowledge integration workshop would be summirised with a short note presenting main theme, workshop participants and key outcomes. The workshops summary notes would be made available on the project website.

D7.17 : Newsletter 4 [43]

An annual newsletter will promote ENOS' progress (task 7.3.3) among the technical community, policy makers, regulators and the public. The newsletter will be made available in both an electronic format on ENOS website and in printed form to be distributed at special events. The contents, structure and format of the newsletter will be developed by the newsletters editor CO2GeoNet-TTUGI jointly with the Scientific Editors.

D7.18 : Final plan for exploitation of results [45]

The final update of the plan for dissemination and exploitation of ENOS results will focus on follow-up activities after the end of the project, based on the main outcomes and messages from the project (Task 7.3.1 in WP7).

Schedule of relevant Milestones

Milestone number[18]	**Milestone title**	**Lead beneficiary**	**Due Date (in months)**	**Means of verification**
MS2	Establishment of scientific editor committee	10 - IRIS	3	First meeting of Scientific Editor Committee
MS6	update of plan for dissemination and exploitation of results	10 - IRIS	7	Dissemination plan delivered to all partners
MS10	Establishing of the web-platform	12 - OGS	7	Web-site available for ENOS partners and general public
MS13	Input from End-User Committee 1	10 - IRIS	11	Key outcomes from meeting
MS23	Input from End-User Committee 2	10 - IRIS	23	Key outcomes from meeting
MS32	Input from End-User Committee 3	10 - IRIS	35	Key outcomes from meeting
MS34	Advisory board input 2	1 - BRGM	36	report and note on impact on ENOS
MS35	End of all field activity	1 - BRGM	36	End of CO2 injection and ENOS data acquisition
MS36	Input from End-User Committee 4	10 - IRIS	47	Key outcomes from meeting

Work package number [9]	WP8	Lead beneficiary [10]	20 - CO2GeoNet
Work package title	Promoting CCS through Training and education		
Start month	1	End month	48

Objectives

In WP8, ENOS will address the need for training of young scientists to build the skill-base necessary for large scale development of CO2 storage in Europe. The objective of WP8 is to provide the upcoming generation of scientists with up-to-date CCS skills and therefore to support objectives of the SET-Plan on European Energy Education and Training Initiative (2012). Valuable input will also be provided by WP5 on communication. In particular WP8 will aim to:
- Develop intensive training weeks, for young scientists, dedicated to Onshore CO2 geological storage and the implementation of the EU- Directive and will be based on latest research results and real-life experience.
- Build awareness on climate change and opportunities for mitigation action utilising CCS through building e-learning courses
- Initiate a university cooperation on CO2 storage education and a coordinated Master and post-graduate Master programmes through the development of a network of institutions and laboratories, and the development of educational modules
- Provide short courses for journalists and media to raise awareness on CCS and enhance communication between scientists and journalists.

Description of work and role of partners

WP8 - Promoting CCS through Training and education [Months: 1-48]
CO2GeoNet, BRGM, BGR, BGS, CGS, CIUDEN , OGS, TNO, UNIROMA1, UNOTT
Task 8.1 Education and training for the European research community (CO2GeoNet-GEUS, BRGM, BGS, CGS, CIUDEN, UNIROMA1 and CO2GeoNet-GeoEcoMar)
Context:
Five successful CCS schools were held during the COACH and CGS Europe projects giving a well-established concept to build on. Furthermore CO2GeoNet was involved in the organisation of and presented at previous IEAGHG summer schools and the EAGE European lecture tour.
The purpose of the CGS Europe Spring School on CO2 Geological Storage was to offer an advanced course on geological storage of carbon dioxide, allowing for knowledge sharing and learning about near zero-emission power generation delivered by CGS Europe and CO2GeoNet researchers and scientists. The evaluations of the two sessions held were very positive and showed that there is a high level of satisfaction with the content, and coherency of the sessions. It is proposed that this success should be captured and continued by the development of topical CO2 storage schools.

Description of work:
Topical CO2 storage Schools will be prepared and organized (i.e. one week intensive schools for young researchers (MSc and PhD students, post-graduate students, early-career researchers). The CO2 storage school course material will be further developed and updated with the most recent results from the storage pilots on site assessment, characterisation and risk management. The preparation of the courses will take advantage of the interaction between project partners and the cross-disciplinary environment in ENOS.
Three intensive schools on CO2 Geological storage are planned for countries with planned storage sites used by the ENOS project (Czech Republic, Italy and Spain). Each school will cover 7 days of lectures and exercises and will target young researchers. The overall objective is to communicate knowledge and understanding of CO2 geological storage from real-life experience at ENOS pilot sites including monitoring, modelling and verification (and an introduction to capture and transport for context)in order to enthuse and engage the next generation of scientists.

Impact:
Promoting CCS by teaching real-life experience from the ENOS storage sites will foster interest in the upcoming generation, fill the expected skill gap identified by the SET-plan and initiate knowledge transfer and capacity building, needed for the widespread deployment of the technology. In addition, the schools and lecture tours will help to create international networking opportunities to the next generation of scientists.

Task 8.2 Developing and providing an e-learning course (BGR, BGS, CGS, CO2GeoNet-GeoEcoMar, OGS, CO2GeoNet-GEUS, CO2GeoNet-HWU, CO2GeoNet-TTUGI, CO2GeoNet-UNIZG-RGNF, UNOTT, UNIROMA1)
Context:

E-learning and blended learning are common, up-to-date education tools used at modern universities. A variety of tools and platforms are available for these purposes. E-learning is a flexible and convenient educational method, providing a wider community of users with learning materials. It can be accessed at any time and any place allowing users to learn at their own pace. ENOS will provide and promote multi-media information and e-lectures on the web-site. The utilisation of e-learning and training for the broader community will help to grow public awareness on climate change and mitigation action utilising CCS.

Description of work:
WP8 will organise e-learning: internet based training on CCS, reaching out to a broad audience. Therefore, ENOS will develop 10 e-lectures on various aspects of CCS , containing generic knowledge (aimed at the general public) and as well specific technical knowledge on CO2 storage , based on state-of-the-art understanding from comprehensive ongoing R&D efforts (aimed at students or stakeholders).
The 10 e-lectures will be grouped into three e-learning series covering the following topics:
- Climate change and importance of CCS technology for decarbonisation of energy and industry
- Geosciences applied to geological storage of CO2
- Regulatory and social aspects of CCS technology
Each e-learning series will be published as an e-book.
The planned activities of this task are:
a) internal workshop for the development of a curriculum
b) agreement on e-learning tools, platform and on common design and layout templates
c) preparation of lecture material
d) internal workshop for first presentation and discussion of lecture drafts
e) improvements and adaptations of e-lectures
f) internal workshop for final discussions of e-lectures
g) publication of e-lectures/e-books on the project web-site or/and a suitable external platform

Impact:
E-learning will provide training and dissemination of the cutting edge research results to a much wider audience. The specific technical content of the e-lectures will contribute to the dissemination of ENOS research results while the generic content will help raising public awareness on CCS.

Task 8.3 CCS educational programme (UNIROMA1, CO2GeoNet-GEUS, CO2GeoNet-HWU, CO2GeoNet-TTUGI, CO2GeoNet-UNIZG-RGNF, UNOTT)
Context:
A non-exhaustive mapping of EU universities, research centres and laboratories with expertise and competences in CCS was collected in the SET Plan Energy Education & Training Report Carbon Capture and Storage, assessment report (2012) and a list of courses covering the CCS chain was compiled. The outcome showed needs and highlighted possible gaps in E&T in the CCS chain. If Europe is to deploy CCS, the manpower needed for storage (site characterisation + monitoring) is slightly higher than required for capture whereas the needs are about equal for the rest of the World. However, in the next 15 years, the need in manpower in Europe will be much higher for storage than for capture. Degree courses including CO2 storage study are therefore necessary to support long term deployment. ENOS will foster such capacity building, by developing cooperation between participating universities.
Some universities in Europe already have a programme for harmonising higher education, establishing international curricula or for completion of the Double Degree requirements (120 ECTS), where two separate diplomas are conferred to the student according to the local regulations. Other universities are part of an international group called ‘Universitas 21,’ where they exchange students on their undergraduate programmes for entire semesters, offering the chance to study abroad. UNIROMA1 and UNOTT are already partner in the Erasmus Mundus Program, which supports teaching activities shared for a total of 120 ECTS over a two year course. Other exchange programmes are already active between the University partners in ENOS, which can facilitate the the transfer of grades from the host institute to the home institute.

Description of work:
The internationalization of higher education as well as the international mobility of students, contributes to the development of a European generation which share needs and objectives. University networks, supported by research institutes and the other partners of ENOS will build a framework for a Master-level course that specifically addresses CO2 storage practise and techniques, starting from site characterization to monitoring techniques, in order to produce a new professional training, specifically preparing to manage CCS techniques and solve specific problems. Existing schemes, programmes and curricula in the courses given by university partner will be improved and focused on CCS activities, following the industry needs and, while at the same time retaining the necessary broad knowledge basis to

offer flexible curricula responsive to the market needs of the low carbon economy. This task will focus on education for the future and will provide a plan to meet the needs and fill the gaps within CCS Education and Training in Europe in order to support the objectives of the SET-Plan on European Energy Education and Training Initiative (2012). During the first 12 months, a plan for joint MSc and PhD programme will be designed. A possible framework for such programme will be investigated as well as the different role of ENOS partners, i.e. the Universities, institutions and industry. Led by the university partners, the ENOS project will prepare a possible structure.
For the following 24 months, 5 students, one in each of the partners CO2GeoNet-HWU, CO2GeoNet-TTUGI, CO2GeoNet-UNIZG-RGNF, UNOTT, UNIROMA1 shall be offered support to attend courses at the other partner institutes. At the end of the project an evaluation report on the experience of the students and institutes to ensure lessons learned will be available to support future activities.

Impact:
This task aims to enable long term impacts from ENOS by fostering enhanced collaboration between universities at the forefront of CCS research and by providing the basis for sound CO2 storage education for the upcoming generation of scientists

Task 8.4 Raising awareness by training workshops for journalists and media (CO2GeoNet-IGME, BRGM, BGS, CGS, CIUDEN, CO2GeoNet-GEOINZ, TNO, UNOTT, UNIROMA1)
Context:
Interaction with the media is regarded as a major channel for effective dissemination to the general public and an effective way of promoting CCS. Scientific matters can however be difficult to communicate, and the media has a role to clear misconceptions and provide impartial information. During the CGS Europe project period, focus on organisation of opportunities for direct interaction between researchers and journalists resulted in a more in-depth learning about the technology and an improved communication between researchers and journalists. Other key events were the CO2GeoNet Open Forum and workshops with science journalists. The participation of science journalists to events such as the annual CO2GeoNet Open Forum was an excellent opportunity for supporting a thorough understanding of the technology, and the journalists had the opportunity of information exchange with some of the most prominent researchers in the field and thus access to verified scientific information.

Description of work:
The ENOS project will continue the action that was started by the CGS Europe project and further develop interaction with media through direct interaction with science journalists as well as local journalists near the project pilot sites (Italy, Czech Republic, Spain). Direct exchange with media professionals and press releases can be the best channel for the dissemination of complex technical and scientific knowledge, such as the multidisciplinary research area of the geological storage of CO2.
Participation of science journalists to events planned in connection with the annual CO2GeoNet Open Forum, where the latest research developments are presented, will be an excellent opportunity to promote CCS by providing an understanding of the technology, greater than what can be achieved through reading documents or internet resources.
In the backyard of the pilot projects, i.e. in the local community, WP8 in coordination with WP5 will arrange events, where journalists and targeted local stakeholders will have the opportunity for face-to-face exchanges with some of the most prominent researchers in the field, offering accurate, cutting edge and direct access to verified scientific information. In this context, important issues to be communicated are safety, monitoring and site management. Activities will be co-organised with European Union of Science Journalists' Associations, CSLF and IEAGH whenever possible.

Impact:
By creating a lasting relationship with journalists and supporting in depth understanding of the CO2 geological storage technology, ENOS will participate in the raising awareness on CCS. This will also enable debates of CCS on a sound scientific basis.
Interaction with other WPs WP8 will benefit from the knowledge integration and results exploitation plan developed in WP7 to identify topics that should be included in the different training activities and in the interaction with the media. Particular interaction will be with WP5 coordination with local population, where communication activities towards the general public will also be undertaken.

Participation per Partner

Partner number and short name	WP8 effort
1 - BRGM	2.50

Partner number and short name	WP8 effort
2 - BGR	3.00
3 - BGS	2.80
4 - CGS	3.00
6 - CIUDEN	2.00
12 - OGS	1.00
17 - TNO	1.00
18 - UNIROMA1	5.50
19 - UNOTT	3.50
20 - CO2GeoNet	0.00
TTUGI	3.80
UNIZG-RGNF	3.20
HWU	3.30
IGME	4.20
GEUS	8.00
GEOINZ	1.00
GEOECOMAR	3.00
Total	50.80

List of deliverables

Deliverable Number[14]	Deliverable Title	Lead beneficiary	Type[15]	Dissemination level[16]	Due Date (in months)[17]
D8.1	E-book: Climate change and importance of CCS technology for decarbonisation of energy and industry	2 - BGR	Websites, patents filling, etc.	Public	10
D8.2	Joint education activities – Report 1, including outcome of internal workshop for the development of the joint curriculum	18 - UNIROMA1	Report	Confidential, only for members of the consortium (including the Commission Services)	10
D8.3	Report on awareness raising course for journalists workshop and interactions with media – months 1-12	20 - CO2GeoNet	Report	Public	13
D8.4	E-book: Geoscience applied to geological storage of CO2	2 - BGR	Websites, patents filling, etc.	Public	14

List of deliverables

Deliverable Number[14]	Deliverable Title	Lead beneficiary	Type[15]	Dissemination level[16]	Due Date (in months)[17]
D8.5	ENOS Spring School 1 on CO2 storage	20 - CO2GeoNet	Websites, patents filling, etc.	Public	21
D8.6	E-book: Regulatory and social aspects of CCS technology	2 - BGR	Websites, patents filling, etc.	Public	22
D8.7	Report on awareness raising course for journalists workshop and interactions with media – months 13-24	20 - CO2GeoNet	Report	Public	25
D8.8	ENOS Spring School 2 on CO2 storage	20 - CO2GeoNet	Websites, patents filling, etc.	Public	33
D8.9	Report on awareness raising course for journalists workshop and interactions with media – months 25-36	20 - CO2GeoNet	Report	Public	37
D8.10	Evaluation of joint Master and post-graduate Master educational programme based on first experience	18 - UNIROMA1	Report	Public	37
D8.11	Outcome of building and providing an e-learning course	2 - BGR	Report	Public	38
D8.12	Outcome of WP8 - Promoting CCS through Training and education	20 - CO2GeoNet	Report	Public	45
D8.13	ENOS Spring School 3 on CO2 storage	20 - CO2GeoNet	Websites, patents filling, etc.	Public	45
D8.14	Report on interactions with media and journalist final report 37-45	20 - CO2GeoNet	Report	Public	45

Description of deliverables

Task8.1
D8.5, D8.8 D8.13 reports on each ENOS Schools CO2GeoNet-GEUS, M21,33,45

Task 8.2
D8.1 - E-book: Climate change and importance of CCS technology for decarbonisation of energy and industry, BGR (M10)
D8.4 -E-book: Geoscience applied to geological storage of CO2, BGR, (M14)
D8.6 - E-book: Regulatory and social aspects of CCS technology , BGR (M22)
D8.11 - Outcome of building and providing an e-learning course, BGR (M38)

Task 8.3
D8.2 - Joint education activities – Report 1, including outcome of internal workshop for the development of the joint curriculum, UNIROMA1 (M10)
D8.10 - Evaluation of joint Master and post-graduate Master educational programme based on first experience, UNIROMA1 (M37)

Task 8.4
D8.3 D8.7 D8.9 D8.14 - Report on awareness raising course for journalists workshop and interactions with media year 1, 2,3,4 CO2GeoNet-IGME (M13, 25, 37 and 48)
D8.12 Outcome of WP8 - Promoting CCS through Training and education, CO2GeoNet-GEUS (M45)

D8.1 : E-book: Climate change and importance of CCS technology for decarbonisation of energy and industry [10]

Task 8.2 - Report on the first experiences on e-learnings course for students and the civil society, and provision of e-learning materials on a web platform

D8.2 : Joint education activities – Report 1, including outcome of internal workshop for the development of the joint curriculum [10]

Task 8.3 - Report on the preparation for university cooperation to set the basis for a coordinated Master and post-graduate Master programmes on CO2 storage (development of a network of institutions and laboratories, and educational modules/lectures)

D8.3 : Report on awareness raising course for journalists workshop and interactions with media – months 1-12 [13]

Task 8.4 - Report on short courses for journalists and media, an on enhancing scientist-journalist communication, leason learnt

D8.4 : E-book: Geoscience applied to geological storage of CO2 [14]

Task 8.2 - Report on the experiences on e-learnings course for students and the civil society, leasons learnt, and provision of e-learning materials on a web platform

D8.5 : ENOS Spring School 1 on CO2 storage [21]

Task 8.1 - Report on the training courses for young scientists on onshore CO2 geological storage and latest research, leasons learnt

D8.6 : E-book: Regulatory and social aspects of CCS technology [22]

Task 8.2 - Report on the experiences on e-learnings courses for students and the civil society, leasons learnt, and provision of e-learning materials on a web platform

D8.7 : Report on awareness raising course for journalists workshop and interactions with media – months 13-24 [25]

Task 8.4 - Report on short courses for journalists and media, an on enhancing scientist-journalist communication, leasons learnt

D8.8 : ENOS Spring School 2 on CO2 storage [33]

Task 8.1 - Report on the training courses for young scientists on onshore CO2 geological storage and latest research, leasons learnt

D8.9 : Report on awareness raising course for journalists workshop and interactions with media – months 25-36 [37]

Task 8.4 - Report on short courses for journalists and media, an on enhancing scientist-journalist communication, leasons learnt

D8.10 : Evaluation of joint Master and post-graduate Master educational programme based on first experience [37]

Task 8.3 - Outcome of the cooperation between universities on a coordinated Master and post-graduate Master programmes, leasons learnt, recommendations

D8.11 : Outcome of building and providing an e-learning course [38]

Task 8.2 - Outcome of the e-learnings course for students and for the civil society, leasons learnt, recomendations

D8.12 : Outcome of WP8 - Promoting CCS through Training and education [45]

Task 8.4 - Report on the experiences from the different training activities, e-learning, intensive schools, cooperation between universities on a coordinated Master and post-graduate Master programmes, and on interaction with media and journalists, synthesis report

D8.13 : ENOS Spring School 3 on CO2 storage [45]

Task 8.1 - Report on the promiting of onshore CO2 geological storage through intensive training courses for young scientists, leasons learnt from all 3 schools

D8.14 : Report on interactions with media and journalist final report 37-45 [45]

Task 8.4 - Report on the interaction with journalists and media, and on enhancing scientist-journalist communication, leasons learnt

Schedule of relevant Milestones

Milestone number[18]	Milestone title	Lead beneficiary	Due Date (in months)	Means of verification
MS12	plans for WP8 education activities	20 - CO2GeoNet	10	Report on workshop
MS13	Input from End-User Committee 1	10 - IRIS	11	Key outcomes from meeting
MS23	Input from End-User Committee 2	10 - IRIS	23	Key outcomes from meeting
MS32	Input from End-User Committee 3	10 - IRIS	35	Key outcomes from meeting
MS34	Advisory board input 2	1 - BRGM	36	report and note on impact on ENOS
MS35	End of all field activity	1 - BRGM	36	End of CO2 injection and ENOS data acquisition
MS36	Input from End-User Committee 4	10 - IRIS	47	Key outcomes from meeting

Work package number [9]	WP9	Lead beneficiary [10]	1 - BRGM
Work package title	Management		
Start month	1	End month	48

Objectives

- To execute smoothly and efficiently the operational, legal, financial and administrative management of the ENOS project and consortium.
- To manage site operations

Description of work and role of partners

WP9 - Management [Months: 1-48]
BRGM, BGS, CGS, CIUDEN , IRIS , SOTACARBO, TNO, UNIROMA1, UNOTT, CO2GeoNet
Task 9.1 Communication with the EC and contractual reporting (BRGM)
– Communication with the EC and the consortium participants for all contractual, legal, financial and administrative issues
– Submission of deliverables to the EC in due time
– Supporting Partners in issues with H2020 framework

Task 9.2 Operational management of the project by the Management Board (BRGM, CIUDEN, BGS, TNO, UNIROMA1, CGS, IRIS, CO2GeoNet-GEUS)
– Hold and attend Management Board meetings every two months (mainly webconferences) to discuss the overall progress of the project, address arising difficulties, discuss emerging ideas or opportunities, take specific decisions;
– Monitor the progress of ENOS
– Prepare the annual General Assembly meetings, where strategic decisions will be taken;
– Organise the consultation with the Advisory Body;

Task 9.3 Site activities management (CIUDEN, BGS, Sotacarbo or UNIROMA1,TNO, CGS)
Practical site operations are always subject to uncertainties related to operational and legal issues that have to be taken into account while building and managing a project.
At the beginning of the project, precise plans for each site will be prepared. The plan will include:
- Necessary data to be exchanged – management of potential IPR issues
- Detailed timing of the different activities
- Necessary logistics
- Staff to be involved from each institute
- Risks and mitigation plan
- Management of datasets produced and open access

Plans will be regularly updated and deviations will be explained. No major field activities will be planned in the last year of the project, in order to be able to buffer any unplanned minor delays.

Participation per Partner

Partner number and short name	WP9 effort
1 - BRGM	24.00
3 - BGS	10.90
4 - CGS	8.00
6 - CIUDEN	11.00
10 - IRIS	5.00
16 - SOTACARBO	4.00
17 - TNO	5.00

Partner number and short name	WP9 effort
18 - UNIROMA1	5.00
19 - UNOTT	3.00
20 - CO2GeoNet	0.00
GEUS	8.00
Total	83.90

List of deliverables

Deliverable Number[14]	Deliverable Title	Lead beneficiary	Type[15]	Dissemination level[16]	Due Date (in months)[17]
D9.1	Plan for site activities	6 - CIUDEN	Report	Confidential, only for members of the consortium (including the Commission Services)	4
D9.2	Minutes of Management Board and General Assembly meetings for Year 1	1 - BRGM	Report	Confidential, only for members of the consortium (including the Commission Services)	13
D9.3	Updates to site activity plans 1	6 - CIUDEN	Report	Confidential, only for members of the consortium (including the Commission Services)	16
D9.4	Minutes of Management Board and General Assembly meetings for Year 2	1 - BRGM	Report	Confidential, only for members of the consortium (including the Commission Services)	25
D9.5	Updates to site activity plans 2	6 - CIUDEN	Report	Confidential, only for members of the consortium (including the Commission Services)	28
D9.6	Minutes of Management Board and General Assembly meetings for Year 3	1 - BRGM	Report	Confidential, only for members of the consortium (including the Commission Services)	37
D9.7	Updates to site activity plans 3	6 - CIUDEN	Report	Confidential, only for members of the consortium (including the Commission Services)	40
D9.8	Minutes of Management Board and General	1 - BRGM	Report	Confidential, only for members of the	48

List of deliverables

Deliverable Number[14]	Deliverable Title	Lead beneficiary	Type[15]	Dissemination level[16]	Due Date (in months)[17]
	Assembly meetings for Year 4			consortium (including the Commission Services)	
D9.9	detailed Project Management Plan	1 - BRGM	Report	Confidential, only for members of the consortium (including the Commission Services)	3
D9.10	Update of detailed Project Management Plan 1	1 - BRGM	Report	Confidential, only for members of the consortium (including the Commission Services)	16
D9.11	Update of detailed Project Management Plan 2	1 - BRGM	Report	Confidential, only for members of the consortium (including the Commission Services)	28
D9.12	Update of detailed Project Management Plan 3	1 - BRGM	Report	Confidential, only for members of the consortium (including the Commission Services)	40

Description of deliverables

Task 9.2
D9.2 D9.4 D9.6 D9.8 Minutes of Management Board and General Assembly meetings for Year 1, 2,3 and 4; M 13, 25, 37, 48 BRGM

Task 9.3
D9.1 Plan for site activities , M 4,CIUDEN (BGS,CGS, Sotacarbo, TNO, UNOTT)
D9.3 D9.5 D9.7 Updates to site activity plans, M 16, 28 and 40 CIUDEN(BGS,CGS, Sotacarbo, TNO, UNOTT)

D9.1 : Plan for site activities [4]

Task 9.3 Specific planning for the activities to be conducted on each site within project scope, including data to be shared, logistics, staff, activity schedule, risks/mitigation plan and dataset management .

D9.2 : Minutes of Management Board and General Assembly meetings for Year 1 [13]

Task 9.2 Compilation of the minutes of the management Board meetings and of the annual Genral assembly in year 1

D9.3 : Updates to site activity plans 1 [16]

Task 9.3 Update of D9.1

D9.4 : Minutes of Management Board and General Assembly meetings for Year 2 [25]

Task 9.2 Compilation of the minutes of the management Board meetings and of the annual Genral assembly in year 2

D9.5 : Updates to site activity plans 2 [28]

Task 9.3 Update of D9.1

D9.6 : Minutes of Management Board and General Assembly meetings for Year 3 [37]

Task 9.2 Compilation of the minutes of the management Board meetings and of the annual Genral assembly in year 3

D9.7 : Updates to site activity plans 3 [40]

Task 9.3 Update of D9.1

D9.8 : Minutes of Management Board and General Assembly meetings for Year 4 [48]

Task 9.2 Compilation of the minutes of the management Board meetings and of the annual Genral assembly in year 4

D9.9 : detailed Project Management Plan [3]

Task 9.2 A detailed Project Management Plan with a Gantt chart and a Work Breakdown Structure (WBS), a schedule per task, responsible partner related subtasks, related deliverables, and dependencies to other tasks.

D9.10 : Update of detailed Project Management Plan 1 [16]

Task 9.2 Update of project management Plan. (D9.9)

D9.11 : Update of detailed Project Management Plan 2 [28]

Task 9.2 Update of project management Plan. (D9.9)

D9.12 : Update of detailed Project Management Plan 3 [40]

Task 9.2 Update of project management Plan. (D9.9)

Schedule of relevant Milestones

Milestone number[18]	**Milestone title**	**Lead beneficiary**	**Due Date (in months)**	**Means of verification**
MS19	Advisory board input 1	1 - BRGM	18	Advisory body report and note on impact on the project
MS34	Advisory board input 2	1 - BRGM	36	report and note on impact on ENOS
MS35	End of all field activity	1 - BRGM	36	End of CO2 injection and ENOS data acquisition

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	Decision on sites and modelled to be used in task 2.1 and 2.2	WP2	1 - BRGM	3	Minutes of data evaluation meeting
MS2	Establishment of scientific editor committee	WP7	10 - IRIS	3	First meeting of Scientific Editor Committee
MS3	Hontomin 3D Geological model	WP1	6 - CIUDEN	3	Data available
MS4	International collaboration input to Work programme planned	WP1, WP2, WP3, WP4, WP5, WP6	1 - BRGM	3	D6.1
MS5	Start of field activities in Sulcis Fault lab	WP3	16 - SOTACARBO	5	Staff at field
MS6	update of plan for dissemination and exploitation of results	WP7	10 - IRIS	7	Dissemination plan delivered to all partners
MS7	Hontomin 3D dynamic model	WP1	6 - CIUDEN	6	Data available
MS8	first geochemical investigation in Hontomin	WP1	1 - BRGM	6	Samples acquired
MS9	Soil Gas Monitoring installed in Hontomin	WP1	2 - BGR	6	Data acquired
MS10	Establishing of the web-platform	WP7	12 - OGS	7	Web-site available for ENOS partners and general public
MS11	Start of injection in Hontomin	WP1	6 - CIUDEN	7	First tonnes injected
MS12	plans for WP8 education activities	WP8	20 - CO2GeoNet	10	Report on workshop
MS13	Input from End-User Committee 1	WP1, WP2, WP3, WP4, WP5, WP6, WP7, WP8	10 - IRIS	11	Key outcomes from meeting
MS14	Draft Real Option Schemes for CO2 buffer and CO2-EOR	WP4	20 - CO2GeoNet	12	Discussed and validated schemes by partners of Tasks 4.1, 4.2 and 4.3

Milestone number[18]	Milestone title	WP number[9]	Lead beneficiary	Due Date (in months)[17]	Means of verification
MS15	Definition of KPI and preliminary thresholds	WP1	1 - BRGM	12	Validation by partners
MS16	Identification of main geochemical processes	WP4	17 - TNO	14	Geochemical model outcome supplied to partner in Task 4.1.1
MS17	Start of field activities in GeoEnergy test bed	WP3	3 - BGS	17	Staff at field
MS18	second geochemical investigation on site	WP1	1 - BRGM	18	Samples acquired
MS19	Advisory board input 1	WP9	1 - BRGM	18	Advisory body report and note on impact on the project
MS20	Start of group meetings with citizens	WP5	18 - UNIROMA1	18	First meeting documents
MS21	Decision on designs for considered separation processes	WP4	17 - TNO	18	Approved list of process designs by partners in Tasks 4.1.1 and 4.1.2
MS22	Feedback to CO2 injection operations in Hontomin	WP1	6 - CIUDEN	21	Data available
MS23	Input from End-User Committee 2	WP1, WP2, WP3, WP4, WP5, WP6, WP7, WP8	10 - IRIS	23	Key outcomes from meeting
MS24	Selection of production scenario(s)	WP4	17 - TNO	24	Definition of scenario supplied to partner in Task 4.1.2
MS25	Specific conditions from other sites to determine drilling rig applicability	WP2	6 - CIUDEN	28	Report
MS26	Launch of the Public Information tool	WP5	6 - CIUDEN	24	First version available online
MS27	Transfer of data, pending potential updates, of Tasks 4.1 and 4.2 to Task 4.3	WP4	17 - TNO	30	Notes with data from Tasks 4.1 and 4.2 in agreement with needs in 4.3
MS28	Last geochemical investigation at hontomin	WP1	1 - BRGM	30	Samples acquired
MS29	End of injection in Hontomin	WP1	6 - CIUDEN	31	Injection stopped

Milestone number[18]	Milestone title	WP number[9]	Lead beneficiary	Due Date (in months)[17]	Means of verification
MS30	End of field activities in GeoEnergy test bed	WP3	3 - BGS	37	no more staff at field
MS31	End of field activities in Sulcis Fault lab	WP3	16 - SOTACARBO	37	no more staff at field
MS32	Input from End-User Committee 3	WP1, WP2, WP3, WP4, WP5, WP6, WP7, WP8	10 - IRIS	35	Key outcomes from meeting
MS33	Update of thresholds	WP1	1 - BRGM	36	Validation by Partners
MS34	Advisory board input 2	WP1, WP2, WP3, WP4, WP5, WP6, WP7, WP8, WP9	1 - BRGM	36	report and note on impact on ENOS
MS35	End of all field activity	WP1, WP2, WP3, WP4, WP5, WP6, WP7, WP8, WP9	1 - BRGM	36	End of CO2 injection and ENOS data acquisition
MS36	Input from End-User Committee 4	WP1, WP2, WP3, WP4, WP5, WP6, WP7, WP8	10 - IRIS	47	Key outcomes from meeting

1.3.5. WT5 Critical Implementation risks and mitigation actions

Risk number	Description of risk	WP Number	Proposed risk-mitigation measures
1	Staff availability: in time, staff leaving partner's staff	WP9	The WP leaders will regularly monitor staff availability with involved partners in order to ensure availability and continuity in case of staff changes in the team. This may also concern key personnel e.g. WP leaders or the coordinator. The use of the project platform, gathering all key materials for the project will provide a sound basis for ensuring continuity. The involvement of high level staff in the General Assembly will ensure potential issues are taken into account by partners head offices.
2	Delays in the execution of tasks	WP9	Work package leaders are requested to deliver a WP status report every 4 months. This guarantees a continuous monitoring of the execution of tasks within the WPs and early warning will allow to mitigate potential delays and manage their impacts. No major research activity is planned during the last year of the project.
3	Partners new to EU projects	WP9	The coordinator will support partners without sufficient experience with the execution of EU projects whenever necessary. 4 partners in the consortium have no experience in FP6 or 7 projects
4	Lack of communication and information exchange between partners	WP7, WP9	In order to ensure an efficient and effective execution of the project, partners on all project levels need to communicate regularly and in an expedient way. The coordinator and the WP and task leaders are specifically responsible to stimulate communication and collaboration between all those involved. In particular WP7, aiming at integrating the knowledge created by the project, will collect information from all WPs, provide an overview to all participants and organize events to share knowledge. The availability of electronic communication is advantageous for regular and uncomplicated interaction between partners. WP7 will build a web-based platform to ensure easy exchange of information, results and documents.
5	Risk of scarce collaboration from societal stakeholders	WP5	Particular emphasis will be given in the preparation phase to set the right conditions for collaboration in the different societal contexts involved and for peer support between project partners to overcome bottlenecks.
6	Limited injection at hontomin. Site operations always entail a risk. CO2 Injectection could be either delayed or very limited due to either surface or	WP1, WP6, WP7	Experience gathered during hydraulic characterization phase and operation start-up provide solutions for avoiding problems. Equipment breakdown is solved storing spare parts on site, even of the main components. Delay in supply of CO2 is mitigated using 3 CO2

Risk number	Description of risk	WP Number	Proposed risk-mitigation measures
	subsurface problems. Operation injections in Hontomin already started and 2000t of CO2 were already injected. Therefore the probability of failure is low.		tanks installed on site. Issues related to reservoir injectivity would bring new insights on pressure / flow management.
7	Risk of limited or no activity possible at the GeoEnergy test bed or sulcis Fault lab. Both site are under construction and there are risks of delay and potentially not to be able to inject CO2. In that case the activities in WP3 would be strongly impacted. Both sites already have their financing secured from national funds. The probability of both sites failing is low.	WP3, WP7	The advance of the preparation of the sites will be monitored carefully by the management team. In case one of the sites is not available in time, deployment of the monitoring technologies at the other site will be considered, as well as using ECCSEL infrastructures and/or the sites from the international collaboration (in Canada, Australia or South africa) In case of delay, some buffer time in the last year of the project has been planned.
8	Problems in getting access to background data related to sites. Background data is usually sensitive data. Exchange of data is however necessary for the work to be undertaken in ENOS. This risk is the highest for Q16Maas site, where exploitation data from a gas field is to be dealt with.	WP1, WP2, WP3, WP4, WP6	At project proposal stage,Site owners provided to the consortium commitment letters detailing pre-existing data that will be provided to participants. What data will be necessary has therefore been clearly identified and data to be provided from outside of ENOS funding outlined to ensure it will be available where needed for ENOS activities. The management of issues arising will be dealt in the management WP in the site operation plans. For Q16maas : timely arrangement are made with the site owner to get access to site-specific data. The FID related to the use of Q16-Maas as a storage location for the ROAD project is expected to be taken in Q4 2016. After FID, there will be more clarity about the status of the field and the availability of data and support for the study from the stakeholders involved.

1.3.6. WT6 Summary of project effort in person-months

	WP1	WP2	WP3	WP4	WP5	WP6	WP7	WP8	WP9	Total Person/Months per Participant
1 - BRGM	45	15	12	0	4	5	6	2.50	24	113.50
2 - BGR	10	0	32	0	2	1	3	3	0	51
3 - BGS	0	6.20	31	0	0	7.20	5.40	2.80	10.90	63.50
4 - CGS	0	0	10	9	4	17	15	3	8	66
5 - CIEMAT	6	0	0	0	0	0	1	0	0	7
6 - CIUDEN	103	18.50	1	0	21	8	3	2	11	167.50
7 - flodim	4	0	0	0	0	0	1	0	0	5
8 - GGR	11.40	0	0	3.50	0	0	0.50	0	0	15.40
9 - IDIL	0	0	4	0	0	0	1	0	0	5
10 - IRIS	0	0	8	10	0	3.50	15.20	0	5	41.70
11 - NHAZCA	0	0	6	0	0	0	1	0	0	7
12 - OGS	40	0	40	0	2	6	14	1	0	103
14 - SGIDS	0	0	0	3	0	5	1	0	0	9
15 - SILIXA	4.50	0	3	0	0	0	1	0	0	8.50
16 - SOTACARBO	5.60	10.40	10.60	0	8	5	1	0	4	44.60
17 - TNO	16	0	5	30	14	8	10	1	5	89
18 - UNIROMA1	1	0	57	0	40	4	4	5.50	5	116.50
19 - UNOTT	8	12	4.50	0	9	6	1	3.50	3	47
20 - CO2GeoNet	0	0	0	0	0	0	0	0	0	0
· GSB-RBINS	0	0	0	24	0	0	1	0	0	25
· TTUGI	0	0	0	0	2.30	5.90	11.30	3.80	0	23.30
· UNIZG-RGNF	0	0	0	0	0	7.30	1	3.20	0	11.50
· HWU	4	26	16	0	3	0	1	3.30	0	53.30

	WP1	WP2	WP3	WP4	WP5	WP6	WP7	WP8	WP9	Total Person/Months per Participant
· IGME	20.20	0	0	0	2	2	3.40	4.20	0	31.80
· GEUS	0	0	0	0	0	0	3	8	8	19
· GEOINZ	0	0	0	0	0	1	7	1	0	9
· GEOECOMAR	0	0	2.50	0	4	6.20	7.30	3	0	23
· METU	0	0	0	6	0	0	1	0	0	7
· GBA	0	0	0	0	4	7	3	0	0	14
Total Person/Months	278.70	88.10	242.60	85.50	119.30	105.10	123.10	50.80	83.90	1177.10

1.3.7. WT7 Tentative schedule of project reviews

Review number [19]	**Tentative timing**	**Planned venue of review**	**Comments, if any**
RV1	20	Brussels	
RV2	34	Brussels	
RV3	48	Brussels	

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 fillings, videos, etc.
OTHER	
ETHICS	Ethics requirement
ORDP	Open Research Data Pilot

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

VA	if virtual 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.

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

Changes for the preparation of the Grant Agreement

Section	Change	justification
Measures to maximise impact	Added general IPR description for the results of the project	Requested from evaluation
Milestone 12	Title changed from WP8 workshop on planning WP8 education To Plans for WP8 Education	clarification
Milestone 17 30 31	Related WP was 2 changed to 3	Correction of typo
WP7	Added sentence on communication	Requested
WP3 task 3.2	Silixa added to list of partners	Correction of missing data (no additional cost incurred)
WP7 Deliverable	Added one missing deliverable: last issue of the newsletter D7.17	Missing data
WP7 Task	CO2GeoNetTTUGI clearly responsible for task 7.3.3	
Deliverable list	All deliverables with dissemination level RE have been put as CO (RE is not an option any more)	Those deliverables are internal ones: plans for international collaboration etc
Deliverable WP3	Adaptation of delivery time for D3.10 from 33 to 36 D3.13 from 34 to 36 D3.14 from 35 to 36 D3.15 from 36 to 35	To take into account the shifted start of the project and the fact that some field activities depend on seasons and take into account better task dependency
Deliverables WP1	Delivery time for 1.2 from month 8 to 14	If the project will start in late autumn we will have problems with the installation which is roughly scheduled for project month 3. Installation during winter times is difficult and we would like to shift this

		by a couple of months to early spring. This will result in a delay of the delivery date as we ideally need reference data of 1 year for the threshold assessment.
Section 4.2	Added info on subcontracts Ciuden: part of the sub contracts have been moved to contract BGS: info added Uniroma: The planned subcontracting has been moved to contracts. However part of personnel costs have been moved to sub contract (see justification) CO2GeoNEt: info added	-Ciuden requalification of contract cf H2020 rules -BGS: info requested - uniroma: The costs for personnel for these two tasks have been moved from direct costs to subcontracting following the recent (October 2015) EC interpretation of the eligible costs in H2020 (see List of issues applicable to particular countries), since personnel costs that according to the Italian national legislation (law 240/2010) "assegni di ricerca" and "collaborazioni" are considered as staff personnel (in-house consultant), have now been classified as subcontracting/services. The amount (70k€) allocated as subcontract refers to personnel costs related to "assegni di ricerca" which have been reclassified as subcontract in compliance with EC indications. The work in these two tasks concerns the activities of guidance for the integration of the input from the local communities in the research process and the work for coordination and elaboration of the work with the local communities and relates to D5.9 and D5.7.
Section 4.2	Remove table on CO2GEoNet staff effort	Already included in part A
Section 3.4	Removed LRI costs from TNO	As the EC did not accept the requested compensation for the LRI, the LRI access costs have been set to zero, consequently leading to a lowering of the total eligible costs.
Section1.2	Added table on site status	To answer comment from evaluation
1.2 and 4.1	Duero site removed	ENDESA withdrawal
Section 3.3	Endesa removed from consortium description	ENDESA withdrawal
Deliverable D1.11	Responsible from ENDESA to CIUDEN	ENDESA withdrawal
Budget	Endesa Budget and staff effort passed to Palencia 3 and CIUDEN	ENDESA withdrawal
Budget	TNO changes of budget and staff effort	*Changes in person months:* Swap between WP3 and 4: the equivalent of 2 person months was shifted from WP4 to WP3 to compensate workload in WP3.

		WP7: As the preparation and updating of the dissemination plan and accompanying dissemination activities requires more work, 5 person months have been added. WP8: 3 person months have been added to have a more balanced representation of TNO's technological achievement in the training programme. These changes did not lead to an increase in the personnel costs for TNO. *Change in travelling costs:* WP8: A more balanced contribution from TNO in the training activities has resulted in a modest increase of the travelling costs with 2250 Euro.
Section 3.4	Adjusted travel costs for BRG and Silixa Added sentence clarifying the meaning of CFS and GA	
Section 4.2	Re inserted able on CO2GEoNet and Palencia 3 staff effort and corrected figures (no ore rounded figures)	As requested and correction in the figures to fix the incoherences.
Section 3.4	"The beneficiaries will base their contracts and subcontracts on the 'best value-for-money… " added	*Upon request*
Section 3.4	"All equipment and other items that will be claimed 100% as cost of the project will be exclusively used for the activities in the project; as a consequence, if the equipment is also used for other activities outside the project, only part of its cost (corresponding to the percent of use within the project) will be charged." Added	*Has been added for clarification for each partner that will sign.*

Table 3.4a	TNO other costs corrected	*Requested change*
Table 3.4a	HWU high computing details added	*Requested change*
Section1.2 table 1.2	Site status table corrected to add sulcis pilot	*Was missing*
Table 3.4a	Correction of bgs travel details	*Typo on the cost for WP3 travel*
Table 3.4a	CIUDEN correction of typo: Equipment → other costs and services	*Mistake on the title of the line.*
Section 3.2	Changes in MB members (names)	*Due to staff changes in CIUDEN and BRGM the WP leaders and therefore members of the MB have changed*
Staff effot WP 1 4 7 for GGR	Changes in staff effort	*Due to salary raises.*
Table 3.4a	CIUDEN	*Added justification for costs calculations*
Budget	Correction of max grant for Ciuden	*I made a miscalculation: ciuden claims the initial amount from proposal stage (2 685 225.00) + additional money for taking over 1 endesa task: 4525*
WP2 task 2.1.2	Clarification of task for CIUDEN (words in blue added): For the Hontomin site, CIUDEN will develop a model using a free code and provide with dynamic simulations based	*Request from partner as they don 't have a model available at hand to perform the work.*
Deliverable	Correction of name of D2.1	*Coherence with WP2 deliverable list*
Deliverable	Correction of name of D5.2	*Coherence with WP5 deliverable list*
WP6 description	Correction of deliverable number in the text of task 6.3	
WP1 description	Adding GGR to task 1.4 partners	*Was missing : they were already listed in 1.4.3*
WP1 description	GEogreenn→ GGR	
WP3 description	Correction of delivery month in the text of D3.13	*Coherence*
Staff effort for BGS	Correction of staff effort	*Change of position (and therefore salary) of key staff involved*

Table 3.4a	Added information on intercontinental travels in BRGM other costs	*Requested*
Section 3.4	*and avoiding any conflict of interest. Added*	*Requested*
WP3 description	*Adding silixa in the fooling sentence* Task 3.2.2: Monitoring CO2 migration through fault planes in the sub-surface At the Sulcis Fault Lab, OGS will undertake geophysical measurements using downhole tools and surface techniques,to examine if the migration of CO2 along the fault and its proximity can be tracked. Seismic techniques will include borehole measurements using wireline and Silixa DAS-VSPTM, cross well applications and seismic interferometry (in surface-borehole and cross-well geometry).	*Upon partner request. To avoid ambiguity*
Deliverable	*Postponing deliverable in August to September (M12 → 13, 24 → 25, 36 → 37* *Consequently moved D4.10 from M38 to M 39*	*To take into account the summer break*
Risks	*R8 added mention of ECCSEL infrastructures in mitigation*	
Risks	*R6 and R10 removed*	*Requested. Was duplicated*
Section 3.1	*Update of the GANTT chart*	*For coherence with other changes*
Table 3.4	*Removal of SDG and updating budget for IPF and ENAGAS*	*SDG withdrawal from project*

Section4.1 13.	*Removing staff is provided by **SDG, removing mention of SDG in efforts and staf***	*SDG withdrawal from project*
Section4.2	*Update of palncia 3 third parties staff effort*	*SDG withdrawal from project*
WP5 satff effort	*Removed BGS*	*I don t know why it was there. Not involved in the WP*

Changes introduced by the 1st Amendment
Changes related to Withdrawal of Palencia 3

WP	Activity	Old	New	Reason
1	Task 1.4.3	"CIUDEN and PLC-3 will work on the specifications of the alert system for its integration on an industrial full chain project"	"CIUDEN, with SOTACARBO, and likely other industrial actors, will work on the specifications of the alert system for its integration on an industrial full chain project"	This will also rely on the end user committee in WP7
2	Task 2.3	CIUDEN will work with PLC-3 for acquiring the required data to design the rig machinery and all the associated engineering studies in order to provide a cost effective solution to support the development of drilling activities within the Palencia-3 characterization process, that will likely be deployed during the ENOS timeframe, using the solution provided by the project. It is therefore expected that the FEED (Front-End Engineering Design) study developed will be tested in 2017 as part of the committed tasks of the exploratory permit Palencia 3, using funds outside of ENOS. The results from this engineering design and test will be used for potential implementation at the Sulcis site, by SOTACARBO. Implication of the diameter of the drilled well for its use as future monitoring or injection	CIUDEN will work with SOTACARBO, and likely with other sites, for acquiring the required data that support the basic design of a rig machinery and all the associated engineering studies in order to provide a cost effective solution to support the development for drilling activities within the SULCIS characterization process, which will be deployed after the ENOS timeframe, using the solution provided by the project. It is therefore expected that the FEED (Front-End Engineering Design) study developed will likely be tested after the ENOS timeframe as part of the committed tasks of the exploratory permit of SOTACARBO, using funds outside of ENOS. Implication of the diameter of the drilled well for its use as future monitoring or injection well will be studied with input from BRGM.	. No deep drilling is planned during the project . Other opportunities of testing the light drilling will be looked for through the end user committee

		well will be studied with input from BRGM. outcomes Demonstration of cost effective solutions to execute key characterization activities such as the drilling of wells to have a precise description of the reservoir and caprock. The engineering works will be applied to Palencia-3 site to demonstrate its effectiveness. PLC-3 will use their own resources to execute this drilling at the site These light drilling activities will provide significant cost savings in the characterization phase of this demo site and other future sites onshore in Europe.	outcomes Development of cost effective solutions to execute key characterization activities such as the drilling of wells to have a precise description of the reservoir and caprock. The light drilling activities will provide significant cost savings in the characterization phase of this demo site and other future sites onshore in Europe.	
2	Task 2.4	Remove PLC 3		
2	D2.5	Report on drilling activities for extension to other sites – M38 – CIUDEN, Sotacarbo, PLC-3, BRGM	D2.5: Drilling activities study for extension to other sites [44] Light drilling equipment FEED will be performed under boundary conditions determined by the singularities from different sites, particularly, geological and geo-mechanical characteristics. A study analyzing the drilling rig applicability to different sites will be performed, identifying the achievable improvements. Following tasks are related with D2.5: Tasks 2.3 and 2.4.	

2	D2.1	Report on FEED study for light drilling – M15 – CIUDEN, PLC-3	D2.1: Report on FEED study on light drilling [21] Regarding CIUDEN experiences from well drilling works at Hontomín site, required data and engineering studies for the basic design of a light drilling rig will be performed, in order to provide a cost effective solution for the exploration phase of other sites. Following tasks are related with D2.1: Tasks 2.3 and 2.4	
2	MS25	MS25 Drill experiment based on ENOS FEED study performed by PLC-3 (external event) 6 - CIUDEN 24 Report from operator	Specific conditions from other sites to determine drilling rig applicability – M28	
3	Task 3.4	Sotacarbo and PLC-3 will provide expertise based on their real-life experience at large storage and industrial sites. (…) PLC-3 with support from all partners will consider how technologies and techniques tested in WP3 could be integrated into a monitoring plan for the PLC-3 site.	Sotacarbo and end user committee (in WP7) will provide expertise based on their experience at fault lab, large storage and industrial sites. (… Sotacarbo with support from all partners will consider how technologies and techniques tested in WP3 could be integrated into a monitoring plan for the Sulcis pilot site.)	
5	Remove participation		Remove PLC 3	Was giving input from their experience
6	Task6.1, task 6.2,		Remove PLC 3 Funds to be used for	Support of international

	task 6.3		international collaboration (travel)	collaboration and site development
7			Remove PLC3 Funds to be used to support the end user committee and the knowledge integration WS	End user committee will be essential to replace the industrial input from PLC3 No funds were allocated to rent rooms for the knowledge integration ws
9			Remove PLC 3	

Section	Change	justification
1.2 list of sites	**Removal of Palencia 3 in text and table 1.1.1**	**Palencia 3 withdrawal**
Table 1.2 summary of the objectives and tangible outcomes of the technical WPs	• FEED study for low cost smart drilling, that will be tested outside ENOS	**Palencia 3 withdrawal**
3.2 **Organisational structure and decision making**	Numbers of the consortium	Palencia 3 withdrawal
3.3 consortium as a whole	Removal of Palencia 3	Palencia 3 withdrawal
3.4 Resources to be committed	Removal of Palencia 3 and reallocation of funds to other beneficiaries	Palencia 3 withdrawal
4.1 13	Removal of Palencia 3	Palencia 3 withdrawal
4.2 thrid parties	Removal of Palencia 3	Palencia 3 withdrawal
4.1 infrastructure	Removal of Palencia 3	Palencia 3 withdrawal

Other changes (not related to Palencia 3) withdrawal

Section	What	Old	new	motivation

WP3	Responsible for D3.2	CO2GeoNet-HWU	IRIS	CO2GeoNet-HWU not involved in the task 3.2.4
Milestones	MS 5 related to WP:	WP5	WP3	mistake
WP8	Deliverable 8.12 : Outcome of WP8 - Promoting CCS through Training and education	November 2019 (M39)	May 2020 (M45)	to ensure that the report cover all WP8 activities.
WP8	Deliverable 8.5, 8.8, 8.13	17, 29, 40	21,33,45	Spring school will be held in March-April so report in May. The dates for delivery were not shifted after according to the starting date
WP7	Postpone D7.3, D7.6, D7.11 Results of Open D7.5, D7.10, D7.15 D7.7,D7.12, D7.16 Short notes summarizing knowledge integration workshop	(OGS, Month 7, 19, 31) (OGS, Month 19,31, 43)	months 10, 22, 34, months 22, 34, 45	Open Forum is in May Integration Ws next to Open Forum in May
WP7	Postpone D7	44	46	Take into account input from WP5 with last deliverable due M46
Section 3.3	Removal of investor club	ENOS investor Club paragraph	Remove	Requested by BGR
Section 4.1 5	Removal of CV María del Rocío Maldonado Pérez			Requested by CIEMAT, person left CIEMAT

Changes for the 2nd amendement

Section	What	Old	new	motivation
4.2	Subcontracting for	No	Fluid sample	BRGM unable

	BRGM	subcontracting	analysis	to perform analysis for safety issues
4.2	Subcontracting for UNIROMA1	Subcintracting for "assegni di recerca"	No subcontracting	"assegni di ricerca" recognized as personnel cost
WP1 description		Gas and water samples will be acquired at Hontomin and processed at BRGM's laboratory in order to get major and trace element analyses	Gas and water samples will be acquired at Hontomin and processed at nan external laboratory in order to get major and trace element analyses	BRGM unable to perform analysis
Deliverables	Dates for deliverables D3.1, 3.3, 3.4, 3.7,3.8,3.9,3.15	Jul 18, April 19, April 19, April 19, April 19, May 19, May 19, Jul 19	Sept 19, Jul 19, Jul 19, Jul 19, Jul 19, Sept 19, Sept 19,	Delays in setting up experimental sites
Bank account				Change of BRGM bank account
Milestones	Date of MS17 and MS30	M17, M31 (Apr 2019)	M32 and M35 (Jul 2019)	Delays in setting up experimental sites
Budget	Shift of budget from Subcontracting to personel costs for UNIROMA			"assegni di ricerca" recognized as personnel cost
Budget	Shift of Budget From other costs to subcontracting for BRGM			To cover
PARTB	GANTT			Update of WP3

Table of Contents

1. Excellence

1.1 Objectives

Context of the project

Currently, the few large-scale CO_2 Capture and Storage (CCS) demonstration projects in Europe that are in operation or preparation are storing CO_2 in deep geological formations offshore, (e.g. Sleipner and Snøhvit - NO, ROAD - NL, Peterhead and White Rose - UK). The onshore large-scale integrated CCS demonstration projects that were in preparation under the EEPR[1] and NER300[2] schemes have largely been either cancelled or suspended (e.g. Janschwalde - DE, Belchatow - PL, Florange - FR, Getica - RO, Compostilla-Duero - ES). Although there are general financial and economic constraints involved in getting large-scale integrated projects off the ground, the challenges are much greater when the storage site is onshore. This is because local communities, and other stakeholders, have more immediate concerns as to whether the storage will be safe and environmentally sound, and as to whether local socio-economic benefits will emerge from this approach to climate and energy issues, such as the creation or preservation of local jobs. However, in order to reach the EU's ambitious goal of an 80% reduction in greenhouse gas emissions by 2050, while ensuring the security, flexibility and competitiveness of energy supply, deployment of onshore CO_2 storage will be crucial. Therefore, ENOS will focus on onshore storage, with the demonstration of best practices through pilot-scale projects and field laboratories, integration of CO_2 storage in local economic activities and creating a favourable environment for CCS onshore through public engagement, knowledge sharing and training.

The ENOS project is an initiative of CO_2GeoNet, the European Network of Excellence on the geological storage of CO_2, and a result of its recognition of the need to support onshore storage as a priority in today's context. CO_2GeoNet is committed to facing the technical and societal challenges for CCS through coordinated research and the global dissemination of scientific knowledge on CO_2 storage.

Objectives of the project

The objective of the project is to enable the development of CO_2 storage onshore in Europe by:

1) **Developing, testing and demonstrating in the field, under "real-life conditions", key technologies specifically adapted to onshore contexts.**
   Research and Development (R&D) at pilot sites and experiments under real-life conditions will allow demonstration of technologies for safe and environmentally sound storage in relevant environments. The portfolio of field sites in ENOS will also provide great opportunities for on-site training and dialogue with local authorities and civil society.
2) **Contributing to the creation of a favourable environment for onshore storage across Europe,** by i) supporting knowledge sharing to maximise the benefits of demonstration from each site, ii) integrating research results and setting out best practices on key topics based on the findings from real-life experiments, iii) supporting the preparation of new pilot projects and upscaling from pilot to demonstration, iv) bringing innovation to society through dialogue and communication and v) promoting CCS through training and education.

Involvement of a range of stakeholders and the general public in the development of best practices will enable the project partners to discuss, test and include wider requirements for CO_2 storage implementation. This will produce well integrated research outcomes and, at the same time, increase understanding by stakeholders, including the public, of the necessity for wide implementation of CO_2 storage. In this framework of improved understanding, the project will support the preparation of new onshore pilots and demonstration projects in various countries and geological settings in Europe, also taking into account the specific socio-economic context of the territories concerned and local benefits such as job creation or preservation.

Although the project is designed to address concerns specific to onshore storage, a number of outcomes from onshore pilots and field experiments will be also useful for offshore storage development. In particular, it is easier and cheaper to test certain storage technologies onshore rather than offshore. This will be highlighted in the best practices that will be produced by ENOS.

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[1] *European Energy Programme for Recovery*

[2] *Financing instrument funded from the sale of 300 million emission allowances from the New Entrants' Reserve of the EU Emissions Trading System*

1.2 Relation to the work programme topic LCE 15 2015

In order for the EU to reach its commitment of an overall reduction of greenhouse gas emissions of at least 80% by 2050, CCS needs to be deployed widely and applied to power plants and key industries by then. This means storing 3 to 13 billion[3] tonnes of CO_2 across Europe by 2050. In light of these figures, Europe cannot rely solely on the North Sea, despite its great and readily available storage potential; CO_2 geological storage also needs to be deployed onshore. Developing onshore storage, relatively near the emission points, will contribute to reducing the costs of CCS, enable territories to manage their CO_2 emissions locally, and build lasting public confidence in CCS as a mitigation option that can also contribute to local economic development. By developing technologies to enable onshore geological storage and demonstrating best practices, ENOS will contribute to the deployment of a key technology for CO_2 emission reduction by 2050. In addition, through reciprocal knowledge-sharing activities with storage pilot and demonstration sites outside of Europe, ENOS will ensure that advancements are truly moving beyond global state of the art and that the value of the European sites in ENOS is maximised. Onshore sites also offer a relatively cheap option to develop CCS technologies and strategies that can then be adapted for offshore as needed, thus ENOS will also contribute to the wider CCS community.

Progressing technologies from TRL 4-5 to TRL 6

ENOS will focus on progressing technologies that have already reached Technology Readiness Level (TRL) 4 (validated in laboratory) or TRL5 (validated in relevant environment, i.e. in the field, occasionally/with small equipment) with the aim of bringing them to TRL6 (demonstrated in relevant environment, i.e. in the field, over long periods with adapted equipment) by the end of the project. The technologies considered will be those most needed to enable onshore CO_2 storage, advancing site characterisation operation, risk assessment, monitoring and management of leakage risks. These are necessary to answer specific onshore storage concerns, such as:

a. Increased data availability for improved site characterisation, through low cost and smart drilling adapted to onshore context;
b. Improved site characterisation enabling a better assessment of storage capacity and performance, particularly for onshore deep saline aquifers;
c. Adapted and specific monitoring technologies and strategies for onshore settings;
d. Preservation of groundwater used for human consumption;
e. Preservation of onshore terrestrial and aquatic ecosystems, to protect the environment and human health;
f. Detection and quantification of any CO_2 leakage (emissions) at ground surface;
g. Increased understanding and prevention of induced seismicity, crucial to onshore context;
h. Management of multiple uses of the subsurface;
i. Integration of onshore CO_2 storage with local economic activities.

Real-life conditions

Real-life conditions are critical to the objectives of the Work Programme. ENOS has therefore built a comprehensive portfolio of sites, representing a variety of geological and socio-economic contexts and different stages of the storage lifecycle. This set of sites, with a good range of onshore contexts in various Member States, will allow technologies already at levels TRL4-5 to be tested and increased to TRL6, while favouring CO_2 storage development across Europe. All the proposed sites have either already benefited or shall benefit from funding outside the present call (industrial, national, European or own funding) and their operational plans extend beyond the scope of the ENOS project. The activities proposed in ENOS are complementary to those already funded and will enable additional research on these sites, liaising with other sites and comparison of results and experience, therefore maximising knowledge sharing in Europe and smart alignment of financial resources from various European stakeholders. The sites can be divided into three categories: operational storage pilot, field laboratories for leakage simulation and storage sites in the planning and characterisation phase. *Table 1.1* summarises the sites operated by ENOS partners and the issues related to onshore storage that they will be used to address.

Operational storage pilot site:

Hontomin – *ES*: The Spanish CO_2 storage technology development site, where injection at 1 500 m depth in a fractured carbonate reservoir in an anticlinal domal structure began in 2014. The site has been developed and equipped through the EEPR scheme and national funding and has been recognised by the European Parliament[4] as

[3] *Energy Roadmap 2050 - Impact assessment and scenario analysis*

[4] European Parliament Resolution P7_TA(2014)0009 Bullet 17

a key test facility for onshore CO_2 storage. The site will allow acquisition of experience in a complex setting on issues that a future CO_2 storage operator might face, e.g. pressure management, low matrix permeability, impact of fractures or control of induced seismicity. A significant budget (2M€) from ENOS will be dedicated to buying and injecting 10ktonnes of additional CO_2 in order to work in real-life conditions. At Hontomin ENOS will a) test safe injection and innovative monitoring tools, b) develop a protocol for safe management of the site including induced seismicity control c) underpin the importance of local community engagement during the operational phase.

Field laboratories for leakage simulation:

CO_2 will be injected at two sites in order to simulate unwanted migration and leakage of CO_2, and advance our ability to detect and quantify CO_2 leakage onshore. The experiments will enable a better understanding of the processes involved in CO_2 migration within overburden, provide critical field data on CO_2 migration in a faulted context and reactivity in an aquifer and offer the opportunity to test cutting-edge monitoring technologies.

Sulcis Fault Lab - *IT*: As part of the 10 year Italian R&D program for CCS demonstration in Sardinia, an experimental open research platform is being created to study CO_2 flow along faults. CO_2 will be injected near a fault at 200-300 m depth from 2017 onwards. Wells will enable monitoring of the CO_2 behaviour underground.

GeoEnergy TestBed *(GTB)* - *UK*: GeoEnergy Research Centre, GERC (a UNOTT and BGS joint venture) owns and funds a site that will enable fully-monitored injection and migration of CO_2 into the Sherwood Sandstone (an important UK resource for CO_2 storage, oil & gas extraction, and a major onshore aquifer) at depths of up to 250 m. It will enable the study of a heterogeneous mudstone caprock, injection into a shallow near-surface control aquifer (~ 25 m depth), and research into leakage migration along localised natural faults. Site characterisation is underway, with the first borehole planned for summer 2015, and CO_2 injection will start end 2016.

Storage sites in the planning and characterisation phase:

LBr-1- *CZ*: LBr-1 is a depleted oil field in the Czech Republic where a small-scale storage pilot is in preparation through the REPP-CO_2 project (see page 7). The reservoir, Miocene sandstones at ~1100 m depth hydraulically connected to an aquifer, is a typical example of a hydrocarbon-bearing structure in the Vienna Basin, one of the oldest hydrocarbon provinces in Europe. The site will be used to i) assess the potential for unwanted migration and/or leakage through abandoned boreholes and faults and ii) investigate reservoir behaviour in the presence of CO_2 and hydrocarbons, including possible mobilisation of hydrocarbons and use of CO_2 for Enhanced Oil Recovery (EOR).

Q16-Maas site - *NL:* The Dutch gas field Q16 Maas with onshore surface installations is currently under consideration, as part of a Dutch programme (see page 6) for the development of a CO_2 buffer for CO_2 utilisation. The 2 800 m deep Triassic sandstones of the gas reservoir have an estimated storage capacity of about 1.8 Mt CO_2. This large buffer will offer storage for industrially produced CO_2 in the wintertime and back production in summertime for greenhouse horticulture companies and thus guarantee the security of supply with increasing demand for CO_2, which is commonly used in greenhouses to enhance plant growth. Underground buffering is the only solution considering the scale of the buffer capacity needed. Such buffer storage could also be necessary for other uses of CO_2 and for collecting emissions before sending them to larger storage sites, including offshore. Site specific data will be used to study the conditions of back production of CO_2 (for use or transfer) and to assess the economic viability of implementing such facilities.

Sulcis pilot - *IT:* As part of the 10 year Italian R&D programme for CCS demonstration in Sardinia, a full chain pilot project is under preparation. The target reservoir is a limestone aquifer at a depth of about 1 300 m. The initial 3 year programme (2014-2017) is funding activities ranging from site characterisation to test injection, in addition to the fault test infrastructure mentioned above. It includes i) geological and geochemical studies; ii) seismic survey, geological and geophysical modeling and exploration; iii) experimental injection of CO_2. In ENOS, this site will allow analysis on applicability of low cost drilling technology and possibly implementation of smart characterisation tools.

More details on the different sites are given in the Section **4.1** 'Participants' under 'Infrastructure proposed by the partners - test sites'.

Country	Site	Type of storage	Depth	Reservoir	Phase	Issues related to onshore storage addressed
Spain	Hontomin	Deep saline aquifer	1500 m	carbonate	injection	b. Site characterisation techniques enabling a better assessment of storage capacity and performance c. Onshore adapted and specific monitoring technologies and strategies d. Preservation of groundwater used for human consumption e. Preservation of onshore ecosystems, to protect the environment and human health f. Localisation and quantification of any CO2 leakage at ground surface g. Increased understanding and prevention of induced seismicity
UK	GeoEnergy Test bed (GTB)	Injection site into shallow aquifer with caprock	250 m	sandstone	characterisation and injection	c. Onshore adapted and specific monitoring technologies and strategies d. Preservation of groundwater used for human consumption e. Preservation of onshore ecosystems, to protect the environment and human health f. Localisation and quantification of any CO2 leakage at ground surface
Italy	Sulcis Fault Lab	Injection tests through faults	250 m	fault through volcanic rock, clays,limestones	characterisation and injection	c. Onshore adapted and specific monitoring technologies and strategies d. Preservation of groundwater used for human consumption e. Preservation of onshore ecosystems, to protect the environment and human health f. Localisation and quantification of any CO2 leakage at ground surface
Czech Rep.	LBr-1	Depleted oil field	1100 m	sandstone	characterisation	d. Preservation of groundwater used for human consumption i. Integration of onshore CO2 storage with local economic activities f. Localisation and quantification of any CO2 leakage at ground surface h. Management of the multiple uses of the subsurface
Netherlands	Q16Maas	Buffer storage in depleted O&G fields	2800 m	sandstone	characterisation	i. Integration of onshore CO2 storage with local economic activities h. Management of the multiple uses of the subsurface
Italy	Sulcis pilot	Deep saline aquifer	1500 m	limestone	characterisation	a. Low cost and smart drilling to increase data availability for improved site characterisation b. Site characterisation techniques enabling a better assessment of storage capacity and performance

Table 1.1: Site portfolio for ENOS and issues these sites will help to address

Site	Country	Type of site	Status as of April 2016	Operations for ENOS
Hontomin	Spain	Storage reservoir	Operating. 2000 t of CO2 injected	CO2 injection and monitoring
Geo Energy Testbed	UK	Leakage simulation	under construction (drilling) expected start of operations: 2017	Simulation of leakage and deployment of monitoring methods in aquifer environment in WP3
Sulcis Fault lab	Italy	Leakage simulation	Under characterisation Expected start of operations: 2018	Simulation of leakage and deployment of monitoring methods in fault environment in WP3
Sulcis Pilot	Italy	Exploration permit	Exploration permit has been granted and exploration has started	The site will be used as test site for feasibility of the guidance documents from WP2 and 3
LBr-1	Czech Republic	Storage reservoir	Site characterisation and risk assessment are being performed in REPP-CO2 project (Czech-Norwegian project) which will finish in November 2016	Studies to assess the potential for unwanted migration and/or leakage through abandoned boreholes and faults and investigate reservoir behaviour in the presence of CO2 and hydrocarbons, Combination of CO2 storage with possible Enhanced Oil Recovery in terrestrial conditions of the Vienna Basin. Study on trans-boundary issues. No field activities planned.
Q16-Maas	Netherlands	Storage reservoir; Depleted wet gas field	Production of wet gas (gas with condensate)	Study on using the reservoir for buffer storage; no field activities planned

Table 1.1.1: Site portfolio status as of April 2016

Local community engagement

Onshore CO_2 geological storage is highly reliant on the confidence the local authorities and population will place in the technologies and the storage projects. ENOS will undertake innovative work to involve the local population with the research teams and create a space for dialogue to encourage a favourable environment where storage can be implemented. This work will be undertaken at sites in the planning and injection stages.

Knowledge sharing in Europe and globally

Building on experience and initiatives from CO_2GeoNet, an ambitious programme of knowledge sharing and dissemination will be undertaken in order to maximise the impact of ENOS and other CCS projects. The aim is to pass on the experience gained from onshore experimental sites within the ENOS portfolio and worldwide to projects under creation in Europe and thus improve their chances of coming to fruition. The resulting knowledge will also be passed on to the next generation of scientists, through dedicated training sessions, and integration of specific modules into academic curricula. Knowledge-sharing activities to be undertaken in collaboration with operators of international sites outside of Europe are described in WP6.

1.3 Concept and approach

Overall concept

The main objective of ENOS is to help to remove the immediate hurdles to onshore CCS deployment by further developing key technologies and preparing a favourable (societal, regulatory and technological) environment.

The main challenge facing onshore CCS is to gain the confidence of the public, but also of operators, emitters, investors, policy-makers, and regulators. This incorporates:

- Demonstrating through practical experience that injection operations can be run safely and efficiently onshore, which is key for optimizing operations and to enable a positive regulatory environment;
- Ensuring that estimated matched storage capacities are sufficiently reliable and also affordable to verify, which is needed to enable investment in projects and therefore the deployment of CCS;
- Demonstrating our capacity to understand, detect and manage potential leakage risks, which is key for regulatory issues and to demonstrate storage is environmentally sound and safe for human health;
- Integrating CO_2 storage into the local economic activities so that the benefits are also reflected at the local scale, which is vital to enable the deployment of CCS;
- Engaging the local population in the storage projects, without which project development is impossible.

The experience acquired on these issues at the various sites will be compared with other experiences worldwide, and then integrated into protocols, proposed standards and best practices. This knowledge will be made available to operators, regulators and scientists through the ENOS innovation management strategy and education and training. Involvement of industrial partners and input from external stakeholders will ensure that the deliverables are fit for purpose.

Project position in R&I

ENOS will focus on validating onshore CO_2 geological storage, as a whole, through action at pilot scale (TRL6) such that it is ready for moving to large-scale integrated CCS demonstration projects (TRL7), by:

- advancing innovative technologies already tested at lab or smaller scales (TRL4-5) to TRL6 by validating them in relevant real-world environments;
- improving the range, sensitivity, response time and/or portability of existing technologies;
- adapting existing technologies used in other domains by applying them to CO_2 storage;
- integrating single technologies into a coherent system and validating it with large-scale site operators;;
- improving existing methodologies by applying them to real-life data from sites in the injection or characterisation phase.

Work Programme

The ENOS work programme will be organised into 9 work packages (WP) as follows. A first group of WPs (1 to 4) will focus on demonstrating technologies able to tackle key issues for onshore CO_2 storage in close connection with the local communities (WP5). The 4 key issues identified are: ensuring safe storage operations (WP1), ensuring robust storage capacities and cost-effective characterisation (WP2), managing leakage risks for protection of the environment and groundwater (WP3) and integrating CO_2 storage with local economic activities (WP4). WP5 will aim to establish a collaborative relationship between research teams and the local communities, focussing around new/future pilot sites. It will bring research outcomes and their impacts on society to the population and bring concerns and societal challenges to the researchers.

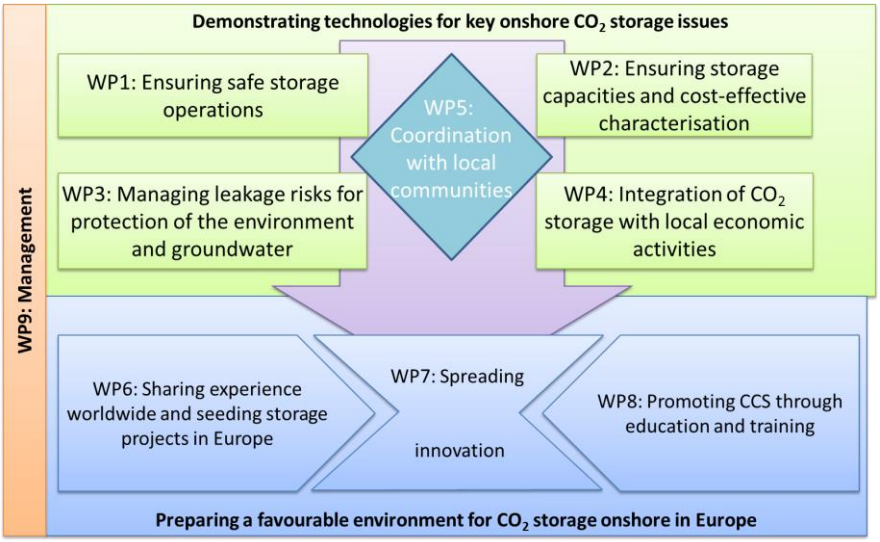


Figure 1: ENOS Work Package (WP) structure

The second group of WPs (6 to 8) will prepare a favourable environment for CCS onshore in Europe. Relying on the results from WP1-5, they will maximise the impact and innovation potential of ENOS. WP6 aims to share experience with other onshore projects in the world, and drawing on all past experiences, to support the preparation of new pilot and demonstration projects in Europe. By integrating research outcomes and bringing them to stakeholders and the market, WP7 will allow the spreading of innovation achieved in ENOS, mainly through best practices and identification and protection of project intellectual property. WP8 will address training and capacity building needs for a new generation of scientists. Lastly, WP9 will be dedicated to project management.

Figure 1 illustrates the ENOS project structure. More details on objectives, progress beyond the state of the art and the innovation potential of each WP are given in section "1.4 Ambition".

Link to national and international research and innovation activities

International cooperation with onshore pilots and demonstration projects across the world will be set up through a programme including storage site twinning, focus groups centred around operative issues and the creation of a leakage simulation alliance. Fostering experience sharing and research alignment between existing sites is key to maximize the investment made at individual sites and to support the large scale deployment of CCS. The collaboration through ENOS will ensure greater reliability and visibility of results. In addition, it will help promote European expertise around the World. The partners that will participate in the collaboration programme (see intention letter in Section 4) are:

- Batelle in the USA, running an EOR-storage large-scale test in the oil-bearing carbonate reefs of the Michigan Basin,
- CO2CRC running the Otway site in Australia
- Kansas Geological Survey, preparing to inject CO_2 at a pilot scale in Wellington Field in Sumner County, in the USA.
- KIGAM in South Korea running an onshore pilot Janggi
- K-COSEM Leakage simulation site, Environmental Impact Test (EIT) facility at Eumseong
- SACCCS in South Africa, currently preparing a pilot as part if the South African CCS road Map
- CMC in Canada setting up a leakage simulation site, where CO_2 will be released at 300-500m depth

Detailed Framework for the international collaboration is described in WP6.

ENOS has been endorsed by the CCS Joint Programme of the European Energy Research Alliance (EERA) of the SET-Plan, thanks to the proposed work programme that addresses the alliance research priorities – see letter in Section 4. Several partners of ENOS are members of EERA, this will ensure a close relationship all along the project for mutual benefit.

Several partners (BGS, BRGM, CIUDEN, OGS, Sotacarbo, TNO) are members of ECCSEL, the European distributed, integrated Research Infrastructure, drawing together Centres of Excellence on CCS research from 10 countries across Europe.

ENOS will take advantage of different national initiatives in Europe and proposes to extend the activities already included in national projects. Such initiatives include:

- REPP-CO_2 project in the Czech Republic: Funded by a Norway grant of 2.2M € complemented by 0.6M€ partners' contribution, REPP-CO_2 aims to characterise the LBr-1 site as a potential storage site. The project (led by CGS with IRIS participation), embracing site characterisation, geological modelling, basic risk assessment and plans for site monitoring is being carried out from January 2015 to April 2016. Site-specific activities planned within ENOS will be a direct follow-up to the outcomes of this 1st-phase.
- The Italian government has decided to back a 10-year research programme dedicated to CCS in Sardinia. The programme will be financed by the Regional Government of Sardinia and the Ministry of Economic Development. The site development and operations will be managed by Sotacarbo. Along with capture technology development, the Sulcis initiative includes the realization of a CO_2 storage small scale pilot which aims to characterise the storage area, and to test and demonstrate the storage potential in deep underground aquifers and in unmined coal seams in the Sulcis area. An experimental open research platform is also being created to study CO_2 flow along faults (Sulcis Fault Lab). ENOS will use this facility and test tools for characterising the pilot site.
- A Dutch national research project with a budget of about 250 k€ is being developed for the Netherlands Energy Innovation Programme. Site-specific data from the Q16-Maas gas field will be made available to the ENOS project, for studying CO_2 Utilisation concept related to buffer storage and economic impacts.
- In the UK, the GeoEnergy Test Bed (GTB) will benefit from direct investment from the site owners (BGS and UNOTT) worth £3.5M, with additional direct investment from the £60M Phase 1 UK Government support for the GeoEnergy Research Accelerator (G-ERA) – forming part of the UK Midlands Energy Research Accelerator (ERA) - and with proposed additional investment from the £190M Phase 2 support is being sought. The GTB will be extensively used by ENOS to demonstrate leakage risk management.

In addition, the project will also benefit from all the national R&D programmes in which the participants are involved. These programmes are listed in the consortium description in Section 3.3.

1.4 Ambition

Progress beyond the state of the art

Progress on CCS in Europe has slowed down recently. There are currently only two commercial-scale operations in Europe (Sleipner and Snøhvit both in offshore Norway), and despite policy and financial drivers, no new major CO_2 storage project has been sanctioned onshore. This slow development is partly due to the lack of sufficient financial incentives but also, importantly, to a lack of feed-back on the regulatory framework for CO_2 transport and storage, operational experience, cost visibility and public acceptance. Overcoming those issues is ENOS ambitious target.

Significant investment in research has been made by the EC through FP6 and FP7. The knowledge acquired through these earlier projects will serve as the basis for ENOS but will be further validated and integrated as required in order to be instrumental in CO_2 storage deployment. The consortium has extensive expertise and will rely on field work to address the most urgent issues preventing the wide deployment of onshore storage. Based on practical experience, WPs 1 to 5 will undertake applied R&I to provide solutions for the identified barriers to implementing safe and environmentally sound storage. For this purpose, ENOS address a variety of issues by gaining experience from different sites across Europe, and will tackle different challenges from a broad spectrum of disciplines: geosciences and metrology, economics and social sciences. Outcomes from each discipline will be seen from the perspectives of the other disciplines. Only with this integration of knowledge can CO_2 storage significantly progress and build the vital level of confidence for all stakeholders. A less ambitious programme focusing on merely one or two issues, while helping, would fail to deliver the expected impacts.

For WPs 1-5, aiming at demonstrating key technologies, the state of the art and the progress by ENOS beyond this state of the art are presented in each WP description in Chapter 3. A summary of the ambitious tangible outcomes brought by each of these technical WPs is given in Table 1.2.

WP	Objective	Tangible outcomes
1	Demonstrate safe and environmentally sound injection management: - Test injection strategies - Provide tools for injection and reservoir monitoring	Demonstration of: • History matching for site conformance • Cost-effective injection strategies in a tight fractured reservoir • Mitigation techniques and reduction of uncertainties for induced seismicity • Reservoir monitoring tools for site conformance at pilot scale, ready for use at demonstration/flagship sites: ○ Validation of Silixa's IDAS as part of a 3D seismic survey

	- Provide monitoring data integration solutions and alert systems	○ Extension of the range of application for the removable deep fluid sampler ○ Validation of Flodim sampler and probe • Smart Monitoring integrated approach • Development of Workflow to integrate operation, monitoring and modelling data into risk management and alert system
2	Provide bankable capacity assessment convincing to stakeholders and operators by: - Quantifying the reliability of estimates - Lowering the cost for characterisation	Development and validation of • A reliability index for capacity assessment, therefore improving capacity assessment TRL • A smart characterisation methodology to optimise exploration costs based on existing data • FEED study for low cost smart drilling,
3	Demonstrate safe storage through effectiveness of leakage monitoring techniques and strategies: - Demonstrate ability to monitor groundwater - Demonstrate ability to monitor leakage pathways (faults and boreholes) up to the surface Provide integrated monitoring solution	Demonstration of: • Monitoring strategies to demonstrate there is no unwanted migration or leakage of CO_2 at storage sites, including diffuse leakage and leakage through faults and boreholes; • Tool-box of techniques to assess the geochemical reactivity of groundwater and definition of key parameters to monitor for early leakage detection. • Monitoring at pilot scale ready for use at demonstration sites. Tools and techniques will include: ○ Innovative optic fibre tools for groundwater monitoring (TRL4,5 to 6,7) ○ GASPro-MS Multi sensor probe (TRL6 to 7) ○ Biosensor tools, adapted for CO_2 application (TRL5 to 6) ○ DAS for leakage pathway characterisation using iCABLE, (TRL6 to 7) ○ Tool measuring CO_2 flux from saturated to vadose zone (TRL5 to 6) ○ Low cost GasPro-CO_2 probe network (TRL 6 to 7) ○ Diffuse leakage detector (TRL 5 to 6) ○ Soil gas techniques with improved sensitivity and discrimination of the CO_2 source (from TRL4,5 to 6,7) ○ Including discrimination of the CO_2 source (from TRL4 to 6) ○ Ground CO_2 mapper – autonomous robot (from TRL5 to 6) ○ Multispectral thermal airborne detector (from TRL 5 to 6) ○ UAV for CO_2 air concentration mapping (TRL 5 to 6) ○ Tool for leakage quantification (TRL4 to 6) These tools will address both the need for wide-areal techniques to identify leakage and for detailed point data to confirm and quantify leakage.
4	Integrate the CO_2 storage concept into given economic activities by tackling technical, economic and regulatory issues.	• Technical feasibility of combined condensate production, CO_2 buffering and permanent storage in the Q16 Maas gas field, the Netherlands • EOR and storage coupling based on both technical and economic factors for LBr-1 field. Assessment of the market potential and economic viability of CCS taking into account synergies and conflicts, legal and regulatory aspects.
5	Engage the local population Develop best practices integrative of societal aspects Verify how the integration of societal input can increase awareness and confidence	• A methodology to link the scientific and technical development of the best practices with societal concerns and implementation issues at local level • Developed relationship between R&D community and local population • Online public information tool, providing information relevant to the population based on their input and feed-back • Enhanced relationship between the ENOS pilot sites and the local populations

Table 1.2 summary of the objectives and tangible outcomes of the technical WPs

Innovation potential

ENOS has been designed to produce innovations that are fit for purpose and near to market, so as to be instrumental in CO_2 storage deployment. Overall, the WPs are directed at advancing to the next step in the innovation cycle: through rigorous field testing, a wide variety of methods and tools will be developed and/or adapted to reach at least TRL6. A number of the products that result from the work programme are or will be of commercial interest and of value to both storage operators (e.g. light drilling, injection strategies etc.) and regulators (e.g. ground water protection guidelines, microseismicity mitigation techniques). WP7 will develop an innovation management strategy and identify the opportunities for bringing to market the main outcomes of the project, through ongoing evaluation and protection of arising project intellectual property, discussion with industry and end-users, publications and communiqués. For each activity in the detailed WP description, precise progress beyond the state of the art is described as well as the outcomes to be produced by the ENOS project.

2. Impact

2.1 Expected impacts

ENOS, the aim of which is to enable onshore CO_2 storage in Europe, will have the following needed impacts:

Demonstration of safe and environmentally sound storage - ENOS will participate in the CO_2 injection activities at Hontomin and deploy modelling and monitoring techniques that will further demonstrate the concept of environmentally sound storage. Fieldwork at leakage simulation sites will prove our ability to understand leakage risks and thereby to mitigate them. In particular, improved understanding of fault behaviour will shed light on one of the last major unknowns for the safety of storage. If unforeseen leakage did occur, then new monitoring methods will ensure it is more likely to be detected early and that possible emissions to the atmosphere can be quantified with greater precision. Early leakage detection will permit rapid response, thereby limiting the amount and impact of any leakage.

Optimising safe operations and fine tuning of regulatory issues - Integrated workflows validated in ENOS with a clear link to Risk Management will allow regulators to have a better overview of site behaviour, thus offering a collaborative link between site operators and regulatory authorities. The development of a protocol for daily management of injection and an alert system will allow integration of monitoring data and thereby optimisation of injection and storage while ensuring safety. Through consultation with representatives of regulatory authorities, ENOS will develop best practices targeted to support them. ENOS will rely on and further develop the current involvement of the CO_2GeoNet association in actions such as the ISO TC265 standard definition and the review of the European CO_2 Storage Directive, as well as the established relationships between CO_2GeoNet Members and regulating bodies in several countries. The End-User Committee, in WP7, will include representatives of regulatory bodies in different Member States. This engagement with policy makers and regulators will support fine tuning of regulatory issues based on the latest research outcomes and strong integrated expertise offered by the consortium.

Increased confidence of the local population - The demonstration of safe and environmentally sound storage is key to building confidence in the local population. This includes demonstration of the ability to manage and mitigate leakage risks and to ensure the protection of groundwater resources. This will be achieved by the validation of monitoring tools for leakage detection and their integration into a comprehensive and effective monitoring programme. Most importantly, an innovative and cooperative process will be developed to involve the local population in ENOS and to integrate their concern into the research agenda as far as practicable with the aim of increasing the confidence of the local population and the general public in the long term. An on-line communication tool, providing real-time information on site operations will be created, based on the needs expressed by the local community.

Increased confidence of operators, emitters and investors - Site operators, emitters and investors need greater visibility on the implications of CCS project developments and their economic potential to advance CCS as a favourable option. In addition to providing key technologies, sensors and protocols adapted to their needs, ENOS will improve the reliability of capacity estimates, participate in de-risking early site characterisation and outline methods for clearly communicating storage capacity and uncertainties to these end users. In order to improve the business case for CCS, ENOS will investigate opportunities to integrate CO_2 storage in the economic development of a region.

Public awareness - ENOS will publish documents that are complementary to existing material, for civil society and industry, to explain the CO_2 storage technology. Online dissemination materials will be made globally and openly accessible through the project and partner websites. Work with the media will be undertaken, in particular in relation to the experimental and pilot sites, in collaboration with site operators.

Enhanced and effective cooperation between key stakeholders and Member States - The ENOS project is building on the pan-European coverage and expertise of CO_2GeoNet. The portfolio gathers sites in several Member

States and ENOS will ensure maximum cooperation between these sites. Testing technologies in real-life conditions up to TRL6 requires field work that is costly, both in terms of capital costs and operational costs. Therefore, the ENOS project has chosen to work on sites that already benefit or have benefitted from other funding from national and European sources. The added value of the ENOS project working closely with existing operational/field test sites will be to enable i) additional testing of innovative technologies at these sites, ii) longer test periods, and iii) a site portfolio approach necessary to demonstrate technologies across the storage cycle and in a wide range of geological, socio-economic and national contexts. This is a cost-effective way to advance onshore CO_2 storage development onshore across Europe. The knowledge-sharing activities will also foster collaboration outside of the ENOS consortium between a wide range of stakeholders (European and national policymakers, regulators, emitters from power and industry, transport and/or storage operators etc.) across Member States and globally. This enhanced and effective cooperation is essential for achieving the objectives of the project, i.e. enabling the development of CO_2 storage onshore in Europe by demonstrating technologies and preparing a favourable environment across Europe.

Accelerating demonstration - All the impacts described above will contribute to this broad impact: they will all help accelerate demonstration of CCS. In addition, WPs 6-8 dedicated to creating a favourable environment for CO_2 storage onshore in Europe will allow the acceleration of demonstration by:

- Better identifying storage project opportunities across Europe and providing a stepping stone for new onshore storage pilots and demonstrations to develop;
- Enhancing knowledge transfer from existing sites worldwide to catalyse new projects;
- Bringing key technologies, developed in ENOS and necessary for CCS deployment onshore, to operators and engineers;
- Building a roadmap for upscaling identified synergies of CO_2 storage with CO_2 utilisation;
- Training and educating scientists and engineers to face the challenges of CCS.

Improving innovation capacity and integration of new knowledge

ENOS will produce innovations that are adapted to the needs of implementing CO_2 storage and facilitate uptake by the market. Through a broad communication strategy, ENOS will aim to expand understanding in potential end-user sectors in order to increase the number of players in the potential supply-demand chain for CCS thereby expanding the potential market for CCS in Europe. The participation of industrial representatives from different sectors and input from the advisory body will ensure alignment of ENOS outcomes with needs. 4 SMEs are involved in the consortium and will use ENOS as an opportunity to expand their area of service/expertise by validating technologies and thereby strengthening their competitiveness. A number of activities in the work programme are dedicated to lowering the cost of storage, ensuring revenue for storage (by addressing Storage and Utilisation coupling issues) and de-risking the investment decision for storage. All this will contribute to making CCS a real possibility for companies to consider in order to lower their emissions while not jeopardizing their competitiveness and balance sheet. A number of outcomes (e.g. monitoring tools) from ENOS will also be applicable to offshore storage sites.

By demonstrating/ validating technologies for safe and efficient storage, ENOS will help the growth of an industry sector dedicated to CCS. However this sector will only develop if there is a strong political will for implementing CCS and if incentives (or penalties) are established for storing (or emitting) CO_2.

Many technologies developed in ENOS can also be extended for other uses of the underground (such as energy storage, oil and gas, geothermal energy, groundwater management etc.) and therefore be of interest for a broader spectrum of companies in Europe. Such opportunities will be identified in the exploitation of results plan.

2.2 Measures to maximise impact

The structure of ENOS has been designed in order to maximize the impact of the research results, and more precisely to maximize the uptake of knowledge by industry, government and regulators, society and the scientific community. The Consortium also strives for a maximum disclosure of the project results while carefully screening to what extent the knowledge of individual partners needs to be protected (see 'IPR management and open access'). The Management Board will systematically and transparently decide if and how knowledge needs to be protected and subsequently what can be disseminated. Dissemination and exploitation of project results will play a significant role in the ENOS project. While the first five WPs are dedicated to significantly advancing technologies and knowledge for enabling onshore CO_2 storage, WPs 6, 7 and 8 aim to develop, integrate and disseminate these advances and therefore ensuring ENOS will positively impact the deployment of CCS in Europe. WP7 will integrate all the research outcomes into best practices and plan the exploitation and dissemination of results. WP6 will liaise with other pilot projects and identify opportunities to develop new storage sites or to up-scale pilots. Finally WP8 will disseminate the results both towards the new generation of scientists through education and

training and towards the general public through interaction with the media. Dissemination of knowledge to the public living near envisaged storage projects and to engage them in the decision making, is considered to be of crucial importance for turning onshore storage projects into a success; public participation is central to WP5.

WP	Expected impacts	Measures to maximise impact
6	• Leverage research investments • Support research alignment between site operators • Enhance knowledge and experience sharing within the European CCS community • contribute to the acceleration of CCS development onshore, • Increase the worldwide visibility of ENOS activities and site portfolio	• Establishing durable close partnerships between CO_2 storage pilots and demonstration projects in Europe and worldwide: setting up site twinning partnerships, a leakage simulation site alliance and focus groups; • Preparing further development of ENOS sites to maximise the full value of the pilot projects for research and for upscaling to higher TRL levels leading to market uptake • Identification of promising opportunities for future pilot/demo sites, and geological settings in Europe with significant untapped storage potential. • Producing a roadmap for upscaling identified synergies of CO_2 storage with CO_2 utilisation
7	• Demonstration of safe and environmentally sound storage • Contribute to the acceleration of CCS development onshore, • Spreading innovation to end-users	• Organisation of internal knowledge integration workshops • Set up of scientific editor committee to coordinate research integration, plan for dissemination , and support exploitation of ENOS results • Production of concise best practices tailored to stakeholders needs • Set up of knowledge-sharing platform • Set up of ENOS website
8	• Educate the next generation through capacity building to meet the future needs inherent to CO_2 storage deployment • Set the basis for CCS education • Favour debates around CCS on a sound and scientific basis	• Providing intensive training courses, for young scientists, on onshore CO_2 geological storage outlining latest research • Enhancing university cooperation to set the basis for a coordinated Master and post-graduate Master programmes on CO_2 storage through the development of : o a network of institutions and laboratories o educational modules/lectures • Providing e-learning course for students allowing wider access to research results and for the civil society • Providing short courses for journalists and media, enhancing scientist-journalist communication

Table 2.1: Expected impacts and measures to maximise them

a) Dissemination and exploitation of results

The dissemination and exploitation of results plan will include:

- Innovation management strategy with plans for the main outcomes of the project. The aim is to bring the results nearer to the market and make sure they are useable by stakeholders;
- End-use communication plan (see section below), with events and conferences to be organized;
- Input to training and education, identifying which research results should be included in training and education and how;
- Strategic events to be attended to promote ENOS results.

The plan will take into account the different target groups for the dissemination of results:

- The scientific community in particular through publication and promotion of open-access to data sets produced in ENOS.
- Industry, through the consultation with end-user representatives, the production of fit for purpose best practices and organisation of workshops and conferences to promote the near market outcomes of ENOS.
- Governments to support development or adjustment of their CCS enabling policies through provision of scientific advice
- Regulators and environmental agencies by providing guidelines on safe storage for policy fine tuning
- International and European standardisation organisations to evaluate existing standards and develop new standards

- Students and young scientists by providing training and education, using the cutting edge ENOS results and state of the art background.
- Environmental NGOs to provide them with independent balanced information on CO_2 storage
- General Public through media by creating a trust based exchange relationship with journalists to provide them with impartial scientific input on CO_2 Geological Storage.

For all the target groups CO_2GeoNet is excellently positioned as the association already has extensive experience in spreading research results to the wider community including the target audiences mentioned above. The Association has representatives in 19 European countries and liaises with the main entities dealing with CCS in Europe including the EC, ZEP, EERA CCS JP and ECCSEL and globally including GCCSI, CSLF, IEA-GHG and UNFCCC.

ENOS, in WP6, will enhance knowledge and experience sharing with other EU projects and with onshore pilot sites in the World. This will allow to compare and to validate ENOS outcomes with results from other sites and research results globally and will also offer a worldwide visibility amongst the main actors of CCS in the World. ENOS will direct particular attention to 'real- life' dissemination and exploitation of results to and with stakeholders engaged with the storage projects in the ENOS portfolio and to targeted dissemination related to new developments in CCS policy and roadmaps during the lifetime of the ENOS project. The preliminary plan for dissemination of the project results is delineated in Table 2.2. Target audiences will be asked for feedback so that follow-up actions for research or market-uptake can be better defined.

ENOS has been endorsed by the European Energy Research Alliance CCS Joint Programme (EERA CCS JP) of the SET-Plan, thanks to the proposed work programme that aligns the major research performing organisations in the framework of EERA and the SET Plan. Outputs from ENOS will inform the EERA CCS JP research priorities. Many ENOS partners are also participants in the EERA CCS JP.

The dissemination and exploitation of results from ENOS will be coordinated by WP7. A summary of preliminary dissemination and exploitation plans of the ENOS results is given in Tables 2.2 and 2.3 respectively. These plans will be regularly updated based on integration of the research activities and through the work of the scientific editors who will be responsible for identifying and facilitating the opportunities for bringing to the market the main outcomes and messages of the project, through publications and communications, contacts with end users and patents where relevant. In addition representatives of the end-users will be sitting on the Advisory Body (cf Section 3.2) and will thus be regularly consulted.

Target	Dissemination tool	Specific dissemination action	Project management steering
Project consortium	Annual meeting and workshops ENOS knowledge-sharing platformer	Presentation and discussion of project results Archiving of ENOS intermediate and final results	Identify project results and assign presentation tasks Maintenance and update of archive
External stakeholders	Annual CO_2GeoNet Forum in Venice	Session dedicated to ENOS results	Identify project key results
Media journalists	Press release Short courses	Provide updates on the project and CCS in general Establish relationships with media	Identify key outcomes and opportunities for exchange
industry ZEP	Workshop	Involvement in end user committee	Establishing and maintaining contacts with end-users
EERA CCS JP	Workshop and position paper	Joint organisation of dissemination event	Provide timely input Identify joint actions
Scientific community	Scientific journals	Publications of ENOS results	Identification of publishable results
Young professionals	CO_2 storage school	Promotion in doctoral schools, research institutes and potential operators or site owners	Identification of key knowledge to transfer
Students	E learning CCS educational programme	Promotion of education opportunities in partner universities	Identification of key knowledge to transfer to student
EC DGs	Lunch tables	Presentation of the impact of the ENOS outcomes for CCS deployment	Establishing contact with DGs Identification of key messages
Local	Online info-tool	Organisation of the interaction	Develop local contacts

communities around sites	Workshops, local media	between scientists and local communities	Identification of understandable message
Public at large	Website	Publish documents and video with information about CCS and ENOS easily understandable	Key message identification and vulgarisation

Table 2.2 Preliminary dissemination plan

Target user	Description of project result and use
R&D community	Advance in the state of the art Datasets acquired at the field sites to use for further study
Potential site operator	Roadmap with input for business plan Best practices for business and industry Technical guidelines for capacity estimates, smart site characterisation, monitoring site conformance and for planning and implementing storage sites Technologies ready for use at demonstration scale (see table 2.1)
Geo-engineering industry	Technologies validated at pilot scale that can be applied for other underground uses, such as light drilling, sensors and samplers.
Standardisation organisation	Best Practice and standard development
Policy maker	Roadmap for the region deployment of CCS with economical impact, to be used for assessing potential policies Best practices for government and regulators
Regulator	Technical guidelines on monitoring and site conformance Best practices for regulators, to be used for implementing the EU CCS directive and for interaction with the local population Technologies ready for use at demonstration scale (see table 2.1)
NGO and local community	Easily understandable and scientifically sound information , in particular : Best practices on what makes a sound CO_2 Storage project Online information tool

Table 2.3: Provisional exploitation plan

IPR management and Open access

Knowledge generated and used within the project will be properly managed, with any arising IP protected and exploited effectively while allowing for open access publications and the transfer of data generated to open repositories for training and/or dissemination as appropriate. Knowledge management will be based on the legal requirements defined in the official documentation published by the European Commission: '*H2020 Rules for Participation'*, and will be conducted by following the definitions and statements in the Consortium Agreement.

Generated knowledge of commercial interest will be safeguarded and protected for exploitation by the owner (s) in accordance with the terms negotiated and outlined within the Consortium Agreement. The consortium agreement will be based on usual DESCA model and provisions. The Intellectual property of produced results in ENOS will be shared between the participants in the task. Partners in the project will have the right to use the results for non-commercial purposes. Co-owners of a result shall ask permission to other coowners before granting an exploitation license.

An exploitation plan will be developed between consortia partners in the course of the project, coordinated by the Scientific Editors in collaboration with the relevant partners. Both documents will seek to ensure that IP exploitation is undertaken by the partners best positioned to do so with apportionment of fair reward to all contributing parties.

The WP7 coordinator will take on the role of Project Dissemination and Exploitation Manager and will manage the knowledge generated in terms of dissemination and exploitation. In this role, he will report to the General Assembly, which has overall responsibility and decision making authority. Throughout the duration of the project, the Scientific Editors will review a list of IP to be protected, agree a timetable for filing protection activities and establishing other protections as relevant. They will actively seek professional advice in making decisions concerning IP, including whether research output dissemination needs to be delayed to allow for appropriate IP protection. This strategy for using and disseminating the knowledge during the lifetime of the project and beyond will be considered at each General Assembly. Where appropriate, IPR review and proposed protection will be supported by IP teams from relevant institutions, guiding on appropriate ownership, protection and exploitation

models available to the consortia to ensure that all new knowledge generated through the project is protected and/or exploited as appropriate and in line with the objectives of the funding stream.

ENOS will strive to provide open access to as much of its data as possible. Data acquired at sites through ENOS will be made available for further research by the scientific community on an open access policy. For data where strategic interest might be impacted, open access will be delayed for a determined time not exceeding 2 years (embargo time). The data will be gathered by site owners and stored and maintained on the already existing UK Research Council-funded CCS Knowledge Hub, which has been designed for the purpose of gathering and giving access to public domain documents and data from all UK CCS RC-funded research projects and other projects willing to grant access to their public datasets. For LBr-1, data are already gathered in a different database, which will be used to provide open-access. The ENOS website will serve as a gateway, presenting the different datasets available data and providing links. The process for third parties to get access to the data will also be clearly presented. Data produced in ENOS will mainly be measurements related to site operations in Hontomin, leakage simulation experiments at GTB and Sulcis Fault Lab, project deliverables will also be stored for long term availability in the UKCCSRC data hub for access after ENOS. Each site operator will be responsible for gathering and integrating the collected data.

b) Communication activities

The dissemination and exploitation of *results* plan is an important part of the larger detailed communication plan of the ENOS project. The project will perform dedicated communication to highlight the *actions* in the project which will be closely related and complementary to dissemination and exploitation. Key communication activities that will be undertaken by ENOS, include:

- Organisation of the annual Open Forum in Venice,
- Biannual newsletter sent to relevant stakeholders,
- Public pages of the ENOS Website, integrating social media such as Twitter, linkedIn and Facebook, and providing access to open data.
- Promotion of training and education programme, using the existing networks,
- Participation at key events, not only strictly CCS events (COPs etc.),
- Organisation of workshops with journalists.
- Press releases at start and end of project and important milestones achieved at the sites

3. Implementation

3.1 Work plan — Work packages, deliverables and milestones

The ENOS work programme will be organised into 9 work packages (WP) as depicted in figure 1. A first group of WPs (1 to 4) will focus on demonstrating technologies able to tackle key issues for onshore CO_2 storage in close connection with the local communities (WP5). A second group of WPs (6 to 8) will prepare a favourable environment for CO_2 storage onshore in Europe. Relying on the results from the previous WPs, they will maximise the impact and innovation potential of ENOS. The timing of the different activities is presented in figure 2. All field activities and main research tasks will be performed in the first 3 years of the project in order to leave time for development and further integration of results, and to allow interaction with stakeholders during the finalisation of best practice documents.

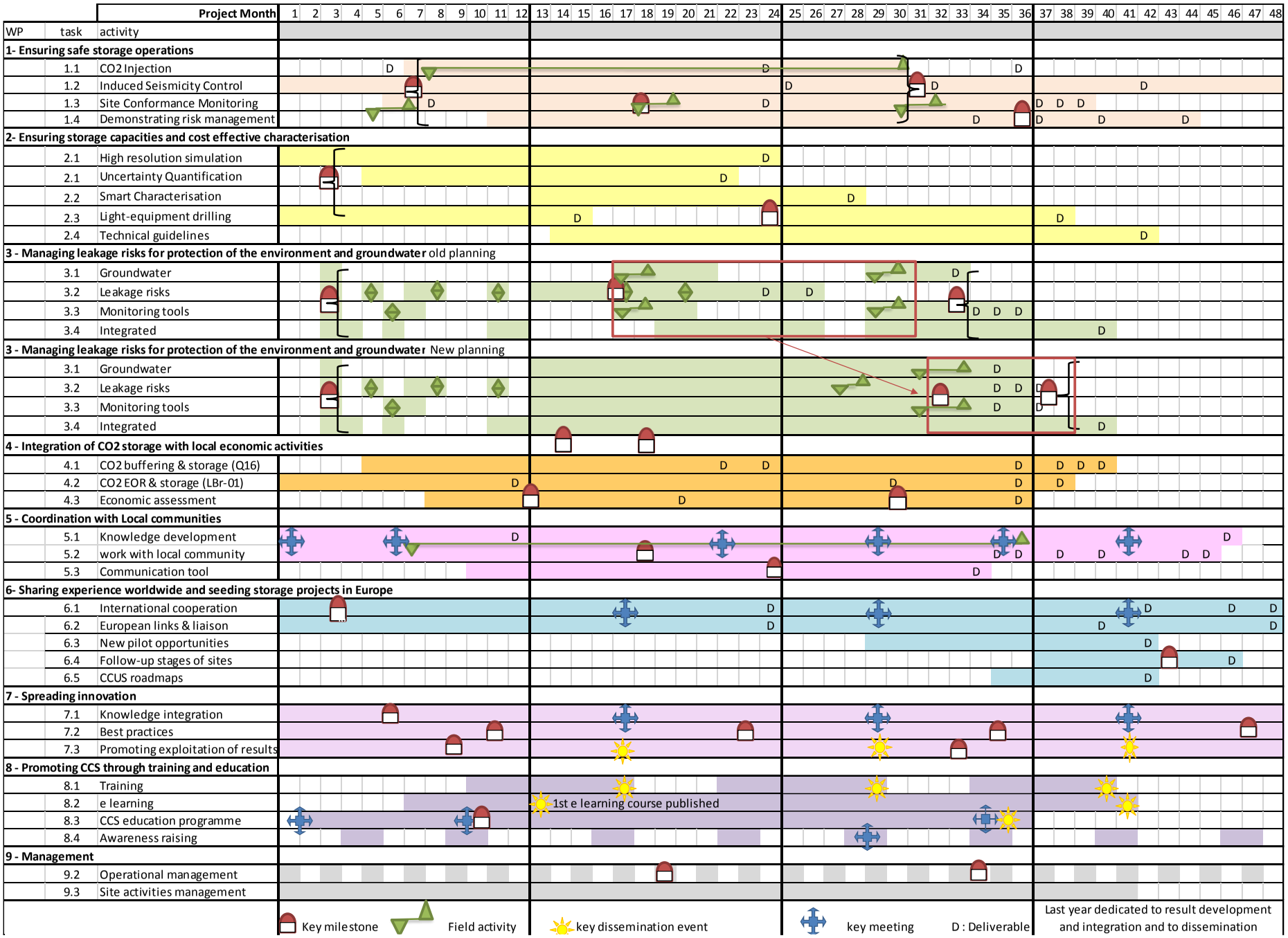


Figure 2: ENOS GANTT chart over the 4 years

3.2 Management structure and procedures

Organisational structure and decision making

The consortium is well aware of the ambitious and specific nature of this Research and Innovation action, such as:

- coordination of field activities, each with its own uncertainties and risks;
- High ambitions in the number of issues addressed and the resulting high number of WP
- 19 participants, representing 30 partners when one counts the 10 Members of the CO_2GeoNet Association participating as third parties;
- Many different nationalities, languages, cultural backgrounds and habits.

Consequently, the participants of the consortium have jointly decided how to best match the organisation and management of ENOS to these challenges, according to the following principles:

- The proposed organisational structure is relatively simple with bodies and formal duties clearly identified so as to assure high-level commitment of the participants, efficient operational management
- The work plan is structured into nine work packages of manageable size, each with clear descriptions of objectives, tasks, deliverables and time planning.
- Designated responsibilities for each of the work packages, tasks and deliverables from the very beginning. This means that all participants have a clear understanding of their expected contribution and commitment, which makes delivery of the project's results more efficient and reliable.
- Most work package leaders are also involved in the site activities (as owner, co-owner or as major actor).

Project Management

The Project Management will be carried out under the legal umbrella of the EC H2020 contract and a Consortium Agreement signed by the Participants. In addition, CO_2GeoNet members are bound by the Association's statutes and the CO_2GeoNet Consortium Agreement. A dedicated work package is devoted to the project management (WP9'Management'). The work is carried out by the Coordinator in conjunction with the Management Board.

BRGM, member of CO_2GeoNet, is the Coordinator. BRGM i) has significant experience in coordinating European projects (e.g. Ultimate CO_2), ii) hosts the head office of the CO_2GeoNet association, iii) was CO_2GeoNet Network Manager during the FP6 CO_2GeoNet project, iv) was coordinator of the FP7 CGS Europe project, a pan-European Coordination Action on CO_2 Geological Storage that pooled together the expertise of 34 key research institutes across 28 European countries, with CO_2GeoNet acting as a nucleus, and v) has much experience in CCS networking activities in Europe and globally.

The coordinating person is Marie Gastine from BRGM. She is an experienced and fully trained project manager. She will be supported by a nominated deputy from BRGM for the daily tasks and by the contractual, financial and legal divisions of BRGM as support services. As Coordinator, BRGM will be responsible for:

- Communication with the EC and the consortium participants for all contractual, legal, financial and administrative issues
- Submission of deliverables to the EC in due time
- Coordinating the work of the Management Board
- Monitoring the progress of the project in order to ensure ENOS will deliver the expected outcomes in a timely manner.

The operational management of the project will be carried out by the Management Board, comprising the coordinator and the work package leaders. It will be the responsibility of the MB members to:

- Hold and attend Management Board meetings every two months (mainly web/phone-conferences) to discuss the overall progress of the project, address arising difficulties, discuss emerging ideas or opportunities, take specific decisions;
- Prepare the General Assembly meetings, where strategic decisions will be taken;
- Organise consultation with the Advisory Body;
- Organise and support the contractual reporting to the EC at mid-term (18 months) and at the end of the project period (36 months).

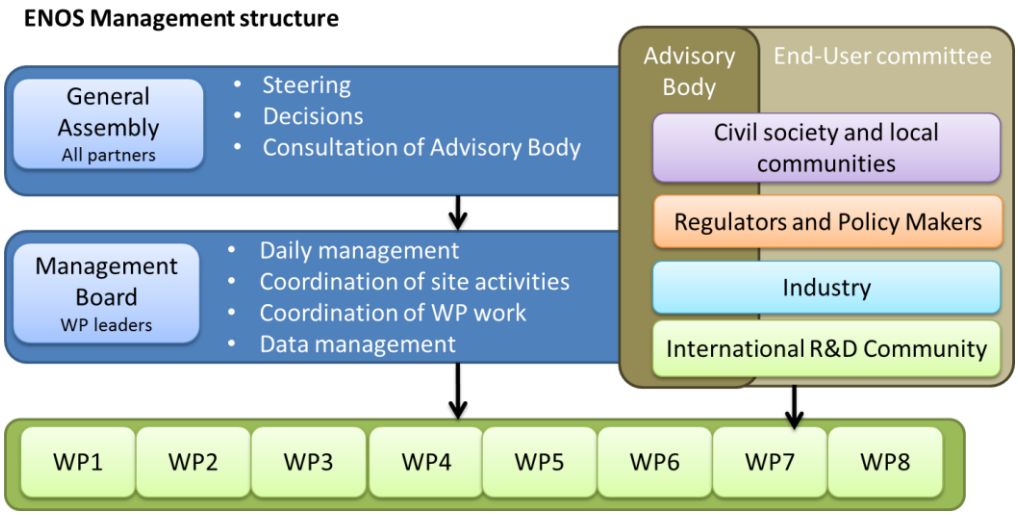


Figure 3: ENOS Management Structure

Organisational structure

The organisational structure is designed to guarantee clear responsibilities, close coordination and effective communication within the ENOS consortium and towards external stakeholders. This will facilitate successful project management and will ensure the delivery of the results and impacts envisaged.

The organisational structure of the project will comprise:

- **General Assembly**

The General Assembly (governing body) is formed of high-level representatives of the participant organisations, having the necessary authority for making commitments. The main responsibilities of the General Assembly are to:

- steer the project
- take advice from the Advisory Body
- make decisions on issues raised by the Management Board
- discuss and approve strategic project issues

The General Assembly meets once a year, next to an ENOS event, to reduce expenses. If necessary an exceptional General Assembly will be called by the coordinator. The Coordinator convenes and chairs the General Assembly meetings, and is in charge of recording the minutes and the actions/decisions taken during the session. The assembly will be chaired by Isabelle Czernichowski-Lauriol. One or more representatives of the European Commission can be invited to attend the General Assembly meetings during its deliberations related to the contract, as observers with speaking rights.

- **Advisory Body**

The Advisory Body is composed of external persons representing End-Users of the outcomes of ENOS and international R&D community. The anticipated members will be key representatives of Industry, Regulatory bodies, NGO/civil society, Partners from international collaboration, the Global CCS Institute.

The exact composition of the Advisory Body and the names of the selected persons will be decided at the 1st General Assembly meeting. The role of the Advisory Body will be to give advice to the General Assembly on:

- the relevance of ENOS activities with recommendations for the actions to come
- the innovation management plans and draft best practices
- the effectiveness of intermediate and final results
- dissemination and use of the project results

Three Advisory Body meetings will be held during the course of the project and will be scheduled next to key project events for convenience (workshops or General Assembly meetings). The Advisory Body will elect a Chairperson during its first meeting who will be responsible for steering the meeting and providing a written report to the General Assembly. Interaction with the Advisory Body will also occur on an informal and ad-hoc basis during the course of the project in the case of specific emerging issues.

- **Management Board**

The Management Board (operational body) is composed of:

- Marie Gastine, BRGM, project Coordinator and WP9 leader
- Lionel Loubeau Gavilanes, CIUDEN, WP1 leader
- Pascal Audigane, BRGM, WP2 leader

- Ceri Vincent, BGS, WP3 leader
- Ton Wildenborg, TNO, WP4 leader
- Samuela Vercelli, UNIROMA1, WP5 leader
- Vit Hladik, CGS, WP6 leader
- Roman Berenblyum, IRIS, WP7 leader
- Niels Poulsen, CO_2GeoNet-GEUS, WP8 leader

The combination of key actors of CO_2 geological storage research, through their insight and experience in multi-partner project management and coordination activities at national and EU project level, forms the optimum operational setting for the efficient management of the consortium. The good balance on geographical origin, gender and age is an additional strength for achieving the project's results.

The Management Board will be responsible for:

- Preparing logistics and content of the General Assembly meetings, including list of decisions to be taken;
- Making sure that the points raised and decisions made by the General Assembly are correctly addressed
- Organising the meetings of the Advisory Body;
- Ensuring good coordination between the project work packages;
- Organising and supporting the contractual reporting to the EC.

The Management Board will meet at least every two months, mainly in connection with ENOS events or through webconferences. Meetings will be chaired by the Coordinator who will also prepare the minutes.

- **Work Package Leaders**

Each work package Leader is responsible for the tasks and deliverables under his/her work package. He/she will liaise with the task leaders and their teams and meet with them as appropriate. Each work package Leader has a seat in the Management Board. WP leaders will organise ad hoc meetings to coordinate the WP activities. Such meetings will be conducted either though phone conferences or in conjunction with other ENOS events in order to save on travel expenses.

Contact with the European Commission

The coordinator will act as the intermediary between all participants and the Commission's services. The DG Research scientific officer in charge of the project will be invited to key ENOS events.

Decision-making mechanisms

Key decisions within the project will be the remit of the General Assembly. Decisions by the General Assembly will preferably be taken on a consensus basis, but when this is not possible, by vote. Voting rights of participants and third parties and mechanisms for decision-making, will be detailed in the Consortium Agreement, prepared during the negotiation phase of the contract. Decisions of the General Assembly requiring the agreement of the European Commission will be submitted by the Coordinator for approval and will only be executed once agreement has been obtained. Minor decisions on operative issues can be taken by the Management Board, which will give the flexibility needed for an effective day-to-day operational management, taking into account the constraints and opportunities that may arise. These decisions will be reported to the General Assembly, which may overrule Management Board decisions.

Innovation management

Innovation management will be dealt within WP7 and will be the basis for the development of the dissemination and exploitation of the results plan. Scientific Editors, in coordination with WP leaders, will be responsible for this, as described in WP7 description (Section 3) and 'measures to maximize impacts' set out in Section 2.2.

Risks related to project implementation

The ENOS work programme is based on real-life experiments. Such activities entail high uncertainty and therefore present risks for the project in addition to the risks inherent in research. ENOS will set up the appropriate measures to mitigate those risks, as described in Part A.

3.3 Consortium as a whole

ENOS is an initiative of CO_2GeoNet, the European Network of Excellence on the geological storage of CO_2, created in 2004 through a FP6 project and now a non-profit scientific Association since 2008, active on both the EU and global scene to help enable efficient and safe CO_2 storage. Current membership is 26 research institutes spanning 19 European countries. ENOS builds on CO_2GeoNet's strength, expertise and added value: a reputed, independent, multidisciplinary, pan-European scientific body with established links to key initiatives and stakeholders at an international level (GCCSI, CSLF, ISO TC265, IEAGHG, UNFCCC), experienced in research, training, scientific advice and various forms of dissemination activities with stakeholders. The European coverage

of CO_2GeoNet combined with the international collaboration set up in ENOS will allow community-based research integration, verification of best practices and cross-disciplinary communication. This will ensure excellence in science and completeness in addressing the multidisciplinary challenges of implementing CO_2 storage.

The consortium is composed of most of the members of CO_2GeoNet and completed by CIEMAT, SGIDS and University of Nottingham and several industrial companies: Geogreen, Silixa (SME), IDIL (SME), Flodim (SME), NHAZCA (SME) and Sotacarbo. For the purpose of enabling onshore CO_2 storage in Europe, the consortium has the necessary pan-European coverage (17 countries are involved), gathers the required high level of expertise in CO_2 geological storage from research institutes and academia, complemented by experience and know-how from site owners and technology providers. Industry partners in the consortium will ensure that the technologies validated in ENOS are relevant for their activities and can be deployed in the near term. The consortium has the necessary links with national, European and international networks to maximise the impact of ENOS and to spread innovation, for example, the GCCSI will support the project and have a strong leveraging effect in knowledge sharing, disseminating and creating favourable conditions to implement CO_2 storage in Europe and around the world. The members of CO_2GeoNet are involved either as full partners or as third parties in the consortium, depending on their involvement in the project.

Together the participants bring an extensive and unique experience in CO_2 geological storage, demonstrated by a wide range of European and national projects, which will feed into the work carried out under ENOS. Key projects that ENOS partners participated in that provide a strong foundation for the proposed work programme include:

- FP6 CO_2GeoNet, CASTOR, CO_2ReMoVe, EU GeoCapacity, ULCOS, INCA-CO2, GRASP, INTAS;
- FP7 CGS Europe, CO_2CARE, ULTimate-CO_2, SITECHAR, ECO$_2$, RISCS, R&Dialogue, IMPACTS, ECCSEL PPI and PPII, STRACO2, COMET;
- French ANR and ADEME projects such as EM-Hontomín, CIPRES, H-CUBE, CO_2-Dissolved, FISIC, MANAUS, COPTIK, France Nord, ULCOS-TGRBF, AMIRAL, IMPACTS-CO_2, MOME CO2;
- EUROGIA+ CO2FieldLab
- UK projects ASGARD, CASSEM, ETI UK SAP; Dutch CATO programs; German Federal Ministry of Education and Research projects CLEAN & MONACO
- EEPR-funded projects: OXY-CFB-300 Compostilla – (Duero/Hontomín sites).

Industry involvement

The consortium includes 6 industrial partners. They represent different segments of the potential CCS business:
Geogreen, is an engineering company dedicated to CO_2 storage, which could in the future propose storage solutions to emitters. Technology providers are represented in ENOS through innovative SME's: SILIXA Flodim, NHAZCA and IDIL. All have interest in the results of the project and will provide their expertise but also express the end- user view on the ENOS innovation. The participation of the SMEs is limited (in relation to the total amount of the project), but this corresponds to their research investment capacities. They are nonetheless important actors in the consortium and they will be involved in the integration of results as much as possible.
Sotacarbo is a research company, tightly involved with industry partners.

3.4 Resources to be committed

Justification of major other direct cost

The table below presents the justification for the travel and other costs for all partners and third parties. Travel cost estimation are done on an average costs basis and will be subject to changes according to destination and duration. The number of travels, in particular in communication and dissemination may vary from predicted according to opportunities arising during the project.

The beneficiaries will base their contracts and subcontracts on the 'best value-for-money' considering the quality of the service proposed (also called 'best price-quality ratio') or on the lowest price and avoiding any conflict of interest. Beneficiaries that are 'contracting authorities' or 'contracting entities' (within the meaning of the EU public procurement Directives 2004/18/EC and 2004/17/EC — or any EU legislation that replaces these Directives) must moreover comply with the applicable national law on public procurement. These rules normally provide for a special procurement procedure for the types of contracts they cover.

All equipment and other items that will be claimed 100% as cost of the project will be exclusively used for the activities in the project; as a consequence, if the equipment is also used for other activities outside the project, only part of its cost (corresponding to the percent of use within the project) will be charged.

Note in the following table CFS: stands for Certificate on FIncancial Statements and GA for General Assembly

1/ BRGM	**Cost (k€)**	**Justification**
Travel	69.4	**Field activities**: WP1: - 3 sampling campaigns for geochemical monitoring:3x3.5k€ - 3 geophysics field activities 10.5k€ ; WP3: - Field campaigns to test optic fibre tool 3x6k€ **Attending WP Meetings**: WP1 6k€; WP2 3k€; WP3 2k€ ; WP9 5k€ **Attending Workshops**: WP5 2k€; WP7 2.4k€; WP8 5k€ (CO_2 storage schools) **International collaboration**: WP6 5k€
Other goods and services	132	4k€ for CFS ; 50k€ for Advisory Body travel task 9.2, (about intercontinental travels: 3 meetings and 2 or 3 members coming from overseas) 50k€ for international collaboration partner travel to ENOS sites task 6.1: collaboration with USA (2 entities) ,Canada, South Korea (2 entities), South Africa and Australia Support one or 2 visits from each entity: about 10 intercontinental travels 20k€ for General Assembly organisation (4); 8k€ for fluid sample analysis in WP1.
Total	201.4	
2/BGR		
Travel	48.9	**Field activities:** 24.9k€: 6 x (2 Persons, 4 days) to Hontomin (WP1) and 6 x (2 Persons, 4 days) to the Geoenergy testbed (WP3) **WP 1 & 3:** annual WP meetings, ENOS GA (2 Persons 2 days twice per project year) 10k€, two conferences in Europe (e.g. EGU): 6k€, **WP 6.4**: 4 Travels (1 person 2-3 days) to Q16-Maas site in order to review the site development plans and one WP meeting : 2k€, **WP 8:** Travel to three WP8 workshops preparing CO_2 storage school e-lectures: 3 x 1 Person three days 2k€, Conference and General Assembly attendances 3 x 1 Person for 2-3 days including conference fees 4k€,
Equipment	23.5	WP 1 (14.1k€) and WP 3 (9.4€). to refurbish parts of monitoring stations and/or replace devices during the continuous 3-year monitoring program for a minimum of 5 complete stations operated (3 x Hontomin, 2 x Geoenergy Test Bed) 10k€ for 5 data loggers (Gantner e-reader or similar); 4.5k€ for 5 new IR-CO_2-Sensor for low concentrations; 4.5k€ replacement of the 5 soil humidity sensors (TDR Pico Prime); 4.5k€ for new Router/Modem (UTM capability) devices with faster data transmission for the 5 considered stations .

Other goods and services	23.4	WP 1 (11k€) and WP 3 (8.4€). to refurbish parts of monitoring stations and/or replace devices during the continuous 3-year monitoring program for a minimum of 5 complete stations (3 at Hontomin, 2 at the Geoenergy Testbed): 3.1k€ for 26 test gases cans with different concentrations; 4k€ for 30 tanks of ultrapure methanol for fuel cells; 5.7€ for 12 Nafion-Tubes for soil gas drying purpose and 18 small membrane pumps ; 2.7k€ for 8 solar panels and 16 replacement batteries for short power failures; 4.5k€ for Router/Modem (UTM capability) and real time data transmission via UMTS network to a central data server. 4k€ for CFS
Total	95.8	
3/BGS		
Travel	100	Majority is costs for travel and subsistence for field activities at Sulcis Fault Lab and San Vittorino site. Funds will also be spent on travel and subsistence for attending key ENOS meetings, workshops and events, internal project activities (hereafter referred to as 'ENOS meetings' to reduce text length) and promoting ENOS results through presentations at external conferences. WP2 – 3k€ for travel and subsistence (T&S), attendance of 1 person to 3 ENOS meetings and 1 conference (5 days per meeting). WP3 – Field work T&S and local travel to GTB, 151 days in the field 43.2 k€; ENOS meetings (attendance at 13 meetings of 5 days each), 13.9 k€; Conference attendance (3 people) 5.6 k€. WP6 – Attendance at 7 ENOS meetings (1 person, 5 days per meeting) 9.6 k€; Attendance at conference and side event 2 k€ (1 person, 5 days); room hire for side event 5 k€; attendance at 1 ECCSEL event 1 k€ (1 person, 5 days). International collaboration travel: 4k€ (1 persons, 3 days) WP7 – Attendance at 5 ENOS meetings (1 person, 5 days per meeting) 7.7 k€. WP8 – Attendance at 3 ENOS summer schools (1 person, 5 days per school) 4 k€; attendance at 1 ENOS meeting (1 person, 5 days) 1 k€
Services	52.8	5k€ for CFS. WP3 – Shipping/transporting equipment to and from field sites 7.8 k€; Consumables for field and laboratory experiments including CO2 4.1k€; flight hire 6.9 k€; purchase optic fibre 22 k€; groundwater equipment 4.2 k€; lab costs and sample analyses 2.8k€;
Total	152.8	
4/CGS		
Travel	41.3	5k€ - WP4 –WP and Task meetings and events for dissemination 3k€ - WP5 –WP workshops (6 workshops * 500€) 20 k€ WP6 - Task 6.1 – international cooperation – twinning visit in the USA, participation in workshops; Task 6.2 – European links & liaison; Task 6.3 meetings with stakeholders in the region 6,5 k€ - WP 7 –knowledge integration workshops, 4 Open Forum, dissemination events 1,8 k€ - WP8 –CO_2 Storage School in the Czech Republic , short course for journalists 5 k€ - WP9 –General Assembly and Management Board meetings
Other goods and services	7	software for 3D geological data management, software for geochemical analyses and modelling, software for well data management, consumables
Total	48.3	
5/CIEMAT		
Travel	4.5	WP meetings and/or ENOS GA (2 persons, 4 GA or WP1)
Equipment	0	
Other goods and services	0	
Total	4.5	
6/CIUDEN		
Travel	34.3	- Travel cost for attending General Assembly, networking trips, conference attendance , EC reviews, workshops: 11k€ - Travel cost for attending Field activities:14.3k€ - Travel cost for attending Task 6.1 International cooperation: 9k€
Other goods and	1291	- CO_2: 1030.75K€ (for maximum of 10kton CO_2 for test injection). the planned quantity of CO2 is 10.000 tons, and the current best market price is

services		103,075 €/ton - N_2: 0.93K€ (according to the flow of CO_2 injected and current price) - Propane: 24.80K€ (according to the flow of CO_2 injected and another Technology development Platform (TDP) needs and current price: to inject 10.000 tons of CO2, we need 41.330 kg of propane, and the current best market price is 0,6 €/kg. - Salt: 36.68K€ (according to the flow of CO_2 injected and current price) In order to inject 10.000 tons of CO2, we need 447,33 tons of salt and the current best market price is 82 €/ton. - Diesel Oil: 28.84€ (according to the flow of CO_2 injected and another TDP needs and current diesel price. Energy is produced by a diesel generator). In order to inject 10.000 tons of CO2, we need 68.670 l of diesel oil and the current best market price (0,42 €/l) - TDP facilities maintenance: 58.50K€ (electric and mechanic maintenance and spare parts, for instance diesel generator, pumps, air compressor, fridge machines, heater and so on, as well as communications network maintenance, and passive seismic grid maintenance). - Well maintenance: 80 k€ (it will be workover operations on wells which are necessary to change some items from the well completions after the injection tests and before the introduce the geophysics devices. The slick line service used for this job is one of them). - Maintenance and spare parts of the lab: 2.56k€ (it is necessary to check using our Lab facilities the composition of the fluid from the reservoir in order to know if the chemical composition have the expected values). - Works and services related to improve local communities public perception, to develop workshops, scientific and general meetings and training sessions to accomplish the dissemination, engagement and education aims of ENOS (catering, bus, coffee break, brochures, lectures´s subsistence allowance, etc): 22.54k€ - Audit certificate on the Financial Statements: 5.4K€ (3 audit for the 3 reporting periods).
Total	1321.3	
7/Flodim		
Travel	9	Hontomin Field activities in WP1 (3 surveys)
Services	5	Shipping of material to Hontomin for field activities WP1
Total	14	
8/GGR		
Travel	7.5	WP1: 3.5k€ as 1 GA attendance 0.5k€+ 4 Technical meetings (Hontomin) 4*0.75k€ WP4: 2k€ as 1 GA attendance 0.5k€+ 3 Technical meetings (Utretch) 3*0.5k€ WP7: 2k€ as 2 GA attendance 2*0.5k€+ 2 Technical meetings (Utretch) 2*0.5k€
Equipment		
Other goods and services	71.4	WP1&4: 3 rental periods of 4 months for fluid flow and geomechanics/geochemistry software (GEM) 3*23.8k€
Total	78.9	
9/IDIL		
Travel	2.5	Participation to 4 GAs
Equipment	-	
Other goods and services	-	
Total	2.5	
10/IRIS		
Travel	32.5	WP3: 8 k€ to be used for field trips, WP and task meetings. Corresponding approximately to 8 travels for 1 person for 3 days.

		WP4: 11 k€ to be used for WP and task meetings. Corresponding approximately to 11 travels for 1 person for 3 days. WP7: 8.5 k€ to be used for trips to open forum, WP and scientific committee meeting. Corresponding approximately to 8 travels for 1 person for 3 days. WP9: 5 k€ to be used for project management and GA meetings. Corresponding approximately to 5 travels for 1 person for 3 days.
Equipment		
Other goods and services	32	WP3: 8 k€ would be used for DNA sequencing and identification WP7: 20 k€ would be used for developing design of the website and promotion materials WP9: 4 k€ to be used for CFS
Total	64.5	
11/NHAZCA		
Travel	9.5	Field activities (WP3): 7.5 k€ (3 persons x 10 days to Sulcis) WP meetings and ENOS GA: 2 k€ (1 person attending 4 GA meetings)
Equipment	2	WP 3: 2k€ (optical camera and lenses for RPAS system)
Other goods and services	4	WP3: 4k€ (corner reflectors for Radar, optical prisms for total station, optical target for RPAS, rental of RPAS systems supporting apparatus)
Total	15.5	
12/ OGS		
Travel	80	**Field activities**: WP1 28 k€: Field activities in Spain Hontomin of personnel (Geophysicists, Field Engineers and technicians) for scouting and at least-two acquisitions, to perform time-lapse borehole geophysical acquisition, including mobilization, demobilization and in-field QC; WP3 22 k€: Field activities in Italy Sulcis of personnel (Geophysicists, Experts of Remote sensing, Field Engineers and technicians) for scouting and at least-two acquisitions, to perform plume monitoring surface and borehole geophysical acquisition, including installation assistance, mobilization, demobilization and in-field QC, and UAV drone operations. **Project meetings, conferences/workshops, travels for international collaborations :** WP1 8 k€: averaged 900 € x 3 Meetings at Hontomin in Spain and in Europe x 2 persons (coordinator, acquisition and different key experts involved in data analysis and integration) = 5.4 k€, 2.6 k support for 2 persons/European conference or workshop; WP3 5 k€: 1000 € 2 meetings x 1 person in Europe, 500 € x 2 Persons x 3 Meetings at Sulcis, focused on borehole instrumentation, geophysical monitoring and remote sensing; WP5 3k €: 1000 € x 1 persons x 1 meeting in Hontomin, 500 € x 2 persons x 2 meetings at Sulcis, for contacts with the local population regarding geophysical monitoring and remote sensing techniques; WP6 5.7k€: 1650 € x 1 person x 3 international meetings for set-up collaborative actions between storage sites; WP7 6.5 k€: 400 € x 2 persons x 4 meetings for the organization and support during the Open Forums; 500 € x 2 persons x 2 meetings in Europe for knowledge integration workshops; 325 € x 1 person x 4 meetings for definition, realization and further development of the web site and knowledge sharing platform; WP8 1.8 k€: 900 € x 1 person x 2 meetings in Europe with partners for setting and preparing contents for e.learning courses.

Other goods and services	62	20 k€ for consumables for and during the Hontomin surveys (freight cost, gasoline and car rental) in WP1; 30 k€ for consumables for and during the Sulcis surveys (freight cost, gasoline and car rental)WP3; 2 k€ WP6 consumables (software tools for webinars); 8k€ WP7 for room rental at the open forum and the knowledge integration workshops 2 k€ WP8 consumables (software tool for e-learning).
Total	142	
14/SGUDS		
Travel	6.4	WP4: 1k€ for WP meetings WP6: 1k€ for WP meetings, 2.4k€ for international collaboration WP7: 2k€ for 4 GA
Equipment	-	
Other goods and services	-	
Total	6.4	
15 / Silixa		
Travel	20.9	**Field activities:** 2x(2 Persons, 12 days) to Hontomin , 4x(1 Person, 4 days) to Sulcis 2 500€ for project meetings
Equipment	45.8	WP1: 27k€ iDAS components (triggering mechanism, GPS Antenna, external data storage Raid, additional data storage hard drives, acquisition cards) additional parts and/or replace components during the continuous 2-year monitoring program for the seismic surveys at the Hontomin site. WP 3: 18.8k€, to purchase, splice and terminate the icable for the seismic surveys at the Sulcis site: 17.5k€ hybrid fibre optic cable (iCable) and 1.3k€ cable terminations (U-bend and E2000 connectors)
Services	9	handling and logistics for field activities (shipping costs x 5)
Total	75.7	
16/SOTAC ARBO		
Travel	15	1000 € for participating in 4 GAs 1500 € for participating in WP2 and WP3 meetings 12.500 € for international collaboration: • visit to South African CO2 storage site (2 persons, 2x2500 €); • visit to Korean CO2 storage site (2 persons, 2x2500 €); • visit to Australian CO2 storage site (1 person, 2500 €).
Equipment	-	
Other goods and services	3.6	3.5k€ for CO2 and consummables for the CO2 injection operation
Total	18.6	
18 / TNO		
Travel	48.1	WP1Travelling and subsistence for two field visits of 2 persons to Hontomin site during 3 days: 2*2*900 €=3.6 k€; travelling and subsistence for 2 person to 3 technical meetings during 2 days: 3 * 1.4 k€ = 4.2 k€; 2 presentations at conferences for one person during 3 days: 2 * 950 € = 1.9 k€; total 9.7 k€ WP3 Travelling and subsistence for visits to the UK field experiment for 2 persons during 4 days: 4*725 €=2.9k€, one person to two conferences during 3 days: 2*950 € =1.9k€; one person for travelling and subsistence to 1 technical meeting during 2 days: 700 €; total 5.5 k€

		WP4 Travelling and subsistence for one person at 4 conferences during 3 days: 4*950€ =3.8 k€; attendance of 6 technical meetings by one person for two days: 6*700 €=4.2 k€; 2 visits of 3 days to EOR site in Czech Republic for 2 persons: 2*1.4 k€=2.8 k€; 3 visits to buffer site in the NL by two persons: 3*200 €=600 €; organisation of stakeholder meeting: 600 €; total : 12 k€ WP5 Organisation of 4 workshops with stakeholders in Rotterdam area: 4*575 € = 2.3 k€; attendance of 3 technical meetings for 2 persons during 2 days: 3*1.2=3.6 k€; conference for one person: 400 €; total 6.3 k€ WP6 Travelling and subsistence for one person for two 3-day conference: 0,8 k€; travelling and subsistence for technical/stakeholder meetings by one person: 2.2 k€; organisation of stakeholder meetings: 1 k€; total 4 k€ WP7 Attendance of 4 dissemination events/knowledge integration workshops by one person for 2 days: 4*700 €=2.8 k€, 1 conference by 1 person for 3 days: 1000 €= 1k€; workshop organisation costs: 1000 €; total 4.8 k€ WP8 Training during CO2 storage schools: Training during CO_2 storage schools: travelling and subsistence for 1 persons for one event during 3 days: 0.8 k€; total 0.8 k€ WP9 Management board meetings: Travelling and subsistence for 2 persons in 2 meetings during 2 days (incl. travelling): 2*1.450 k€=2.9 k€; travelling and subsistence for 1 person in 3 meetings during 2 days: 3 * 700 €=2.1 k; total 5 k€
Equipment	19	WP3: 10 k€ Soil gas measuring equipment. WP4: 9 k€ Laboratory analysis and fluid chemistry.
Other goods and services	7.5	WP9: 7.5 k€ Certificate financial statement at the end of the project.
Total	74.6	
18/UNIROMA1		
Travel	80	**Field activities (WP1, WP3 and WP5)** 51 k€ **:** 2 persons x 6 days to Hontomin 5K€, 3 persons x 70 days to Sulcis 46 k€ **WP meetings (WP5, WP3, WP6, WP8):** 10-12 trips for 1 person destination tbd10k€ **International collaboration trips (WP6)** 1 person to Korea and 1 to South Africa for one week (7,5 k€) **Knowledge integration workshops or other dissemination events (WP7)** destination tbd, 2 trips of 2-3 days for 1 person (2,5 k€) **Organisation of educational activities (WP8)** 3-4 trips to the partner universities for 1 person (4k€) **Meetings of the management board and ENOS GA (WP9)** destination tbd, 4-5 trips for 1 person (5k€)
Equipment	62	**WP1 (2k€) and WP3 (60k€). Material for construction and maintenance of**: - minimum of 5 complete stations at Sulcis site for water monitoring 10K€; - 50 GasPro-pCO2 at the Sulcis site; 2 GasPro-CO2 at Hontomin 50K€; - the autonomous robot to continuously map CO2 concentrations 2K€;
Other goods and services	75	**WP5 Support for activities with the population**: contract to a market research firm for the selection of random sample participants' (5K€); for organisational support to group activities with the population (including organisations and management of appointments, catering, incentives to the participants, recording, transcriptions of meeting recordings) for 50 meetings (60K€); transcription of final interviews (5K€). **WP8 Support of 1 student for attending activities at partner universities (task 8.3**) 5k€
Total	217	
19/UNOTT		
Travel	20.7	Meetings and workshop attendance: WP2 3k€ ; WP5 4k€ ; WP7 2.5k€ (4GA) ; WP8 3.2k€ International cooperation on field sites: WP6 8k€
Equipment		
Other goods and	32.7	Support for modelling simulations and data analysis: WP1 8.2k€ WP2 7k€; WP3 8k€ WP9 4.5k€ CFS and auditing costs; WP8 5k€ training materials

services		
Total	53.4	
20/CO2GENET		**GBA**
Travel	6	WP5: Participation of task 5.1 workshop: 2 k€: 1 person x 2 days; WP6: Participation at task 6.5 meeting; 1,5 k€: 1 person x 1,5 days WP7: Participation at Knowledge Integration workshop (task 7.1): 2,5 k€: 1 Person x 2,5 days
Equipment		
Other goods and services		
Total	6	
20/CO2GENET		**GeoEcoMar**
Travel	14.9	**WP3 (2 k€)** 1 person X 2 technical meetings **WP5 (2 k€)** 1 person X 2 technical meetings/workshops **WP6 (4 k€)** 1 person X 4 international collaboration/ project meetings **WP7 (3 k€)** 1 person X 3 dissemination events/ knowledge integration workshops **WP8 (3.9 k€)** Teacher mobility for the CO2 storage schools (1 person X 3 schools)
Equipment		
Other goods and services	1	**WP3 (1 k€)** consumables
Total	15.9	
20/CO2GENET		**Geoinz**
Travel	5.1	**WP Meetings and ENOS GA**: 4 meetings x 1 person x 0,600 k€ = 2,8 k€; **WP6** workshops and working meetings: 1 meetings x 1 person x 0,6k€ = 0,6 k€ **WP7** workshops and working meetings: 2 meetings x 1 person x 0,6k€ = 1,2 k€ **WP8** workshops and working meetings: 1 meetings x 1 person x 0,5k€ = 0,5 k€
Equipment		
Other goods and services		
Total	5.1	
20/CO2GENET		**GEUS**
Travel	8.6	travel and accommodation costs as teacher on 3 schools (WP8.1) (3 x 1,5k€), Travel cost related to 3 workshops in WP8.2 (3x0,5k€), 3 workshops in WP8.3 (3x0.5k€), and travel related to WP9, management(1.1k€) This is student travel and accommodation support related to the planned 3 intensive schools
Equipment		
Other goods and services	36	Travel and accommodation funds for students for the 3 schools (3*12*1k€)
Total	44.6	
20/CO2GENET		**GSB-RBINS**
Travel	4.5	3 k€ - WP4: GA (1 person * 4 meetings * 300€), WP (1 person * 3 meetings * 300€) and Task meetings (1 person * 2 meetings * 300€) and events for specific dissemination (1 person * 1 meeting * 300€) 1.5 k€ - WP 7: knowledge integration workshops (1 person * 1 meeting * 300€), Open Forum (1 person * 3 meetings * 300€), general dissemination events (1 person * 1 meeting * 300€)

		It is foreseen to combine site visits and one-on-one ad-hoc (technical) discussions, necessary for especially WP4, with WP or task meetings. If respecting the timeline of WP7 requires additional visits, then these will be planned accordingly
Equipment	5	5 k€ - WP4 - high-end CPU hardware costs: The geo-economic evaluations that will be made, are extremely computing intensive, and hardware needs to be updated frequently since calculation time forms an important practical limit for the multi-nested Monte-Carlo simulations. This sum is based on replacing/upgrading our two 6-core machines. Software costs are limited, since our simulator is in-house developed, but may include GIS licences if the need for such package would arise.
Other goods and services		
Total	9.5	
20/CO2GENET		**HWU**
Travel	9.3	9.3 k€ Project meetings, national and international conferences/workshops (WP2 2*1.5 k€; WP5 2 k€ ; WP7 2*0.75 k€; WP8 2*1.4 k€)
Equipment	19	19k€ High performance computing -- Three high performance computing (HPC) nodes with parallel processing capabilities necessary to perform multi-phase flow simulations listed in WP2 and WP3. -- Two workstation computing machines equipped with powerful graphics processing units (GPUs) for visualization of the CO2 flow simulation results.
Other goods and services	1	1k€ External audit certificate
Total	29.3	
20/CO2GENET		**IGME**
Travel	11.8	**Field activities:** WP1 (2k€ = 2 persons x 10 days to Hontomín) + WP5 (2k€ workshops with researchers) + 2k€ for project meetings and GA **Cooperation and education activities:** WP6 (1.5 k€ = 750 € for the EERA CCS research workshop + 750 € for project meetings) + WP7 (2.9 k€ = 1.5 k€ for knowledge integration workshops and 1.4 k€ for scientific editors and project meetings) + WP8 (1.4 k€ awareness raising workshops)
Equipment		
Other goods and services	12	**12** k€ for organization of 6 awareness raising workshops x 2 k€ (rental of rooms, catering, invited speakers…)
Total	23.8	
20/CO2GENET		**METU PAL**
Travel	3.5	WP4 : WP meetings 1k€ (1 persons for 2 meetings) WP7: General Assembly 2.5k€ (1 person for 4 meetings)
Equipment		
Other goods and services		
Total	3.5	
20/CO2GENET		**TTUGI**
Travel	8	**WP5 (1 k€)** 1 person attending 2-days local workshop = 1000€. **WP6 (3 k€) 2** person attending 2 knowledge exchange workshops = 4*750€. **WP7 (2 k€)** 1 person attending 2 GA meetings= 2*1000€. **WP8 (2 k€)** 1 person attending 2 internal workshops= 2*1000€.
Equipment		

Other goods and services	6.5	**WP6 (1.5 k€) organization of common workshop with Baltic Sea Region CCS Network (BASRECCS)** **WP7 (5 k€)** for printing and distribution of annual ENOS Newsletter to the special events
Total	14.5	
20/CO2GEONET		**UNIZG-RGNF**
Travel	5.8	**WP6** EERA research workshop, 1 person*€600 ENOS- Baltic Sea Region CCS network joint workshop, 1 person*€600 ENOS scoping workshop and monitoring technology demonstration, 1 person*€600 **WP7** 1st knowledge integration workshop, 1 person*€500 2nd knowledge integration workshop, 1 person*€500 3rd knowledge integration workshop, 1 person*€500 Kick-off meeting, 1 person*€500 Final GA meetings (other GA meetings in conjunction with other events), 1 person*€500 **WP8** Internal workshop for development of curriculum, 1 person*€500 ; Internal workshop for for first presentation, 1 person*€500 Internal workshop for final discussions, 1 person*€500
Equipment		
Other goods and services	5	**WP8** Student support for attending courses at other partner institutes
Total	10.8	

4.1. Participants

1. Bureau de Recherches Géologiques et Minières (BRGM)

Description of the entity:

BRGM, France's leading public institution in the Earth Science field, has three main activities: scientific research, support for government policy, and international cooperation and development assistance. BRGM has been among the pioneers in research on CO_2 geological storage, participating from 1993 in the first European research project (Joule II) and in the first pilots worldwide (Sleipner, Weyburn, In Salah, Nagaoka, Ketzin, Lacq-Rousse, Hontomín, etc.). BRGM is also carrying out research activities at natural CO_2 fields, such as Montmiral in France, and at natural CO_2 seepage areas in Italy, Germany and France. Its fields of expertise are site selection and characterisation, predictive modelling, risk analysis, monitoring and safety management, thus addressing a wide range of the issues related to CO_2 geological storage. BRGM was strongly involved in the tentatives to set up a demonstration project for CO_2 storage in France (Ademe France Nord and TGR BF). BRGM has been manager of the CO_2GeoNet European Network of Excellence on the geological storage of CO_2, initiated in 2004 through an EC FP6 contract, now a legally registered Association under French law. BRGM was President of the CO_2GeoNet Association from 2011 to March 2015. Recently, BRGM was the coordinator of the FP7 CGS Europe project (2010-2013), a Pan-European Coordination Action on CO_2 Geological Storage involving 34 research institutes over 28 countries, including the CO_2GeoNet Association. BRGM is currently coordinating the FP7 ULTimate CO_2 project (2011-2015) dedicated to the understanding of the long term fate of geologically stored CO_2 and is involved in the ECCSEL H2020 INFRADEV-3 project on CCS Research Infrastructure that will start mid 2015 after two ECCSEL Preparatory Projects Phase I and Phase II carried out in FP7. BRGM is also a member of ZEP, EERA CCS, French Club CO_2 and is representing France in CSLF and ISO TC265 on CCS.

Contribution to the Work Plan and expertise brought to ENOS:

BRGM will coordinate the proposal and therefore be in charge of the WP management. BRGM will also coordinate the WP2 ensuring storage capacities and cost-efficient characterization. Given its wide expertise, BRGM will be involved in a wide range of activities in ENOS.
On the technical level, BRGM contribution will consist mainly in:
- Validation of monitoring techniques at Hontomin (WP1)
- Integration of monitoring measurements (WP1)
- Development of methodologies for assessing reliability of capacity estimates (WP2)
- Validation of smart characterization methodologies (WP2)
- Validation of groundwater monitoring and of downhole gas sensor using fiber optics (WP3)

BRGM will strongly participate to the dissemination and innovation development, the preparation of best practices (WP7), the international collaboration (task leader) and training (WP8)

BRGM is involved in:

- 3 of the 4 tasks in **WP1** Ensuring safe storage operations (Task 1.2 Induced seismicity: monitoring, control and hazard mitigation; Task 1.3 Monitoring safe underground storage behavior; Task 1.4 Demonstrating operational risk management)

- 2 of the 4 tasks in **WP2** Ensuring storage capacities and cost-effective site characterization (WP Leader): (Task 2.1 Quantify reliability of storage capacities estimates; Task 2.4 Technical guidelines on storage capacities estimates and cost-effective site characterisation)

- 2 of the 4 tasks in **WP3** Managing leakage risks for protection of the environment and groundwater

- **WP5** Coordination with local communities (Task 5.1 Knowledge development and integration in a societal perspective)

- **WP6** International Cooperation & seeding pilots and demos in Europe (Task 6.1 International cooperation; Task 6.2 European links, liaison and knowledge exchange)

- **WP7** Spreading innovation for Research integration and Best practices

- **WP8** Promoting CCS through training and education (Task 8.1 Education and training for the European research community; Task 8.4 Raising awareness by training workshops for journalists and media)

- **WP9** Management (WP Leader)

Staff

Coordinator: Marie GASTINE obtained an environmental engineering degree from Politecnico di Milano and an engineering degree from Ecole Centrale Paris. She joined BRGM in 2007 and has since been working on CO_2 Geological storage flow modeling, including work on the ADEME demonstrator projects (France Nord and TGR BF). She has been deeply involved in several European projects, such as CO_2GeoNet, CGS Europe, *COMET, *R&Dialogue, ECCSEL PPI and * ECCSEL PPII (*as BRGM project manager). She was WP leader in COMET and assisted the coordinator –her colleague I. CZERNICHOWSKI-LAURIOL - in CGS Europe. She has therefore the necessary experience in managing large European projects. From 2013 she overviewed CCS activities in the Water Environment and Eco-technology division of BRGM and participates regularly in national and European networks focused on CO_2 Storage: French Club CO_2, EERA-CCS and ZEP. She will be Coordinator of ENOS, overseeing the smooth running of the programme of activities and consortium management.

Isabelle CZERNICHOWSKI-LAURIOL will chair the General Assembly. She will advise Marie GASTINE and the Management Board in management and strategic issues. She will review deliverables of WP6 and WP7, mainly those dealing with future plans for research and CO_2 storage pilots and demonstration projects in Europe, international and European collaboration, best practice documents. She holds an Engineering degree in geology (ENSG Nancy, 1984) and PhD in geosciences (INPL, 1988). She joined BRGM in 1988, has been involved in CO_2 storage since 1993, was President of CO_2GeoNet from July 2011 to March 2015, Coordinator of FP7 CGS Europe project (2010-2013), CCS Programme Officer at the French National Research Agency from February 2010 to Feb. 2014 (part-time secondment), and is presently Programme Officer on Geo-Energy (CO_2 and energy storage, geothermal energy) at BRGM's Division of Research and Development.

The technical work will be mainly performed by the following staff:

Sandrine GRATALOUP is a geologist engineer. She graduated from Ecole du Pétrole et des Moteurs (IFP School) with an engineer degree in Exploration Geology in 2002 and from the Paris National School of Mines with an international Post-Master degree in Engineer and Environmental Geology in 2005. She worked in 2003-2004 at ANDRA, the French National Agency for Radioactive Waste Management, as a geologist for geological and hydrogeological modeling. She joined BRGM in 2006 and works in the Geology Department. She is involved in several national and international projects for geological storage of CO_2. Her main activities are focused on geological characterisation and modelling of underground formations. In ENOS, she will be in charge of WP2 management.

Julie LIONS is a hydrogeochemist. In 2004, she obtained a PhD in hydrochemistry and hydrogeology. Since 2005, she joined BRGM to become involved in projects concerning groundwater hydrochemistry and CO_2 geological storage. She focuses on geochemical and long term reactive transport modelling with respect to safety aspects of geological CO_2 storage and impacts on groundwater quality. She is also deeply involved in experimental works and field investigations for water-rock interactions in shallow groundwater. In ENOS, she will be in charge of task 3.1

Thomas LE GUENAN joined BRGM in January 2008 to work on safety issues for geologic storage of CO_2 under the Risks and CO_2 storage Safety department. He is now in charge of the safety criteria and impacts of CO_2 storage programme, which comprises around 20 BRGM projects on the subject. He holds a multidisciplinary master level degree from the Ecole Centrale Paris, a French non-specialized engineering school, and a Master of Science degree in environmental and land planning engineering from the Politecnico di Milano University. He was involved in the EUROGIA+ CO_2FieldLab and ANR SENTINELLE projects on monitoring protocols issues, and on the FP7 CO_2CARE project on risk management issues. He is main author of the preliminary risk assessment performed for the ADEME TGR-BF project. In ENOS, he will be in charge of Task 1.4

Publications

- 2014, Manceau J.C., Rohmer J. Ranking importance of uncertainties for the assessment of residual and dissolution trapping of CO_2 on a large-scale storage site. Energy Procedia, Volume 63, pp 3658-3664.
- 2014, Bader A.G., Thibeau S., Vincké O., Delprat Jannaud F., Saysset S., Joffre G.H., Giger F.M., David M., Gimenez M., A. Dieulin A., Copin D. CO_2 Storage Capacity Evaluation in Deep Saline Aquifers for an Industrial Pilot Selection. Methodology and Results of the France Nord Project. Energy Procedia, Volume 63, pp 2779-2788.
- Lions, J., Devau, N., de Lary, L., Dupraz, S., Parmentier, M., Gombert, P., and Dictor, M.-C., 2014. Potential impacts of leakage from CO_2 geological storage on geochemical processes controlling fresh groundwater quality: A review. International Journal of Greenhouse Gas Control 22, 165-175.
- Lions, J., Humez, P., Pauwels, H., Kloppmann, W., and Czernichowski-Lauriol, I., 2014. Tracking leakage from a natural CO_2 reservoir (Montmiral, France) through the chemistry and isotope signatures of shallow groundwater. Greenhouse Gases: Science and Technology. 4, 225–243.
- Lary, L. D., Manceau, J. C., Loschetter, A., Rohmer, J., Bouc, O., Gravaud, I., Chiaberge, C., Willaume, P. & Yalamas, T. (2014). Quantitative risk assessment in the early stages of a CO_2 geological storage project: implementation of a practical approach in an uncertain context. *Greenhouse Gases: Science and Technology*.

Past experience

ADEME –TGR- BF: The TGR-BF project was carried out within the framework of the second phase of the ULCOS European Program, the aim of which was to search for breakthrough process routes in order to reduce for CO_2 emissions within steel production. The project aimed at demonstrating the feasibility of the Top Gas Recycling Blast Furnace (TGR-BF) technology at an industrial site, namely Florange in Lorraine, France. One of the blasts was to be adapted to implement the TGR-BF technology and then integrate this in a CO_2 Capture, Transport and Storage chain. A nearby deep saline aquifer was considered for the CO_2 storage.

This project is coordinated by ArcelorMittal and funded by ADEME, the French Environment and Energy Management Agency. It should initially have covered the feasibility and exploration phase before a further operational phase during which 100 000 t of CO_2 were expected to be injected.

However, at the end of 2012, ArcelorMittal announced the withdrawal of its carbon capture project from the European Commission funding program call, which would have funded the operational phase following the TGR-BF project. This withdrawal interrupted at the same time TGR-BF studies with, for example, cancellation of geophysical and geological exploration of the potential storage area (seismic acquisition, drillings and associated analyses).

BRGM was the reference institute of the project for geoscience research studies. It was in charge of research activities for the geological storage feasibility: identification of the geological site location, its characterization before injection (geology, hydrogeology…), the evaluation of CO_2 injection impacts and risk analysis and monitoring.

EC FP7 - CGS Europe: BRGM was Coordinator of CGS Europe, a 3-year Coordination Action on CO_2 Geological Storage funded by the EC 7th Framework Programme (2010-2013). BRGM managed the large Consortium (34 key research institutes across 28 countries (24 MS and 4 AC)) and supervised the progress of the

work programme in accordance with the contract with the EC. Activities included i) Integration and networking amongst the partners and externally with stakeholders, ii) Developing a knowledge repository containing key data accessible via the Web, iii) Knowledge development and sharing and iv) knowledge dissemination, through the website, workshops, brochures, interaction with media, etc. The main objective was to develop a credible, independent and representative pan-European scientific body of expertise on CO_2 geological storage. This was achieved through expansion of the CO_2GeoNet Association.

ULTimateCO_2 (http://www.ultimateco2.eu/): BRGM is currently coordinator of this four-year FP7 project

CO_2Field Lab (https://www.sintef.no/projectweb/co2fieldlab/): BRGM is involved in monitoring, modelling, dissemination activities and coordinates the French part

2. Bundesanstalt für Geowissenschaften und Rohstoffe - The Federal Institute for Geosciences and Natural Resources (BGR)

Description of the entity:

The Federal Institute for Geosciences and Natural Resources (BGR) is the central 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). BGR's main scientific areas are: Energy resources, mineral resources, groundwater, soil, final disposal of radioactive waste, deep subsurface use & geological CO_2 storage, geoscientific information and fundamentals, control of nuclear weapons test ban, and geo-hazard assessment.

Contribution to the Work Plan and expertise brought to ENOS:

BGR provides their soil gas monitoring stations, mobile and/or continuous flux chambers for a three year period of monitoring at Hontomin and the GeoEnergy test bed site. BGR will offer certain lab capacity to other partner with respect to gas analysis (compositional and isotope analysis). Building on experience in training and dissemination activities, BGR will help to promote information and knowledge sharing regarding CCS.

BGR is involved in:

- **WP1**. Ensuring safe storage operations (Task 1.3 Monitoring safe underground storage behaviour)

- 2 of the 4 tasks in **WP3**. Managing leakage risks for protection of the environment and groundwater (Task 3.3 Development of surface monitoring tools (Task Leader) and; Task 3.4 Integrated monitoring solution)

- **WP5** Coordination with local communities (Task 5.1 Knowledge development and integration in a societal perspective)

- **WP6**. International Cooperation & seeding pilots and demos in Europe (Task 6.4 Knowledge development and integration in a societal perspective)

- **WP7** Spreading innovation for Research integration and Best practices

- **WP8** Promoting CCS through training and education (Task 8.2 Building and providing an e-learning course (Task leader))

Staff

Dr. Stefan Schlömer will serve as a contact person/coordinator for BGR´s activities in ENOS and is taskleader of WP3.3 Stefan Schlömer is a trained mineralogist and holds a Ph.D. in Applied Geology. After his Ph.D. he has been working for AGIP/EniTechnology in Milan before joining BGR in 2002. Since then he is working in the division "Geochemistry of Energy Resources and Gas Monitoring" and was involved in various national and international CCS projects (CO_2REMOVE, CLEAN, MONACO) and is coordinating the gas and isotope laboratory of the division.

Stefan Knopf holds an MSc in Earth Sciences. His research has covered petroleum geology, regional geology of Germany and especially various aspects regarding geological CO_2 storage. One main focus is to evaluate CO_2 storage potentials in Germany, which involves the development of capacity estimation methodologies. He has managed CCS projects regarding potential conflicts of use between CO_2 storage and geothermal energy use ("Geothermie-Atlas") and brine migration risks ("CO2BRIM"). His work includes activities as a guest lecturer on CCS at the University of Hannover. Furthermore, he was a lecturer for two CGS Europe Spring Schools on CO_2 geological storage. He will serve as leader of Task 8.2 (Building and providing an e-learning course) in the proposed project.

Dr. Franz May has been involved in research projects on CCS projects and natural analogues since 25 years. He is head of the unit CO_2 storage processes and technologies

Publications

- Schlömer, S., Furche, M., Dumke, I., Poggenburg, J., Bahr, A., Seeger, C., Vidal, A. & Faber, E. (2013): A review of continuous soil gas monitoring related to CCS - Technical advances and lessons learned. – Applied Geochemistry, 30, 148-160
- Schlömer, S., Möller, I. & Furche, M. (2014): Baseline soil gas measurements as part of a monitoring concept above a projected CO_2 injection formation: a case study from Northern German. – International Journal of Greenhouse Gas Control, 20, 57-72
- Castillo, S. Knopf, C. Kervévan, F. May, CO2-DISSOLVED: a Novel Concept Coupling Geological Storage of Dissolved CO_2 and Geothermal Heat Recovery – Part 2: Assessment of the Potential Industrial Applicability in France, Germany, and the U.S.A, Energy Procedia, Volume 63, 2014, Pages 4519-4535, ISSN 1876-6102
- Franz May, Stefan Knopf, Christian Müller, and Peer Hoth: CO_2 Storage Options in Germany. AAPG studies in geology ; 59, pp 35-45
- Sauer, U., Schütze, C., Leven, C., Schloemer, S. & Dietrich, P. (2013): An Integrative Hierarchical Monitoring Approach for Detecting and Characterizing CO_2 Releases. – Energy Procedia, 37, 4257-4267

Past experience

The Federal Institute for Geosciences and Natural Resources (BGR) is the central geoscientific authority in Germany providing neutral and independent information and advice to the German Federal Government. It is subordinate to the Federal Ministry for Economic Affairs and Energy and has a staff of around 700 people. BGR was one of the founding members of CO_2GeoNet at the time of the EC contract and is now a cooperating partner of the CO_2GeoNet Association as defined by a cooperation agreement signed between the CO_2GeoNet Association and BGR. Since 2000, BGR has been examining various aspects of the geological storage of CO_2 in various locations and regions inside and outside Germany, partnered by national and foreign research institutions, geological surveys, and industry players. BGR is one of the competent authorities in Germany according to the Geman CCS law and is committed in relevant international committees, such as ISO TC 265, IEA-GHG. BGR is involved in international capacity building and exchange on CO_2 storage with developing countries.

Research activities currently focus on the following topics:
Storage options (e.g., projects: Storage Catalogue of Germany, GESTCO, GEOCAPACITY, CO2STORE).
Subsurface processes (by laboratory experiments, natural analogue studies & geochemical simulations (e.g., projects: COORAL, CLEAN, DYNAMIS; CSEGR).
Development of Safety and Monitoring concepts and guidelines (e.g., project STABILITY).
Field testing of gas-geochemical monitoring methods (e.g., projects CASTOR, CLEAN) and tool development for sub-aquatic and microbiological monitoring (e.g., projects CO2ReMoVe, CLEAN)
Impact of CO_2 on the environment (e.g., projects RISCS, NASCENT, CO_2GeoNet).

3. Natural Environment Research Council (NERC) as represented by the British Geological Survey (BGS)

Description of the entity:

The British Geological Survey is a component organization of the Natural Environment Research Council (NERC), which is the UK's leading body for basic, strategic and applied research and monitoring in the environmental sciences. The British Geological Survey (BGS) itself was founded in 1835 and is the world's longest established national geological survey. BGS carries out strategically important research including in the energy and natural resources sectors and assessing vulnerability to environmental change and hazards, often in collaboration with the national and international scientific academic community. BGS seeks to advance the understanding of the structure, properties and processes of the solid Earth system through interdisciplinary surveys, monitoring and research for the benefit of society. BGS is a public sector organization responsible for advising the UK government on all aspects of geosciences, as well as providing impartial geological advice to industry, academia and the public. It is the UK's premier provider of objective and authoritative geoscientific data, information and knowledge for sustainable use of natural resources, reducing risk and living with the impacts of environmental change. NERC has the UK's largest academic CO_2 storage research group. ENOS will be staffed by the CO_2 Storage Research Team within the BGS Energy Programme. BGS is an ISO 9001:2000 accredited organization (cert. FS 71346), with independently provided certification of its management systems.

BGS is a leading player in the field of underground CO_2 storage. We have a leading research role in a number of major EU/industry and government funded projects. Over the last few years BGS have carried out more than 40 CO_2 storage projects for the EU, industry and the UK and overseas governments, with a current annual CCS budget of over 2 million Euros. The BGS CO_2 storage team comprises 25 researchers with expertise in a wide variety of fields including advanced seismic monitoring, reservoir modelling, leakage detection, monitoring planning, technical risk assessments

Contribution to the Work Plan and expertise brought to ENOS:

BGS will be work package leader of WP3 (Managing leakage risks for protection of the environment and groundwater) and will also contribute strongly to WP2 bringing expertise in understanding storage site behaviour and assuring storage capacity. BGS will contribute to WP6 through established links with other CO_2 storage pilot and test injection sites worldwide. BGS will contribute to WP7 and 8 utilising its extensive experience in capacity building, knowledge sharing and communicating on geological storage of CO_2 to a wide range of audiences both in the UK and internationally.

BGS is involved in:

- Task 2.1 and 2.2 in **WP2** to provide expertise on geological factors relating to smart site characterisation and uncertainty in capacity estimates
- all tasks in **WP3** to undertake fieldwork to advance monitoring technologies and techniques and to improve understanding of the risks presented by faults. BGS is leading WP3 and leading on Task T3.4 (Integration into monitoring solution).
- Tasks 6.1 – 6.4 in **WP6** as leader of the 'leakage simulation alliance' and supporting the task to identify opportunities for new pilots/upscaling of pilots
- Tasks 7.1 and 7.2 in **WP7** as part of the Scientific Editor Committee and to provide input to best practice and dissemination outputs.
- Tasks 8.1, 8.2 and 8.4 in **WP8** to present at the training courses, support preparation of e-learning materials and to support the tasks for communication with journalists.
- in **WP9** Management as WP leader on the MB and as Site Contact (GeoEnergy Test Bed)

Staff

Ceri Vincent has geological CO_2 storage expertise with 15 years' experience working on or managing projects. She has supported experts in South Africa and China in assessing CO_2 storage options. Ceri coordinated the South Africa-EU Cooperation on CCS (SAfECCS) project. She was a significant contributor to the BGS report for

DECC (UK Government) on the shale gas potential of the UK in 2013. Current research interests include undertaking CO_2 storage assessments for the UK, South Africa and China. She co-wrote a 2014 paper on "Assessment of storage capacity for CO_2 in saline aquifers near hydrocarbon fields, northern Songliao Basin, China." Greenhouse gases: science and technology. From April 2015, she will be the Chair of the Executive Committee for the CO_2GeoNet Association - the European Network of Excellence on the Geological storage of CO_2.

Dr. David Jones is a project leader/principal geochemist responsible for leading BGS surface gas monitoring for CCS projects. Involved in research on many CO_2 Storage projects since 2001 including Weyburn, In Salah, CO_2GeoNet (originally an EU FP6 funded project) and the EU FP6 CO_2ReMoVe, he has also led large projects including the EU FP7 RISCS project (Research Into Impacts and Safety in CO_2 Storage: www.riscs-co2.eu), the UK Energy Technology Institute's (ETI) Measurement Monitoring and Verification UK Requirements study and BGS' input for the CO_2 Field Lab project in Norway (http://www.sintef.com/Projectweb/co2fieldlab). David is an investigator on a Science and Technology Facilities Council grant on 2D CO_2 Flux mapping; is BGS lead for the follow on ETI-MMV study and for the UKCCSRC co-funded proposal on generating links between test injection sites in the UK, Canada, South Korea and Australia.

Dr. Christopher Rochelle is a senior geochemist with extensive experience in fluid-rock interaction processes over a wide range of pressures and temperatures and one of his main research areas is underground CO_2 storage. Chris has extensive experience designing, constructing, operating and interpreting laboratory experimental investigations into fluid-rock interactions over a wide range of temperatures and pressures; experience in the rates and magnitudes of geochemical reaction processes. His research interests include geochemical reactivity of gases in the subsurface and the impacts of supercritical CO_2 and CO_2 rich fluids on host rocks, caprocks and borehole materials under deep basinal conditions.

Jonathan Pearce is a principal geoscientist and sediment geochemist specialising in geological CO_2 storage, fluid rock interactions, fracture leakage mechanisms, long-term geochemical interactions in reservoir and cap rocks, practical and technical implementation of CO_2 storage regulations with a focus on monitoring storage operations; assessing risks and storage permit applications. He is leader of the CO_2 Storage Team at BGS; Deputy Director GeoEnergy Research Centre (GERC)and heavily involved in the development of the GeoEnergy Test Bed. Jonathan is Storage Coordinator for the CCS Joint Programme of the European Energy Research Alliance (EERA) and was Editor of the Guide to Assessment of Impacts from Potential Leakage from CO_2 Storage for the RISCS Project. He was project leader of the CO_2 storage tasks for Near Zero Emissions Coal (NZEC) and played a significant part in the official team advising DECC on the UK CCS competition for the first demonstration.

Michelle Bentham is a senior geoscientist and carbon dioxide storage expert at BGS. She is a UKCCSRC Research Area Champion for regulation and site leasing; on the expert working group for site selection of CO_2 storage sites for ISO T265; a member of the taskforce for the application of United Nations Framework Classification for Fossil Energy and Mineral Resources, UNFC 2009, to injection projects and was the BGS lead in the CO_2stored project for the ETI and the Crown Estate. She is highly skilled in assessing CO_2 storage potential and methodologies; CCS capacity building; CCS monitoring and verification and CCS storage site characterisation.

Luke Bateson is a senior geoscientist with expertise in the application of remote sensing techniques to monitoring CO_2 storage sites. He has experience in 3D visualisation of large datasets, optical remote sensing techniques and image processing and interpretation.

Maxine Akhurst is an experienced project leader with expertise in regulatory issues relating to geological storage of CO_2. Maxine was project leader for the CO_2 MultiStore project where she led and managed research activities to reduce the risks to the economic and business case. She was also WP leader for the SiteChar project where she led appraisal and characterisation for an offshore storage site including preparation of 3D geological models of aquifer and hydrocarbon fields.

Helen Taylor is a senior geochemist responsible for key inputs to the ULTimate CO_2 project which will assess the long term fate of CO_2 in the reservoir. Helen is leading the Communication and Networking WP for ECCSEL (European Carbon Dioxide Capture and Storage Laboratory Infrastructure) where she will coordinate activities to

develop the communication strategy and outreach plan and engage with stakeholders ahead of implementation in 2015.

Publications

- Bateson, L., Vellico, M., Beaubien, S.E., Pearce, J.M., Annunziatellis, A., Ciotoli, G., Coren, F., Lombardi, S., Marsh, S., 2008. The application of remote-sensing techniques to monitor CO_2-storage sites for surface leakage: Method development and testing at Latera (Italy) where naturally produced CO_2 is leaking to the atmosphere. Int. J. Greenhouse Gas Control 2, 388-400
- Jones, D.G., Barkwith, A.K.A.P., Hannis, S., Lister, T.R., Gal, F., Graziani, S., Beaubien, S.E., Widory, D., 2014. Monitoring of near surface gas seepage from a shallow injection experiment at the CO_2 Field Lab, Norway. Int. J. Greenhouse Gas Control 28, 300-317
- Jones, D.G., Beaubien, S.E., Barlow, T.S., Barkwith, A.K.A.P., Hannis, S.D., Lister, T.R., Strutt, M.H., Bellomo, T., Annunziatellis, A., Graziani, S., Lombardi, S., Ruggiero, L., Braibant, G., Gal, F., Joublin, F., Michel, K., 2014. Baseline variability in onshore near surface gases and implications for monitoring at CO_2 storage sites. Energy Procedia 63, 4155-4162
- Jones, D.G., Barlow, T., Beaubien, S.E., Ciotoli, G., Lister, T.R., Lombardi, S., May, F., Möller, I., Pearce, J.M., Shaw, R.A., 2009. New and established techniques for surface gas monitoring at onshore CO_2 storage sites. Energy Procedia 1, 2127-2134
- Rushton, J.C., Wagner, D., Purser, G., Pearce, J.M., Rochelle, C.A. 2013. Green River CO_2 natural analogue, Utah: insights into Fe mobilisation from jarosite fracture mineralisation. Mineralogical Magazine 77(5):2102 doi:10.1180/minmag.2013.077.5.18

Past experience

BGS has experience in developing monitoring programmes for a variety of proposed and active storage sites. BGS developed and maintains the IEAGHG web-based site monitoring selection tool. Through projects such as EU FP7 RISCS, QICS and ECO2, BGS have demonstrated their field expertise in monitoring CO_2 storage sites. Through the EU FP7 SiteChar project, BGS demonstrated how risk assessment is critical to development of an effective and efficient storage site monitoring programme. Working with the UK Crown Estate, as Development Manager for the online CO_2 Stored database, BGS is currently working optimisation of storage resource on the UK Continental Shelf. Other recent projects include Weyburn monitoring; EU FP7 CO_2ReMoVe; Otway Basin and Gorgon reviews; UKCCSRC CASSEM; EU FP7 funded CO_2CARE; the joint industry project CO_2MultiStore ; EU FP7 funded ULTimateCO_2. We have also carried out a major study for the IEAGHG/GCCSI on managing storage resources. BGS have participated in capacity building activities such as supporting national experts in assessing geological storage potential in South Africa (SAfECCS) and China (UK NZEC; COACH) and have presented in training courses on geological storage in the UK, South Africa, China and South Korea. BGS also participated in the COACH and CGS-Europe CCS schools.

Infrastructure/ major equipment provided to ENOS

GeoEnergy TestBed - More detail is provided in the section 'Infrastructure proposed by the partners – test sites'

4. Czech Geological Survey (CGS)

Description of the entity:

Czech Geological Survey (CGS / Czech Republic) is the leading geological research institution in the Czech Republic. It is a state research institute supervised by the Ministry of Environment. Its staff counts about 300 people, round 200 of them being university graduates.

Geo-energy related activities of CGS have developed a significant knowledge in the field of CO_2 geological storage, monitoring of CO_2 and methane migration, formation water geochemistry, mineralogical, optical and geochemical characterisation of the reservoir rocks and seals.

CGS has rich experience with participation in international research projects in many areas of geoscience, including European Framework Programmes (FP6, FP7, Horizon 2020) and other types of multilateral cooperation. CGS is member of EuroGeoSurveys and the Czech national country representative in ENeRG (European Network for Research in Geo-Energy). Since 2013 CGS has been a member of CO_2GeoNet.

Contribution to the Work Plan and expertise brought to ENOS:

CGS is currently leading a Czech-Norwegian research project focusing on screening an assessment of the LBr-1 depleted oilfield as potential site for a pilot CO_2 storage project in the Czech Republic. Results and achievements of this project will be provided to ENOS as input information for further research work, especially in WP3 and WP4. Moreover, CGS' project management skills and experience in co-ordination of activities at international level will be used in WPs 6-9.

In ENOS, CGS will lead WP6 and will be responsible for liaising project activities with the LBr-1 pilot site in the Czech Republic.

CGS is involved in:

- 3 of the 4 tasks in **WP3** Managing leakage risks for protection of the environment and groundwater
- **WP4**. Integration of CO_2 storage with local economic activities (Task 4.2 CO_2 storage and oil production)
- **WP5**. Coordination with local communities (Task 5.1 Knowledge development and integration in a societal perspective)
- All tasks in **WP6** International Cooperation & seeding pilots and demos in Europe (WP leader) and leader for Task 6.4 Preparation of follow-up stages for ENOS pilot sites
- All tasks in **WP7** Spreading innovation
- 3 of the 4 tasks in **WP8** Promoting CCS through training and education (Task 8.1 Education and training for the European research community; Task 8.2 Building and providing an e-learning course; Task 8.4 Raising awareness by training workshops for journalists and media)
- in **WP 9** Management as WP leader on the MB and as LBr-1 Site Contact

Staff

Vit Hladik is research coordinator for Environmental and Geo-Energy Technologies at Czech Geological Survey. His professional focus is research and project management in the field of CO_2 geological storage, incl. rich experience with participation in international projects. He acted as project coordinator of the FP6 CO_2NET EAST project (CO_2 capture and storage networking extension to new Member States) and TOGEOS (Towards geological storage of CO_2 in the Czech Republic), a Czech-Norwegian R&D project funded by EEA/Norway Grants, and was Management Board member of the FP7 CGS Europe project. At present, he coordinates REPP-CO_2 – a Czech-Norwegian project funded by Norway Grants, aiming at preparation of a research CO_2-storage pilot project in Czechia. Vit is the Czech national representative in European Network for Research in Geo-Energy (ENeRG), member of two Task Forces of the European Technology Platform on Zero-Emission Fossil Fuel Power Plants (ETP ZEP), member of EuroGeoSurveys Task Force on CCS, and CGS representative in the CO_2GeoNet network.

Vit possesses MSc degree in applied geophysics from Charles University in Prague, and MBA from Nottingham Trent University / Brno Business School. He will lead WP6 of ENOS, and will be responsible for local coordination related to the LBr-1 project site.

Juraj Francu is a senior researcher at Czech Geological Survey. His primary focus includes gas and petroleum geochemistry and basin modeling. His experience embraces field and laboratory measurements of gases and rocks in deeper and shallow subsurface, research on microbial reduction of CO_2 to methane at depth of about 1000 m and microbial oxidation of methane to CO_2 in the shallower horizons, genetic relationships among gases occurring in different horizons above natural gas accumulations and gas storages up to the soil pore system, pore water chemistry and associated gases in the oil and gas bearing basins in the Czech Republic and the Caspian region. Juraj also participated in the TOGEOS Czech-Norwegian R&D project, contributing with the basin thermal model and geochemistry.

Juraj finished his MSc. and PhD. at the Comenius University in Bratislava and at the Slovak Academy of Sciences in Bratislava, Slovakia. He worked as visiting scientist at the Institute of Organic and Petroleum Geochemistry, Forschungszentrum Juelich, Germany, University of Missouri-Columbia, University of Utah, USA, and RWTH University in Aachen, Germany.

Publications

- Hladík, V. - Kolejka, V. - Lojka, R. - Fott, P. - Vácha, D. (2009): CO_2 emissions and geological storage possibilities in the Czech Republic. – Slovak Geological Magazine, February 2009,, 29-41. ISSN 1335-096X
- Hatzignatiou, D. - Riis, F. - Berenblyum, R. - Hladík, V. - Lojka, R. - Franců, J. (2011): Screening and evaluation of a saline aquifer for CO_2 storage: Central Bohemian Basin, Czech Republic. – International Journal of Greenhouse Gas Control 5, 6, 1429-1442. ISSN 1750-5836. DOI 10.1016/j.ijggc.2011.07.013
- Šliaupa, S. – Lojka, R. – Tasáryová, Z. – Kolejka, V. – Hladík, V. – Kotulová, J. – Kucharič, L. – Fejdi, V. – Wojcicki, A. – Tarkowski, R. – Uliasz-Misiak, B. – Šliaupiene, R. – Nulle, I. – Pomeranceva, R. – Ivanova, O. – Šogenova, A. – Šogenov, K. (2013): CO_2 storage potential of sedimentary basins of Slovakia, the Czech Republic, Poland and the Baltic States. – Geological Quarterly 57, 2, 219-232. ISSN 1641-7291. DOI 10.7306/gq.1088

Past experience

- partner in EU GeoCapacity (FP6, Assessing European Capacity for Geological Storage of Carbon Dioxide);
- coordinator of CO_2NET EAST (FP6, focused on CCS knowledge transfer and awareness raising in new EU Member States and Candidate Countries;
- coordinator of TOGEOS (Towards geological storage of CO_2 in the Czech Republic), Czech-Norwegian project funded by EEA/Norway Grants;
- partner and Management Board member in CGS Europe (FP7, Pan-European coordination action on CO_2 Geological Storage);
- provider of CO_2 geological storage –related expertise and consultancy services to Czech regulators, especially the Ministry of Environment, inlc. advice on implementation of the European CCS Directive in the Czech national law.

Infrastructure/ major equipment provided to ENOS

LBr-1 - More detail is provided in the section 'Infrastructure proposed by the partners – test sites'

5. Energy, Environment and Technology Research Center (CIEMAT)

Description of the entity:

CIEMAT is a public research body that reports to the Ministry of Economy and Competitiveness and whose activities are carried out in the areas of Energy, Environment and Technology in the framework of the National Plan for Scientific Research, Development and Technological Innovation ; in EU R&D Programmes, and cooperating with the Autonomous Communities, universities, and enterprises, as well as with intergovernmental bodies and R&D centers from other countries, with special attention to Latin America and the Mediterranean.

Contribution to the Work Plan and expertise brought to ENOS:

CIEMAT will be contributing to ENOS in WP1, Ensuring safe storage operations, Task 1.4 Integrated alert system, Subtask 1.4.2 Update and validation of the risk model. CIEMAT, in collaboration with CIUDEN developed a probabilistic methodology for estimating geological storage risks for the Hontomin Technology Development Plant site. The ad hoc model implemented on a probabilistic simulation object-oriented framework will be a basic tool for the validation of Task 1.4 risk model.

CIEMAT is involved in:
WP1. Ensuring safe storage operations:
- Task 1.4 Demonstrating operational risk management
* Subtask 1.4.2 Update of risk assessment (Subtask leader)
* Subtask 1.4.3. Technical Guidelines for operational risk management

Staff

Antonio Hurtado Bezos. PhD. Mining Engineer. Scientist of CIEMAT has over 15 years of experience in risk management and assessment in both the industrial sector and scientific research in the area of the geological environment altered by human activity. Currently working on the development of methodologies for risk assessment of geological sites for both CO_2 geological storage and unconventional hydrocarbon exploitation, and previously in the selection, characterization, capacity estimation and determination of uncertainties associated with geological storage of CO_2.

Sonsoles Eguilior Díaz. PhD. in Physics. Scientist working in the CIEMAT, with more than 15 years of experience, where has worked in the areas of safety and risk assessment and the development of transport models in inhomogeneous media under advective-diffusive processes. Currently her main line of work is the development of global models for evaluation of risks associated with geological storage of CO_2 and uncertainty treatment associated with long-term risks.

Fernando Recreo Jiménez. Degree in Geology .Master in Hydrogeology, More than 20 years of experience in nuclear waste repositories performance assessment. Currently is Head of the CO_2 Geological Storage Programme of CIEMAT.

Julio Rodrigo Naharro. PhD. Mining Engineer. Scientist of CIEMAT with 10 years of experience in CCS technologies, the last five in relation to the CO_2 Geological Storage, particularly in the study of natural analogues of CO_2 Storage and leakage. Currently he is working on the geochemical risks related to the CO_2 injection using the TOUGHREACT and PetraSim codes.

Publications

- Methodological development of a probabilistic model for CO_2 geological storage safety assessment. A. Hurtado , S.Eguilior , F.Recreo. Int J Energy Environ Eng (2014)
- Desarrollo Metodológico del Modelo Probabilista de Evaluación de Seguridad de la Planta de Desarrollo Tecnológico de Hontomin .A.Hurtado, S.Eguilior, F.Recreo. In. Técnicos Ciemat #1230, 2011
- Implementación del Modelo Estocástico de Evaluación de Seguridad de la PDT. Modelo de Pluma. A. Hurtado, S. Eguilior, F. Recreo. Inf. Técnicos Ciemat #1343. 2015

- Modelo Probabilista de Evaluación Integrada del Comportamiento de la Planta de Desarrollo Tecnológico de Hontomin. Versión 2. A. Hurtado, S. Eguilior, F.Recreo. Inf. Técnicos Ciemat #1346, 2015.
- Diffuse soil CO_2 flux to assess the reliability of CO_2 storage in the Mazarrón–Gañuelas Tertiary Basin (Spain). Rodrigo-Naharro, J., Nisi, B., Vaselli, O., Lelli, M., Saldaña, R., Clemente-Jul, C., Pérez del Villar, L. Fuel 114, 162-171 (2013).

Past experience

The CIEMAT research team has an experience of more than 20 years in performance assessment and risk analysis of deep geological repositories for high activity radioactive wastes. Since 2007, activities were devoted on CO_2 geological storage performance assessment and risk analysis. As a collaborator of CIUDEN it has developed a probabilistic methodology for risk analysis for the Hontomin Technology Development Plant site.

6. Fundación Ciudad de la Energía (CIUDEN)

Description of the entity:

The Fundación Ciudad de la Energia (CIUDEN) is a public law body created by the Spanish Government in 2006 to support and promote international cooperation to enhance European competitiveness through strategic research partnerships with industry, SMEs, Universities and research institutions. The scope of CIUDEN´s Clean Coal Technologies Programme is the development of efficient, cost effective and reliable CCS technologies. In this sense, CIUDEN is involved in the development of several Research Infrastructures, as the Technology Development Plant on CO_2 Storage in Hontomín. Furthermore, CIUDEN has experience in several EU projects, as the so-called OXYCFB300 Compostilla Project funded under the European Energy Programme for Recovery (EEPR), ECCSEL Preparatory Phases, R&Dialogue or IMPACTS. Networking and knowledge sharing expertise comes from the active participation of Ciuden in taskforces within EU Knowledge Sharing CCS Network, CO_2Geonet and Global CCS Institute activities. In addition, Ciuden has experience in arranging training activities, as the courses performed with national universities.

Contribution to the Work Plan and expertise brought to ENOS:

With the aim of providing the needed commitments for the correct development of the ENOS proposal, Ciuden is showing the activities and background information that will enable the project to achieve the expected outcomes; these are the following:

- CO_2 and brine injection strategies. These are included as the core part of T.1.1. and will take advantage of the experiences acquired until now, which includes the CO_2 and brine injection tests that have already been done, in order to better define the more innovative approaches, as explained in the proposal.

- Data acquisition and interpretation of the 30 passive microseismic monitoring stations located all around the Hontomin site for induced seismicity risk management purposes (T.1.2) in the vicinity of the CO_2 injection activities. These data will also be used as part of the integration activities that will be located at T.1.4. The geophones are divided in 2 types, both of 3 components, 20 of them were provided by Sara Electronics with a frequency of 4,5Hz, whereas the other 10 were provided by Lennartz with frequency of 0,5Hz. The existing data will also be available if needed, to establish the baseline for a better understanding of the initial conditions. The passive seismic network is in operation since 2011.

- Reservoir geochemical monitoring. Apart from the deep sampler which is going to be developed in T.1.3, and all its associated activities in lab and simulation, according to project needs, Ciuden will provide data from the sampling to be performed at Hontomin H-I Injection well using the U-tube tool, and will give access to data from former sampling surveys.

- Geophysical monitoring. Several activities will take place in the frame of ENOS, mainly at T.1.3 (3D VSPs, crosshole seismic, seismic noise correlation or seismic interferometry…), Ciuden wants to highlight that data from former VSPs surveys will be available for the partners, if needed, to provide input in the definition of the surveys to be done during the project. In addition, data acquired using iDAS, the retrievable set of hydrophones in the monitoring well H-A and the crosshole data collected from electrodes installed in both wells (HI and HA) will be also available for the partners to accomplish the activities explained in T.1.4.

- Soil gas monitoring. Ciuden will provide the existing data from natural flow emissions acquired during the characterization phase at Hontomin, as well as the data from the meteorological station which is in operation since June 2010 providing data of different nature (temperature, moisture, solar radiation, wind speed and direction, pluviometry…). These data will allow a better definition of the threshold values in T.1.3.

- Shallow groundwater monitoring. A monitoring network was established in 2012 at Hontomin, consisting of 3 new Wells in the surroundings of H-I and H-A Wells, measuring piezometric levels (m), temperature (ºC), pH, ORP (mV) and LDO (mg/l); and 5 existing ones that provide piezometric levels. The necessary data will be

available for the ENOS partners and will allow a complete definition of the monitoring input that is going to allow the risk model to be updated.

- Monitoring data in the Wells. Pressure and temperature in the wellhead and at different depths all along the wells, up to 1,500m will be available according to the project goals.

- CO_2 injection will be carried out with controlled pressure, temperature and flow rates, thus different phases will be tested. The facility also offers the possibility of co-injecting brine and CO_2, with or without tracers. The data will be provided during operations in order to better define the simulation and history matching activities within ENOS.

Furthermore, Ciuden will also provide to the involved partners in ENOS activities all the needed information for accomplishing the satisfactory execution of the committed Works, that may include existing models and data from surveys already performed, establishing the confidentiality agreements when needed.

CIUDEN is involved in:

- all tasks of **WP1** Ensuring safe storage operations (WP leader)

- 3 of the 4 tasks in **WP2**. Ensuring storage capacities and cost-effective site characterisation (A minor contribution in Task 2.1 for exchange of information on modelling data; Task 2.3 Low Cost Drilling (task leader) and Task 2.4 Technical guidelines on storage capacities estimates and cost-effective site characterisation).

- **WP3**. Managing leakage risks for protection of the environment and groundwater (Task 3.4 Integrated monitoring solution)

- all tasks in **WP5** Coordination with local communities, and Leader of Task 5.3 Development of a Public Information Tool for CO_2 storage sites

- 3 of the 5 tasks in **WP6** International Cooperation & seeding pilots and demos in Europe (Task 6.1 International cooperation; Task 6.2 European links, liaison and knowledge exchange; Task 6.4 Preparation of follow-up stages for ENOS pilot sites)

- all tasks in **WP7** Spreading innovation

- 2 of the 4 tasks in WP8 Promoting CCS through training and education (Task 8.1 Education and training for the European research community; Task 8.4 Raising awareness by training workshops for journalists and media)

- in **WP9** Management as WP Leader in the MB and as Hontomin Site Contact

Staff

1. **José Carlos de Dios** (Male) is Low Carbon Technologies Manager at Fundación Ciudad de la Energía (CIUDEN), entity attached to the Spanish Ministry of Industry, and Director for the exploration and operation activities at the CO2 Geological Storage Pilot Plant in Hontomín (Spain).

Education

- M.Sc.Mining Engineer. Technical University of Madrid
- Master in Business and Administration (MBA Executive)

Professional Experience

Long experience in energy, mining and environmental sustainability projects for 27 years, occupying the position of technical manager and CEO in several companies, related with the industrial processing and technological development. Actually working as technological manager and responsible for the Spanish Pilot Plants of CO2 Capture, Transport and Storage attached to CIUDEN. He is responsible in particular for front end engineering design (FEED), construction, commissioning and operation of the Storage Pilot Plant, the design and supervision of the site geological characterization, modeling and monitoring of the injection strategies, including the safety

supervision for the operational phase and the public engagement activities. Long experience in the performance of relationship with industry, research centers and academia in the international framework, R+D projects leadership and the European institutional relationship. Particularly on CCS activities, occupying the following positions:

- Project Manager on CO2 storage activities within OXYCFB300 Project (EEPR and Spanish Government)
- Member of the Steering Board in IMPACTS Project
- Member of the Executive Board and General Assembly in ECCSEL Infradev Project
- Member of CCS EU Network

2. **Juan Andrés Marín Vidal.** (Male), PhD. Mining Engineer by the University of Oviedo, Master in Labour Risks Prevention (Safety, Hygiene and Ergonomics) by UPM. Head of Ciuden´s Technical Development Plant for Geological Storage of CO2 at Hontomin. He has worked in mining and construction industries for more than 10 years related with engineering and R+D projects, at the positions of the design, development and commissioning. Before his current position in Ciuden, he worked as a Head of the Underground Construction Area of FSB, a public foundation focused on the promotion and development of R+D projects in the areas of energy, mining and environment.

3. **Lionel Loubeau Gavilanes** (Male), Industrial Engineer by the "Universidad Pontificia de Comillas", Master in Environmental Technology by the University of Vigo. He works for CIUDEN since 2006, starting as Project Manager during the engineering phase, construction and commissioning of the Flue Gas Cleaning System of the Capture and Transport Technology Development Centre located in Cubillos del Sil (Spain), continuing as Purchasing Director of CIUDEN. Currently working as New Markets Responsible at the Business Development Unit on issues related to CO2 Capture and Storage, new developments and Public Perception. He was involved in the Research and Dialogue Project, covering management, technical, public engagement and knowledge sharing issues. He has worked in energy and construction industries for more than 15 years related with engineering and R+D projects, at the positions of the design, development and commissioning. Author of over 10 publications (conferences, deliverables and books included).

4. **Miguel Angel Delgado Calvo** (Male), R&D Project Manager at Fundación Ciudad de la Energía (CIUDEN). He received his Master's Degree in Chemical Engineering by the University of Salamanca (2004). In 2006, he got a Master in Industrial Safety whereas in 2014 he finished an Executive MBA (European Business School, EEN). His main activities cover following areas: Development, innovation and deployment of gasification processes; CCUS; energy system integration aspects; European Union policies relating to carbon capture and storage and engineering, economic and quantitative analysis regarding advanced energy production. Author of over 30 publications (peer-review articles, conferences, deliverables and books included).

5. **Juan Ignacio Salvador Parrilla** (Male), Hontomin Plant systems responsible at CIUDEN. Industrial Engineer. (UPM, ETSII Madrid). Microsoft Certified Engineer in Databases and Networks. 30 years IT experience, developing projects related to control process, networks and communications, databases, logistic, BI and data mining between others, always related to power production or green industries.

Publications

- Alcalde, J., Martí, D., Calahorrano, A., Marzan, I., Ayarza, P., Carbonell, R., Juhlin, C., Pérez-Estaún, A. (2013). Active seismic characterization experiments of the Hontomín research facility for geological storage of CO_2, Spain. International Journal of Greenhouse Gas Control 19, 785-795.
- Alcalde, J.; Ignacio Marzán, Eduard Saura, David Martí, Puy Ayarza, Christopher Juhlin, Andrés Pérez-Estaún, Ramon Carbonell (2014). 3D geological characterization of the Hontomín CO_2 storage site, Spain:

Multidisciplinary approach from seismic, well-log and regional data. Tectonophysics, In Press, Corrected Proof, Available online.

- Lupion, M.; Perez, A.; Torrecilla, F.; Merino, B. (2013). Lessons learned from the public perception and engagement strategy – Experiences in CIUDEN´s CCS facilities in Spain. Energy Procedia 31, 7369-7379.
- Pool, M., Carrera, J., Vilarrasa, V., Silva, O., Ayora, C. (2013). Dynamics and design of systems for geological storage of dissolved CO_2. Advances in Water Resources 62, Part C, p. 533-542.
- Vilarrasa, Víctor, Silva, Orlando, Carrera, Jesús, Olivella, Sebastià (2013). Liquid CO_2 injection for geological storage in deep saline aquifers. International Journal of Greenhouse Gas Control, 14, p.84-96.

Past experience

EU funded projects: IMPACTS; OXY-CFB-300 EEPR; R&Dialogue; BRISK; MACPLUS; FLEXIBURN; RELCOM; O2GEN; EM-Hontomin ;

National projects and other large initiatives: CIUDEN-ULe Project, FPA041 GCCSI Contract

Infrastructure/ major equipment provided to ENOS

Hontomin - More detail is provided in the section 'Infrastructure proposed by the partners – test sites'

7. Flodim (Flodim)

Description of the entity:

Flodim is a cavity Survey and Well Logging Services Company with operations in all of Europe and in South America.
Flodim is also a Company with significant Research & Development capabilities dedicated to downhole technologies, such as Solution Mining, some O&G specific subjects and all of the new underground projects : deep Geothermy, Energy Storage, H2 storage and of course CO_2 storage.

Contribution to the Work Plan and expertise brought to ENOS:

- New Bottom Hole Sampling system (Sampling chamber is also a transport container and a PVT cell)
- High Temperature Geochemical instrument (P, T, GR, CCL, pH, Redox potential, Conductivity and dissolved O2), versus depth or versus time.
- Potentially specific Video instruments and generally any Cased Hole instrument that can give information on an existing well together with a self-sufficient lightweight logging unit (up to 2000m).

Flodim is involved in:
WP1 – task 1.3 Monitoring safe underground storage behavior and more specifically, 1.3.1. Alternative deep geochemical monitoring
WP7 - Spreading innovation for Research integration and Best practices

Staff

Jean-Paul CRABEIL, manager, founder of Flodim, HEI, Schlumberger 6 years, Geostock 9 years
Karl ANTIER, Engineer EOST, Operation manager in charge of field Services organization
Emilien BELLE, Earth Sciences and Environment Doctor, Survey specialist, in charge of new Domains
Fabien ESPEUT, R&D manager, Polytechnic Nice, CGG field and development engineer

Publications

September 2014	Electrochemical Casing Cutter pattent
October 2014	SMRI Conference of Groningen (NL), EZ Cutter
December 2014	New Bottom Hole Sampling System pattent
April 2015	SMRI Conference of Groningen (US), EZ Cutter

Past experience

- Cavity Survey:	Sonar, Laser-Image, Interface measurement
- Geothermy:	ELS representative in the FONGEOSEC and in the COGEWI projects
- New R&D projects :	Cavity suite (Sonar, Casing Cutter, EZ blanket), Deep Geothermal projects (HT color video, HT BHS system), Oil & Gas (EZC 2", EZ level, EZ com).
- Collaborations:	Eurostar project, 'Pole Mer' and Idronaut (I) French cluster, Fongeosec Deep Geothermy project
- Partners:	Multiline (D), Robertson (UK), Century WL (USA), Ground Search (Aus)

8. Geogreen (GGR)

Description of the entity:

Geogreen (www.geogreen.eu) is an international company offering engineering services dedicated to the transport and geological storage of CO_2, and consulting services on the CCS chain (including all economic aspects).

Geogreen results from a joint venture by three leading French players in the field: IFP Energies nouvelles, Géostock (underground storage of hydrocarbons), and BRGM (Bureau de Recherche Géologique et Minière), which are pooling their respective expertise in order to position themselves in the world market for the geological storage of CO_2 and thereby contribute to reducing emissions of greenhouse gases.

The perfect technical complementarity of its experts enables Geogreen to provide the industries concerned with a comprehensive range of services, covering the whole chain from the transport of CO_2 to its geological storage, from upstream expertise to engineering and project development. In the longer term, Geogreen will offer injection site operation assistance, inspection and maintenance services, and monitoring services related to post-injection control of storage sites

Geogreen has developed a portfolio of projects ranging from pre-feasibility studies for a given CCS project (capture orientation, transport pre-routing and design, storage site selection) to site pre-selection. On top of technical design, Geogreen has also developed a strong expertise in economical evaluation of solutions.

Contribution to the Work Plan and expertise brought to ENOS:

Geogreen contribution will mainly be on site modeling (WP1 and WP4) both geological and dynamical. For the two sites, earth model will be elaborated at the early stage of the project to ensure a consistent data set for the subsequent modeling tasks.
The contribution to WP1 will be mainly on the design of the injection test based upon the different scenario modelled for Hontomin to ensure the operational success. The dynamic modeling shall particularly focus on the mechanical impact of the storage due to CO_2 injection. The monitoring data acquired along the project will be integrated on a regular basis to analyze deviations and ensure consistency of the model with the on-going operations. Towards, the end of the project, the static and dynamic models will be updated with the modeling and monitoring work performed in ENOS. Based upon its industrial experience on hydrocarbon storage, Geogreen will contribute to the establishment of the Technical Guidelines
The contribution to WP1 will be mainly on the assessment of the geochemical impact and CO_2 quality changes during the buffering in the Q16 Maas gas field. The dynamic modeling shall particularly focus on the geochemical impact of the storage during to CO_2 production.

Geogreen is involved in:
WP1 Ensuring safe storage operations

- Task 1.1 Reliable CO_2 injection procedures

- Task 1.4 Demonstrating operational risk management

WP4 Integration of CO_2 storage with local economic activities

- Task 4.1 CO_2 buffering and re-production for greenhouse horticulture

WP7 Spreading innovation for Research integration and Best practices

Staff

Dr. Yann LE GALLO is a CO_2 storage expert and serves as the project director for all projects related to risk assessment and reservoir simulation. To that extent, he acts as project coordinator for the Manaus Risk assessment project and he manages Geogreen contribution in European projects such as UltimateCO_2. He is a regular reviewer for several journals (IJGGC, SPE, OGST, IECR) and is part of the Technical Committee for definition of standard on risk assessment of geological storage of CO_2 (ISO/TC-265). He was formerly an assistant professor at Institut Français du Pétrole (now IFPEN). He holds both a doctorate and master's degree in chemical engineering from the Illinois Institute of Technology in the US and an engineering degree (Diplôme d'Ingénieur) from Ecole Supérieure de Chimie Industrielle de Lyon in France (now ESCPE Lyon). He was involved in nearly all of IFP CO_2 storage projects between 2000 and 2007 such as CO_2REMOVE, DYNAMIS, & GEOCAPACITY. In addition, he taught reservoir simulation courses for the IFP School and initiated the Reactive Modeling Course for CO_2GeoNet. He is a member of SPE.

Gilles MUNIER, Geogreen CEO graduated from Paris National School of Mines in 1981 in the field of geosciences. He joined the underground hydrocarbon storage industry in 2001 and began managing CCS-related projects after he joined Geostock in 2006 (PICOREF, INJECTIVITE, INTEGRITE, and METSTOR projects). As Geogreen CEO, Gilles has increased the company's global presence, operating budget, and project portfolio - with clients/contacts and various levels of activity taking place in Europe, North and South America, and the Middle East, as well as international clients such as the IEA-GHG, GCCSI, and UNIDO. Beyond his work as CEO, Gilles brings specialized knowledge in geosciences, economic analysis, corporate strategy, and financial forecasting to the Geogreen shareholders and engineering team. He served as project director for the CCS roadmap elaboration for Saudi Arabia, as a speaker on CCS-related topics for numerous events across the world including the World Energy Dialogue in Riyadh in November 2011, some ANR-Ademe events from 2007 to 2013. As industry stakeholder representative, Gilles MUNIER was co-chairman during the CCS summit in France in October 2007, and also speaker at a workshop organized by SPE in Dubrovnik in May 2008, and co-chaired SPE CCS workshop held in Cadiz in august 2009 and in Beijing in august 2010. He was also a speaker during the CO_2Geonet meeting held in Bucharest in September 2008, and also speaker during different sessions of European Commission meetings between 2009 and 2013. He is Geogreen Representative at the Club CO_2 both in France and in Romania. He is a member of SPE

Publications

- Y. Le Gallo Quantitative assessments of CO_2 injection risks for onshore large scale CO_2 storage. Proceedings of the 14th Annual CCUS conference, Pittsburgh, April 2015
- J. Rohmer, A. Loschetter, D. Raucoules, M. de Michele, Y. Le Gallo, D. Raffard "Improving Persistent Scatterers Interferometry (PSI) analysis in highly vegetal / agricultural areas for long term CO_2 storage monitoring" Proceedings of International Conference on Greenhouse Gas Control Technologies 12th, Energy Procedia, 2014, 63, 4019-4026
- B. Issautier, S. Fillacier, Y. Le Gallo, P. Audigane, Ch. Chiaberge, S. Viseur "Modelling of CO_2 Injection in Fluvial Sedimentary Heterogeneous Reservoirs to assess the impact of geological heterogeneities on CO_2 Storage Capacity and Performance" Proceedings of International Conference on Greenhouse Gas Control Technologies 11th, Energy Procedia 37, 5181-5190
- Laude, O. Ricci, G. Bureau-Cauchois, J. Royer-Adnot, A. Fabbri. CO_2 capture and storage from a bioethanol plant: carbon and energy footprint and economic assessment. international journal of Greenhouse Gas Control, 2011, 5, 1220-1231.
- "Carbon capture and storage: technologies, policies, economics, and implementation strategies" CRC Press, 2011

Past experience

Framework for Carbon Capture and Sequestration Program in the Kingdom of Saudi Arabia

Geogreen Scope of Work: (1) evaluation of CO_2 sources, (2) pooling strategy, (3) transport conceptual design, (4) source / sink matching strategy elaboration, (5) GIS building, (6) writing of a book on all worldwide CCS issues including technical, regulatory, development, financing, (7) strategic advices for future CCS development (R&D and operation, (8) training on Carbon Capture, CCS economics, CDM implementation at King Abdullah Petroleum Studies And Research Center

ULTIMATECO_2 FP7 project: Long-term fate of CO_2 in geological storage

Geogreen Scope of Work: 3D geological modeling, Hydrodynamic simulations of injections of CO_2, and uncertainty assessment with geochemistry and geomechanical modeling at local and regional scales.

COCATE FP7 project: Large scale CCS transportation Infrastructure in Europe

Geogreen Scope of Work : Flue gas pooling network and main pipeline transport design - Optimization of pipeline and boat transport for sink in North Sea, network management, metering philosophy, basic design of transport pipelines, project development design, economics and real option analysis for newcomers

Services for CO_2-EOR design

Geogreen Scope of Work : Phase 1: Site selection and detailed studies for CO_2 reinjection and EOR (Venezuela) - Onshore oil fields, capacity assessment, 3D injection reservoir modeling, risk assessment, transport system design, Project development design, Phase 2: Detailed CO_2-EOR assessment including 3D modeling and simulation, well analysis, conceptual design for transport, qualitative and quantitative risk analysis, monitoring and development plans and economic assessments.

Owner's engineering for development of storage in aquifer ULCOS-BF Project

Geogreen Scope of Work : 3D geological modeling, Petrophysical interpretation, Hydrodynamic simulations of injections of CO_2, Construction of the storage complex, Analysis of risks, Design of wells, including well logs, administrative engineering, pipeline transport basic design, Seismic works declaration and danger study

GCCSI/IEA GHG Review for Policy makers of CCS deployment worldwide

Geogreen Scope of Work : Regional analysis of storage suitability, capacity assessment, planning of deployment, onshore and offshore statistical cost models, GIS and database implementation, identification of gaps and short term candidates

9. IDIL Fibres Optiques (IDIL)

Description of the entity:

IDIL Fibres Optiques is a French company specify in the conception and fabrication of optical fibers systems.

Contribution to the Work Plan and expertise brought to ENOS:

Validation of CO_2 optical measurement technology at GEoENergy test bed.

IDIL is involved in:
- **WP3**. Managing leakage risks for protection of the environment and groundwater (Task 3.1 Groundwater protection: Geochemical monitoring and potential impact of leakage on potable aquifers, and more specifically, the subtask Increasing the TRL of groundwater quality monitoring tools)
- **WP7** Spreading innovation for Research integration and Best practices

Staff

Lionel Quétel Project manager

He received a Master in Optical-Electronical engineering in 1994 from Rennes I University and Ph. D. degrees in optical engineering in 1997 From Lilles University.
From 1998 to 2003, he was Fiber Bragg Grating project manager in Highwave Optical Technologies (France).
Since 2004, he is the Optical Component manager in IDIL Fibres Optiques (France).

Publications

- OFC 2015 "Reliable Expanded Beam Connector Compliant with Single-mode Fiber Transmission at 10 Gbit/s" Sy Dat Le, Michel Gadonna, Monique Thual, Lionel Quetel, Jean-Francois Riboulet, Vincent Metzger, Douglas Parker, Alain Philippe, and Sebastien Claudo

Past experience

2014/2016 French National Project COPTIK Co2 sensor development
2013-2015 RLDO project: Optical passive component development
2010-2012 DECIDII project: Bridge monitoring with FBG sensors

10. International Research Institute of Stavanger (IRIS)

Description of the entity:

IRIS AS - International Research Institute of Stavanger - is a recognized research institute with high focus on applied research, equally owned by the University of Stavanger and the regional foundation Rogaland Research. Rogaland Research was established in 1973, and because of a technical re-structuring of its ownership, IRIS was established in 2006. The continuation of Rogaland Research's activities provides IRIS with a long and proud history right from the start. Research activities started in the area of social science, but quickly developed to include petroleum. Today IRIS remains an independent research institute with research and research-related activities in petroleum, new energy, marine environment, biotechnology, social science and business development.

Contribution to the Work Plan and expertise brought to ENOS:

IRIS has a long experience in IOR/EOR methods including, but not limited to CO_2 EOR. In the project IRIS would contribute with its broad simulation experience. Another contribution is within biological environmental monitoring. IRIS is also involved as a work package leader in WP7.

IRIS is involved in:

- **WP3**. Managing leakage risks for protection of the environment and groundwater (Task 3.1 Groundwater protection: Geochemical monitoring and potential impact of leakage on potable aquifers and Task 3.1 Groundwater protection: Geochemical monitoring and potential impact of leakage on potable aquifers)

- **WP4**. Integration of CO_2 storage with local economic activities (Task 4.2 CO_2 storage and oil production and 4.3 Building the socio-economic case)

- In 3 of the 5 tasks of **WP6** International Cooperation & seeding pilots and demos in Europe (Task 6.1 International cooperation; Task 6.4 Preparation of follow-up stages for ENOS pilot sites; Task 6.5 Roadmap for upscaling identified synergies of CO_2 storage with CO_2 utilisation)

- All tasks in **WP7** Spreading innovation (WP Leader)

- As WP leader on the MB in **WP9** Management

Staff

Roman Berenblyum holds chemical engineer degree from University of Chemical Technology in Moscow, followed by PhD from Danish Technical University. Dr. Berenblyum has joined IRIS in 2006 and currently holds position of Research Director on Field Studies and New Recovery Technology. Romans research interests are within simulation of IOR / EOR processes including gas and water based methods, in-situ mobility control, PVT modelling, CO_2 utilisation and storage and analytical reservoir models. Roman Berenblyum has been involved in both research and engineering projects with among others for Statoil, ConocoPhillips, TNK-BP, ADNOC, PetroEcuador, PDVSA. Dr. Berenblyum is coordinating IRIS Energy activities within Norwegian and international networks such as EERA CCS and Shalegas and CO_2GeoNet. Roman participated in a number of training courses and workshops organised both by IRIS and other parties. Roman Berenblyum is an active member of SPE serving in journal and conference reviewing committees.

Astri JS Kvassnes has an MSc in geology from University of Bergen, and a PhD from Massachusetts Institute of Technology/Woods Hole Oceanographic Joint Program in Marine Geology, specializing in hard-rock geochemistry. She has experience as a Post Doc at IfM Geomar in Kiel, Germany and five years as a research scientist at the Norwegian Institute for Water Research in Bergen and Oslo. She has held a position at IRIS as a Senior Research Scientist and business developer for Carbon-dioxide Capture and Storage since 2013. She bridges the gap between marine ecology, geology, geochemistry and modeling so that Carbon Capture and Storage (CCS) can help the petroleum industry prevent climate change in a sustainable manner. She has been a member of the Task force for CO_2GeoNet since 2014.

Catherine Boccadoro holds a Molecular Genetics Master from Paris University followed by a PhD from Cambridge University, UK in Microbial Ecology and Microbial Biosensors for the detection of pollutants in the environment. She has joined IRIS in 2007 leading and taking part in projects related to bioremediation, microbiology and environmental response to pollutants in the environment, development of biosensors and microbial and molecular tools for environmental monitoring. She is leading the Biotechnology research group in the Environment Department at IRIS, which works in close collaboration with the Energy Department on problematics related to the O&G industry including environmental monitoring, oil spill biotechnology, reservoir microbiology and CO_2 utilisation and storage.

Publications

- Screening and Evaluation of a Saline Aquifer for CO_2 Storage - Central Bohemian Basin, Czech Republic. J. of Greenhouse Gas Control 5(6),pp. 1429-1442.
- Second EAGE CO_2 storage workshop. Physical phenomena during CO_2 injection: from lab to field.2010.
- Implementation of the EU CCS directive in Europe: Results and development in 2013. Shogenova, A. and others (including Kvassnes). http://dx.doi.org/10.1016/j.egypro.2014.11.700
- Microbial response and molecular marker target species for CO_2 exposure in the marine environment. Boccadoro, K. ; Ramanand, S. ; Maeland, M. ; Internal report 2015 (article in prep).
- Quantitative analyses of hydrocarbon-degrading bacteria in the marine environment for the development of markers of petroleum pollution. 15th International Symposium on Microbial Ecology. 24-29 August 2014. Seol, South-Korea

Past experience

- Tjelbergodden value chain: CO_2 EOR
- CO_2 EOR for Ekofisk field
- Evaluation of CO_2 injectivity and storage at Tubaen formation, Snohvit
- Screening of CO_2 storage in Czech Republic
- Microbial response and molecular marker target species for CO_2 exposure in the marine environment.
- Microbial community changes following petroleum exposure in the marine environment.
- Development of molecular microbial markers for the detection of Petroleum exposure in the marine environment.

11. Natural HAZards Control and Assessment (NHAZCA)

Description of the entity:

NHAZCA (Natural HAZards Control and Assessment) is a Spin-off Company of "Sapienza" University of Rome, international leader in the analysis and monitoring of natural hazards and large infrastructures for the management and mitigation of risks.

NHAZCA provides specialized consultancies in the geological, geotechnical and civil engineering fields through innovative remote sensing techniques, developed also through the collaboration with CERI (Research Centre of "Sapienza" University of Rome), IMG S.r.l. (promoting partner) and prestigious entities such as the European Space Agency (ESA).

NHAZCA is a reference partner for entities and companies in charge of land and urban planning, civil protection, oil & gas, mining, large infrastructures and conservation of the architectural and monumental heritage.

Our main solutions are:

- Risk Assessment
- Geotechnical Monitoring
- Structural Health Monitoring
- Early Warning Systems
- Geological Design
- Engineering Design

Contribution to the Work Plan and expertise brought to ENOS:

NHAZCA is involved in:

WP3 Managing leakage risks for protection of the environment and groundwater

- Task 3.2 Understanding risk of CO_2 migration through faults and boreholes for effective monitoring.
- **WP7** Spreading innovation for Research integration and Best practices

Specifically, NHAZCA aims to provide an analysis of the ground deformations induced by the activities for the storage of carbon dioxide, by a pioneering integration of space, aerial and ground-based remote sensing technologies. By the achieved results, it will be possible to identify pros and cons of the different technologies and to design a suitable technical protocol (in terms of costs and benefits) to be adopted in similar applications.

Interferometric analyses will be performed by high resolution satellite SAR images (available from the Space Agencies archives) in order to investigate both the historical ground deformation (i.e. 2010-2015) of the test site area and those deriving from the storage activity in the near future (both in uplift and subsidence) with millimetric accuracy. Specifically, for a comprehensive characterization of the phenomenon during injection phases, corner reflectors (i.e. passive devices allowing the optimal backscatter of the radar signal emitted by the satellite) will be installed in the test area on a regular grid in order to achieve high resolution displacement information. RPAS (Remotely Piloted Aircraft Systems) surveys will be also performed for the acquisition of an accurate DEM (Digital Elevation Model), suitable for both the refinement of the interferometric analyses and, eventually, to perform multi-temporal digital image correlation for the detection of ground deformation. Such integration represents the most relevant improvement respect to the state of art in the field of remote sensing techniques applied to Oil&Gas issues.

During the storage operation, a continuous topographic monitoring by automatic total station will be also performed in order to correlate the ground deformation to the injection activities.

Such integrated approach represents an accurate and comprehensive control system of the CO_2 injections both at local and regional (some km^2) scale, thus fitting with the main objectives of the project (i.e. developing, testing and demonstrating in the field, under "real-life conditions", key technologies specifically adapted to onshore contexts).

Staff

Paolo Mazzanti, **PhD**, co-founder and CEO of NHAZCA S.r.l. and lecturer of Remote Sensing at "Sapienza" University of Rome.
Paolo is PhD in Earth Sciences and is the organizer of the International Course on Geotechnical and Structural Monitoring (directed by Dr. John Dunnicliff). He is also lecturer at several master degree courses on natural hazards and at national and international professional courses.
On September 2011 receives the first award at the FMGM (Field Measurement in GeoMechanics) Symposium and in 2012 receive the award for Young GIN Engineer.
He is invited lecturer at several conventions and international research centres and is author of
more than 60 scientific papers inherent the following main thematic: a) terrain deformation monitoring by remote sensing techniques; b) Terrestrial and Satellite SAR Interferometry; c) geological and geomorphological characterization of sub aerial, subaqueous and coastal landslides; d) numerical modelling of quick landslides and snow avalanches; e) landslides forecasting analysis; f) thermal behaviour of rock masses.

Alfredo Rocca, PhD, Project Manager and head of InSAR division at NHAZCA S.r.l.

Alfredo is PhD in Earth Sciences with a strong expertise on ground deformation analysis and monitoring. In 2011 attended a 6 months long stage at the European Space Research Institute (ESRIN) of the European Space Agency (ESA) in Frascati (Rome) in the frame of the Earth Observation Program. On 2012 was visiting Researcher at the Institute of Space and Earth Information Science (Chinese University of Hong Kong). He is co-author of several scientific papers and conferences proceedings of national and international relevance.

Alfredo is co-organizer of the course titled "Satellite SAR Interferometry for Geologists and Engineers".
His main skills and interests are: a) numerical modeling for the stress-strain analysis by finite difference methods; b) analysis of satellite SAR data by DInSAR techniques; c) study of deformation processes by ADInSAR techniques (processing and interpretation by stacking interferometry methods such as Persistent Scatterers and SBAS); d) landslides monitoring.

Dr. Alessandro Brunetti, Project Manager at NHAZCA S.r.l.
Alessandro is graduated in Engineering Geology and is expert geologist in remote sensing for the mitigation of natural and anthropic risks. He was involved in the MODE TInSAR Incubation Project with ESA (European Space Agency) for the development of new solutions for the application of TInSAR technique to geotechnical and structural monitoring. He was also promoter of some national research and development programs like: "Promotori Tecnologici III Edizione" (by the Province of Rome) and "PRO.DI.GIO" (by the Lazio Region).
His main skills and interests are: a) processing and interpretation of ground-based InSAR data for geotechnical and structural monitoring; b) projects management; c) geological, geomechanical and geostructural surveys, also by innovative remote sensing techniques; d) landslide monitoring.

Prof. Francesca Bozzano, co-founder and President of NHAZCA S.r.l.
Francesca is Full Professor of Engineering Geology at "Sapienza" University of Rome and Director of CERI - Research Centre on Prediction, Prevention and Mitigation of Geological Risks.
She is author and co-author of more than 90 scientific papers published on international magazines and
national and international conference proceedings.
She is referee of some national and international scientific magazines.

She has been involved in the following research activities:
a) analysis of the evolution processes of slopes affected by erosive processes, mainly performed in the
frame of PhD activities; b) landslides phenomena triggered by rainfalls and earthquakes, with the recent implementation of monitoring activities; c) geotechnical and compositional characteristics of fine-grained sediments for large spectrum applications; d) technical geology of Rome subsoil, with recent applications to urban cavities; e) geotechnical analysis in the frame of seismic micro-zoning in some urban areas of Central Italy; f) geotechnical support in the frame of in situ experimental activities for the development of new
techniques for the remediation of polluted aquifers.

Publications

- Gandolfo L., Brunetti A., Bozzano F., Bratus A., Busnardo E., Floris M., Genevois R., Mazzanti P., Saporito F., 2015. The Ligosullo (UD, Italy) Landslide, Revisiting of Past Data and Prospects from Monitoring Activities. G. Lollino et al. (eds.), Engineering Geology for Society and Territory, Volume 5, Springer International Publishing, Switzerland, 171-175.
- Rocca A., Mazzanti P., Bozzano F., Perissin D., 2015. Advanced Characterization of a Landslide-Prone Area by Satellite a-DInSAR. G. Lollino et al. (eds.), Engineering Geology for Society and Territory, Volume 5, Springer International Publishing, Switzerland, 177-181.
- Bozzano F., Esposito C., Franchi S., Mazzanti P., Perissin D., Rocca A., Romano E., 2015. Analysis of a Subsidence Process by Integrating Geological and Hydrogeological Modelling with Satellite InSAR Data. G. Lollino et al. (eds.), Engineering Geology for Society and Territory, Volume 5, Springer International Publishing, Switzerland, 155-159.
- Rocca A., Mazzanti P., Perissin D., Bozzano F., 2014. Detection of past slope activity in a desert area using multi-temporal DInSAR with Alos Palsar data. Italian Journal of Engineering Geology and Environment, Casa Editrice Università La Sapienza, Rome, Italy, DOI: 10.4408/IJEGE.2014-01.O-03
- Mazzanti P., 2012. Remote monitoring of deformation. An overview of the seven methods described in previous GINs. Geotechnical Instrumentation News, Dicembre 2012, pp. 24-29.

Past experience

Over the last 5 years NHAZCA provided several consultancies and services to more than 20 national and international clients, including international Firms and Public Entities.

Among the most relevant which NHAZCA was involved in it is worth to mention the monitoring by Satellite InSAR of moraines and glaciers deposits in Antarctica, of the ground deformation of unstable slopes in the Sultanate of Oman and several landslide and artificial dams in Italy.

Furthermore, NHAZCA recently performed an analysis of ground instability processes in order to investigate the relationship with gas extraction and storage over the last 20 years in a site in Central Italy.

NHAZCA was promoter of “MODE TInSAR” (Monitoring Deformation by Terrestrial SAR Interferometry), an incubation project by ESA (European Space Agency) aiming at the development of TInSAR applications for the monitoring of natural and structural instability problems.

In the last two years NHAZCA provided highly professional courses to more than 100 Firms and Public Entities coming from more than 30 countries, thus providing to end-users the necessary background about the recent innovations in the field of geotechnical and structural monitoring and in the analysis of natural hazards for risk mitigation purposes.

12. National Institute of Oceanography and Experimental Geophysics (OGS)

Description of the entity:

The mission of OGS, a national Italian institute under the control of the Ministry of University and Research, is to promote, coordinate and perform studies and research on the Earth and its resources, more specifically, applied geophysical and environmental disciplines, marine sciences, seismicity, hydrodynamic and geodynamic phenomena, in collaboration with other national, international, and European institutions. The institute, located in Trieste and Udine, has a staff of about 270 units (about 100 on temporary contracts), and a long tradition in (on and offshore) geophysical exploration, physical oceanography, marine biology and Earth observation. OGS coordinated or participated in more than 70 EU-funded research and demonstration projects in the fields of Energy, Environment and Marine Sciences. OGS has built solid networks and partnerships in Europe, in developing countries and in transition-economies' countries. Moreover, due to its long-term collaboration with the industry of the energy sector, OGS has developed high-technology competence and skills, to manage the acquisition of onshore (surface and borehole) and offshore geophysical and oceanographic data, as well as data processing and interpretation.

Contribution to the Work Plan and expertise brought to ENOS:

OGS is involved in:

WP1: Ensuring safe storage operations (2 of the 4 tasks)
Task 1.3 Monitoring safe underground storage behaviour - 1.3.2 Innovative geophysical monitoring
Task 1.4 Demonstrating operational risk management - 1.4.1Integration of monitoring data, 1.4.3 Technical Guidelines for operational risk management.

WP3: Managing leakage risks for protection of the environment and groundwater (3 of the 4 tasks)
Task 3.2 Understanding risk of CO_2 migration through faults and boreholes for effective monitoring - 3.2.2 Monitoring CO_2 migration through fault planes in the sub-surface
Task 3.3 Development of monitoring tools
Task 3.4 Integrated monitoring solution

WP5: Coordination with local communities (one of the 3 tasks)
Task 5.1 Knowledge development and integration in a societal perspective

WP6: International Cooperation & seeding pilots and demos in Europe (3 of the 5 tasks)
Task 6.1 International cooperation - 6.1.3 Experience sharing Focus groups
Task 6.2 European links, liaison and knowledge exchange
Task 6.4 Preparation of follow-up stages for ENOS pilot sites

WP7: Spreading innovation (one of the 3 tasks)
Task 7.1 Research integration - 7.1.2 Web site and Knowledge Sharing Platform

WP8: Promoting CCS through Training and education (one of the 4 tasks)
Task 8.2 Building and providing an e-learning course

OGS can provide seismic vibrator source, borehole seismic tools, multichannel recording system and drone equipped with high tech remote sensing instruments.

Staff

Flavio POLETTO has the degree “Dottore in Fisica” (Trieste University). He is a senior geophysicist (Director of Research) coordinator of the OGS Borehole Geophysics Group. He was awarded two Honourable mentions for the Best papers in Geophysics (2001, 2002), a Best Paper by ASCE Earth & Space Exploration and Utilization of Extraterrestrial Bodies (paper ‘’MOONBIT SWD laboratory testing with lunar regolith simulant”, ESA project, 2010), and “Legends of SWD Award” (Joint SEG/SPE SWD Workshop Galveston, TX, 2013). He was scientific and technical coordinator of many projects with EU and Oil industry (Eni and other Oil industries) focused on borehole seismic and geosteering research, acquisition and data processing. He is inventor of patents on SWD and Tunnel SWD methods, published about 50 journal articles, and is author of many international conference’s presentations on borehole seismics (VSP, crosswell), acoustic, seismic wave propagation and seismic interferometry with applications to oil and geothermal exploration. He is the scientific coordinator of the OGS Instrumented-well Test Site (PITOP). He is author of the book “Seismic While Drilling – Fundamentals of drill bit seismic for exploration”, Poletto and Miranda (2004, see OGS bibliography). His expertise and research activity include new variants and innovative methods for SI wavefield representation, borehole instrument calibration (including DAS), source emission analysis by ground-force monitoring, and joint use of borehole EM and seismic methods.

José M. CARCIONE has a degree in ``Licenciado in Ciencias Físicas" (Buenos Aires University), a degree ``Dottore in Fisica" (Milan University), and a Ph.D. in Geophysics (Tel-Aviv University). From 1978 to 1980 he worked at the ``Comisión Nacional de Energía Atómica" at Buenos Aires. From 1981 to 1987 he was employed as a research geophysicist at YPF (national oil company of Argentina). Presently, he is Director of Research at OGS. He was awarded the Alexander von Humboldt scholarship for a post-doc at Hamburg University (1987-1989). In 2007, he received the Anstey award at EAGE in London. He published more than 200 journal articles on acoustic and electromagnetic numerical modeling, with applications to oil exploration and environmental geophysics. He is the author of the book "Wave fields in Real Media – Theory and numerical simulation of wave propagation in anisotropic, anelastic, porous and electromagnetic media" (see the OGS bibliography). He has been editor of "Geophysics" since 1999. He has coordinated many projects funded by the EU and private companies.

Stefano PICOTTI has a degree in Physics, and a Ph.D. in Polar Sciences. As researcher at OGS, he has developed particular expertise in the field of seismic tomography, non-conventional processing, seismic modeling and calculation of physical properties of rocks and fluids. He participated and coordinated projects focusing on reservoir characterization and geological sequestration of CO_2. He developed algorithms for the evaluation of seismic attenuation (quality factor), and for the estimation of the petrophysical characteristics of reservoirs, including seismic anisotropy. He developed algorithms to build realistic reservoir models, and applied modelling techniques to the evaluation of the sensitivity of the seismic and EM methods to the changes in the rock properties during and after the CO_2 injection, in particular for the detection of possible CO_2 leakages. He applied the tomographic technique on the optimization of the site monitoring during and after the CO_2 injection. He published 34 articles on national and international journals.

Enrico PRIOLO is senior researcher at OGS. He has experience in numerical modeling of seismic wave propagation and earthquake simulation, seismic site response estimation, as well as seismic monitoring. He was a director of the OGS Seismological Department in 2003-2008. At present, he is responsible of the Collalto Seismic Network, which is the first Italian seismic network, managed by a public institute, devoted to monitoring the activity of gas storage in an underground depleted gas reservoir.

Andrea SCHLEIFER is a senior electronic engineer, coordinator of the acquisition activity in the Borehole Geophysics Group of the OGS Geophysical Section. He has been manager of the acquisition-system and borehole-instrumentation development, preparation and utilization activity in more than 35 field surveys of borehole geophysics (including seismic, distributed acoustic DAS by fiber optic sensors and EM applications), for downhole and joint surface-borehole innovative instrumentation testing and experimental monitoring purposes. Since 2009 he is the technical coordinator of the geophysical-experimental PITOP infrastructure with instrumented wells (OGS Test Site of Piana di Toppo in Italy).

Gualtiero BÖHM holds a MSc in Geological sciences. He is senior researcher at OGS, with over 25 years deep experience in seismic methods, in particular in the development of new algorithms for seismic tomography. He is the responsible of the CAT3D project, that develops the software tomographic package CAT3D, own by OGS. This software has been and is being applied for hydrocarbons and gas-hydrates search, seismotectonic studies, near surface applications, civil engineering studies, and monitoring underground CO_2 storage. He was involved in many projects for oil companies (Eni-Agip, Norsk Hydro, Fina, Elf, OMV, Saudi Aramco and Enterprise), concerning tomographic inversion and processing of real data; he participated in numerous national and European projects, and for some of them acted as scientific responsible for OGS, as the Wise research project of the Italian national research program in Antarctica and the European projects on CCS in Coal beds (MoVeCBM), and on C02 Site Closure Assessment (Co2Care). He published over 50 papers in international journals and almost 100 works in international conference proceedings.

Michela VELLICO is an environmental engineer, with a Ph.D. in Applied Geophysics and Hydraulics. Her main technical expertise is in remote sensing techniques, particularly their applications for CCS studies. In this field, she has been involved in the following EC projects: CO_2 GeoNet (testing the use of remote sensing methodologies in the leaking sites of Latera and the Laacher See), Geocapacity and CO_2StoP (providing datasets to the European WebGIS of storage sites, and storage capacity calculation), ECCSEL PPI and ECCSEL PPII. She has also contributed to national projects related to CCS (for ENEL and Cesi Ricerca), and has been actively involved in all the studies performed by the OGS Research aircraft equipped with high-tech remote sensing instruments.

Publications

- Carcione, J. M., 2015, Wave Fields in Real Media. Theory and numerical simulation of wave propagation in anisotropic, anelastic, porous and electromagnetic media, 3rd edition, Elsevier.
- Picotti, S., Grünhut, V., Osella, A., Gei, D., Carcione, J. M., 2013, Sensitivity analysis from single-well ERT simulations to image CO_2 migrations along wellbores, The Leading Edge 32(5), 504-512. DOI: 10.1190/tle32050504.1.
- Poletto F., B. Farina, G. Böhm, and K. Wapenaar, 2014. Seismic interferometry by tangent-phase correction: Geophysical Prospecting. DOI: 10.1111/1365-2478.12209.
- Poletto F., and F. Miranda, 2004. Seismic-While-Drilling. Fundamentals of Drill-Bit Seismic for Exploration: Handbook of Geophysical Exploration, Seismic Exploration. Vol. 35. Elsevier, Amsterdam. Release Date: 30 Jun 2004, Imprint: Pergamon, eBook ISBN: 9780080474342, Print Book ISBN: 9780080439280, Pages: 546.
- Priolo, E., M. Romanelli, M. P. Plasencia Linares, M. Garbin, L. Peruzza, M. A. Romano, P. Marotta, P. Bernardi, L. Moratto, D. Zuliani, and P. Fabris (2015). Seismic monitoring of an underground natural gas storage facility: The Collalto Seismic Network, Seismol. Res. Lett. 86, no. 1, 109--123, doi: 10.1785/0220140087.

Past experience

Past OGS research on CCS has been focused on: storage sites identification and characterization, subsurface imaging by geophysical methodologies, on-shore and off-shore storage sites monitoring, remote sensing, impact assessment on marine ecosystem, and development of advanced monitoring techniques for data acquisition, processing and modelling. In particular, OGS has been involved in the following European projects on the geological storage of CO_2: CO_2-NET2, CASTOR, INCA-CO_2, CO_2GeoNet, GeoCapacity, CO_2ReMoVe, MOVE-

CBM, RISCS, ECO_2, SiteChar, CGS Europe, CO_2CARE, and ECCSEL. OGS is Secretary General of CO_2GeoNet (the European Network of Excellence on the Geological Storage of CO_2) and coordinator of the EERA Joint Program on CO_2 Geological Storage.

Relevant borehole activities have been performed at the OGS instrumented Test Site Piana di Toppo (PITOP, Italy), in particular for acoustic calibration of iDAS by co-located geophones in borehole and surface trenches. These activities include crosswell investigations (CO_2Monitor project), with evaluation of borehole seismic, resistivity and EM methods.
Thanks also to a fruitful collaboration with other CO_2GeoNet members, OGS has tested and implemented some innovative remote sensing techniques to indirectly monitor CO_2 leakages through joint interpretation of data acquired by instruments mounted on board of aircrafts, helicopters or drones.
Finally, worthy to be mention is the collaboration of OGS with the Italian Economic Development Ministry (MISE), for the definition of methodologies and operational monitoring protocols to ensure safe injection/extraction operations. In this ongoing collaboration, OGS have already given a substantial contribution to write the Italian national guidelines for geophysical monitoring of oil & gas exploitation activities.

13. State Geological Institute of Dionyz Stur (SGIDS)

Description of the entity:

The State Geological Institute of Dionyz Stur (SGIDS) is a state contributory organization acting as Slovak Geological Survey supervised by the Ministry of Environment of the Slovak Republic. The activities are focused in the solutions of the geological research and exploration projects, creation and application of the information system in geology, registration, collection, evidence and making accessible the results of geological works carried out at the territory of the Slovak Republic and overseas. The particular engagement is linked with the geological mapping, mineral resources, processing of mineral resources, hydro-geological survey, engineering geological survey, environment, facilities for the storing of gas, liquids and wastes, extraction of raw minerals, reference laboratory services etc.

Contribution to the Work Plan and expertise brought to ENOS:

Engagement within WP4 lead by TNO and the activity focusing on the cross-border impact study of the prospective Czech pilot LBr-1.

WP6 because of the activities linked with the depleted gas deposit in Brodske (Slovak Republic) and the managing leakage risks and protecting groundwater.

Provision of both geological and hydro-geological expertise meeting the expected selected tasks of the ENOS project.

SGIDS is involved in:
- **WP6**. International Cooperation & seeding pilots and demos in Europe (Task 6.4 Preparation of follow-up stages for ENOS pilot sites; Task 6.5 Roadmap for upscaling identified synergies of CO_2 storage with CO_2 utilisation)
- **WP7** Spreading innovation for Research integration and Best practices

Staff

Dr. Ludovit Kucharic, PhD
Comenius University, Bratislava 1965-1968 Slovakia
Charles University Prague 1968 – 1971 Czech
Diploma: geology, specialization applied geophysics
Comenius University Bratislava 1981-1986 SlovakiaPhD (CSc) Thesis: A reflection of geological phenomena in geophysical fields in the Spissko - gemerske Ore Mts. (in Slovak).Awarded 1986
KEY QUALIFICATIONS
Long term experience with geological and geophysical data interpretation
Geological mapping
Evaluator of project regarding geology and environment for INTAS, EC Brussels, Hungary Academy of Science
Orientation in the international environment regarding impacts of energy production
Global overview on European necessities and problems from environmental, raw material and energy point of views
Presentation of achieved results on the conferences and workshops in the Europe, some presentation concerning to CO_2 storage and connected problems have been on call: Petten 2006, Zagreb, 2007, Bratislava, 2009, 2010, Fontainebleau (France) 2009, Prague, 2010, Venice 2010, 2011,2012, Trondheim (Norway) 2010.
Contributor to the EC Directive creation regarding geological storage of CO_2; member of Slovakian group creating the National law on this issue
Holistic approach to cycle raw materials exploitation, utilisation and storage by surviving principle of sustainable development.
Publication activity – more than 125 (papers, posters, presentations - (selected publications see www.**researchgate**.net/), above 60 reports (manuscripts).

MSc. Michal Jankulár, PhD.

Comenius University in Bratislava, Slovakia 2003 – 2005 Faculty of Natural Sciences, Master of Science degree in Environmental geochemistry,

Comenius University in Bratislava, Slovakia, Faculty of Natural Sciences 2005 – 2012 PhD. study in Environmental geochemistry.

MAIN ACTIVITIES AND RESPONSIBILITIES

State monitoring program of selected old environmental loads in Slovak republic – *member of work team - responsibility for part of the project*

Research on vulnerability of groundwater for management of sustainable exploiting of groundwater in Bratislava municipality (existing and potential contamination sources for groundwater, sensitivity of aquifers, statistics, GIS) – *member of work team*

Publications

- Potential, Capacities Estimation, and Legislation for CO_2 storage in the Geological Formations of the Slovak Republic. Slovak Geological Magazine. / Ľudovít Kucharič, Ľubomír Tuček, Dušan Bodiš, Martin Radvanec, Ján Wallner, Katarína Čechovská, Zoltán Németh, Ivan Baráth, Alexander Nagy, Ján Derco, Boris Antal, Vladimír Bezák, Pavol Šesták - In: (2013), - 142 s.
- CO_2 storage potential of sedimentary basins of Slovakia, the Czech Republic, Poland and the Baltic States. / Saulius Šliaupa, Richard Lojka, Zuzana Tasáryová, Vladimír Kolejka, Vít Hladík, Júlia Kotulová, Ľudovít Kucharič, Vladimír Fejdi, Adam Wójcicki, Radoslaw Tarkowski, Barbara Uliasz-Misiak, Rasa Šliaupiené, Inara Nulle, Raisa Pomeranceva, Olga Ivanova, Alla Shogenova, Kazbulat Shogenov - In: Geological Quarterly. - ISSN 1641-7291 - Vol. 57, Issue 2(2013), - S. 219-232.
- Case for CO_2 geological storage-site Bzovík central Slovakia volcanic area. / Ľudovít Kucharič - In: Slovak Geological Magazine. - č. 2008(2009), - s. 73-80.
- CO_2 storage opportunities in the Central-NE Europe. / G. V. Georgiev, M. Larsen, N. Christensen, P. Scholtz, G. Falus, V. Hladik, L. Kolejka, Júlia Kotulová, Ľudovít Kucharič, A. Wojcinski, B. Saftic, B. Goricnik, M. Car, C. S. Sava, M. Bentham, N. Smith - In: Natural Cataclysms and Global problems of the Modern Civilization. Special edition of Transaction of the International Academy of Science. Baku, Azerbaidzhan, September, 24-27th 2007 . - Baku-Innsbruck: H&E, ICSD/IAS, 2007. - s. 736-741.
- Preliminary results of the Slovakian national project regarding carbon dioxide storage in underground spaces. / Ľudovít Kucharič, Martin Radvanec, Ľubomír Tuček, Zoltán Németh, Dušan Bodiš, Katarína Čechovská, Ján Derco, Juraj Michalko, Ján Wallner, Peter Liška, Boris Antal - In: Energy Procedia. 10th International Conference on Greenhouse Gas Control Technologies. Amsterdam, The Netherlands, 19-23 September 2010. - Vol. 4, (2011), - s. 4921-4929.

Past experience

6thFP **CO_2 Net East**

6thFP **Geocapacity** – Estimation of Europe for CO_2 storage

CGS Europe - Pan-European Coordination action on CO_2 Geological Storage

CO_2STOP – European Atlas on Suitable Geological Structures for CO_2 Storage

14. Silixa (Silixa)

Description of the entity:

Silixa manufactures the world's highest performance distributed fibre optic sensors for temperature and acoustic monitoring. Ultima™ DTS offers the best spatial resolution available on the market for continuous temperature measurements along the FO cable. iDAS™ enables the user to listen in to digital-quality sound at every point along the cable. Both systems have been used successfully in the oil & gas, industrial and environmental sector.

A hybrid cable with more sensitive acoustic detection thresholds than currently commercially available and temperature change detection capability is being developed by Silixa and will be tested at the Sulcis fault laboratory and compared with other commercially available tools (which will be installed at the site through the national programme). This cable detects the arrival of CO_2 based on the differing physical properties of the CO_2 plume compared with the native groundwater. It utilises advanced silica engineering to optimise the interaction between the acoustic signal with the backscattered light. Through careful tuning of the iCable optoacoustic characteristics, Silixa can achieve a 15dB to 30dB improvement in the acoustic Signal to Noise Ratio compared to the use of standard cable. This breakthrough performance allows the iDAS to detect passive signals orders of magnitude lower than previously possible, or in the case of active seismic mode, to enable the operator to use significantly fewer repeat seismic shots or lower source effort. The seismic survey will provide a better characterization of the faults and leakages into borehole. Moreover Distributed Temperature Sensor measurements during the injection phase will contribute to the leak detection and characterization. TRL of this application will be brought to 7 through testing in wells in the freshwater zone

Contribution to the Work Plan and expertise brought to ENOS:

Silixa will be responsible for the iDAS data acquisition as part of the two 3D seismic surveys, in the Hontomin site. Silixa will also contribute to groundwater monitoring using innovative tools in the Sulcis site. These tools include an intelligent fibre optic cable (iCable) for enhanced seismic and temperature measurements for a better characterization of the faults and leakages in the Sulcis site.
Silixa will be mainly involved in the definition of the activities in Hontomin and Sulcis areas (WP1 and WP3) and in the definition of the best practices and innovative techniques (WP7).

Silixa is involved in:

WP1 Ensuring safe storage operations

- Task 1.3 Monitoring safe underground storage behaviour (Subtask 1.3.2 Innovative geophysical monitoring)

WP3 Managing leakage risks for protection of the environment and groundwater

- Task 3.1 Groundwater protection: Geochemical monitoring and potential impact of leakage on potable aquifers)

WP7 Spreading innovation for Research integration and Best practices

Staff

Dr Tom Parker, co-designer of Silixa's iDAS and ULTIMA units, is Silixa's Chief Technical Officer and has extensive expertise in fibre optic monitoring. Leading Silixa's R&D programmes he brings a clear direction of technical leadership to the company and is a world authority in distributed temperature, strain and acoustic sensing. Tom holds a PhD in Solid State Physics from Imperial College London and a first class degree in Physics from University College London. He is co-author on eight sensing patents, and has numerous international publications. Tom won a Metrology for World Class Manufacturing Award and British Telecom Technological Innovation Award for an extremely fine-resolution optical wavelength meter that he co-invented with Mahmoud Farhadiroushan, CEO of Silixa Ltd.

Dr Michael Mondanos, Silixa's VP of Industrial Applications, has over 15 years' experience in fiber optic monitoring. Holding a PhD in Optical Fibre Sensing from Imperial College, University of London he has not only

an in-depth technical knowledge of the fibre optic monitoring systems, but also a significant expertise in operations, project management, and strategic planning. He authored several international publications and he is a widely acknowledged expert in the energy industry.

Dr. Athena Chalari, Silixa's Environmental Engineer since 2012, has considerable experience in fibre optic monitoring for environmental applications. Athena holds a PhD in Marine Geosciences from University of Patras, Geology Department. She has field experience and expertise in data processing and geological interpretation. She has several international publications and has providing training in several distributed fibre optic workshops.

Dr Freifeld has been collaborating with Silixa as an external consultant. His research interests focus primarily on geologic sequestration of CO_2 in which Dr Freifeld has gained significant experience and track record through field installation and demonstrations in saline and depleted gas aquifers. Other research projects include understanding thermal and hydrologic conditions in arctic regions and monitoring geothermal systems. Currently he is the Principal Investigator at Lawrence Berkeley National Laboratory for a demonstration of coupled carbon sequestration and geothermal energy production. Dr Freifeld leads Berkeley Laboratory's collaborations with the Australian CO_2CRC Otway Project and the EU funded CO_2SINK program in Ketzin, Germany. He has over 100 publications and has received 7 awards in reservoir management and downhole techniques.

Publications

- Mondanos, M., Farhadiroushan, M. and Parker, T. (2007) Sensing System using optical fiber suited to high temperatures. International Patent: WO/2007/066146.
- Mondanos, M., Giles, I., Weir, K. (2005) Fibre optic polarimetric temperature sensor using low coherence source employing intensity and wavelength compensation. Proc. SPIE 5855, 17th International Conference on Optical Fibre Sensors, 647 (August 30, 2005); doi:10.1117/12.623280.
- Chalari A. , Mondanos M. , Finfer D. , Christodoulou D., Kordella S., Papatheodorou G., Geraga M., Ferentinos G. 2012. Short-term monitoring of a gas seep field in the Katakolo bay (Western Greece) using Raman spectra DTS and DAS fibre-optic methods. AGU Fall Meeting 3-7 December 2012.
- Ethan Castongia, Dante Fratta, Herb Wang, Michael Mondanos, Athena Chalari 2013. An initial test of an Intelligent Distributed Acoustic Sensing (iDAS) in the ice in Lake Mendota. AGU Fall Meeting 9-13 December 2013.
- Coleman, T., A. Chalari, B. Parker, J. Munn, and M. Mondanos. Accepted. Monitoring Borehole Flow Dynamics Using Heated Fiber Optic DTS in a Fractured Rock Aquifer. EGU General Assembly 2014, April 27-May 02, 2014, Vienna, Austria.

Past experience

Silixa is developing complementary signal processing techniques and application-customisation to form the base iDAS model into a number of specific tools: for example, flow meter, security sensor or seismic sensor. These projects involve seeking to resolve further specific technological uncertainties which fall within the definition of qualifying R&D for these purposes.

Previous experience includes participation in ZONeSEC programme under FP7 (call: SEC-2013.1.6-3) for pipeline surveillance and INTERFACES programme under Marie Curie Initial Training Networks (ITN) (Call: FP7-PEOPLE-2013-ITN). Moreover, Silixa in collaboration with the Fundación Ciudad de la Energia (CIUDEN) had performed iDAS seismic surveys and DTS trials in the Hontomin site for the development of a Deep-Well Heat Pulse Monitoring system for CO_2 sequestration. Silixa have also performed DTS trials in collaboration with CSIRO and the Australian National University (ANU) for CO_2 sequestration and iDAS seismic surveys in collaboration with Lawrence Berkeley National Laboratory at several CO_2 sequestration sites as the Australian CO_2CRC Otway Project, the Canadian Aquistore project and the US EPRI Energy Technology Assessment Center.

15. Società Tecnologie Avanzate Carbone S.p.A. (Sotacarbo)

Description of the entity:

Sotacarbo is a research and development company (shareholders: ENEA – the Italian National Agency for New Technologies, Energy and Sustainable Economic Development – and Sardinian Regional Administration) on clean energy and CCS.
Recently, Sotacarbo has been designed by the Sardinian Regional Government as the Centre of Excellence on Clean Energy, i.e. the regional and national reference for the development of the technologies for the sustainable use of fossil fuels (coal in particular) and clean energy (including carbon capture and storage), with the aim to collect knowledge and infrastructures in order to back and also to boost Italy's energy policy.
The activities programme of the Centre of Excellence includes theoretical and experimental studies on "zero emissions" technologies for power generation, production of energy carriers from coal, biomass and CO_2, pre-, post- and oxy-combustion carbon capture CCS and CO_2 geological storage.
Since 1988, Sotacarbo represents Italy in the International Energy Agency – Clean Coal Centre.

Contribution to the Work Plan and expertise brought to ENOS:

As the Sulcis (South-West Sardinia, Italy) site owner, Sotacarbo will coordinate all the activities carried out in such a site. Most of these activities will use the infrastructures (currently under development with Italian national funding) for site characterization and small-scale carbon dioxide injection to analyze CO_2 leakage in the faults.
In this context, Sotacarbo will be mainly involved in the definition of the experimental activities in Sulcis area (WP2 and WP3), in the work with Southern Sardinian local communities (WP5), in the activities to promote international cooperation (WP6), in the definition of the pest practices (WP7) and in knowledge staring and education activities (WP8).
Finally, Sotacarbo will also contribute to ENOS project through the organization of the following annual editions of the International Sulcis CCS Summer School, organized (together with the International Energy Agency – Clean Coal Centre, ENEA, the University of Cagliari and CO_2GeoNet) every July in its Research Centre in Carbonia, Italy. The school does not involve extra costs for ENOS, being funded through the national program.

Sotacarbo is involved in:

- **WP2** Ensuring storage capacities and cost-effective site characterisation (Task 2.3 Low Cost Drilling; Task 2.4 Technical guidelines on storage capacities estimates and cost-effective site characterisation)

- **WP3**. Managing leakage risks for protection of the environment and groundwater (Task 3.4 Integrated monitoring solution)

- all tasks in **WP5** Coordination with local communities (Task 5.1 Knowledge development and integration in a societal perspective; Task 5.2 Work with the local communities; Task 5.3 Development of a Public Information Tool for CO_2 storage sites)

- **WP6** International Cooperation & seeding pilots and demos in Europe (Task 6.1 International cooperation; Task 6.4 Preparation of follow-up stages for ENOS pilot sites)

- **WP7** Spreading innovation for Research integration and Best practices

- **WP9** Management as the Sulcis Site Owner

Staff

Mr. Giuseppe Girardi Age: 64 (male)
Profession: Graduated (cum laude) in Mechanical Engineering from University of Rome, he joined ENEA since 1978. He has directed the Diagnostic & Control Section of the Engineering Division, operating in basic and industrial oriented research activities. He has been involved in R&D programs on combustion and power plants, managing several projects and then playing the role of vice director of the Engineering Division. During the last decade he has directed the Energy Plants and Processes Division – operating in the fields of advanced power plants, low and zero emissions technologies, hydrogen technologies, decentralized power generation - and manager of Clean Coal/Zero Emission Project at ENEA. Now he's responsible of sustainable fossil fuels and CCS programs at ENEA, and Vice-president of Sotacarbo, giving advising and support to government both in technology innovation and energy strategies. He's also: President of Italian section of International Flame Research Foundation; Italian technical delegate in European Energy Research Alliance; Italian representative in the CCS-European Industrial Initiative of SET Plan; Italian delegate in the technical group of CSLF; member of Task Force "Technology" of ZEP European technological platform; Italian representative in Working Party Fossil Fuels.

Dr. Alberto Pettinau Age: 39 (male)
Profession: Dr. Pettinau is graduated in Mechanical Engineering and Ph.D. and he is currently Technical Manager of Sotacarbo. Dr. Pettinau is engaged, since 2004, in several research and development programs. He worked as Chief Scientist and Project Manager in several national and international research projects (including the project "Centre of Excellence on Clean Energy", funded with 8.4 M€ by the Sardinian Regional Government). His research is mainly focused on conventional and advanced gasification processes, oxyfuel combustion, carbon capture and storage and coal/biomass/CO_2 to liquids. He is the scientific coordinator of the Annual International Sulcis CCS Summer School (organized by Sotacarbo with Enea, University of Cagliari and International Energy Agency – Clean Coal Centre) and author of 50 publications (in international journals, books and conference proceedings) and a number of technical reports. He also cooperates as reviewer with several international journals.

Mr. Enrico Maggio Age: 47 (male)
Profession: Enrico Maggio is graduated in Mechanical Engineering at the University of Cagliari. He works in Sotacarbo since 1999 and he is currently Technical Manager. His main research activities are focused on coal and biomass gasification, advanced clean coal technologies, renewable sources, energy efficiency, carbon capture and storage, and experimental data processing. Mr. Maggio worked as Project Manager in several national and international research projects (including the project "Research on Electric System", funded with 3 M€/year by the Italian Ministry of Economic Development). He is also author of some publications on coal gasification and carbon capture and storage.

Mr. Alberto Plaisant Age: 41 (male)
Profession: Alberto Plaisant is graduated in Geological Science and he obtained a Master Degree in "Remote sensing and Geografic Information System (GIS)" in 2003. He works in Sotacarbo since 2005, where he is currently chief of the CO_2 Storage Team and vice chief of the Advanced Diagnostic Team. His research activities are mainly focused on CO_2 geological storage and site characterization. He has gained a 15-years experience and a wide knowledge on the Sulcis site from the geological and environmental points of view. He also has experience on laboratory-scale characterization of coal and biomass, gas analysis, CO_2 capture processes. Finally, Alberto Plaisant is co-author of several technical and scientific publications.

Publications

- V. Tola, A. Pettinau. Power generation plants with carbon capture and storage: a techno economic comparison between coal combustion and gasification technologies. Applied Energy, 2014;113:1461-1474.

- G. Girardi, E. Maggio, A. Pettinau, A. Plaisant, P. Deiana. Italian technology centre on CCS and clean energy: activities and international cooperation. Proceedings of the Asia Clean Energy Foru, 2014, Manila, Philippines, June 16-20, 2014.
- Plaisant, P. Deiana, G. Girardi, E. Maggio, A. Pettinau. Centre of Excellence on Clean Energy: Characterization of Sulcis coal basin for CO_2 geological storage. Proceedings of the 9th CO_2GeoNet Open forum, Venice, May 20-21, 2014.
- Pettinau, F. Ferrara, C. Amorino. Techno-economic comparison between different technologies for a CCS power generation plant integrated with a sub-bituminous coal mine in Italy. Applied Energy 2013;99:32-39.

Past experience

- Coordinator of the "Centre of Excellence on Clean Energy" Project, on carbon capture technologies by pre-, post- and oxy-combustion approaches and CO_2 geological sequestration.
Overall cost: 8.4 M€, funded by Sardinian Regional Government (2014-2016).

- Coordinator of the "Electric System Research" Project, on carbon capture technologies, power generation from biomass and energy efficiency.
Overall cost: 30 M€, funded by the Italian Ministry of Economic Development (2013-2023).

- Partner of the "Carbomicrogen" Project, on zero-emissions distributed power generation from coal.
Overall cost: 1.3 M€, funded by the Italian Ministry of Education and Research (2006-2010).

- Partner of the "COCACORK" Project on rotary kiln gasification for CO_2-free power generation.
Overall cost: 2.2 M€, funded by the European Commission's Research Fund for Coal and Steel (2007-2010).

- Coordinator of the "COHYGEN" Project, on a gasification pilot platform for CO_2-free hydrogen production from coal.
Overall cost: 12 M€, funded by Italian Ministry of Education and Research (2003-2008).

Infrastructure/ major equipment provided to ENOS

Sulcis (fault lab and pilot) - More detail is provided in the section 'Infrastructure proposed by the partners – test sites'.

16. Netherlands Organisation for Applied Scientific Research (TNO)

Description of the entity:

TNO is the largest fully independent Research, Development and Consultancy organisation in the Netherlands with a staff of about 5,400 and a total annual turnover of about 515 million Euros. Its primary tasks are to support and assist trade and industry including SME's, governments and others in technological innovation and in solving problems by rendering services and transferring knowledge and expertise. TNO provides contract research and specialist consultancy, as well as grant licenses for patents and specialist software. Also TNO tests and certifies products and services, and issues an independent evaluation of quality

Contribution to the Work Plan and expertise brought to ENOS:

TNO will bring in its expertise on monitoring subsurface CO_2 storage and its impacts (induced seismicity) and knowledge on developing practical technical guidelines for storage site operators. Geochemical modelling knowledge in TNO will be used to evaluate the impact of fluid-rock interactions on the purity of reproduced CO_2 gas streams. Engineering expertise on gas separation at TNO is central in developing the required separation techniques. Reservoir engineering expertise will be used to develop novel approaches for enhancing oil production and simultaneous CO_2 storage. Stakeholder analysis and techniques for engagement will be deployed to come to an active participation role of the stakeholders including the public. Regulatory hurdles in simultaneous oil production and CO_2 storage will be investigated and possible solutions will be defined. TNO will develop a plan for dissemination of project results to various stakeholder groups in industry, government, NGOs and the public at large.

TNO is involved in:

- **WP1**. Ensuring safe storage operations (Task 1.2 Induced seismicity: monitoring, control and hazard mitigation; Task 1.4 Demonstrating operational risk management)

- **WP3**. Managing leakage risks for protection of the environment and groundwater (Task 3.3 Development of monitoring tools; Task 3.4 Integrated monitoring solution)

- all tasks in **WP4**. Integration of CO_2 storage with local economic activities (WP Leader) and leader of Task 4.1 CO_2 buffering and re-production for greenhouse horticulture

- all tasks in **WP5** Coordination with local communities

- **WP6**. International Cooperation & seeding pilots and demos in Europe (Task 6.4 Preparation of follow-up stages for ENOS pilot sites; Task 6.5 Roadmap for upscaling identified synergies of CO_2 storage with CO_2 utilisation (Leader))

- all tasks of **WP7** Spreading innovation

- **WP8**. Promoting CCS through training and education (Task 8.4 Raising awareness by training workshops for journalists and media)

- **WP9** Management as WP Leader in the MB and as Q16 Maas Site Contact

Staff

Dr. Filip Neele is has a PhD in geophysics and holds a position as senior scientist and project manager in the field of CCS. Since 2006 he has been involved in a range of CCS projects: seismic monitoring, (geological) site characterisation, CCS chain integration and economical assessment. His special interest concerns the analysis and optimisation of the carbon capture, transport and storage chain. He coordinated the EU FP7 CO_2Europipe project, on the development of large-scale CCS infrastructure in Europe. He is also coordinating the MiReCOL project on the Mitigation and Remediation of CO_2 Leakage.

Dr. Ir. Cor Hofstee holds a PhD in the field of fluid flow through porous media. He worked in several countries (Australia, Niger, USA, Germany and the Netherlands) and for several research institutes and universities. Since

2001, he has been working for TNO, where he is currently active as a senior reservoir engineer. As such, he was involved in numerous oil and gas projects for a variety of operators. Furthermore, he managed in a number of screening and technical feasibility studies concerning CCS. He is currently involved in a number of EC projects including CO_2Geonet, IMAGE and MiReCOL.

Tom Mikunda is energy policy consultant at TNO. With a background in environmental science, environmental policy and economics, his work focuses primarily on policy and regulatory issues concerned with carbon capture and storage technologies. He has over 5 years experience in many aspects of European and international climate policy, closely observing the development of global climate negotiations under the UNFCCC. Between 2010 and 2014, he led the regulatory component of the €60 million Dutch national CCS research programme, CATO2. He has also advised and informed industrial and governmental stakeholders on issues such as transboundary CO_2 transport, CO_2 stream compositions and the long-term liability of storage sites, and has also partaken in CCS capacity building missions in developing countries including Brazil, Indonesia, Mexico, Mozambique and South Africa.

Dr Ton Wildenborg is a senior geoscientist and project manager at TNO, who has over 30 years of experience in projects dealing with waste management, CO_2 storage, performing risk assessment in CO_2 storage projects and developing regulations for CO_2 storage. He received his Master's Degree in Earth Sciences at Utrecht University in 1982. In the same year he started a PhD research project which was successfully defended in 1990. He was one of the lead authors of the IPCC Special report on CO_2 Capture and Storage and he facilitated the process of developing the OSPAR Framework for Risk Assessment and Management (FRAM). Ton was also engaged in studies supporting the development of the EU Storage Directive (analysis of storage scenarios and input for guidelines for CO_2 storage) and he advised the North Sea Basin Task Force in the development of guidelines for Monitoring, Verification, Accounting and Reporting of CO_2 storage. He was manager of the finalized EU project CO_2ReMoVe, which developed the technological basis for monitoring and verification of CO_2 storage and provided recommendations for monitoring and verification guidelines. Recently he is engaged in developing practicable approaches for regulatory requirements during the closure and post-closure phases of a storage site and the evaluation of the CCS Directive and CCS enabling policies. Ton has been elected as president of the CO_2GeoNet Association.

Publications

- Nepveu, M., Neele,F., Delprat-Jannaud, F., Akhurst, M., Vincké, O., Volpi, V., Lothe, A., Brunsting, S., Pearce, J., Battani, A., Baroni, A., Garcia, B., Hofstee, C., Wollenweber, J. (2014). CO_2 Storage Feasibility: A Workflow for Site Characterisation. Oil & Gas Science and Technology – Rev. IFP Energies nouvelles, DOI: 10.2516/ogst/2014034
- Wildenborg, T., de Bruin, G., Kronimus A., Neele, F., Wollenweber, J., Chadwick, A. Transferring responsibility of CO_2 storage sites to the competent authority following site closure.). Proceedings of the 12th International Conference on Greenhouse Gas Control Technologies (GHGT-12), Austin, USA, Energy Procedia 63 (2014) 6705 – 6716
- M. Kühn, M. Wipki, S. Durucan, A. Korre, J.-P. Deflandre, H. Boulharts, S. Lüth, P. Frykman, J. Wollenweber, A. Kronimus, A. Chadwick, G. Böhm (2013). Key site abandonment steps in CO_2 storage. Proceedings of the 11th International Conference on Greenhouse Gas Control Technologies (GHGT-11), Kyoto (Japan), Energy Procedia, Volume 37, 2013, Pages 4731-4740

Past experience

TNO is the leading research institute in the Netherlands on CCS with involvement in many international projects for almost two decades, including the coordination of EU research programs for subsurface CO_2 storage in aquifers, gas, oil, and coalbed reservoirs. Recently, TNO has performed national and international contract work for site specific evaluations of CCS projects. TNO has expertise over the entire chain from capture to transport to storage of CO_2 and TNO is the leading organization for the CATO project, the Dutch €80 million national program on CCS with more than 40 partners from industry, academia and research organisations. On an international scale, TNO is

active in the oil and gas industry, e.g. well and pipeline flow assurance, sensor development, basin modelling, geological modelling, seismic interpretations, reservoir engineering, prospect evaluation and production forecasting to portfolio management.

Infrastructure/ major equipment provided to ENOS

Q16 Maas buffer project - More detail is provided in the section 'Infrastructure proposed by the partners – test sites'

17. Sapienza University of Rome – CERI Research Centre (UniRoma1)

Description of the entity:

With 21 faculties and over 4500 teaching and research staff, Sapienza University of Rome is an internationally recognised centre of excellence for education and cutting edge research. The Fluid Chemistry Group, Department of Earth Sciences, affiliated with the CERI Research Centre on Geological Risks, represents the university in this proposal. It has specialised in near-surface gas and water geochemistry since 1980, using it as a tool in such topics as basic geology (tectonics, fault mapping, volcanic processes), resource exploration (geothermal, oil and gas, mineral), pollution mapping (garbage dumps, gasoline spills), and geological disposal (nuclear, CO_2). Due to the high social relevance of the issues addressed, since 1999 an interdisciplinary collaboration with social science researchers has been started and is now consolidated into a team work approach to science dissemination and public perception issues. With the addition of social scientists to the group, we have worked to take our knowledge and experience beyond the boundaries of the research laboratory, increasing our involvement at societal level, experimenting innovative approaches to science and society dialogue and researching the perception of technological innovation.

Contribution to the Work Plan and expertise brought to ENOS:

UniRoma1 will act in WP3 coordinating the activities for understanding risk of CO_2 migration through faults and boreholes for effective monitoring. Work will be performed at the Sulcis site, an area where we first conducted baseline monitoring in 2009 and where we are presently involved with other Italian research partners in site characterisation work for the proposed CCS pilot. We will be responsible for coordinating a CO_2 injection test at 200 m depth into a fault; we have already performed three shallow (>20m) injection tests in previous EC funded projects, including one at the Latera site during the NASCENT CCS project. Related to the injection test, within WP3, we will: conduct groundwater and near-surface gas geochemistry monitoring using methods proven within the RISCS project; further develop, test, and deploy innovative monitoring tools (GasPro, GasMapper) that we initially studied at lower Technology Readiness Levels in RISCS and CO_2GeoNet; and perform detailed fault analyses and 3D modelling of CO_2 gas movement using industry standard software like Petrel, Move 2011, and Comsol Multiphysics based on our experience in CO_2GeoNet and industry funded projects. In addition we will collaborate with monitoring at the Hontomin (WP1) site.

In WP5 UniRoma1 will lead the work with local populations for the integration of technical, scientific and societal aspects in the definition of guidelines for CO_2 storage implementation and for providing access to CO_2 storage sites' implementation processes to the public at large. UniRoma1 will bring to the project previous experiences in the study of public perception processes related to the geological storage of CO_2 and dissemination and communication activities carried on in several EC-funded projects like CO_2GeoNet, CGS Europe, ECO_2 and R&Dialogue. In particular UnoRoma1 will build on the experience with long term group work with members of the lay public performed within the ECO_2 project; the management of complex societal dialogue processes within the R&Dialogue project and on a variety of experiences in developing CO storage communication tools by working with multidisciplinary teams, from CO_2GeoNet brochures to ECO_2 video for the young generation "CCS a bridging technology for the energy of the future" to the lay report on public perception "The geological storage of CO_2: and what do you think?".

As a centre of education excellence, we will be very active in the training activities of WP8, particularly as the task leader on the CCS education programme.

UniRoma1 is involved in

- **WP1**. Ensuring safe storage operations (Task 1.3 Monitoring safe underground storage behaviour)

- all 4 tasks in **WP3**. Managing leakage risks for protection of the environment and groundwater (WP3. Managing leakage risks for protection of the environment and groundwater; Task 3.2 Understanding risk of CO_2 migration through faults and boreholes for effective monitoring (Leader); Task 3.3 Development of monitoring tools; Task 3.4 Integrated monitoring solution)

- all tasks in **WP5**. Coordination with local communities (WP Leader) and task leader for Tasks 5.1 Knowledge development and integration in a societal perspective and 5.2 Work with the local communities

- 2 of the 5 tasks in **WP6**. International Cooperation & seeding pilots and demos in Europe (Task 6.1 International cooperation; Task 6.4 Preparation of follow-up stages for ENOS pilot sites)

- **WP7** Spreading innovation for Research integration and Best practices

- all tasks in **WP8**. Promoting CCS through training and education, and Leader of Task 8.3 CCS educational programme

Staff

Salvatore Lombardi. Professor of Hydrocarbon Geology, as Head of the Fluid Chemistry Laboratory has spent more than 30 years researching many aspects of gas and water distribution - migration in various geological environments, risk monitoring and the study of natural systems. He has acted as project leader and/or partner principle investigator in more than 20 EC-funded projects, as well as managing a large number of national and industry-funded projects.

Sabina Bigi (PhD). Assistant Professor in Structural Geology at the Department of Earth Sciences since 1996. Her main research interest is focused on brittle deformation, consisting of the reconstruction and description of faults and fracture networks, thrust tectonics and the interplay between fluids and faults. From 2006 she has been involved in numerous EC projects, working on the migration of fluids through faults and fractures. She is a Member of the Executive Committee of CO_2GeoNet, the European Network of Excellence.

Samuela Vercelli (MAS). Contract researcher in psychosocial processes related to the communication and implementation of innovative energy technologies. Previous Chair and Member of the Executive Committee of CO_2GeoNet European Network of Excellence, she has been involved, as work package or task leader, in several European projects on CO_2 Geological Storage communication, public perception and wider societal dialogue on energy technology innovation (CO_2GeoNet, RISCS, CGS Europe, SiteChar, ECO_2, R&Dialogue).

Stan Beaubien (PhD). Contract researcher in geochemistry at the Department of Earth Sciences since 1996. He specialises in the study of gas migration in the near surface environment, focussing on the controlling chemical-physical processes and using this information to improve innovative site monitoring technologies. He has been involved in 17 EC-funded projects, 9 of which focused on the geological storage of CO_2 (CCS).

Stefano Graziani (MEng). Contract researcher in electronic engineering at the Department of Earth Sciences since 2004. Specialized in visual guidance of robots emulated on FPGA, software and hardware development for remote control and telemetry, and most recently the development, construction, testing, and deployment of systems for environmental monitoring. Currently engaged in the development of low-cost sensors for the measurement of gaseous and dissolved CO_2 within the framework of several European projects on carbon capture and storage of CO_2.

Publications

- Graziani, S., Beaubien, S.E., Bigi, S., Lombardi, S., 2014. Spatial and Temporal p CO_2 Marine Monitoring Near Panarea Island (Italy) Using Multiple Low-Cost GasPro Sensors. Environmental Science & Technology 48, 12126-12133, doi:10.1021/es500666u.
- Beaubien, S.E., Jones, D.G., Gal, F., Barkwith, A.K.A.P., Braibant, G., Baubron, J.C., Ciotoli, G., Graziani, S., Lister, T.R., Lombardi, S., Michel, K., Quattrocchi, F., Strutt, M.H., 2013. Monitoring of near-surface gas geochemistry at the Weyburn, Canada, CO_2-EOR site, 2001-2011. Int. J. of Greenhouse Gas Control 16, Supplement 1, S236-S262, doi:10.1016/j.ijggc.2013.01.013.
- Bigi, S., Battaglia, M., Alemanni, A., Lombardi, S., Campana, A., Borisova, E., Loizzo, M., 2013. CO_2 flow through a fractured rock volume: Insights from field data, 3D fractures representation and fluid flow modeling. Int. J. of Greenhouse Gas Control 18, 183-199, doi:10.1016/j.ijggc.2013.07.011.
- Vercelli, S., Lombardi, S. 2009. CCS as part of a global cultural development for environmentally sustainable energy production. Energy Procedia 1, 4835-4841.
- Ciotoli, G., Etiope, G., Guerra, M., Lombardi, S., Duddridge, G., Grainger, P., 2005. Migration of gas injected into a fault in low-permeability ground. Quarterly Journal of Engineering Geology and Hydrogeology 38, 305-320, doi:10.1144/1470-9236/03-058.

Past experience

Since 1989 the Fluid Chemistry Group, Earth Sciences Department at Sapienza University of Rome has been involved in more than 20 European-Community-funded research projects, including 3 as Project Leader. While the earlier projects were concentrated on the geological storage of nuclear waste, more recently our work has focused on CCS research projects (Nascent, Weyburn, CO_2GeoNet, CO_2ReMoVe, MoveCBM, RISCS, CGS Europe, SiteChar, ECO_2) as well as environmental studies in marine (CRIMEA), lacustrine (APELIK), and waste (Intailrisk) systems. Within the CCS projects we have established ourselves as experts in the use of natural, leaking-CO_2 test sites to better understand gas migration pathways, to study CO_2 reaction/dispersion mechanisms, and to develop and test various monitoring technologies (including continuous monitoring stations, and geochemical, geophysical, geological, biological, and remote sensing techniques), to study ecosystem impacts. We have worked extensively on industrial sites to define baseline trends and monitor for leaks. In addition, we have developed expertise in the dissemination of scientific information, research into public perception of CCS and societal dialogue on energy technology innovation issues (CO_2GeoNet, CGS Europe, SiteChar, RISCS, ECO_2 R&Dialogue). UniRoma1 is one of the founding members of CO_2GeoNet and has been highly active in conducting and facilitating joint research and integration through management of the Network's natural test site at Latera, Italy. URS has also been active in the administration of this Network of Excellence, coordinating Spreading of Excellence Activities and continuing in its present form as a scientific Association, by serving on its Executive Committee.

18. University of Nottingham (UNOTT)

Description of the entity:

The University of Nottingham's position as a world-class University is confirmed by its ranking in the global top 100 league table. We were ranked 8th in the UK for research in the 2014 Research Excellence Framework (REF2014), and are ranked in the top 1 per cent of all universities worldwide. We have 2 nobel laureates including Sir Peter Mansfield who pioneered the invention of Magnetic Resonance Imaging (MRI). We maintain leading expertise in advanced imaging techniques through the Peter Mansfield MRI Centre and the Hounsfield X-ray CT Centre. The University also has a strong record in applied geomechanics research for the mining and minerals sector. Over the last 30 years it has produced some 40 PhDs on geomechanics topics.

Contribution to the Work Plan and expertise brought to ENOS:

UNOTT is involved in:

- **WP1**. Ensuring safe storage operations (Task 1.1 Reliable CO_2 injection procedures)
- 2 of the 4 tasks in **WP2**. Ensuring storage capacities and cost-effective site characterisation (Task 2.1 Quantify reliability of storage capacities estimates; Task 2.4 Technical guidelines on storage capacities estimates and cost-effective site characterisation)

- 3 of the 4 tasks in **WP3**. Managing leakage risks for protection of the environment and groundwater (Task 3.1 Groundwater protection: Geochemical monitoring and potential impact of leakage on potable aquifers; Task 3.3 Development of monitoring tools; Task 3.4 Integrated monitoring solution)

- all 3 tasks of **WP5**. Coordination with local communities (Task 5.1 Knowledge development and integration in a societal perspective; Task 5.2 Work with the local communities; Task 5.3 Development of a Public Information Tool for CO_2 storage sites)

- 3 of the 5 tasks in **WP6**. International Cooperation & seeding pilots and demos in Europe (Task 6.1 International cooperation; Task 6.2 European links, liaison and knowledge exchange; Task 6.4 Preparation of follow-up stages for ENOS pilot sites)

- **WP7** Spreading innovation for Research integration and Best practices
- 3 of the 4 tasks in **WP8**. Promoting CCS through training and education (Task 8.2 Building and providing an e-learning course; Task 8.3 CCS educational programme; Task 8.4 Raising awareness by training workshops for journalists and media)

- **WP9** Management as GeoEnergy Test Bed Site Contact

Staff

Dr Matthew Hall is an Associate Professor of Materials Engineering with over 14 years' experience. In 2013 he became Director of the GeoEnergy Research Centre (GERC); a £3M joint initiative between the British Geological Survey and the University of Nottingham. In 2014 he was awarded the Royal Academy of Engineering Senior Research Fellowship in CO_2 storage and alternative hydrocarbons, sponsored by British Geological Survey. He is a Chartered Scientist (CSci), a Chartered Engineer (CEng), a Member of the Institute of Physics (MInstP), and a Fellow of the Institute of Materials, Minerals & Mining (FIMMM), who in 2007 awarded him the prestigious Silver Medal in recognition of "...outstanding contributions and promotion of the field of materials science, engineering and technology at an international level". His research activities focus on porous materials and he has expertise in micro/ macro-structural characterization techniques of porosity and transport properties including X-ray CT, electron microscopy, gas physisorption, Hg porosimetry, thermophysical properties, and numerical modeling. His interests are in transport phenomena including heat and fluid transport, hygrothermal behavior, physisorption, capillarity, permeability, evaporative drying, ion diffusion, and carbonation. His work focusses on cement and concrete, soils, rocks, clays, and zeolites.

Dr Sean Rigby is Associate Professor and Reader at the Chemical & Environmental Engineering Department, University of Nottingham. His specialist fields include characterisation of porous media, transport in porous media, Enhanced Oil Recovery (EOR), MFX imaging and NMR studies of controlled drug release, synthesis and characterisation of highly-ordered porous solids, rock core and porous media characterisation, flow and permeation in porous solids, enhanced oil recovery, catalysis

Publications

- Hall MR, Mooney SJ, Sturrock C, Matelloni P, Rigby SP. Characterisation of multi-scale pore geometry and correlation with moisture storage function and sorptivity in cement-stabilised soils. Acta Geotechnica 8 1 67-79 (2012)
- Hall MR, Tsang SCE, Casey SP, Khan MA, Yang H. Synthesis, characterisation and hygrothermal behaviour of mesoporous silica high-performance desiccants for relative humidity buffering in closed environments. Acta Materialia 60 89-101 (2012)
- Rigby, S.P., Chigada, P.I., Interpretation of integrated gas sorption and mercury porosimetry studies of adsorption in disordered networks using mean-field DFT, Adsorption **2009,** 15, 31-41.
- Shah, A., Fishwick, R., Wood, J., Leeke, G., Rigby, S., Greaves M., A review of novel techniques for heavy oil and bitumen extraction and upgrading, Energy & Environmental Science **2010**, 3, 700-714.
- Sanna A, Hall MR, Maroto-Valer M. Recent development towards mineral carbonation costs reduction: Post-processing pathways. Energy and Environmental Science 5 7781-96 (2012)

Past experience

Major Research Grants and Contracts

Royal Academy of Engineering, Senior Research Fellowship 'Rock-Fluid Interactions in Carbon Capture and Storage and Alternative Hydrocarbons' sponsored by the British Geological Survey (2014 – 2019), PI £415k

EPSRC (EP/M000567/1), Gas Adsorption Analysis Suite (GAAS) – Strategic Equipment Grant, 2014 – 2017, PI £522k, with Co-I Prof M Schröder, Prof S Tendler, Prof R Mokaya, Prof G Walker, Dr SP Rigby, Dr S Yang

Energy Technologies Institute (ETI), 'Carbon Capture and Storage by Mineralisation: Analysis of UK Opportunities', May 2010 – Nov 2012, £340k (out of total £1.3m), Co-I in collaboration with M Maroto-Valer and M Clifford (UNOTT), A Zimmerman (Caterpillar), M Styles (British Geological Survey)

EPSRC (EP/E059430/1) 3 Yr, In-situ catalytic upgrading of heavy crude and bitumen: Optimisation of novel CAPRI reactor, July 2007, Prof. M. Greaves (PI), S. Rigby (CI) £298,436. Since Prof. Greaves is emeritus I was lead superviser to the PDRA and PhD on the project and managed it day-to-day

EPSRC (EP/J008753/1) 3 Yr, Towards Realisation of Untapped Oil Resources via Enhanced THAI-CAPRI Process Using Novel Catalysts, October 2011, S. Rigby (PI) £252,860 (incl. PDRA)

Infrastructure/ major equipment provided to ENOS

GeoEnergy Test Bed (GTB) - More detail is provided in the section 'Infrastructure proposed by the partners – test sites'

19. The European Network of Excellence on the geological storage of CO_2 (CO2GEONET)

Description of the entity:

CO_2GeoNet is a non-profit Scientific Association comprising a large and growing independent group of leading research institutions in the field of CO_2 storage, unmatched anywhere else in the World. CO_2GeoNet is the only integrated scientific community with comprehensive multidisciplinary expertise, focused on CO_2 storage that is independent of political, industrial or societal pressures. With activities encompassing joint research, training, scientific advice, information and communication, CO_2GeoNet has a valuable and independent role to play in enabling the efficient and safe geological storage of CO_2. CO_2GeoNet was created in 2004 as a Network of Excellence under the EC 6th Framework Programme and lasted for 5 years. In 2008, the Network became a non-profit Association under French law in order to continue after the end of the project. The CO_2GeoNet Network of Excellence has recently expanded its membership, and many partners from the now completed CGS Europe project have become. CO_2GeoNet now comprises 26 partners from 19 European countries and involves more than 300 researchers with the multidisciplinary expertise needed to address every facet of CO_2 geological storage

Contribution to the Work Plan and expertise brought to ENOS:

See the details described for each third party

Staff

See the details described for each third party

A summary of staff effort for the third parties under CO_2GeoNet is given below

CO_2GeoNet third parties	**WP 1**	**WP2**	**WP3**	**WP4**	**WP5**	**WP6**	**WP7**	**WP 8**	**WP 9**	**Total Person/Months per Participant**
CO_2GeoNet-GBA	0	0	0	0	4	7	3	0	0	14
CO_2GeoNet-GEOECOMAR	0	0	3	0	4	6	7	3	0	23
CO_2GeoNet-GEOINZ	0	0	0	0	0	1	7	1	0	9
CO_2GeoNet-GEUS	0	0	0	0	0	0	3	**8**	8	19
CO_2GeoNet- GSB-RBINS-	0	0	0	24	0	0	1	0	0	25
CO_2GeoNet-HWU	4	26	16	0	3	0	1	3	0	53
CO_2GeoNet-IGME	20	0	0	0	2	2	3	4	0	32
CO_2GeoNet-METU-PAL	0	0	0	6	0	0	1	0	0	7
CO_2GeoNet-TTUGI	0	0	0	0	2	6	11	4	0	23
CO_2GeoNet-UNIZG-RGNF	0	0	0	0	0	7	1	3	0	11
Total p.m	24	26	19	30	15	29	39	27	8	217

Publications

See the details described for each third party

Past experience

FP6 CO_2GeoNet project (2004-2009) The work programme was structured around three types of activity: Integrating activities, Joint research, and Spreading of excellence. The consortium comprised 13 founding members across 7 European countries.

FP7 CGS Europe project (2010-2013) the "Pan-European coordination action on CO_2 Geological Storage". The objective was to establish a credible, independent, long-lasting and representative pan-European scientific body of expertise on CO_2 geological storage. The consortium comprised 24 Participants, including the entire CO_2GeoNet Association (11 members as third parties) and 23 partners from the existing CO_2NET EAST and ENeRG networks, EuroGeoSurveys, etc. Together, the partners formed a network of 34 institutes specialized in CO_2 storage matters and offering a wide European coverage across 24 EU Member States and 4 Associated Countries.

CO_2GeoNet also has much experience in networking and collaboration with national, European and international bodies, such as the **ZEP** technology platform, the **EERA** CCS Joint Programme, **CCS Demo Project Network**, **GCCSI, IEAGHG, CSLF**, etc. CO_2GeoNet has responded to consultations and invitations from the EC and Parliament, is a member of the **ISO CCS Technical Committee**, and is a recognized Observer Organisation (Research NGO) at **UNFCCC**.

1. *Geological Survey of Austria (CO_2GeoNet-GBA)*

Description of the entity:

The Geological Survey of Austria, established in 1849, collects and interprets geoscientific information in Austria, lays the foundation for the sustainable use of the geogenic potential and provides them to the public in a systematic manner. In addition, the Geological Survey of Austria operates a geological information service and acts as a service for the public administration. In that context, the Geological Survey of Austria represents the national interests on the international geoscience, especially at European level.

The department of Applied Geosciences elaborates profound datasets dedicated to the exploration of mineral deposits, groundwater, natural hazards and geothermal energy for Austria. It also participates actively in international research projects, in particular with neighboring countries. Since 2004, the Geoenergy Working group (Geothermal Energy, CO_2-Storage and Hydrocarbon Exploitation) at the department of Applied Geosciences is dedicated to the assessment and visualization of potentials and conflicts associated to the extraction and storage of energy (including heat) at the underground. It operates both on national as well as on international level focusing on national and trans-boundary resources. Since 2013, GBA is a member of the CO_2GeoNet association.

Contribution to the Work Plan and expertise brought to ENOS:

WP6, Task 6.4 (Preparation of follow-up stages for ENOS pilot sites): GBA will contribute to the pilot site LBR-1 based on information and knowledge gained from analogues at the Austrian part of the Vienna Basin.

WP6, Task 6.5 (Roadmap for upscaling identified synergies of CO_2 storage with CO_2 utilisation): GBA will be responsible for all activities concerning the Austrian part of the Vienna Basin including stakeholder interaction.

WP7, Task 7.1 (Research integration): GBA will represent the scientific community of Austria at the knowledge integration workshops

WP7, Task 7.2 (Best practices): GBA will actively contribute to the elaboration and review of the best practice guidance documents

CO_2GeoNet-GBA is involved in:

- 2 of the 5 tasks in **WP6** International Cooperation & seeding pilots and demos in Europe (Task 6.4 Preparation of follow-up stages for ENOS pilot sites; Task 6.5 Roadmap for upscaling identified synergies of CO_2 storage with CO_2 utilisation)

- **WP7** Spreading innovation for Research integration and Best practices

Staff

Gregor GOETZL (Age: 39)

Profession: Geophysicist, MSc

Current position: Team leader of Geoenergy working group at the department of Hydrogeology and Geothermics

Professional experience in the topic of the project: Since 2004, Gregor Goetzl is involved at various national as well as international studies on geothermal utilization. From 2010 until 2013, Gregor Goetzl has also coordinated the activities of GBA at the projects CGS-Europe and CO_2Stop, which have been dealing with aspects of geological CO_2 storage. Currently Gregor Goetzl is extending his scientific portfolio coordinating a national study on the potential of shale gas exploitation in Austria. Gregor Goetzl is experienced in numerical modelling, resource assessment as well as economic analyses in the fields of geothermal utilization and geological CO_2 storage. Furthermore he has several years experience in project management and scientific communication.

Anna Katharina BRUESTLE (Age: 31)

Profession: Geophysicist, MSc.

Current position: Scientific assistens of Geoenergy working group at the department of Hydrogeology and Geothermics

Professional experience in the topic of the project: Since 2006, Anna Katharina Bruestle is involved in various national and international studies on geothermal utilization and has also been participating in the projects CGS-Europe and CO_2Stop, which have been dealing with geological storage of CO_2. The project CGS-Europe offered staff exchange to promote cooperation between partners and to enhance knowledge sharing on the topic, which Anna Katharina Bruestle used to work with the colleagues form the Geological survey of Belgium (RBINS) on CCS potential in Austria. During this side project, the technical, economic and geological data of potential CO_2-storage reservoirs in Austria were collected and used to assess the matched capacity and the development probability for the reservoirs (based on the PSS II Simulator developed by Piessens K. and Welkenhuysen K).

Anna Katharina Bruestle is experienced in data acquisition, data processing and numerical modelling for geothermal problems and problems related to geological storage of CO_2.

Publications

Welkenhyusen, K., Brüstle, A., Bottig, M., Ramirez, A., Swennen, R., & Piessens, K. (in preparation). A techno-economic approach towards capacity assessment and ranking of potential targets for geological storage of CO_2 in Austria.

Past experience (since 2010)

- GeoMol (2012 – 2015): Assessment of subsurface potentials in the northern Alpine Molasse basin (EU, Alpine Space).
- CGS Europe (2010 – 2013)
- Transenergy (2010 – 2013): Transboundary assessment of hydrogeothermal resources at the western Pannonian basin and its surrounding (EU, Central Europe).
- CO_2StoP (2012)
- Solcav (2014-2015): Seasonal storage of excess solar energy in subsurface caverns (Bilateral cooperation Austria – Czech Republic).

2. *National Institute for Research and Development of Marine Geology and Geoecology (CO_2GeoNet-GeoEcoMar)*

Description of the entity:

National Institute for Research and Development of Marine Geology and Geoecology - GeoEcoMar, established in 1993, represents the focal point of national excellence in research and consultancy on marine, coastal, river and lacustrine geology, geophysics and CO_2 storage. Concerns relating to the CO_2 geological storage began with the affiliation of the institute to ENeRG in 2001 and continued with participation in national and international projects related to CCS, culminating in becoming a member of the Global CCS Institute in 2010. GeoEcoMar is also the founder member of CO_2 Club in Romania (2007).

Contribution to the Work Plan and expertise brought to ENOS:

CO_2GeoNet-GeoEcoMar is involved in:

- 3 of the 4 tasks in **WP3** Managing leakage risks for protection of the environment and groundwater (Task 3.2 Understanding risk of CO_2 migration through faults and boreholes for effective monitoring; Task 3.3 Development of monitoring tools; Task 3.4 Integrated monitoring solution)

- **WP5**. Coordination with local communities (Task 5.1 Knowledge development and integration in a societal perspective)

2 of the 5 tasks in **WP6**. International Cooperation & seeding pilots and demos in Europe (Task 6.2 European links, liaison and knowledge exchange; Task 6.3 Supporting new pilot and demonstration opportunities)

- all of the tasks in **WP7** Spreading innovation

2 of the 4 tasks in **WP8**. Promoting CCS through training and education (Task 8.1 Education and training for the European research community; Task 8.2 Building and providing an e-learning course)

Staff

Constantin-Stefan SAVA

• Senior Scientist within INCD GeoEcoMar, PhD in Geological Sciences, Phare expert in geophysics and geodesy, coordinator on behalf of GeoEcoMar in national and international projects related to CCS, Coordinator of the Storage Section of the Feasibilitiy Study for GETICA CCS Demonstrative Project, "Impact of communication"- FENCO-ERA project, CO_2 Net East and EU GeoCapacity - FP6 projects, CGS Europe and CO_2 Stop - proiect FP 7, The National Program for Carbon Capture and Storage.

• The "Gheorghe Murgoci" award of the Romanian Academy, National representative in the Governmental Group of ETP-ZEP, Current president of ENeRG.

Alexandra-Constanța DUDU

• Geophysical engineer, scientist within INCD GeoEcoMar, PhD student in CO_2 geological storage, active participation in national and international projects: "Impact of communication" - FENCO-ERA project, CO_2 Net East and EU GeoCapacity - FP6 projects, CGS Europe and CO_2 Stop - FP 7 projects, The National Program for Carbon Capture and Storage, Feasibility Study for the Demonstrative Project GETICA CCS;

• Teacher at the CGS Europe Spring School on CO_2 geological storage, Award for the best paper written by a young author entitled "Monitoring CO_2 geological storage sites", paper presented within the section "Clean and Efficient Technologies for Energy Production, FOREN 2012, Member of the Romanian Society of Geophysics.

Sorin ANGHEL

• Geophysical engineer, Senior scientist within INCD GeoEcoMar, PhD in Geological Sciences, specialization Near Surface Geophysics, Project management course organized by the Academy of Economic Studies, Active participation as project officer in CCS national and international projects: "Impact of communication" - FENCO-ERA project, CO_2 Net East and EU GeoCapacity - FP6 projects, CGS Europe and CO_2 Stop - FP7 proiects, The National Program for Carbon Capture and Storage, Feasibility Study for the Demonstrative Project GETICA CCS;

• Member of Geophysical Society of Romania and Society of Exploration Geophysicists.

Publications

- Dudu A., "Monitoring CO_2 geological storage sites ",paper presented within the section "Clean and Efficient Technologies for Energy Production (based on coal and other primary sources of energy)", FOREN 2012, June 21th 12, published in the conference volume.
- Katja Pietzner, Diana Schumann,, Sturle D. Tvedt, Hans Y. Torvatn, Robert Næss, David M. Reiner, Sorin Anghel, Diana Cismaru, Carmencita Constantin, Dancker D. L. Daamen, Alexandra Dudu, Andrea Esken, Vassiliki Gemeni, Loredana Ivan, Nikolaos Koukouzas, Glenn Kristiansen, Angelos Markos, Emma ter Mors, Oana C. Nihfidov, John Papadimitriou, Irene R. Samoila, Constantin S. Sava, Bart W. Terwel, Claudia E. Tomescu& Fotini Ziogou, Public awareness and perceptions of carbon dioxide capture and storage (CCS): Insights from surveys administered to representative samples in six European countries (Results from over 6000 respondents), INTERNATIONAL JOURNAL OF GREENHOUSE GAS CONTROL, Volume 18, 2013, Pages 256-263, ISSN 1750-5836
- Sava C.S., Carmencita Constantin, S. Anghel, A. Proca, Claudia Tomescu, Alexandra Dudu, Irene Samoila, State of the CCS Activities in Romania, AAPG/SEG/SPE Hedberg Conference - Geological Carbon Sequestration - Prediction and Verification, August 16-19, 2009, Vancouver, BC, Canada.
- Sava C.S., Constantin C., Proca A., Georgescu C., Tomescu C., Dudu A., 2009, Industrial CO_2 Emissions and Storage Possibilities in Romania, Paper presented at CO_2Net Seminar, 1-19 March 2009, Trondheim, Norway.
- Alla Shogenova, Kris Piessens, Jüri Ivask, Kazbulat Shogenov, Roberto Martínez, Kristin M. Flornes, Niels E. Poulsen, Adam Wójcicki, Saulius Sliaupa, Ludovít Kucharič, Alexandra Dudu, Sergio Persoglia, Sam Holloway, Bruno Saftic. 2012 "CCS Directive Transposition into National Laws in Europe: Progress and Problems by the End of 2011", abstract presented at GHGT 11, November 20th 2012, Kyoto, to be published in Energy Procedia 2013

Past experience

• FP 7 CO_2 STOP - Map and assess the capacity of all the possible CO_2 geological storage reservoir formation from Romania in order to be included in an European Storage Atlas.

• EU GEOCAPACITY- Assessing European capacity for geological storage of carbon dioxide. Within this large project, the institute mapped the CO_2 emission sources and CO_2 storage solutions, providing also the first theoretical assessment of the storage capacity of Romania.

• FENCO ERA NET "Scrutinizing the impact of CCS communication on the general and local public.

•Feasibility study (Storage section) for the first CCS Demonstration Project of Romania - GETICA CCS.

3. GEOINŽENIRING d.o.o.Geoinz (CO_2GeoNet-GEOINZ)

Description of the entity:

Geoinženiring, a research SME is engaged in geological engineering and is one of the leading companies of its kind in Slovenia. It was established in 1998 as a limited liability company. Prior to that, it has a noteworthy tradition, which had started in 1946 with its legal predecessors (1946 – 1954 Geological Institute of Slovenia, 1954 – 1991 Geological Institute Ljubljana, 1991 – 1998 Institute for Geology, Geotechnics and Geophysics).

The company's main activities comprise investigations, project designing and consulting in the areas of soil and rock mechanics, engineering geology and engineering geophysics. The co-ordination of these activities allows the firm to provide complete, cost-effective and environmental friendly solutions. The modern measuring and laboratory equipment and extensive data bases enable professional staff to perform wide range of services, such as projects for infrastructure and power plants, geological and environmental hazard, water and mineral resources. GEOINZ has developed a significant knowledge in geo-energy related activities and in particular in CO_2 geological storage and acts as the principal research body in the country.

Contribution to the Work Plan and expertise brought to ENOS:

CO_2GeoNet-GEOINZ is involved in:

- WP6. International Cooperation & seeding pilots and demos in Europe (Task 6.4 Preparation of follow-up stages for ENOS pilot sites)

- all tasks in WP7 Spreading innovation (Task 7.1 Research integration; Task 7.2 Best practices (Task Leader); Task 7.3 Promoting exploitation of ENOS results)
- WP8. Promoting CCS through training and education (Task 8.4 Raising awareness by training workshops for journalists and media)

Staff

Marjeta Car is a senior expert at Geoinženiring. She has more than thirty years of experiences in various applied geophysical fields. Her main expertise related to CCS lies in storage site characterization, capacity estimation, the interpretation of geophysical monitoring datasets and regulatory issues related to geological storage of CO_2. Since 1997 she is the head of Engineering Geophysical Department. She is a national representative in European Network for Research in Geo-Energy (ENeRG) and a member of CO_2GeoNet Association. In 2015 she has been appointed as a national expert in Panel of Experts on CO_2 geological storage at European Federation of Geologists.

Publications

- Car, M., 2009. Reduction of emissions of greenhouse gases by storing CO_2 underground. 1st International Conference Energy Technology and Climate Changes, Velenje , 2009.
- Car, M., 2011. Geological storage of CO_2 – where is Europe? Treaties, Reports, 20th Meeting of Slovenian Geologists, Ljubljana.
- Bavec, M., Car, M., Stopar, R., Jamšek Rupnik, P., Gosar, A., 2012. Geophysical evidence of recent activity of the Idrija fault, Kanomlja, NW Slovenia = Geofizikalni dokazi za recentno aktivnost Idrijskega preloma v dolini Kanomlje. *RMZ - Materials and geoenvironment*, ISSN 1408-7073, Vol. 59, No. 2/3, p. 247-256.
- Delprat-Jannaud, F., Korre, A., Shi, J.Q., McConnell, B., Arvanitis, A., Boavida, D., Car, M., Gastine, M., Grunnaleite, I., Bateman, K., Poulsen, N., Sinayuc, C., Vähäkuopus, T., Vercelli, S. and Wójcicki, A. 2013. State-of-the-art review of CO_2 Storage Site Selection and Characterisation Methods. CGS Europe report No. D3.3, *In*: Korre, A., McConnell, B. and Delprat-Jannaud, F. (*Eds*.), September 2013, 116p.
- Korre, A., Delprat-Jannaud, F., Welkenhuysen, K., Piessens, K., Falus, G., Vähäkuopus, T., Poulsen, N., Wickström, L., Alexandra, D., Vincent, C.J., Car, M., Wójcicki, A., Arts, R., Vit, H., Martinez, R., Komatina,

S., Akervoll, I., Brüstle, A.K., Götzl, G., Brikmane, B. and Hatzignatiou, D. 2014. State-of-the-art of directives and regulatory regimes related to operational and safety risks. CGS Europe report No. D3.5. In Korre, A. and Delprat-Jannaud F. (Eds.), February 2014, 125 p.

Past experience

Geoinženiring has actively participated in previous international CCS related projects:

- EU Geocapacity (EU FP6, 2004 – 2006, partner)

- CO_2NET EAST (EU Coordination Action, 2006 – 2009, associated partner)

- CO_2SToP (EU Contract No. ENER/C1/154-2011-SI2.611598, partner)

- CGS Europe (EU FP7, 2010 – 2013, partner)

and acts as a leading knowledge transfer body for geological storage of CO_2 in the country. CO_2 storage, monitoring and verification, utilization of the deep subsurface is of its particular interest.

4. *Geological Survey of Denmark and Greenland (CO_2GeoNet-GEUS)*

Description of the entity:

Geological Survey of Denmark and Greenland (GEUS), established in 1888, is a research and advisory institute under the Danish Ministry for Environment and Energy. The main mission of GEUS comprises provision of R&D and advisory services for government agencies, local authorities and private enterprises in Denmark as well as internationally. Key scientific areas include: ground water and surface water resources, petroleum resources and subsurface energy storage/disposal, raw materials and minerals resources, geological mapping of Denmark, Greenland and the Faeroe Islands, marine geology, environmental impacts assessment, and physical & electronic data storage for the Kingdom. The activities are organised within five programme areas:

1. Data banks, information technology, and information to the general public; 2. Water resources; 3. Energy resources; 4. Mineral resources and Greenland mapping; 5. Nature and environment.

Current staff is about 333, with some 200 holding academic degrees. Annual turnover is about DKK 338 million (c. 45 million Euro).

Contribution to the Work Plan and expertise brought to ENOS:

GEUS has conducted research pertaining to geological storage of CO_2 since 1993, being one of the European pioneers in this area. GEUS will mainly contribution to the dissemination and innovation development, the preparation of best practices (WP7), international collaboration on training and capacity building, coordination and teaching for spring schools, for development of e-learning and for a European educational programme (WP8).

CO_2GeoNet-GEUS is involved in:

WP7 Spreading innovation for Research integration and Best practices

WP8 Promoting CCS through training and education as WP Leader and in the tasks

- Task 8.1 Education and training for the European research community

- Task 8.2 Building and providing an e-learning course

- Task 8.3 CCS educational programme

WP9 Management as WP Leader in the MB

Staff

Dr. Niels E. Poulsen is senior scientist at GEUS. He holds an MSc and a PhD degree in geology from the University of Copenhagen. For many years he has worked as a scientist with focus on stratigraphy of the latest Triassic to earliest Cretaceous succession and Neogene deposits in Denmark and northern Europe. Niels became part of the CCS team at GEUS in 2008, and has participated in projects such as the COACH (WP3 leader), C02ReMoVe, Mapping of the storage potential of $C0_2$ in the eastern North Sea, Skagerrak, Kattegat and onshore Denmark, CGS Europe and SiteChar projects. He was coordinator for the $C0_2$StoP project. He participates now in the TOPS project as WP and task leader. Niels is GEUS-representative in the $C0_2$GeoNet executive committee now serving as Treasurer.

He participated in the COACH capacity building as teacher during two one-week long Schools; one in April 2009 in Hangzhou and the other in October 2009 in Beijing. These two schools working with methodology, policy and safety attracted in total 80 Chinese students and 30 European students at PhD or post doc level. Niels participated in the EAGE EU 2010-11 Student Leeture Tour on $C0_2$ geological storage teaching at universities in Denmmark, Finland and Sweden. He partici- pated in CGS Europe Spring School on $C0_2$ storage as teacher and task leader.

Publications

- Anthonsen, K.L., Aagaard, P., Bergmo, P.E.S., Erlström, M., Faleide, J.I., Gislason, S.R., Mortensen, G. M. & Snæbjörnsdottir, S.Ó., 2013: CO_2 storage potential in the Nordic region. *Energy Procedia* 37 5080-5092.
- Poulsen, N.E., Chen, W., Dai, S., Ding, G., Li M., Vincent, C.J., and Zeng R., 2011: Geological assessment for CO_2 storage in the Bohaiwan Basin, East China. GHGT-10. Energy Procedia 4: 5990–98.
- Shogenova, A., Piessens, K., Holloway, S., Bentham, M., Martínez, R., Flornes, K.M., Poulsen, N.E., Wójcicki, A., Sliaupa, S., Kucharič, L., Dudu, A., Persoglia, S., Hladik, V.m, Saftic, B., Kvassnes, A.m, Shogenov, K., Ivask, J., Suárez, I., Sava, C., Sorin A. and Chikkatur, A., 2014: Implementation of the EU CCS directive in Europe: Results and development in 2013. Energy Procedia 63 (2014) 6662 – 6670

Past experience

GEUS has conducted research pertaining to geological storage of CO_2 since 1993, being one of the European pioneers in this area. GEUS has lead or contributed to a number of RTD projects, including; SACS Phases Zero, 1 and 2, GESTCO (project manager), CO_2NET 1 & 2 (initiator and co-ordinator of RTD strategy activity), Weyburn (Canadian CO_2EOR), CCP (sub-project on aquifer storage) and CO_2Store (coordinator of 4 onshore site-specific activities), CO_2GeoNet, EU GeoCapacity (project manager) (2006-2008), DYNAMIS (2006–2009), CO_2ReMoVe (monitoring and leader of regulatory work), CASTOR (leads activity on geological storage potential assessment) (2004–2009), CO_2SINK (2004–2010), COACH (work package leader) (2006–2009), ECCO (2008–2011), BIGCCS - International CCS Research Centre (2008-16), AQUA DK - EFP07- II (project manager) (2009-2013), CGS Europe (2010-2013), CO_2CARE ((2010-2013), SiteChar (2011-2013), UltimateCO_2 (2011-2014), CO_2StoP (coordinator) (2011-2013), as well as industrial CCS projects with Vattenfall and DONG. National funding for research in geochemical reactions and EOR with CO_2 is currently active, National project financed by the"High Technology Fund "(on-going). In addition GEUS is engaged in projects for the Norwegian Petroleum Directorate, the University of Oslo and GEO/MOGAS (ongoing).

GEUS is actively engaged involved as member in a series of international networks on CCS including: the Executive Committee if CO_2GeoNet Association (European Network of Excellence focussing on geological storage of CO_2), CO_2NET (Network of CCS stakeholders across Europe), president for ENeRG (European Network for Research in Geo-Energy), EERA (European Energy Research Alliance), EuroGeoSurveys (GEUS participate in the Task Force on CO_2) and European Strategic Energy Technology Plan (SET-plan).

5. *Royal Belgian Institute of Natural Sciences (CO_2GeoNet-GSB-RBINS)*

Description of the entity:

The Geological Survey of Belgium (GSB), department of the Royal Belgian Institute of Natural Sciences (RBINS), is a geo-scientific documentation centre and is a central player in national and international research and development projects. The GeoEnergy group of the Geological Survey of Belgium originated with the exploration campaigns for coal in the Flanders and the Walloon region. The expertise was extended with projects including exploration for hydrocarbons, geothermal energy, heat-cold storage, subsoil gasification of coal, storage of natural gas and reutilizing mining infrastructure. From 2000 on, research is performed on the possibilities of geological storage of CO_2 for national and international projects. This includes coordination of the PSS-CCS projects (Policy Support System for Carbon Capture and Storage; Piessens et al., 2009; Piessens et al., 2012), which were the national umbrella projects on CCS in Belgium, and participation in several other international CCS related projects. The GSB is member of the CO_2GeoNet network of excellence, the European Technology Platform for Zero Emission Fossil Fuel Power Plants, the EuroGeoSurveys expert group on CO_2 geological storage, and the European Federation on Geologists expert panel on geological storage of CO_2.

Contribution to the Work Plan and expertise brought to ENOS:

The GSB-RBINS will contribute mainly to WP4, more precisely on task 4.3, where it will use its expertise on geo-techno-economic assessments of projects with a high geological uncertainty to make a detailed assessment of the two detail case studies (buffer and EOR) to determine their economic value, serving as basis for the further evaluation of socio-economic benefits of integrated CO_2 storage projects.

CO_2GeoNet – GSB-RBINS will be involved in:

WP4. Integration of CO_2 storage with local economic activities (Leader of Task 4.3 Evaluation of impacts on the economics)

WP7 Spreading innovation for Research integration and Best practices

Staff

Kris Piessens graduated as a structural geologist in 1996 at the Katholieke Universiteit Leuven (Belgium), where he obtained his PhD in mineralogy and geochemistry in 2001. After obtaining the title of doctor in geosciences, Kris Piessens was offered a position at the Geological Survey of Belgium (Royal Belgian Institute of Natural Sciences) in 2002. He played a central role in the development of the PSS simulator, which is an ad-hoc economic-environmental tool that provides in-depth insights in national and international CCS implementation, including EOR. He feels well at ease wandering of from the beaten tracks of geosciences towards topics such as sink uncertainty, pipeline transport systems, real options economic analysis, raster routing, and Monte-Carlo analysis.

Kris Welkenhuysen obtained his Master in geology in 2006 from the Katholieke University Leuven (Belgium). He started his career at the Geological Survey of Belgium in 2007 in Cenozoic stratigraphy, after which he got involved in the national CCS projects "PSS-CCS". As part of the GeoEnergy group at the GSB, he took part in several (inter)national projects relating to CO_2 geological storage. Since 2011, he is working on a PhD research on embedding geo-uncertainties in techno-economic CCS simulations and recently CO_2-enhanced oil recovery (CO_2-EOR) was added as a research subject.

Publications

- Welkenhuysen, K., Ramirez, A., Swennen, R. & Piessens, K., 2013. Ranking potential CO_2 storage reservoirs: an exploration priority list for Belgium. International Journal of Greenhouse Gas Control, 17, p. 431-449. http://www.sciencedirect.com/science/article/pii/S1750583613002417

- Welkenhuysen, K., Compernolle, T., Piessens, K., Ramírez, A., Rupert, J. & Swennen, R., 2014. Geological uncertainty and investment risk in CO_2-enhanced oil recovery. Energy Procedia, 63, p. 7878-7883. http://www.sciencedirect.com/science/article/pii/S1876610214026381

- Welkenhuysen, K., 2012. The cost of CO_2 geological storage is more than a number. European Geologist, 33, p.9-13. ISSN 1028-267X http://www.eurogeologists.de/images/content/efg_magazine/egm33_web_small.pdf

- Nesladek, M., Helsen, S., Piessens, K., Van Passel, S., Gaydardzhiev, S., Kryukova, V., Myngheer, S., Janssens, R., Welkenhuysen, K., Compernolle, T., Mathieu, P. & Dusar, M., 2013. Final ACCESS report – Clean Coal Technologies and Carbon Capture and Storage in Kazakhstan: Reflections and ACCESS project results. Myngheer, S., Janssens, R., Welkenhuysen, K. & Compernolle, T. (Eds.), 72p. ISBN 978-90-8913-025-9

- Piessens, K., Welkenhuysen K., Laenen, B., Ferket, H., Nijs, W., Duerinck, J., Cochez, E., Mathieu, Ph., Valentiny, D., Baele, J.-M., Dupont, N. & Hendriks, Ch., 2012. Policy Support System for Carbon Capture and Storage and Collaboration between Belgium-the Netherlands "PSS-CCS", Final report. Belgian Science Policy Office, Research Programme Science for a Sustainable Development contracts SD/CP/04a,b & SD/CP/803, 335p. http://www.belspo.be/belspo/ssd/science/Reports/PSS-CCS_FinRep_AD.2.pdf

Past experience

Gestco

PSS-CCS projects: PSS-CCS phase I (Belspo, 2005-2007), PSS-CCS phase II (Belspo, 2009-2011), PSS-CCS BeNe (Belspo, 2009-2010)

ACCESS (EU Europe-Aid 2010-2012)

CGS Europe (EU FP7 2010-2013)

CO_2StoP (EU 2012-2013)

6. *Institute of Petroleum Engineering, Heriot Watt University (CO_2GeoNet-HWU)*

Description of the entity:

The Institute of Petroleum Engineering (IPE) at Heriot-Watt University (HWU) has been ranked as world-leading in the latest U.K. wide research assessment exercise. It is a member of two major joint research institutes of the Edinburgh Research Partnership in Engineering and Mathematics (http://www.erp.ac.uk), the Maxwell Institute of Mathematical Sciences and the Edinburgh Collaboration of Subsurface Science and Engineering (ECOSSE). Both are part of the EUR 26M funding initiative of the Scottish Funding Council to foster interdisciplinary research in mathematics and engineering across Edinburgh. IPE is also renowned for its world-leading joint academic-industrial research, which provides the opportunity to leverage the outcomes of the proposed network through new industrial collaboration. In addition, IPE is the largest non-commercial user of industry-leading simulation software and value of the annual software donations provided by companies such as Schlumberger, Computer Modeling Group, Weatherford and others exceeds multiple million pounds each year. The value of these donations is substantial in more than purely financial terms. For example, the IPE has more than 160 concurrent licenses for each of the ECLIPSE, CMG, and VIP reservoir simulators - significantly higher than any other university worldwide - enabling research studies beyond the reach of many oil companies. The IPE further owns several clusters and some 100+ workstations for students.

Contribution to the Work Plan and expertise brought to ENOS:

CO_2GeoNet-HWU is involved in:

- **WP1**. Ensuring safe storage operations (Task 1.1 Reliable CO_2 injection procedures)

- 3 of the 4 tasks in **WP2**. Ensuring storage capacities and cost-effective site characterisation (Task 2.1 Quantify reliability of storage capacities estimates; Task 2.2 Smart Characterization (Task Leader); Task 2.4 Technical guidelines on storage capacities estimates and cost-effective site characterisation)

- 3 of the 4 tasks in **WP3**. Managing leakage risks for protection of the environment and groundwater (Task 3.2 Understanding risk of CO_2 migration through faults and boreholes for effective monitoring; Task 3.3 Development of monitoring tools; Task 3.4 Integrated monitoring solution)

- **WP5**. Coordination with local communities (Task 5.1 Knowledge development and integration in a societal perspective)

WP7 Spreading innovation for Research integration and Best practices

- 2 of the 4 tasks in **WP8**. Promoting CCS through training and education (Task 8.2 Building and providing an e-learning course; Task 8.3 CCS educational programme)

Staff

Florian Doster is Global Platform for Research Leaders Assistant Professor for Multi-Scale Multi-Phase Flow Modeling in the Institute of Petroleum Engineering at Heriot-Watt University since January 2014. Previously he has been working at the Department of Civil and Environmental Engineering at Princeton University (2011-2013) and the Department of Mathematics at University of Bergen (2011-2013). He received his PhD in 2011 in physics from University of Stuttgart at the Institute of Computational Physics. His research interests include the study of multi-phase flow phenomena in porous media and the proper physical and mathematical description across scales. He has published 13 peer-reviewed journal articles, 1 book and 1 book chapter and one conference proceeding. He has given 7 invited talks and more than 50 contributed oral and poster presentations at international workshops and conferences. He has also organized 1 workshop as well as 4 sessions and mini-symposia at conferences and serves as reviewer for WRR, TiPM, AIChE, CaVS, AdWR, JFM, CompGeo, VZJ.

Ahmed ElSheikh is an Assistant Professor in Predictive modeling and Uncertainty quantification of subsurface reservoirs at the Institute of Petroleum Engineering, Heriot-Watt University. Previously he has been working at the Center for Subsurface Modeling at the University of Texas at Austin (2012-2013) and the Department of Earth Science and Engineering at Imperial College London (2010-2012). He received his PhD in 2007 from McMaster University, Canada. His research interest is focused on uncertainty quantification of CO_2 sequestration models and optimization of CO_2 injection strategies. He has published 25 peer-reviewed journal articles and organized 5 workshops/mini-symposia at international scientific conferences.

Eric Mackay holds the Foundation CMG Chair in Reactive Flow Simulation in the Institute of Petroleum Engineering at Heriot-Watt University, where he has worked since 1990. His research interests include the study of fluid flow in porous media, such as the flow of oil, gas and water in subsurface geological formations. He has over 150 publications related to predicting and managing oilfield scale and to modelling carbon storage. He delivered a keynote presentation at the SPE International Symposium on Oilfield Scale in 2004, was appointed SPE Distinguished Lecturer on the topic of oilfield scale during 2007-2008, and co-delivers an SPE Short Course on Oilfield Scale Management.

Gillian Pickup is an Assistant Professor in the Institute of Petroleum Engineering at Heriot-Watt University. She holds a BSc degree (first class honours) in Astrophysics from the University of Edinburgh and a PhD in Astrophysics, also from University of Edinburgh. She joined Heriot-Watt University in 1990, initially as a Research Associate, then as a Senior Research Associate and a Research Fellow, before becoming a Lecturer in 2010. Gillian's research interests include geological modelling, flow through porous media and upscaling of small-scale effects for use in larger-scale models. In 2009, she was given an award by SPE Aberdeen for contribution to industry. Since 2005, she has been applying skills acquired in reservoir engineering to the problem of CO_2 storage in deep saline aquifers. Over the past few years she has participated in several multi-disciplinary collaborative projects to evaluate CO_2 storage potential for the UK. She has co-authored a number of papers on the numerical simulation of CO_2 storage, including six in the International Journal of Greenhouse Gas Control.

Publications

- Tavakoli, Yoon, Delshad, Elsheikh, Wheeler, Arnold: Comparison of ensemble filtering algorithms and null space Monte Carlo for parameter estimation and uncertainty quantification using CO_2 sequestration data, WRR, 49, 2013
- Petvipusit, Elsheikh, Laforce, King, Blunt: Robust optimisation of CO_2 sequestration strategies under geological uncertainty using adaptive sparse grid surrogates, Comp. Geo., 18, 2014
- Kang, Nordbotten, Doster, Celia: Analytical solutions for two- phase subsurface flow to a leaky fault considering vertical flow effects and fault properties, WRR, 50, 2014
- Doster, Nordbotten & Celia: Impact of capillary hysteresis and trapping on vertically integrated models for CO_2 storage, Adv. in Wat. Res., 62, 465-474, 2013
- Jin, Pickup, Mackay et al: "Static and Dynamic Estimates of CO_2 Storage Capacity in Two Saline Formations in the UK" (2012) SPE J. 17(4), 1108-1118.

Past experience

- Project DE-FOA-0001037 "Multiscale Modeling of CO_2 Migration and Trapping in Fractured Reservoirs with Validation by Model Comparison and Real-Site Applications" Dep. Of Energy, US call Research for Safe and Permanent Geologic Storage of CO_2, 2014-2017 (with Princeton University and Lawrence Berkley National Lab).
- "Reservoir Simulation of CO_2 Injection in the Forties Aquifer", 2013-2015, in collaboration with University of Durham, sponsored by The Crown Estate.
- "Modelling of CO_2-EOR", 2013-2014, sponsored by the Scottish Government, 2Co, Shell and Nexen.

- Energy Technologies Institute UK Storage Appraisal Project (ETI UK SAP) – 2010-2012. Project partners : Senergy Alternative Energy Ltd, BGS, the Scottish Centre for Carbon Storage (University of Edinburgh, Heriot-Watt University), Durham University, GeoPressure Technology Ltd, Geospatial Research Ltd, Imperial College London, RPS Energy and Element Energy Ltd.
- CASSEM – CO_2 Aquifer Storage Site Evaluation and Monitoring, 2008-2010, funded by TSB and EPSRC. Project partners included AMEC, BGS, UoE, HWU, Marathon, Schlumberger, Scottish Power, Scottish and Southern Energy and the Tyndall Centre.

7. *Instituto Geológico y Minero de España (CO_2GeoNet-IGME)*

Description of the entity:

IGME is the Spanish Geological Survey, recognized as a Public Research Organization. IGME is in charge of the creation and sustainability of the national knowledge infrastructure in Earth Sciences. IGME develops activity in several fields as Geology, Hydrogeology, Mineral Resources, Environmental Geology or Geophysics. IGME staff reaches 375 workers, including over 200 university graduates

Contribution to the Work Plan and expertise brought to ENOS:

IGME will bring to the consortium expertise in induced seismicity studies, coming from previous works related to the Castor Natural Gas Storage studies, and faults natural activity, based on works developed in several active areas of Spain (Lorca and Ossa de Montiel recent earthquakes f.e.) IGME will also provide previous experience acquired in CGS Europe Project and others regarding workshops organization, participation in other networks and will keep on working in the development of new pilot opportunities.

CO_2GeoNet-IGME is involved in:

WP1 Ensuring safe storage operations (Task 1.2 Induced seismicity: monitoring, control and hazard mitigation, and is Leader of the Subtask 1.2.1. Baseline and background of the fault activity)

WP5 Coordination with local communities (Task 5.1 Knowledge development and integration in a societal perspective)

WP6 International Cooperation & seeding pilots and demos in Europe (Task 6.2 European links, liaison and knowledge exchange; Task 6.3 Supporting new pilot and demonstration opportunities)

WP7 Spreading innovation for Research integration and Best practices

WP8 Promoting CCS through training and education (Task 8.4 Raising awareness by training workshops for journalists and media)

Staff

Roberto Martínez is a Mining Engineer graduated at the Polytechnic University of Madrid. Since 2002, first at the Madrid School of Mines and later in the Department of Research in Geological Resources at IGME, he is doing research in Coalbed Methane (CBM) resources and geological storage of CO_2. In this field, he is actively involved in major projects in Spain, such as CENIT CO_2 project. Its activity has been also at a European level through Geocapacity, COMET or CGS Europe Projects. He has developed skills in project coordination, field geology, drilling and logging. At the present moment, he is the Deputy Director of the Department of Research in Geological Resources.

Alicia Arenillas is a Mining Engineer graduated at the Polytechnic University of Madrid. Her expertise is in the field of geological modelling and process simulations and in the last years she has developed deep knowledge about CCS European and National legislation.

José Francisco Mediato M.Sc. in Geology. Fourteen years of experience in basin analysis of Mesozoics, Terciary and Quaternary deposit. An extensive and well-rounded academic and industry background in geology, seismic interpretation, geochemistry and structural geology with specialization in sequence stratigraphy, reservoir characterization, basin analysis, modelling and sedimentology. The last five years concentrated on the construction of 3D geological and geophysical models for CO_2 storage.

Dr. Raúl Pérez Near twenty years of experience in geology of earthquakes, geomorphology tectonic and palaeoseismology. Currently, leader in a project for the use of thermos-gaseous precursor in earthquake

occurrence.Numerous oral and poster presentations at technical conferences. Also, an experienced technical writer with several publications in geologic journals and reports.

Publications

- Júlio Carneiro, Roberto Martinez, Isabel Suárez, Yassine Zarhloule, Abdelkrim Rimi. **Injection rates and cost estimates for CO_2 storage in the West Mediterranean region**. Environmental Earth Sciences 01/2015
- Alla Shogenova, Kris Piessens, Jüri Ivask, Kazbulat Shogenov, Roberto Martínez, Kristin M. Flornes, Niels E. Poulsen, Adam Wójcicki, Saulius Sliaupa, Ludovít Kucharič, Alexandra Dudu,Sergio Persoglia, Sam Holloway, Bruno Saftic. **CCS Directive transposition into national laws in Europe.** Energy Proceedia 01/2013
- Amit Kanudia, Niels Berghout, Dulce Boavida, Machteld van den Broek, Helena Cabal, Júlio Carneiro, Patricia Fortes, Maurizio Gargiulo, João Pedro Gouveia, Maryse Labriet, Yolanda Lechón, Roberto Martinez, Paulo Mesquita, Abdelkrim Rimi, Júlia Seixas,Giancarlo Tosato. **CCS infrastructure development scenarios for the integrated Iberian Peninsula and Morocco energy system**. Energy Proceedia 01/2013
- Suárez, M. A. Zapatero, R. Martínez, M. Marina. **Synthesis of the exploration of formations with a potential for CO_2 storage: Intermediate Depression and Madrid Basin**. Energy Proceedia 02/2009
- R. Martínez, I. Suárez, M. A. Zapatero, B. Saftic, I. Kolenkovic. **The EU Geocapacity Project – Saline aquifers storage capacity in Group South countries**. Energy Proceedia 02/2009

Past experience

IGME has been a very active actor regarding identification and evaluation of CO_2 storage sites in Spain. Briefly, IGME has leaded geological storage work packages in **CENIT CO_2** and **PSE CO_2** Projects, funded by the Spanish Plans of Research. IGME has been a partner in **Geocapacity** Project (6th Framework Programme) and Work Package Leader in **COMET** and **CGS Europe** Projects (7th Framework Programme)

8. *Middle East Technical University - Petroleum Research Center (CO_2GeoNet-METU-PAL)*

Description of the entity:

Petroleum Research Center (PAL) is established in 1991. Routine fuel quality control analyses are performed in the laboratories of the center for gasoline, diesel, biodiesel, fuel oil, LPG and natural gas. A proficiency testing program in Turkey is also conducted by PAL since 2005. Center is also conducting researches related to oil/gas and geothermal reservoir evaluations, natural gas and carbon dioxide storage.

Contribution to the Work Plan and expertise brought to ENOS:

CO_2GeoNet-METU-PAL is involved in:

- **WP4** Performing Slim-Tube Tests in order to back up the simulation work using reservoir core material and doing a thorough literature survey on the novel concepts for EOR in the US, Canada and Europe

- **WP7** Spreading innovation for Research integration and Best practices

Staff

Dr. Çağlar Sınayuç is an assistant professor in METU Petroleum and Natural Gas Engineering Department. Before joining the department he worked for Imperial College London for more than 3 years. He has contributed to the short term modelling studies performed for EU FP 6 CO_2ReMoVe Project. He has performed the modelling studies of Insalah, Snohvit and Sleipner CO_2 storage fields. He is specialized in CO_2 flow modelling, geomechanical effects of CO_2 injection and enhanced CBM recovery. Geothermal reservoir evaluations, natural gas hydrate production technologies and hydraulic fracturing of shale gas reservoirs are the topics of the studies he is currently working and supervising.

Dr. Ender Okandan, has a BSc degree from METU and MSc and PhD with a minor in Chemical Engineering from Stanford University all on Petroleum Engineering. She is an academic member of the Petroleum and Natural Gas Engineering Department and specialises in oil/gas and geothermal reservoir engineering and enhanced oil recovery. She was the leader of the CO_2 storage capacity project in Turkey. She is also the country coordinator of EU FP 7 project, CGS Europe 256725.

Dr. Mahmut Parlaktuna is a Professor and senior expert at Petroleum Research Center - PAL. His expertise is on petroleum, natural gas and geothermal reservoir engineering as well as natural gas hydrates. He was project coordinator or researcher on numerous projects concerning reservoir engineering. Recently, he participated in a CCS project aiming as an EOR application in Turkey.

Publications

- Ors, O. and Sinayuc, C. An experimental study on the CO_2-CH4 swap process between gaseous CO_2 and CH4 hydrate in porous media, Journal of Petroleum Science and Engineering 119 (2014) 156-162.
- Shi, Ji-Quan, Sinayuc, C., Durucan, S., Korre. A. Assessment of carbon dioxide plume behavior within the storage reservoir and the lower caprock around the KB-502 injection well at In Salah. International Journal of Greenhouse Gas Control 7 (2012) 115-126.
- Okandan, E. et al. Assessment of CO_2 storage potential in Turkey, modeling and a prefeasibility study for injection into an oil field. Energy Procedia 4 (2011) 4849-4856.
- Sinayuc, C., Shi, Ji-Quan, Imrie C. E., Syed, A., Korre, A., Durucan, S. Implementation of horizontal well CBM/ECBM technology and the assessment of effective CO_2 storage capacity in a Scottish coalfield. Energy Procedia 4 (2011) 2150-2156.
- Dalkhaa, C., Okandan, E. Sayindere cap rock integrity during possible CO_2 sequestration in Turkey. Energy Procedia 4 (2011) 5350-5357.

Past experience

International Projects

- CGS Europe "Pan-European coordination action on CO_2 Geological Storage" funded within the 7th Framework Programme of the European Community for research.
- Contracted research: “Matin Oil Field: Reservoir Analysis” performed for Matin JV Kazakhstan. The aim was to conduct a reservoir engineering study and predict the effect of water flooding in Matin Oil Field.

National Projects

- TUBITAK KAMAG project completed in 2009, supported by Technological Research Council of Turkey (TUBITAK), which is carried out by METU PAL and Turkish Petroleum Cooperation (TPAO). The project focused on the determination of the amount of CO_2 emissions from industrial facilities such as thermal power plants, steel industry, cement factories and refineries in Turkey, selection of potential storage sites, modeling of storage in a chosen oil field and economical feasibility of transportation of CO_2 to the storage site.
- Kuzey Marmara Natural Gas Storage Field – Cushion Gas Analysis was performed for Turkish Petroleum Company aiming to review the gas reserves and determination of cushion gas required for the field.
- Evaluation of Kizildere Geothermal Field for Zorlu Enerji Project is performed to assess the heat capacity of the field.

9. *Tallinna Tehnikaülikooli Geoloogia Instituut - Institute of Geology at Tallinn University of Technology (CO_2GeoNet-TTUGI)*

Description of the entity:

Institute of Geology at Tallinn University of Technology (TTUGI) is a research and education institution. The **Institute of Geology** (former institute of the Estonian Academy of Sciences) is an independent research, development and teaching institution of the university. TTUGI is a pioneer in CO_2 storage research and education institution in Estonia, providing academic CO_2 storage course to international students. TTUGI participated in EU FP and EC projects (EU GeoCapacity, CO_2NetEAST, CGS Europe and CO_2Stop), made research and provides regular consultations to major national energy company Eesti Energia and to the Ministry of the Environment of Estonia. The main areas of expertise are EU CCS Legislation; CO_2 storage capacity, 3D geological, geochemical, petrophysical and geophysical modelling in the Baltic Sea Region, included in our publications and PhD research of Kazbulat Shogenov. TTUGI is a CO_2GeoNet member since 2014.

Contribution to the Work Plan and expertise brought to ENOS:

TTUGI will contribute to four work packages (WP5-WP8) through:

Knowledge development for local population in WP5 and its integration with knowledge dissemination in WP7

International cooperation and knowledge exchange with recently created Baltic CCS network

through organisation of common workshops with ENOS project in WP6,

Supporting a study focusing on pilot/demonstration project opportunities across Europe by planned and proposed national and regional projects in the Baltic Sea Region especially from countries not participating in ENOS (Finland, Latvia, Lithuania, Poland and Sweden)

Reviewing the follow-up stages of one of the ENOS pilot sites in WP6.4

Spreading innovation in all tasks of WP7, and being responsible for promoting ENOS results through annual ENOS Newsletter, being responsible for the Newsletter technical editing, production and printing in WP7.2.3

ENOS training and education activities within creating a program and lectures for e-learning course in WP 8.2 and teaching of ENOS students in a frame of CCS education programme in WP 8.4

CO_2GeoNet-TTUGI is involved in:

- **WP5** Coordination with local communities (Task 5.1 Knowledge development and integration in a societal perspective)

- 3 of the 5 tasks in **WP6** International Cooperation & seeding pilots and demos in Europe (Task 6.2 European links, liaison and knowledge exchange; Task 6.3 Supporting new pilot and demonstration opportunities; Task 6.4 Preparation of follow-up stages for ENOS pilot sites)

- all tasks in **WP7** Spreading innovation

- 2 of the 4 tasks in **WP8** Promoting CCS through training and education (Task 8.2 Building and providing an e-learning course; Task 8.3 CCS educational programme)

Staff

Dr. Alla Shogenova is a Senior Researcher in the Institute of Geology at Tallinn University of Technology, where she is working since 1989. She is PhD in Geology and Mineralogy since 1992. She was a Visiting Professor in CO_2 Geological Storage at Faculty of Geology, University of Warsaw supported by EU Project Modern University in 2013. From 1994 she is a leader of a number of Estonian and International research projects. A. Shogenova is an author and co-author of about 160 scientific publications including 30 publications and 12 reports in the field of CCS. She has wide research interests in the field of sedimentary geology including rock physics, petrophysics, geochemistry, mineralogy, oil-shale and phosphorite deposits and CO_2 geological storage. She was a leader of Estonian group in the projects FP6 EU GEOCAPACITY and CO_2NetEast, FP7 CGS Europe and CO_2Stop, and since 2007 she is raising public awareness in CCS through CO_2NetEast websites in Estonian and Russian languages. Being a member of the Taskforce Technology in the European Technology Platform for Zero Emission Fossil Fuel Power Plants (ZEP) and member of Scientific Advisory Board of CO_2GeoNet, a member of CO_2NET in 2006-2009 she was also an adviser in CCS for national legal authorities and energy companies in Estonia and Baltic Region since 2008. Dr. Shogenova was a president of the ENeRG (European Network for Research in GeoEnergy) in 2007 and represents Estonia in the ENeRG since 2004. Dr. Shogenova is a supervisor of the Ph.D. research and lecturer for M.S. and Ph.D. students in the field of CCS and CGS, petrophysics and geophysics. Shogenova was an organiser of six CGS Europe project Knowledge Sharing workshops. She cooperated with ICFI in the DG CLIMA contract "Implementation of Directive 2009/31/EC on the geological storage of carbon dioxide (CCS Directive) - support to the implementation report" on behalf of CO_2GeoNet.

Kazbulat Shogenov is a researcher in the Institute of Geology at Tallinn University of Technology, where he is working from 2003. In the 2008 he was graduated from Tallinn University of Technology as a Master of Science in Engineering with Master Thesis in Petrophysics. From 2009 he is a PhD student at TUT, Faculty of Science, in the field of Earth Sciences. His PhD research "Petrophysical models of CO_2 plume at the prospective storage sites in the Baltic Region" is planned for defence in June 2015. In 2012-2013 he was a researcher in OGS, Italy funded by Marie Curie Research Training Networks (EU FP7) - Quantitative Estimation of Earth's Seismic Sources and Structure – QUEST, making research on Seismic numerical modeling to monitor CO_2 storage in the Baltic Sea offshore structure.
K. Shogenov was a participant of the funded by EC FP6 projects EU GEOCAPACITY and CO_2NetEast and FP7 CGS Europe project and EC project CO_2 Stop. He is an author and co-author of number of scientific publications including 10 publications in the field of CO_2 capture and storage indexed by Thomson Reuters WOS. He has multidisciplinary research interests in CO_2 geological storage, rock physics, petrophysics, logging, geophysics, geochemistry and mineralogy, seismic modelling, 3D and 4D Geological modelling, GIS databases, websites design and management. He was/is a technical manager of the ENeRG website in 2008-2011 and of the GeoENeRGY newsletter in 2012-2015.

Jüri Ivask is a researcher in the Institute of Geology at Tallinn University of Technology, where he is working since 1988. He is a participant of several Estonian and International research projects in the field of Geosciences. Dr. Ivask has multidisciplinary research interests in the field of environmental geology including palaeoclimatology, geochemistry; chromatography including other related analytical methods and also CO_2 geological storage. He participated in EC FP6 CO_2NetEast and FP7 CGS Europe Project. He is a manager of the Estonian www site (www.gi.ee/co2net-east). He is also participating in the projects advising industrial companies (e.g. Eesti Energia - www.energia.ee) in the field of CO_2 geological storage (CGS). As a coauthor of the ordered by Eesti Energia research „CO_2 geological storage in Estonia and neighboring regions: analysis of options and storage recommendations" he presented its results on 12.10.2009 at the headquaters of Eesti Energia (www.energia.ee). Dr. Ivask has been an expert in CCS (CO_2 capture and storage) terminology to Ministry of Environment of the Estonian Republic. Dr. Ivask is an author of the Estonian version of the CO_2GeoNet brochure "What does CO_2 geological storage really mean?". He made number of presentations in Estonian to geoscientists and general public and gave several interviews to Estonian Press media about CCS in the Baltic Region. He is a co-author of number

of scientific publications on CCS in Estonian and English. He is also an Estonian representative in the Joint Committee of Antarctic Data Management. Dr. Ivask was graduated from the Tartu University in the field of analytical chemistry and has a PhD. degree in chemistry.

Publications

- Shogenova, A., Piessens, K., Holloway, S., Bentham, M., Martínez, R., Flornes, K.M., Poulsen, N.E., Wójcicki, A., Sliaupa, S., Kucharič, L., Dudu, A., Persoglia, S., Hladik, V., Saftic, B., Kvassnes, A., Shogenov, K., Ivask, J., Suárez, I., Sava, C., Sorin, A., Chikkatur, A. 2014. Implementation of the EU CCS Directive in Europe: results and development in 2013 . Elsevier, The Netherlands. *Energy Procedia* 63, 6662-6670. | DOI |
- Shogenov, K., Shogenova, A., Vizika-Kavvadias, O. 2013. Petrophysical properties and capacity of prospective for CO_2 geological storage Baltic offshore and onshore structures . Elsevier. *Energy Procedia* **37**, 5036-5045. | DOI |
- Shogenova, A., Piessens, K., Ivask, J., Shogenov, K., Martínez, R., Suáres, I., Flornes, K.M., Poulsen, N.E., Wójcicki, A., Sliaupa, S., Kucharic, L., Dudu A., Persoglia, S., Holloway S. and Saftic, B. 2013. CCS Directive transposition into national laws in Europe: progress and problems by the end of 2011. Elsevier. *Energy Procedia* **37**, 7723-7731. | DOI |
- Shogenova, A., Shogenov, K., Pomeranceva, R., Nulle, I., Neele, F. and Hendriks, C. 2011. Economic modelling of the capture–transport–sink scenario of industrial CO_2 emissions: the Estonian–Latvian cross-border case study. Elsevier, The Netherlands. *Energy Procedia* **4**, 2385-2392. | DOI |
- Shogenova, A., Sliaupa, S., Vaher, R., Shogenov, K., Pomeranceva, R. 2009. The Baltic Basin: structure, properties of reservoir rocks and capacity for geological storage of CO_2. Estonian Academy Publishers, Tallinn . *Estonian Journal of Earth Sciences* **58**(4), 259-267. | DOI |

Past experience

1. FP 6 Projects EUGeoCapacity and CO_2NetEast. CO_2NetEast CCS Technology website is working since 2007 in 2 languages: Estonian and Russian, including English-Estonian and English-Russian CCS Dictionary and Glossary .
2. Advising to the Ministry of Environment of Estonia and national energy company Eesti Energia in the field of CCS
3. CO_2GeoNet brochure "What does CO_2 geological storage really mean?" was translated into Estonian and Russian and six Knowledge Sharing workshops were organised and reported to EC during FP7 CGS Europe Project.
4. CO_2 Geological Storage full term course was created and lectured to international students from 9 countries in Tallinn University of Technology in 2012 and in the University University of Warsaw supported by EU Project Modern University in 2013.
5. Cooperation with ICFI in the DG CLIMA contract "Implementation of Directive 2009/31/EC on the geological storage of carbon dioxide (CCS Directive) - support to the implementation report" on behalf of CO_2GeoNet.

10. Sveuciliste u Zagrebu Rudarsko Geolosko Naftni Fakultet - University of Zagreb, Faculty of Mining, Geology and Petroleum Engineering (CO_2GeoNet - UNIZG-RGNF)

Description of the entity:

The Faculty is a part of the University of Zagreb and consists of several institutes – Mining Engineering, Geology, Geological Engineering and Petroleum Engineering. There are altogether 54 professors, 30 assistants and 26 other teaching collaborators. Apart from the primary activity in high education, they are usually engaged both in exploration and research activities and in various expert tasks.
This research covers a wide range of activities. Relevant to the ENOS project proposal are geology (subsurface geological mapping, petroleum geology, hydrogeology, geophysical prospecting) and petroleum engineering (drilling techniques, well fluids, reservoir development, production of HC's and geothermal water, gas management, safety techniques and protection of environment).

Contribution to the Work Plan and expertise brought to ENOS:

Being representatives of a university, all project participants will work in **WP6** where a study focusing on pilot/demonstration project opportunities across Europe will be prepared based on the results of ENOS pilots (Task 6.3 leader - Deliverable 6.6). In **WP7** there is a planned participation in the knowledge integration workshops and in contribution where appropriate to writing the best practices and guidelines for particular target groups in order to streamline the development of storage projects. Other concentration of involvement is going to be in **WP8** and that means taking part in spring schools & lecture tours, building an e-learning course, and particularly in preparation of a CCS education program, i.e. in making a curriculum of Master and post-graduate Master programs. Specific advantages are twofold. Our faculty has already implemented more than average number of e-courses compared to the Zagreb university level and further developments will give us additional experience before the starting of the ENOS project. Our faculty also has a limited experience in the international joint study programs (Joint PhD Study "Geo-engineering and Water Management" with TU Graz and other partners) and there is a formal procedure to make similar projects with the help of the International relations office of the university.

CO_2GeoNet-UNIZG-RGNF is involved in:
- **WP6** International Cooperation & seeding pilots and demos in Europe, leader of Task 6.3 Supporting new pilot and demonstration opportunities
- **WP7** Spreading innovation for Research integration and Best practices
- 2 of the 4 tasks in **WP8** Promoting CCS through training and education (Task 8.2 Building and providing an e-learning course; Task 8.3 CCS educational programme)

Staff

Domagoj Vulin (domagoj.vulin@rgn.hr), Assist. Prof. Petrol. Eng., Graduated petroleum engineer and specialized in reservoir engineering, he has defended the PhD Thesis "Modeling Thermodynamic and Petrophysical Parameters for Geological Storage of Carbon Dioxide" in 2010 and continued to study the sensisivity of parameters that are affecting petrophysical and thermodynamic properties related to CO_2 storage. He has been employed at the Faculty on scientific project sponsored by Croatian Ministry of Science, Education and Sports which was related to CO_2 Enhanced Oil Recovery. His fields of research are hydrocarbon thermodynamics (pVT), petrophysical modeling and reservoir characterization/simulation.

Bruno Saftić (bruno.saftic@rgn.hr), Assoc. Prof., Petrol. Geol., specialized in Geology of mineral resources and applied geophysics. After graduation in 1989 he is affiliated with the Faculty of Mining, Geology and Petroleum Engineering. He teaches various courses in the fields of petroleum geology, coal geology, seismic stratigraphy etc. In 1998 he defended PhD Thesis "Genetic Stratigraphic Sequence Analysis of the Pontian Sediments in the Western part of the Sava Basin". His research is in various field of petroleum geology, firstly mainly in the well log stratigraphy and subsurface mapping and later in regional analysis of the Neogene Pannonian basin system. Since 2005 he is involved in exploration of the regional CO_2 storage potential initiated by participation in several FP

projects (CASTOR, EUGeoCapacity, CO_2NetEAST, ECCO, CGS Europe). He organized two national projects related to geological storage of CO_2, mentored or co-mentored 2 PhD Theses in the field (by D. Vulin and I. Kolenković), and also supervised altogether 5 undergraduate theses and 2 graduate theses with CO_2 geological storage exploration subjects at various geological study programs.

Iva Kolenković Močilac (iva.kolenkovic@rgn.hr), BSc Geol. (Hydrogeology), during the post-graduate study specialised in Petroleum geology, and defended in 2012 the PhD Thesis "Potential for Geological Storage of Carbon Dioxide in Upper Miocene Sandstones of the Western Part of Sava Depression".

Željka Kurelec (zeljka.kurelec@rgn.hr), MA in English, affiliated with the Faculty in capacity of Chief administrator at the Office for postgraduate studies and international cooperation. Acting as the ENeRG secretary since October 2008, and also as the secretary of the CGS Europe FP7 project from 2010 to 2013, she is in charge of all the administration related to EU and other international projects.

Publications

- Vulin. D. (2010): Modeling Thermodynamic and Petrophysical Parameters for Geological Storage of Carbon Dioxide. PhD Thesis, University of Zagreb, Faculty of Mining, Geology and Petroleum Engineering, 138 p.
- Kolenković, I. (2012): Potential for Geological Storage of Carbon Dioxide in Upper Miocene Sandstones of the Western Part of Sava Depression. PhD Thesis, University of Zagreb, Faculty of Mining, Geology and Petroleum Engineering, 151 p.
- Saftić, B., Martinez, R., Donda, F., Car, M., Zapatero, M. A., Suarez, I., Vellico, M., Persoglia, S., Kolenković, I., Vulin, D. (2008): Geological Storage Options in Peri-Mediterranean Countries - Plans for Case Studies. First EAGE CO_2 Geological Storage Workshop - Extended Abstracts / Torp, Tore A. (ur.). Houten : European Association of Geoscientists and Engineers, 13-17.
- Vulin, D., Kurevija, T. & Kolenković, I. (2012): The effect of mechanical rock properties on CO_2 storage capacity. Energy, 45/1, 512-518.
- Kolenković, I. Saftić, B. & Perešin, D. (2013): Regional capacity estimates in deep saline aquifers – Upper Miocene sandstones in the SW part of Pannonian basin. International Journal of Greenhouse Gas Control, 16, 180-186.

Past experience

Faculty pioneered the CGS-related research in Croatia. As a research institution it is country representative in ENeRG (informal organisation – European Network for Research in Geo-Energy) and in CO_2GeoNet since 2013. Our researchers gained international experience in the two research projects: FP6 EUGeoCapacity (STREP) and FP7 ECCO (IP). The main activities included mapping of the regional CO_2 storage potential in various types of sinks, and mainly in transferring the Croatian experience in on-shore CO_2 injection pilot project.
In the coordinated actions FP6 CO_2NetEAST and FP7 CGSEurope, the Faculty has promoted the dissemination of the CCS-related research and knowledge in Croatia and other EE countries.

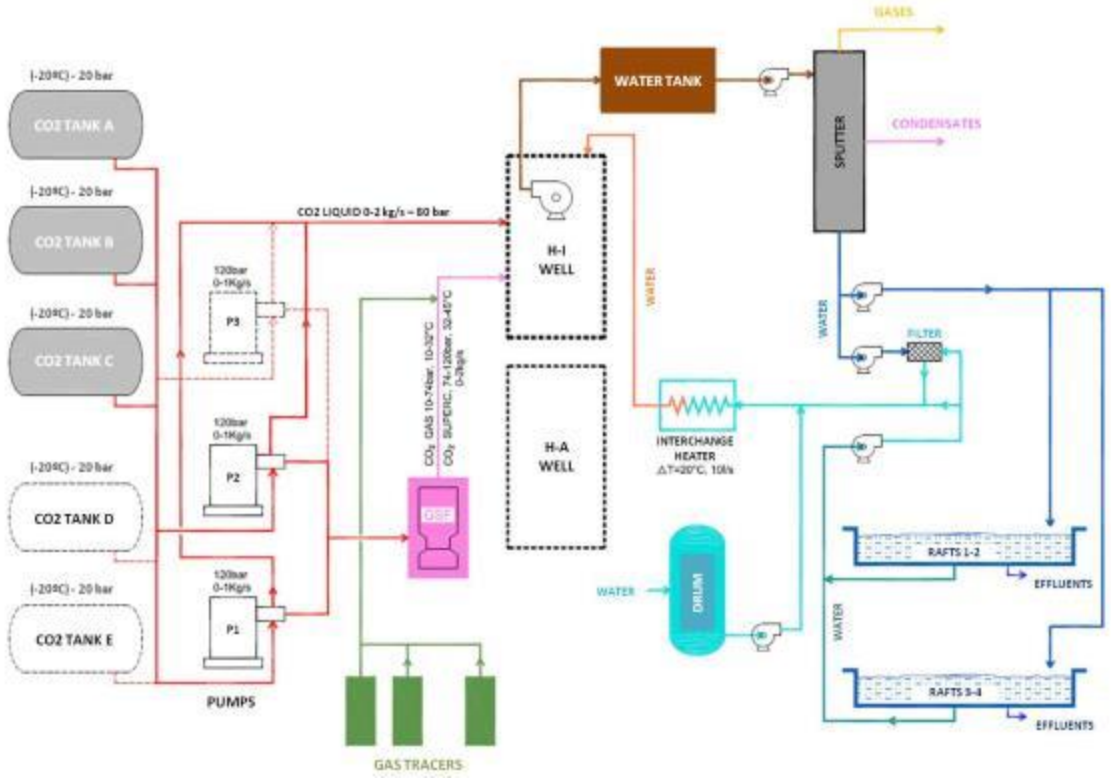
Infrastructure proposed by the partners - test sites

Hontomin, Spain (CIUDEN)

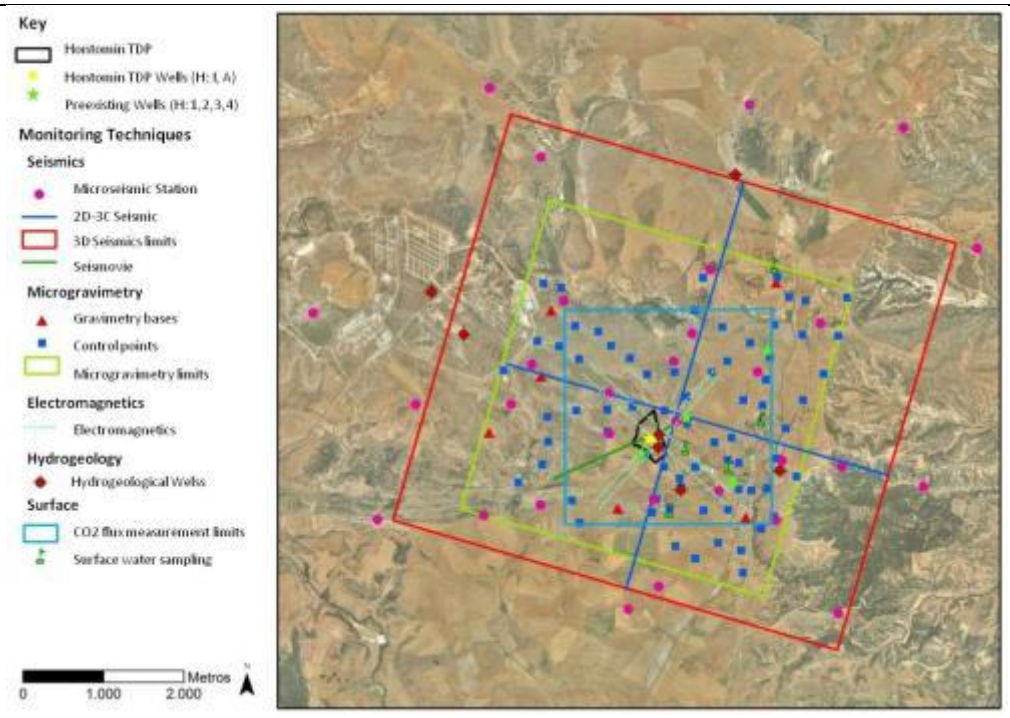
The Hontomín Technology Development Plant is located in Northern Spain, 30 km from the city of Burgos. The site includes one injection well and a monitoring well, both of them located at a depth close to 1580m. Both deep wells are fully instrumented and further monitoring capacities include a shallower hydrogeological monitoring network, and a set of surface tools, such as 30 microseismic stations. The carbonate reservoir forms a dome-like structure, with the presence of faults and fractures, making R&I activities on CO_2 storage easier when compared to ideal huge reservoirs. The Hontomin site offers high flexibility of CO_2 injection conditions being prepared for CO_2 injection in the liquid, gas and supercritical phases and thus is ideal for experimentation of different injection strategies. Its CO_2 injection plant counts on three cryogenic injection pumps allowing injection rates between 0,5 and 2 kg/s and pressures over 80 bar and three cryogenic CO_2 tanks of 50 ton capacity. The installation is complete with a gasifier to adjust the CO_2 temperature and a water injection plant, which plays a crucial role in the pressure control during injection and other operative phases. The water injection plant includes two ceramic plunger pumps capable of up to 125 bar pressure and 300 l/min flow injection each one, a 25 000 l capacity deposit for water mixture preparations and four 2500 m^3 deposits for water storage besides the necessary water treatment equipment. The 1570 m deep injection and the monitoring wells are equipped with instrumentation ensuring the continuous monitoring of injection parameters, such as the U-tube deep fluid sampling system, ERT electrodes, DTS, P/T sensors or hydrophones, and a wide range of surface monitoring techniques that are being applied at the site for the controlling and monitoring of the injected CO_2 behaviour. This facility is owned by Ciuden, and its characterization, design and construction was part of the EEPR-funded OXY-CFB-300 Compostilla Project.

Extensive site characterisation – structural and baseline studies - of the Hontomin site occurred from 2009-2012. A 3-D geological characterization of the site suggests a complex fractured carbonate reservoir with permeability appearing to be lower than originally expected. Extensive hydraulic characterization tests have been performed in 2014 in order to refine CO_2 injection strategies, which will take place in the coming months.

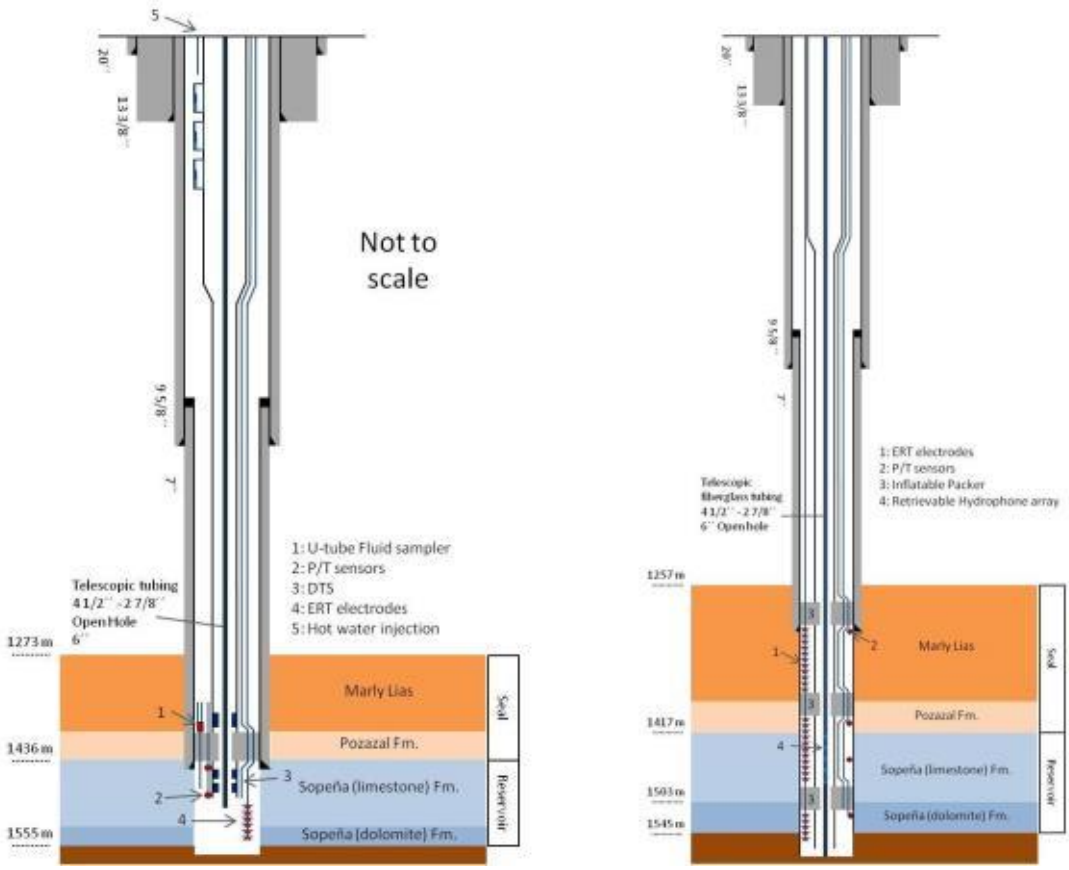
Public engagement activities, including an educational programme on CCS, are being performed since early in the project at both the capture and storage areas, in close collaboration with local councils and promoting interaction with local communities.



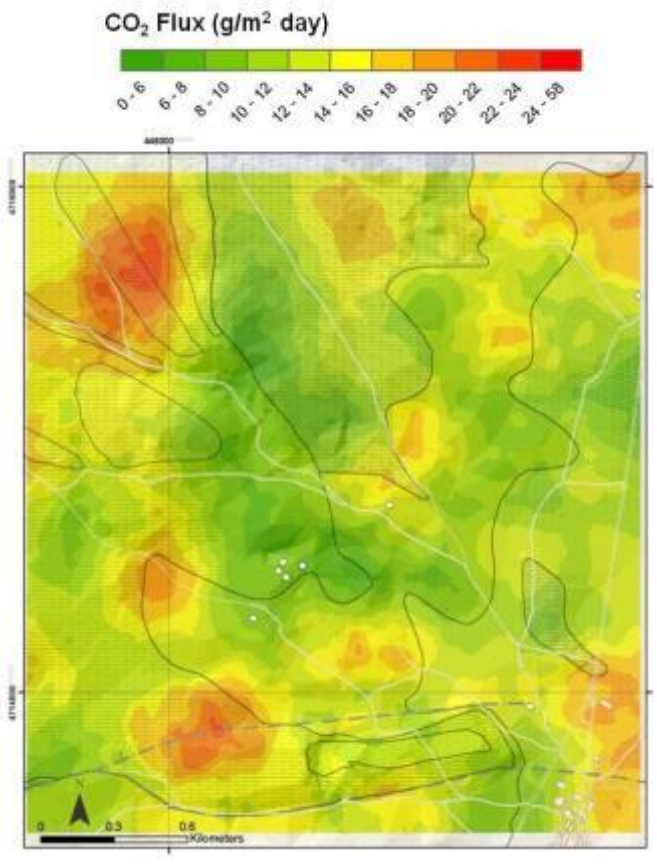
Process diagram of Hontomin TDP. Pressure, temperature and flowrate values included.



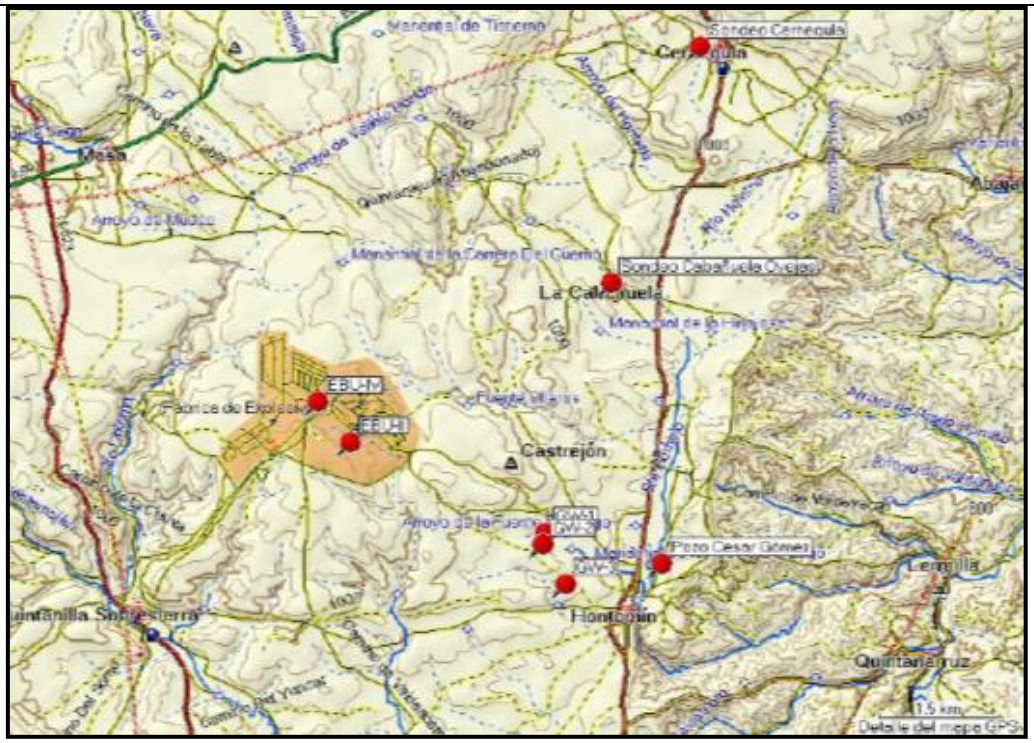
Map including the location of Hontomin TDP and the existing monitoring techniques that have been deployed during the characterization phase. Microseismic and hydrogeology monitoring points will also be included in ENOS



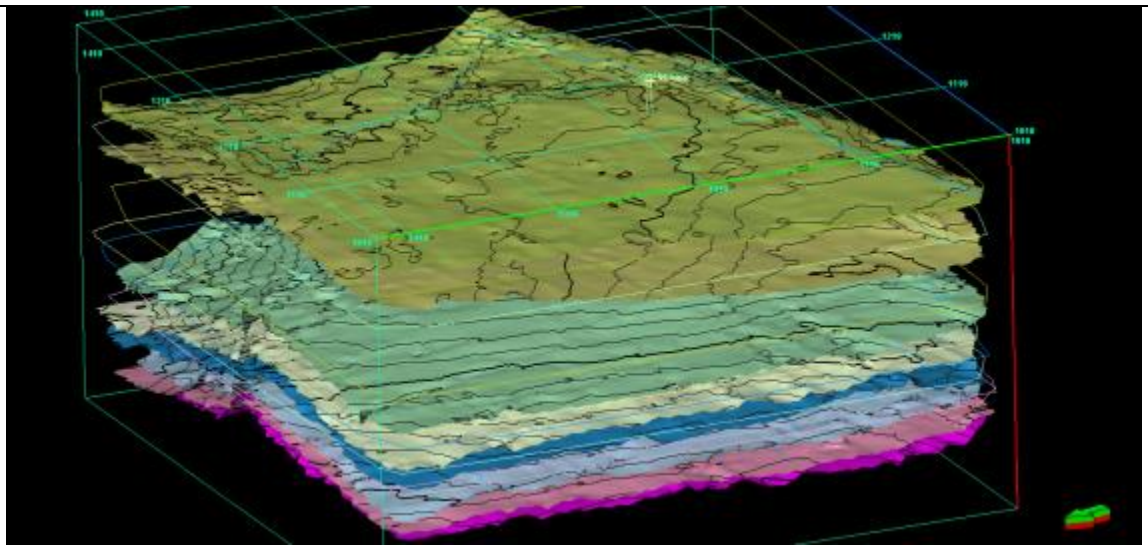
Profiles of Hontomin injection (H-I) and monitoring (H-A) wells



Baseline natural CO_2 flux map at Hontomin



Map including the location of the shallow hydrogeology monitoring points (red dots) at Hontomin

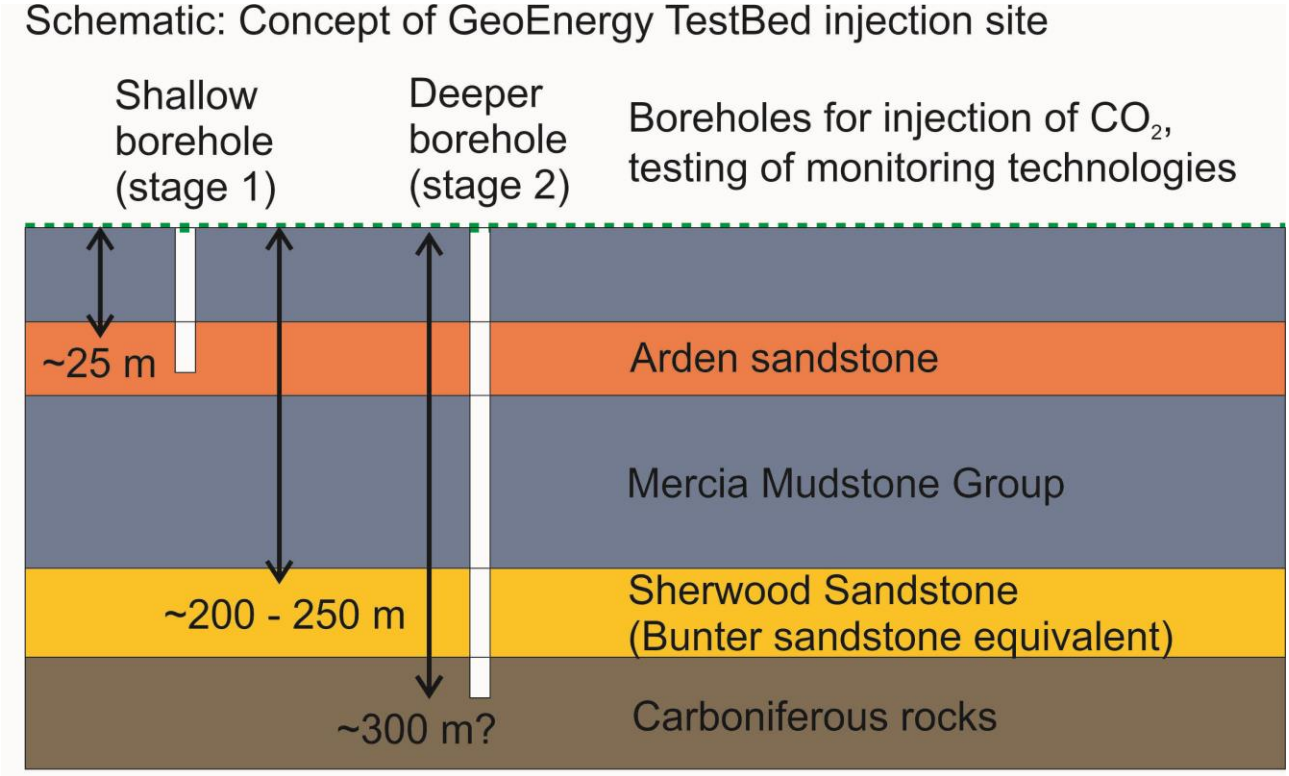


Sketch from 3D Geological model at Hontomin

GeoEnergy Test Bed, UK (BGS and UNOTT)

BGS and the University of Nottingham are working together on the GeoEnergy Test Bed (Located in the UK) which will be a shallow test injection/controlled leakage site, acting as a focal point for collaborative research with partners from Europe and beyond.

At this site, CO_2 will be injected into two shallow aquifer horizons (<300 m) beneath potential caprocks. This site will enable characterisation of shallow migration and leakage processes including studying natural attenuation and proactive remediation techniques for groundwater protection. A range of monitoring techniques will be deployed to establish their efficacy in detecting and tracking CO_2 movement. Geological site characterisation is currently underway. The number of wells to be drilled is not confirmed yet. The intention is to drill into the shallower Arden sandstone (~30 m) then the deeper Sherwood Sandstone Group (Bunter Sandstone Formation equivalent at ~200 – 250 m depth).



Sulcis - Fault Laboratory and Pilot, Italy (Sotacarbo)

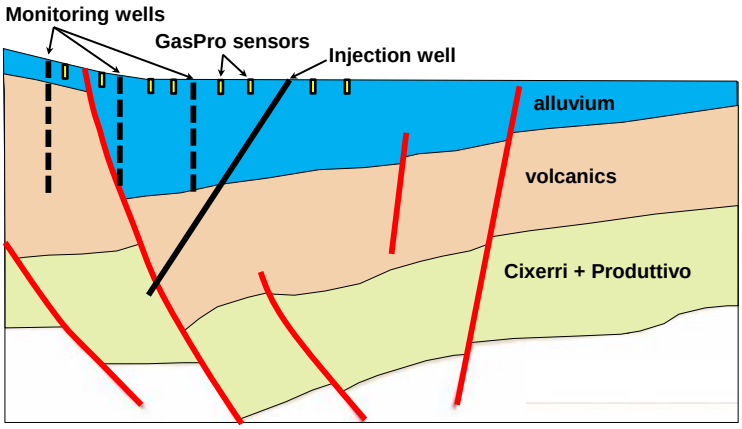
Introduction -context

The Eocene Sulcis Coal Basin, located in the south-western corner of the Island of Sardinia (Italy), hosts extensive sub-bituminous coal deposits that cover an area of approximately 800 km^2 and have reserves estimated to be of the order of 1.2 billion tons. To continue the use of this resource in an environmentally friendly way, an Italian law was recently passed (law No. 9 of 21 February 2014) that will subsidize the construction of a 350 MWe coal-fired power plant / CCS demonstration plant in the Sulcis area, with the eventual injection of the recovered CO_2 into a >1000-1500 m deep saline carbonate aquifer beneath the coal formation. Within this framework a three-year research program has been funded through Sotacarbo S.p.A. by the Region of Sardinia and the Italian Ministry of Economic Development to collect experimental data and information that will lead to the design and construction of the CCS pilot plant, covering the entire geological storage cycle under "real life" conditions. This will include site characterization, medium depth injection tests, and the eventual creation of a pilot site. The total national funding is of the order of 3-4 million Euros, and this is the first phase of a wider, 10-year 30 M€ R&D program. Three ENOS partners are involved in this national program, the research institutes UniRoma1 and OGS, as well as Sotacarbo S.p.A. (other Italian research groups involved in the national program include INGV, RSE, ENEA and the University of Cagliari).

Research performed and infrastructure created at the Sulcis site within the national program will form the backbone of the research planned within ENOS, providing a significant external contribution in terms of both site knowledge and monetary investment that will allow ENOS to achieve important scientific outcomes at a greatly reduced cost to the project. This nationally funded work will include research already performed in 2014 (fracture modelling of the seal and reservoir rock volumes, soil gas surveys at the regional scale to define the baseline and at the detailed scale across inferred faults to define potential gas migration pathways, continuous CO_2 monitoring at five wells, core analysis from two wells and passive seismic monitoring) as well as activities planned and funded for 2015-2016 (re-interpretation and re-processing of the available multichannel seismic lines, and acquisition, processing and interpretation of a new 2D seismic dataset, detailed soil gas surveys, a detailed hydrogeological study, a 2D/3D geoelectrical survey, re-definition of the 3D geological model, modelling of gas migration through faults, and extension of the continuous CO_2 monitoring network to the fault systems).

Sulcis Fault Laboratory

Sotacarbo, UniRoma1, and OGS are working together on the Sulcis Fault Laboratory (located near the SW coast of Sardinia, Italy), which will be designed to study gas migration processes in faults and to test a wide range of monitoring technologies proposed by all ENOS partners (see figure). Much of the infrastructure will be financed using external, national funds, whereas funding from ENOS will be used specifically to conduct and monitor the injection tests. The site will be fully equipped for medium depth CO_2 injection tests along a properly selected fault to better understand gas migration along such structures (via observations and associated fluid flow modelling), to improve monitoring technologies, and to develop a protocol to define permeability of the faults to the gas migration during site assessment work. This infrastructure will include a >200m deep inclined injection borehole, seven shallow piezometers / monitoring wells, one 200m deep vertical monitoring well, and the CO_2 to inject.



Schematic drawing of the Sulcis Fault Lab set-up, focused on injection of CO_2 into a fault at around 200m depth combined with geochemical, geophysical, and hydrogeological monitoring.

Sulcis Pilot

In addition, work will also be performed in the context of the eventual creation of a pilot-scale test site. Sotacarbo is the owner of the exploration permit in the area.

The characteristics of the Sulcis Pilot are:

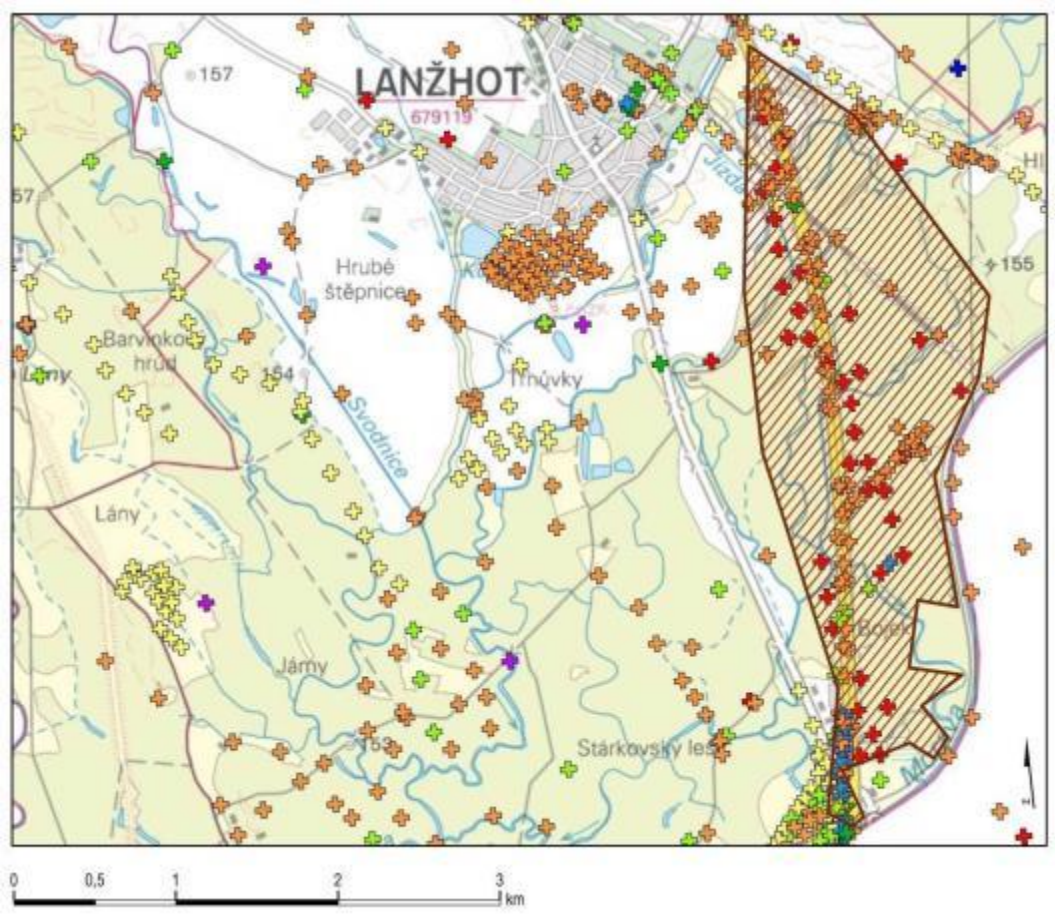
- a 350 MWe coal-fired power plant / CCS demonstration plant,
- injection of the recovered CO_2 into a >1000-1500 m deep saline fractured carbonate aquifer,
- caprock composed of volcanic rock, clays levels and coal bed limestones,

The ongoing national research program will provide surface and subsurface geological data, continuous monitoring data, a preliminary geological model of the area focused mainly on the localization and characterization of faults and their hydraulic behaviour (end of 2016), petrophysical characterization of the rock samples, results of the feasibility study, reprocessed seismic dataset (in progress). In terms of wells, the national program will provide the start of the injection well test for the end of the second year (2015) and of the pilot injection test for the end of 2016. There are some 40 existing wells of different depths (from 300 to 1000 m), meaning that stratigraphy and other well data are available, and an injection well test up to 100 m and a pilot injection test are planned.

LBr-1, Czech Republic (CGS)

LBr-1 is a depleted hydrocarbon field located in the South-Eastern part of the Czech Republic, close to the Czech – Slovak border. The LBr-1 field is the northern one of a pair of 2 neighbouring reservoirs, tectonically and hydrodynamically isolated. The northern reservoir (LBr-1) lies in the Czech Republic, while the southern one is in the territory of Slovakia.

From a geological point of view, the structure belongs to the Vienna Basin.



Map of the LBr-1 field with locations of historical wells (Source: CGS Geofond)

The main oil- and gas-bearing horizons are Middle Badenian sandstones (Lab horizon), especially the 12th, 13th and 14th Badenian, at a depth of ca. 950 m below sea level, i.e., ca. 1150 m below surface. The reservoir rock is medium-grained to fine-grained siliceous sand, with good porosity (up to 32 %) and permeability (locally up to 3,700 mD). In the southern part of the site, the whole Middle Badenian complex is up to 80 metres thick, its thickness gradually decreases in the northward direction, with some sands eventually wedging out at various places.

The productive area, delimited by the southern and northern wedge-outs, is approximately 3,000 metres long and up to 600 metres wide (counting the gas cap), with a total thickness of hydrocarbon-bearing horizons ca. 40 metres. The small size of the reservoir makes it a good candidate for a research CO_2 storage pilot project because it can be filled by a relatively small amount of injected CO_2, and all the processes related to a storage site reaching, or even exceeding its full storage capacity can be studied.

The caprock is mostly formed by Middle Badenian claystones, approximately 100 metres thick, gradually pinching out in the northward direction.

Faults play a significant role in the formation of sealed structures and reservoirs in the Vienna Basin. The southern boundary of the LBr-1 site structure is marked by the Farské faults. From the East, this fault system is

perpendicularly cut by the Brodské fault, running northwards with a westward dip and a downthrow of approximately 120 metres.

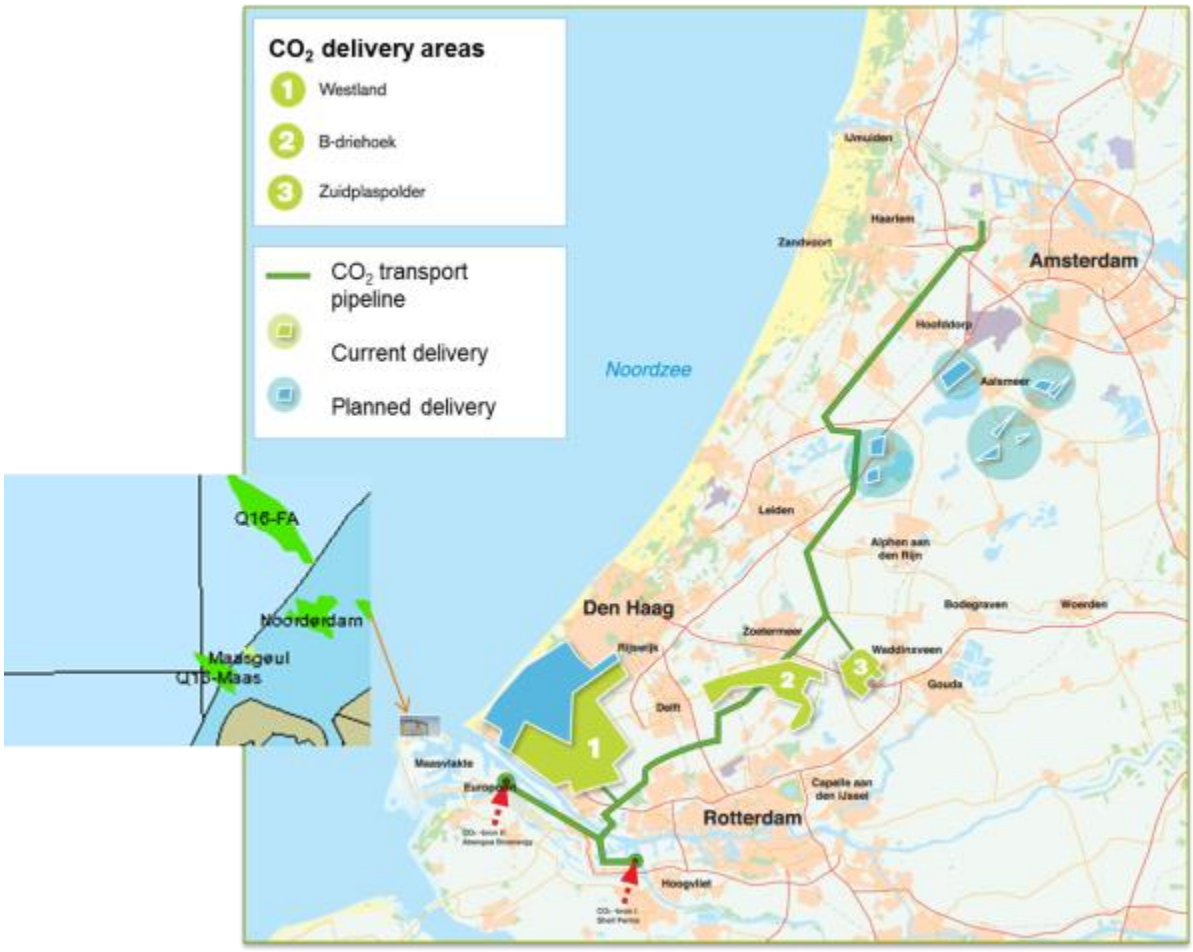
The estimated hydrocarbon reserves of LBr-1 (data from 1950s, probably too optimistic) were 300,000 tons of oil (OOIP) and 100 mil. m^3 of natural gas (OGIP). The main exploitation phase of the field was in 1960s; the total production was ca. 65,000 tons of oil and 30 mil. m^3 of natural gas. During production time, at least 26 production wells were in operation. The production stopped in mid-1970s; then the field was gradually abandoned. Nowadays, a re-abandonment project is ongoing, within which the old wells are being revisited and re-plugged. This brings a good opportunity to get fresh information about the status of old wells abandoned in the 1970s, including new well-log data.

In 2014, the Czech Geological Survey developed the idea of assessing the LBr-1 field as a potential research CO_2 storage site. A comprehensive project proposal aiming at the first, preparatory stage of such a pilot project was prepared and submitted to the CZ08 (CCS) programme of Norway Grants, and the project (titled REPP-CO_2) was, in the end, selected for funding. The Czech Geological Survey and IRIS (International Research Institute of Stavanger, member of CO_2GeoNet and ENOS proposal partner) form the core of the REPP-CO_2 consortium, which embraces five further Czech research-oriented institutions. The project with a total budget of ca. 2.8 mil. € is running from January 2015 till April 2016. Its main activities follow the workflow for developing a storage site according to the EU CCS Directive and include gathering of data for site characterisation, creation of a 3D geological model of the storage complex, numerical simulations of CO_2 injection in the reservoir and related dynamic modelling, risk assessment and development of a site monitoring plan.

LBr-1 site-related activities planned in ENOS are based on the expected outcomes of REPP-CO_2 and represent a direct continuation of work carried out in REPP-CO_2. This concerns the advanced assessment in leakage risks (including contamination of potable groundwater resources) through faults and legacy wells in WP3, appraisal of the possibility to combine CO_2 storage with Enhanced Oil Recovery and study of trans-border issues (Czech Republic-Slovakia) in WP4, as well as more regional and/or future-oriented studies in WP6. In general, ENOS activities related to LBr-1 will represent a significant step towards further development of the LBr-1 pilot project.

Q16 Maas Buffer project, The Netherlands (TNO)

The nearshore condensate gas field Q16 Maas with onshore surface installations – currently operated by ONE, is an attractive prospect for the development of a CO_2 buffer for greenhouse culture (and other forms of CO_2 utilisation; see figure below). It is located just offshore the Maasvlakte in the Rotterdam harbour area. The Ultimate Recovery is estimated at 0.8 billion Nm^3, which is equal to a CO_2 storage capacity of about 2 Mt CO_2. The gas reservoir consists of Triassic sandstones in the Main Buntsandstein Subgroup of the Lower Germanic Trias Group at a depth of about 2800 metres.



Schematic of the existing infrastructure for delivery of CO_2 to the greenhouses and the planned additional infrastructure including the CO_2 buffer

The field was discovered in 2011, production started in April 2014 from the well Maasgeul-03X (MSG-03X) and is planned to cease by the end of 2020. The condensate-gas ratio of the produced gas is reported as about 410 $m^3/10^6$ Nm^3 in the Winningsplan (Production plan to be found at www.nlog.nl). After production, the gas stream is processed in the Maas Treatment Installation from where the natural gas is transported via a pipeline to the GTS export network. The separated LPG and condensate will be transported by truck from the Maas gas treatment Installation.

To develop the gas field into a CO_2 buffer for the greenhouse horticulture, an additional pipeline and compressor are to be constructed and an expansion of the gas treatment installation will be necessary for the purification of the CO_2. Possibly also a new CO_2 injection well has to be drilled and completed.

Site-specific data of the Q16 Maas gas field will be made available for analysis in the ENOS project. A research project with a budget of about 250 k€ is being developed for the Netherlands energy innovation programme (TKI Gas).

Geographical and gelogical setting

The Q16-Maas gas field is located at the southwestern boundary of the West Netherlands basin about 2 km to the west of the Maasvlakte (province of Zuid-Holland). The most important reservoir units are the Solling and the Hardegsen sandstones sequences of the Main Buntsandstein Subgroup. These reservoirs are known for their good production properties in this part of the West Netherlands Basin. The top of the reservoir is bounded by claystones of Triassic and Jurassic age. The gas accumulated in northwest-southeast oriented structural trap. To the northeast it is bounded by faults and the trap is dipping to the southwest.

The well MSG-03X is deviating in northwestern direction. The surface location is on the Maasvlakte. The well reaches the top of the reservoir at a depth of 2845 m below sea level. The gas reservoir itself is located below the North Sea within the three-mile zone.

4.2. Third parties involved in the project (including use of third party resources)

1. BRGM	
Does the participant plan to subcontract certain tasks (please note that core tasks of the project should not be sub-contracted)	YES
Analysis of reservoir water sampled by flodim in task 1.3.1 will be performed by an external laboratory. Analysis shall consist of: - Petrophysical analyses, mainly Bubble Point and gas content (GWR) - As for the dissolved gas, analyses should concern concentrations of CO2 (most important, as a minimum), and possibly O2, N2, H2, H2S, alcanes (C1 to C6) and if possible Carbon13 on CO2 and on CH4. - As for the liquid phase, the analyses should concern concentration of the following elements (the most importants are underlined): Aluminium, Bore, Baryum, Bromures, Calcium, Chlorures, Cuivre, Fluorures, Fer, Bicarbonates, Potassium, Lithium, Magnésium, Manganèse, Ammonium exprimé en NH4, Nitrates exprimés en NO3, Sodium, Nickel, OrthoPhosphates en PO4, Plomb, Rubidium, Sulfates, Silice, Strontium, Uranium, Zinc. It will be contracted on the best value for money	

2. BGR: No third parties/no subcontracting

3. BGS	
Does the participant plan to subcontract certain tasks (please note that core tasks of the project should not be sub-contracted)	YES
It is proposed to carry out a test of a new high precision open path laser system for emission quantification in Task 3.3.3 in WP3. -Scope: this instrument is being developed currently by the Rutherford Appleton Laboratory (RAL) of the Science and Technology Facilities Council (STFC) under a 2 year UK STFC project in collaboration with BGS and Shell. Since the Chirped Laser Dispersion Spectroscopy approach being used is unique to RAL we propose to test the equipment at one of the ENOS field sites through a subcontract to RAL, who will provide calibrated equipment and operators for the test and assist with data processing. The tool will most likely be tested at Sulcis field laboratory as this site is expected to show leakage at the surface, but could be deployed at the GeoEnergy Test Bed. - Cost estimate: A figure of up to 45,000 Euros is included for staff, travel and other costs related to the deployment (30k€ for 1.5 person months of staff time and 15k€ for travel/other costs related to the deployment). - Selection procedure: Only Rutherford are able to test this unique tool as it has been developed by Rutherford in collaboration with BGS and Shell.	

Does the participant envisage that part of its work is performed by linked third parties	NO
Does the participant envisage the use of contributions in kind provided by third parties (Articles 11 and 12 of the General Model Grant Agreement)	NO

4. CGS: No third parties/no subcontracting
5. CIEMAT: No third parties/no subcontracting

6. CIUDEN

Does the participant plan to subcontract certain tasks (please note that core tasks of the project should not be sub-contracted)	YES

Part of the work in task 5.3 will be subcontracted 25,000€

Activitiy to be subcontracted

As exposed in the DOW, WP5 – Coordination with local population will create conditions for ensuring that CO2 storage activities in sites are recognized as a safe operation and for establishing long term relationships with stakeholders and local population. In this sense, intensive activity is requested in WP5 to engage effectively with stakeholders, to ensure understanding of the project and operational activities in site, and to work closely with the local communities.

Following the guidance of the project, these actions will imply to carry out innovative activities aiming to develop knowledge and tools to bridge the gap between the technical side and the societal level of perception on CCS.

In this sense, and specifically stated in WP5 objectives and subsequently detailed in task 5.3, a public information tool for CO2 storage site will be developed to enable people living near a storage site to understand and follow site development and operation. This tool will be also based on input and feedback from the local population and will offer the possibility of including experiences from other sites. Professional support in this area will be needed for the correct creation, development, implementation and update of the requested tool.

Consequently, subcontracting would be considered necessary in these regards in order to accomplish effectively the requested objectives of the project.

Expected cost:

Considering the committed tasks to be accomplished within WP5 (Task 5.3), an initial estimation of 25,000€ for subcontracting the development of a public information tool for CO2 storage sites has been calculated considering hosting licenses, technical services, technological infrastructure and maintenance, if needed.

This estimation has been based on previous experiences and Spanish market prices for development of online tools.

Procedure

The subcontracts will be awarded ensuring the best value for money or, if appropriate, the lowest price following an open market consultation (a contract notice) allowing for a time-limit for receipt of tenders and always under an objective and non-discriminatory evaluation of the tenders.

Does the participant envisage that part of its work is performed by linked third parties	NO
Does the participant envisage the use of contributions in kind provided by third parties (Articles 11 and 12 of the General Model Grant Agreement)	NO

7. Flodim: No third parties/no subcontracting
8. Geogreen: No third parties/no subcontracting
9. IDIL: No third parties/no subcontracting
10. IRIS: No third parties/no subcontracting
11. NHAZCA: No third parties/no subcontracting
12. OGS: No third parties/no subcontracting
14. SGIDS: No third parties/no subcontracting
15. Silixa: No third parties/no subcontracting
16. Sotacarbo: No third parties/no subcontracting
17. TNO: No third parties/no subcontracting
18. UniRoma1: No third parties/no subcontracting
19. UNOTT: No third parties/no subcontracting

14. CO_2GeoNet

10 third parties. Please see the details in the partner descriptions in 4.1

A summary of staff effort for the CO_2GeoNet third parties is given below

	WP1	WP2	WP3	WP4	WP5	WP6	WP7	WP8	WP9	Total Person/ Months per Participant
CO2GeoNet-GBA	0.0	0.0	0.0	0.0	4.0	7.0	3.0	0.0	0.0	14.0
CO2GeoNet-GeoEcoMar	0.0	0.0	2.5	0.0	4.0	6.2	7.3	3.0	0.0	23.0
CO2GeoNet-Geoinz	0.0	0.0	0.0	0.0	0.0	1.0	7.0	1.0	0.0	9.0
CO2GeoNet-GEUS	0.0	0.0	0.0	0.0	0.0	0.0	3.0	**8.0**	8.0	19.0
CO2GeoNet-GSB-RBINS	0.0	0.0	0.0	24.0	0.0	0.0	1.0	0.0	0.0	25.0
CO2GeoNet-HWU	4.0	26.0	16.0	0.0	3.0	0.0	1.0	3.3	0.0	53.3
CO2GeoNet-IGME	20.2	0.0	0.0	0.0	2.0	2.0	3.4	4.2	0.0	31.8
CO2GeoNet-METU PAL	0.0	0.0	0.0	6.0	0.0	0.0	1.0	0.0	0.0	7.0
CO2GeoNet-TTUGI	0.0	0.0	0.0	0.0	2.3	5.9	11.3	3.8	0.0	23.3
CO2GeoNet-UNIZG-RGNF	0.0	0.0	0.0	0.0	0.0	7.3	1.0	3.2	0.0	11.5
Total Person/Months	24.2	26.0	18.5	30.0	15.3	29.3	39.0	26.5	8.0	216.8

Does the participant plan to subcontract certain tasks (please note that core tasks of the project should not be sub-contracted)	YES

CO_2GeoNet-UNIZG 30 k€ subcontracting is planned.

Scope of the subcontract – Task 6.3 (D6.8) is aimed at finding the locations/regions likely to be favorable for future pilot or demonstration projects. This task will use data from existing pilot sites, key recommendations from previous and ongoing research projects. A catalogue of the most prospective candidates for second generation pilots will be developed. It is expected that some of them will be in countries not in ENOS consortium and therefore part of the work of task 6.8 will have to subcontracted to a local entity having the necessary knowledge and expertise.

Based on the coordination through the work in Tasks 6.1 and 6.2 a plan will be made to contact the institutes from countries where the new pilots might be commenced and each of the selected institutes will be required to make a short report covering the subsurface data of the prospective site together with other surface and technical/legal conditions for a pilot study. Reports will have to be according to a specified structure (topics) and should not be more extensive than plan for a pre-feasibility study. Exact number of countries/locations will be determined in during the first 2 years of ENOS in close cooperation with ECCSEL, ZEP etc., but the following countries are among candidates: Poland, Hungary, Lithuania, Latvia, Bulgaria, Finland and Sweden; in addition also Serbia and Bosnia and Herzegovina but this depends on the changes of their respective regulations. Altogether around 6 locations are to be chosen

Cost estimates – 6 subcontracts with the institutes that have the subsurface data (mostly geological surveys),

each can be up to EUR 5000. Selection procedure – due to the specific work and especially data needed it is most likely that only one entity per country (mostly the geological surveys or sometimes the university) could provide the needed information due to the required knowledge and data possession, therefore a negotiated procedure will be used to award the tenders.	
Does the participant envisage that part of its work is performed by linked third parties[5]	YES
See details of the ten linked third parties in the partner descriptions in 4.1	
Does the participant envisage the use of contributions in kind provided by third parties (Articles 11 and 12 of the General Model Grant Agreement)	NO

[5] A third party that is an affiliated entity or has a legal link to a participant implying a collaboration not limited to the action. (Article 14 of the Model Grant Agreement).

Section 5: Ethics and Security

5.1 Ethics

The only ethical issue raised by ENOS is on the collection of personal data related to the activities in WP5 Coordination with the local population.

Supporting information to Ethical issue 4: Personal data

ENOS will develop its activities within the framework of Responsible Research and Innovation – RRI, and will therefore take care to anticipate and assesses potential implications and societal expectations with regard to CO_2 storage research and innovation, with the aim of fostering the design of inclusive and sustainable research and innovation. In particular, in WP5, the societal actors (researchers, citizens, policy makers, business, third sector organisations, etc.) will work together during the research and innovation process in order to better align both the process and its outcomes with the values, needs and expectations of society. The partners will develop together a protocol on how to approach the work with the local communities (task 5.2.1), which will include discussion and definition of ethical aspects related to each site and, more generally, to the activities undertaken. Through a peer review process, comparing and cross checking, they will improve, when relevant, the forms or approaches of each institute.

Understanding fully how people feel about the innovations studied in ENOS and involving them in the process is of the utmost importance. Hence, the partners will aim to create conditions that maximise the potential for collaboration by, among other aspects, analysing the specific ethical issues that need consideration in a way that people will feel completely at ease with the process and confident about the use that will be made of their contribution.

The existing European and national legislation for personal data protection will be strictly followed, in Italy based on the Legislative Decree 30 June 2003, n.196 – Codex for the treatment of personal data, in the United Kingdom based on the Data Protection Act (1998) and comparable Acts in each country (underpinned by EU Directives) in which research activities involving members of the public are to be undertaken. Other relevant ethical codes and their provisions will be consulted and followed as appropriate. Key issues that will be treated concern a) the procedure for informed consent of participants, on the basis that they are aware of the research objectives, funder, context, methods to be employed and use of information gathered; b) the protection of all information collected and to ensure that it is carefully protected, that it is confidential and not released to a third party in a form that allows identification of particular individuals and that it is reported anonymously. It is also worth noting that the research institutes involved have previous experience of undertaking public engagement activities and are sensitive to the ethical issues that might be raised.

An example of an informed consent form is provided in the supporting documents. This form will be adapted according to the national constraints and activities.

5.2 Security

Please indicate if your project will involve:

- activities or results raising security issues: NO
- 'EU-classified information' as background or results: NO

ESTIMATED BUDGET FOR THE ACTION (page 1 of 3)

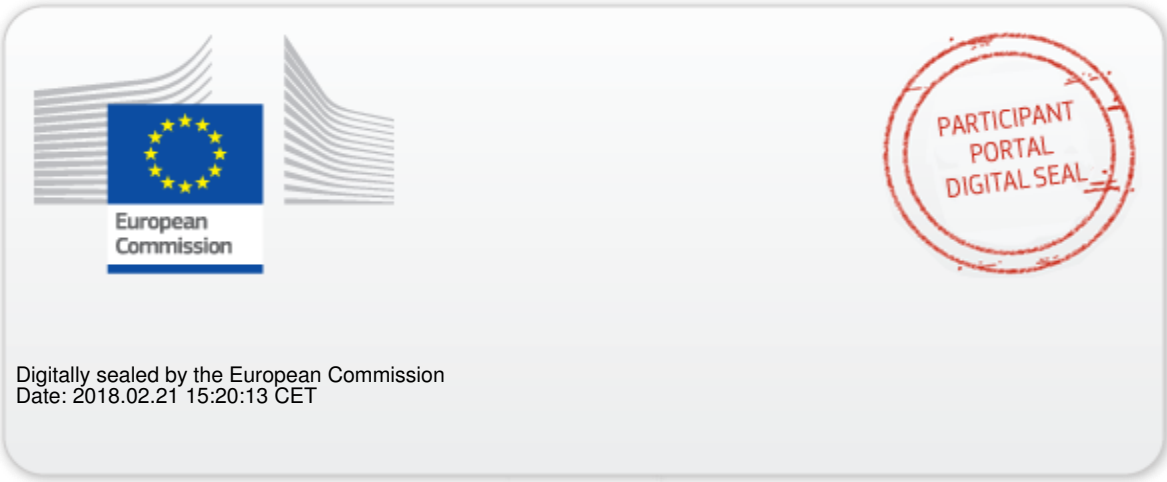
	Estimated eligible[1] costs (per budget category)									EU contribution			Additional information		
	A. Direct personnel costs				B. Direct costs of subcontracting	C. Direct costs of fin. support	D. Other direct costs	E. Indirect costs[2]	Total costs	Reimbursement rate %	Maximum EU contribution[3]	Maximum grant amount[4]	Information for indirect costs	Information for auditors	Other information:
	A.1 Employees (or equivalent) A.2 Natural persons under direct contract A.3 Seconded persons [A.6 Personnel for providing access to research infrastructure]		A.4 SME owners without salary A.5 Beneficiaries that are natural persons without salary				D.1 Travel D.2 Equipment D.3 Other goods and services D.4 Costs of large research infrastructure						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 EU funding
Form of costs[6]	Actual	Unit[7]	Unit[8]		Actual	Actual	Actual	Flat-rate[9] 25%							
	(a)	Total (b)	No hours	Total (c)	(d)	(e)	(f)	(g)=0,25x ((a)+(b)+ (c)+(f) +[(h1)+(h2)]- (m))	(i)= (a)+(b)+(c)+ (d)+(e)+(f)+ (g)+(h1)+(h2)+(h3)	(j)	(k)	(l)	(m)	Yes/No	
1. BRGM	0.00	845847.00	0	0.00	3500.00	0.00	201400.00	261811.75	1312558.75	100.00	1312558.75	1312558.75	0.00	No	
2. BGR	312480.00	0.00	0	0.00	0.00	0.00	95802.00	102070.50	510352.50	100.00	510352.50	510352.50	0.00	No	
3. BGS	478195.00	0.00	0	0.00	45000.00	0.00	152791.60	157746.65	833733.25	100.00	833733.25	833733.25	0.00	No	
4. CGS	179307.00	0.00	0	0.00	0.00	0.00	48300.00	56901.75	284508.75	100.00	284508.75	284508.75	0.00	No	
5. CIEMAT	30702.00	0.00	0	0.00	0.00	0.00	4500.00	8800.50	44002.50	100.00	44002.50	44002.50	0.00	No	
6. CIUDEN	822500.00	0.00	0	0.00	25000.00	0.00	1325300.00	536950.00	2709750.00	100.00	2709750.00	2709750.00	0.00	No	
7. flodim	25000.00	0.00	0	0.00	0.00	0.00	14000.00	9750.00	48750.00	100.00	48750.00	48750.00	0.00	No	
8. GGR	262808.00	0.00	0	0.00	0.00	0.00	78900.00	85427.00	427135.00	100.00	427135.00	427135.00	0.00	No	
9. IDIL	25000.00	0.00	0	0.00	0.00	0.00	2500.00	6875.00	34375.00	100.00	34375.00	34375.00	0.00	No	
10. IRIS	554085.00	0.00	0	0.00	0.00	0.00	64500.00	154646.25	773231.25	100.00	773231.25	773231.25	0.00	No	
11. NHAZCA	25500.00	0.00	0	0.00	0.00	0.00	15500.00	10250.00	51250.00	100.00	51250.00	51250.00	0.00	No	
12. OGS	672565.00	0.00	0	0.00	0.00	0.00	142000.00	203641.25	1018206.25	100.00	1018206.25	1018206.25	0.00	No	
13. PLC-3[13]															
- ENAGAS[14]	0.00	0.00	0	0.00	0.00	0.00	0.00	0.00	0.00	100.00	0.00	0.00	0.00	No	
- IPF[14]	0.00	0.00	0	0.00	0.00	0.00	0.00	0.00	0.00	100.00	0.00	0.00	0.00	No	
Total beneficiary 13	0.00	0.00			0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.00		
14. SGIDS	28000.00	0.00	0	0.00	0.00	0.00	6400.00	8600.00	43000.00	100.00	43000.00	43000.00	0.00	No	
15. SILIXA	83195.00	0.00	0	0.00	0.00	0.00	75700.00	39723.75	198618.75	100.00	198618.75	198618.75	0.00	No	
16. SOTACARBO	192673.40	0.00	0	0.00	0.00	0.00	18645.00	52829.60	264148.00	100.00	264148.00	264148.00	0.00	No	
17. TNO	592213.00	0.00	0	0.00	0.00	0.00	74600.00	166703.25	833516.25	100.00	833516.25	833516.25	0.00	No	
18. UNIROMA1	575000.00	0.00	0	0.00	0.00	0.00	217000.00	198000.00	990000.00	100.00	990000.00	990000.00	0.00	No	
19. UNOTT	357946.00	0.00	0	0.00	0.00	0.00	53400.00	102836.50	514182.50	100.00	514182.50	514182.50	0.00	No	
20. CO2GeoNet[13]															0.00
- GSB-RBINS[14]	112000.00	0.00	0	0.00	0.00	0.00	9500.00	30375.00	151875.00	100.00	151875.00	151875.00	0.00	No	
- TTUGI[14]	81375.00	0.00	0	0.00	0.00	0.00	14500.00	23968.75	119843.75	100.00	119843.75	119843.75	0.00	No	
- UNIZG-RGNF[14]	27000.00	0.00	0	0.00	30000.00	0.00	10800.00	9450.00	77250.00	100.00	77250.00	77250.00	0.00	No	
- HWU[14]	300710.00	0.00	0	0.00	0.00	0.00	29300.00	82502.50	412512.50	100.00	412512.50	412512.50	0.00	No	

ESTIMATED BUDGET FOR THE ACTION (page 2 of 3)

	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.2 Natural persons under direct contract A.3 Seconded persons [A.6 Personnel for providing access to research infrastructure]		A.4 SME owners without salary A.5 Beneficiaries that are natural persons without salary				D.1 Travel D.2 Equipment D.3 Other goods and services D.4 Costs of large research infrastructure						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 EU funding
Form of costs[6]	Actual	Unit[7]	Unit[8]		Actual	Actual	Actual	Flat-rate[9]							
								25%							
	(a)	Total (b)	No hours	Total (c)	(d)	(e)	(f)	(g)=0,25x ((a)+(b)+ (c)+(f) +[(h1)+(h2)]- (m))	(i)= (a)+(b)+(c)+ (d)+(e)+(f)+ (g)+(h1)+(h2)+(h3)	(j)	(k)	(l)	(m)	Yes/No	
- IGME[14]	155041.00	0.00	0	0.00	0.00	0.00	23800.00	44710.25	223551.25	100.00	223551.25	223551.25	0.00	No	
- GEUS[14]	164277.00	0.00	0	0.00	0.00	0.00	44600.00	52219.25	261096.25	100.00	261096.25	261096.25	0.00	No	
- GEOINZ[14]	36131.00	0.00	0	0.00	0.00	0.00	5100.00	10307.75	51538.75	100.00	51538.75	51538.75	0.00	No	
- GEOECOMAR[14]	118495.00	0.00	0	0.00	0.00	0.00	15900.00	33598.75	167993.75	100.00	167993.75	167993.75	0.00	No	
- METU[14]	29700.00	0.00	0	0.00	0.00	0.00	3500.00	8300.00	41500.00	100.00	41500.00	41500.00	0.00	No	
- GBA[14]	63423.00	0.00	0	0.00	0.00	0.00	6000.00	17355.75	86778.75	100.00	86778.75	86778.75	0.00	No	
Total beneficiary 20	1088152.00	0.00	0.00	0.00	30000.00	0.00	163000.00	312788.00	1593940.00		1593940.00	1593940.00	0.00		
Total consortium	6305321.40	845847.00		0.00	103500.00	0.00	2754238.60	2476351.75	12485258.75		12485258.75	12485258.75	0.00		0.00

ESTIMATED BUDGET FOR THE ACTION (page 3 of 3)

(1) See Article 6 for the eligibility conditions
(2) The indirect costs covered by the operating grant (received under any EU or Euratom funding programme; see Article 6.5.(b)) are ineligible under the GA. Therefore, a beneficiary 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 (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/Agency decided to grant for the action) (see Article 5.1).
(4) The 'maximum grant amount' is the maximum grant amount decided by the Commission/Agency. 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 beneficiary's usual accounting practice
(8) See Annex 2a 'Additional information on the estimated budget' for the details (costs per hour (hourly rate)).
(9) 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
(10) See Annex 2a 'Additional information on the estimated budget' for the details (units, costs per unit).
(11) See Annex 2a 'Additional information on the estimated budget' for the details (units, costs per unit, estimated number of units, etc)
(12) Only specific unit costs that do not include indirect costs
(13) See Article 9 for beneficiaries not receiving EU funding
(14) Only for linked third parties that receive EU funding



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