39/25-651-01

Collaboration Agreement

between

Warsaw University of Technology (hereafter WUT)
Pl. Politechniki 1; 00-661 Warsaw
represented by Professor Mariusz Malinowski, PhD, DSc, Vice-Rector for Research

Executive Unit: Faculty of Chemical and Process Engineering
Responsible project manager: [redacted]

– further referred to as **Project Coordinator** –

VSB - Technical University of Ostrava, (hereafter VSB-TUO),
17. listopadu 2172/15, 708 00 Ostrava-Poruba

represented by prof. RNDr. Václav Snášel, CSc., Rector

Executive Unit: Faculty of Materials Science and Technology
Responsible project manager: [redacted]

Taipei Medical University, (hereafter TMU)
No.250, Wuxing St., Xinyi Dist., Taipei City 110, Taiwan
represented by Prof. Mai-Szu Wu, President

Executive Unit: School of Dental Technology
Responsible project manager: [redacted]

– further referred to individually as **Partner** and jointly as **Partners** –

for the following Joint Project

AH-Nano-Cat – “Advanced Hybrid Nanomaterials for Efficient Photo(electro)catalytic Water Purification and Hydrogen Production”

– further referred to as **Joint Project** –

Preamble

Collaborative projects are collaborative ventures towards a joint aim based on the division of labour and involving a number of research partners and/or partners from industry. The Partners wish to specify or supplement binding commitments among themselves in addition to the provisions of the specific national Grant Agreements or equivalent documents (hereinafter »Grant Agreements«) signed by the Partners with each national Funding Agency. The Partners have been granted project funding by their funding agency. They therefore agree as follows:

1. Subject matter of the Agreement

Subject matter of the Agreement is the collaboration for the realization of the Joint Project submitted to the M-ERA.NET Call 2024 and recommended for funding. The Joint Project is co-sponsored by the National Science Centre (NCN) (in the scope of the part implemented by WUT) and the other funding agencies (in the scope of part implemented by the other Partners); the Partners will contribute to the realization of a scientific partnership within the Joint Project. In relation to third parties, the consortium does not act as an independent legal entity.

2. Realization of the work

2.1 The Partners undertake to carry out the agreed areas of work and sub-assignments allocated to them as described in the Project Proposal attached as Annex to this Agreement; the Annex forms an integral part of this. Each Partner will take responsibility for carrying out its own work. All research activities conducted in the framework of this Agreement shall be done in compliance with all applicable laws, regulations, and guidelines of the countries and institutions in which the research is conducted.

2.2 The Partners keep each other informed, by

- a comprehensive sharing of the work results obtained as well as of the progress of the work according to this Agreement,
- exchanging interim and completion reports,
- exchanging information at joint work meetings or meetings of the group,
- a general exchange of information at the overall project level in accordance with the Project Proposal.

2.3 The Partners will entrust professionally qualified employees to carry out the work according to the Project Proposal in a manner that ensures compliance with deadlines indicated therein.

2.4 Where the deadlines cannot be met, this must be promptly notified to Marta Mazurkiewicz-Pawlicka as Project Coordinator, which informs the other Partners.

2.5 Each Partner will appoint a contact person responsible for its share of the work (and provide the relevant contact number and e-mail to the Project Coordinator). All Partners shall be notified immediately of any change in such contact person.

2.6 Project coordination is taken over by WUT, through its project leader Marta Mazurkiewicz-Pawlicka, who is, in particular, responsible for coordinating the work of the individual Partners in terms of time and substance. Where there are departures from the overall work plan and schedule, the project leader will draw this to the attention of the Partners as early as possible and propose measures to overcome the difficulties that have arisen.

2.7 The project leader prepares the work meetings necessary for the realization of the overall work plan and schedule, sends invitations giving reasonable notice and encloses the agenda, chairs the works meetings and is responsible for drawing up and distributing the minutes of the meeting. The meetings may also be held via telephone or video conference.

2.8 The Partners will assign an employee to attend the necessary works meetings and ensure that the targets, approaches, arrangements etc., agreed from a scientific point of view at these meetings are complied with. The Partners shall not deliberate and decide validly in work meetings unless two-thirds (2/3) of its members are present or represented (quorum). Each Member present or represented in the meeting shall have one vote. Decisions shall be taken by a majority of two-thirds (2/3) of the votes cast. A Partner who can show that its own work, time for performance, costs, liabilities, intellectual property rights, or other legitimate interests would be severely affected by a decision made in a work meeting may exercise a veto with respect to the corresponding decision or relevant part of the decision. The veto must be communicated in writing to the other Partners' project managers in writing within 15 calendar days after the vetoing Partner has been informed of the decision to which it wishes to exercise a veto.

2.9 Furthermore, each directly funded Partner is responsible vis-à-vis its own funding agency for the realization of the assumed R&D tasks.

3. Work Results

3.1 The term »Work Results« covers all results such as data, know-how or information, whatever its form or nature, whether or not it can be protected, as well as any rights attached to it, including intellectual property rights, including complied reports and documents which are generated by the Partners in carrying out their work in the Joint Project (e.g. Know-how, inventions, results that are protected by copyright, software). Inventions are defined as Work Results, which may enjoy protection as a patent or utility model under the generating Partner's national law. Software is defined as Work Results, which may enjoy protection as software under the intellectual property laws of the generating Party and not protected as an Invention. As a matter of principle, the Partners shall reasonably consider registration of the intellectual property rights of those work results that are eligible for protection under IP law. Notwithstanding the aforementioned principle, a Partner may decide at its own discretion to make its solely generated Work Results available as Open Source or Open Access as said Partner deems appropriate.

3.2 Work Results that exclusively involve the participation of employees of one Partner belong to that Partner or the Partner's employee according to national legislation.

3.3 Work results which come about through the involvement of two or more Partners belong to these Partners jointly in proportion to the contribution they make. If, in the course of carrying out work in the Joint Project, Joint Work Results are made (at least two Partners are intellectual contributors), and if the features of such Joint Work Results are such that it is not possible to separate them for the purpose of applying for, obtaining and/or maintaining in force the protection of the relevant intellectual property right, the Partners, or the Partner's employee according to national legislation, concerned shall enter into an agreement on the allocation and terms of exercise of their joint ownership ('joint ownership agreement'), to ensure compliance with their obligations under this Agreement. If the respective intellectual contributions of the Partners cannot be documented, the Joint Work Result shall be owned by the Partners, or the Partner's employee according to national legislation, in equal shares.

3.4 The Partner that registers a Work Result that is eligible for registered protection under intellectual property law will inform the other Partners accordingly, who are subject to the confidentiality obligations in this Agreement.

3.5 The Partners mutually undertake to keep confidential the notifications of the other Partners' Work Results and intellectual property right applications until they are published by no action or omission of the other Partners or anyone, they are responsible for.

3.6 The Partners undertake to cooperate and provide each other with maximum assistance in order to develop an implementation plan for the Work Results achieved within the Joint Project. The Partners shall also cooperate in the submission of implementation reports.

4. Rights of use

4.1 For the purposes and the term of the Joint Project, the Partners grant each other a non-exclusive, non-transferable and non-sub licensable complimentary right of use that is strictly required for completing the Joint Project over the Work Results that have arisen during the realization of the Joint Project. A right of use extending beyond the term of the Joint Project, or that is granted for any other purposes, requires a separate written agreement and will be granted at fair and reasonable customary market terms and conditions, taking into consideration the contribution to the Joint Project of the Partner requesting user rights.

4.2 In case of inventions the holders of the rights should, when assessing the utilization fee for a right of use extending beyond the term of the Joint Project or when is granted for other purposes than the Joint Project, take into account any contributions made by the Partners which should be valued as a necessary but insufficient prerequisite for the invention. Such contributions should be appropriately taken into account when assessing the licence fees, for example, through a significant reduction compared with those with no involvement. The same applies accordingly to joint inventions. In case of Partners without such involvement in the invention process, licenses are awarded at customary market terms and conditions.

4.3 Existing research and development results ("Background"), which is made available to another Partner, shall remain the property of the Partner contributing them. Subject to any Third-Party rights the Partners grant each other access rights to the Background needed for the performance of their own work of another Partner for the completion of the Joint Project under the project, in a royalty-free basis, or in case it is needed for any other use including but not limited to commercial use, by a separate written agreement at customary market terms and conditions in accordance with 4.1.

4.4 The right to use of the Work Results for internal, non-commercial research and teaching purposes remains permissible free of charge even after the end of the Joint Project.

5. Financing

5.1 Each Partner bears the costs arising in the context of the realization of this Agreement itself.

5.2 Each Partner is responsible for financing its own portion of the project in accordance with any grant terms and conditions as well as the regulations affecting it and the national law under which the Partner is operating.

6. External Services

6.1 To the extent that a Partner collaborates with a Third-Party, which is understood as being an individual or entity other than the Partners in the context of work for the Joint Project, it must ensure that the other Partners as well as the respective funding entity if required by national regulations for individual Partner Funding Agencies receive at least the same rights to the Third-Parties Work Results as they would have had if the Work Results had been elaborated by the Partner itself.

6.2 Prior to awarding contracts for R&D work in the course of the Joint Project, the other Partners must be informed in writing of the intention to award a contract. Clause 6.1 applies accordingly to the Work Results of the R&D contracts.

6.3 If a Partner wishes to outsource a contract in order to complete its work under the Joint Project, it assumes the relevant responsibility and, in particular, warrants that the contractor treats the information entrusted to it as confidential in accordance with the obligations under this Agreement of the Partner awarding the contract, in particular under clauses 7.1 - 7.4.

6.4 The Partners shall be entitled to include students in the concerned Partner's allocated work, whereby the student may gain access to the Partners' Confidential Information. Any such access shall be subject to a prior signed confidentiality and assignment of rights agreement between the student and Partner in question. The oral examination of the student based on the student's project report shall be held as a non-public-accessible examination behind closed doors. The student may disclose Confidential Information needed to the examiners at the oral examination based on the student's project report when held behind closed doors. As part of such an agreement, the student shall consent in having any examinations held behind closed doors. The report may be subjected to academic plagiarism control through a third Partner by the Institutions and may be archived in accordance with legislation applicable to the Partner at which the student is enrolled.

7. Confidentiality/ Publications

7.1 The Partners will, even after completion or withdrawal from this Agreement, keep confidential from Third-Parties any information received from the other Partners which has been explicitly marked as "confidential" at the time of disclosure, or when disclosed orally has been identified as confidential at the time of disclosure and has been confirmed and designated in writing within fifteen (15) calendar days from oral disclosure at the latest as confidential information by the disclosing Partner is marked as confidential ("Confidential Information"). This applies for three (3) years from completion of the Joint Project.

7.2 The Confidential Information made available by any Partner to the other Partners, e.g. in the form of documents, documentation, data carriers and objects must be treated with care and in particular must be stored in accordance with the duty of confidentiality under Clause 7.1 until its return, destruction or erasure as required by the Partners disclosing the Confidential Information and only used in accordance with the provisions of this Agreement and in particular may not be made the subject of intellectual property right applications. Where the Partner providing the Confidential Information so wishes, the Confidential Information shall be returned or completely destroyed following termination of, or a Partner's withdrawal from, this Agreement.

7.3 The obligations under Clauses 7.1 and 7.2 do not apply to information that can be shown

- to be in the public domain as a result of publication or similar, or
- to enter the public domain through no fault of the Partner receiving it, or
- to have been transferred to a Partner by third Partners without any confidentiality obligation, or
- to have already been known to the receiving Partner prior to its disclosure by any other Partner, or
- to be the result of work by employees of the receiving Partner without the relevant employees having had access to the confidential information,
- to be disclosed by a binding act or official, respectively, judicial order.

7.4 The Partners will take the usual and reasonable steps under these provisions to keep the information confidential, also vis-à-vis their own employees.

7.5 Each Partner may publish the results of its own Work Results. Joint Work Results can be published jointly by the Partners being the joint owners, or, in the case that one or more owning Partner(s) does not wish to participate in the publication, the other owning Partner(s) shall be entitled to publish on its/their own. Substantial contributions to the work shall always be disclosed accordingly. At the same time, reference must be made to the Joint Project in the form provided by the respective Funding Agency. Each Partner is obliged to inform the other Partners of the publications in advance. The Partners will ensure that a publication does not jeopardize any application for intellectual property rights.

7.6 Publications containing Confidential Information or Work Results from other Partners shall require prior written consent from the Partner/s concerned, and the concerned Partners shall consider joint publication. The Project Coordinator shall also be informed. No Partner may unreasonably withhold consent or unreasonably make its consent conditional upon alterations or deletions. Should a publication (original text) be submitted to one or several concerned Partner/s and should such Partner/s raise no objection to the publication within four (4) weeks, consent shall be deemed to have been given. Each Partner is entitled to comment on the academic contents of the draft as well as suggest specific amendments, provided, however, that each authoring Partner alone shall decide the final wording and content of its own text.

7.7 For the avoidance of doubt, the existence of this Joint Project shall never be deemed Confidential Information.

8. Term of the Agreement

8.1 This Agreement shall take effect upon signature by all Partners and shall terminate after all national Funding Agencies have accepted the joint final report, including the financial report, unless it is terminated or otherwise terminated prior to that. Clauses 3, 4, 7, and 9 shall survive termination of the Agreement.

8.2 If a Partner commits a serious breach of or repeatedly breaches its obligations under this Agreement and the breach has not come to an end within thirty (30) calendar days from a written request by the other Partner, the other Partner may terminate the Agreement with immediate effect.

8.3 If a Partner is prevented from fulfilling its obligations other than the payment obligations under the Agreement as a result of extraordinary events beyond the Partner's control and which the Partner could not have foreseen when the Agreement was entered into (force majeure), this shall not be regarded as a breach. In such cases, the other Partner shall, however, be entitled to terminate the Agreement if the result would otherwise be a material delay in the completion of the Project. Where a Partner leaves the Joint Project, the obligations of the remaining Partners in relation to it shall then end upon its departure. Nevertheless, the departing Partner retains its obligations vis-à-vis the other Partners in relation to earlier works under Clauses 2, 3, 4, and 6 of this Agreement. Confidential Information it has received from other Partners must continue to be treated as confidential in accordance with the provision in clause 7. The obligation of the remaining Partners under clauses 3, 4 and 6 of this Agreement only applies to a departing Partner in relation to results that were obtained prior to its departure and to intellectual property rights that were registered prior to its departure.

8.4 The other Partners' obligations under clause 7 of this Agreement continue to apply in respect of the departing Partner.

8.5 If the Agreement is terminated vis-à-vis a Partner in breach, the other Partner can claim compensation for the loss caused by the breach in accordance with the provisions set out in clause 9.

9. Guarantee/ Liability

9.1 The Partners will carry out the work undertaken by them in the context of the Joint Project properly and to the best of their knowledge, taking into account the latest scientific and technical developments. The Partners do not assume any guarantee that the work results will not infringe on any intellectual property rights or to the effect that specific results will be achieved. However, as soon as a Partner becomes aware of any such intellectual property rights, it will inform the other Partners of the same without undue delay.

9.2 If a Partner uses another Partner's Work Results or Background under the terms of the Agreement, then such use shall in every respect take place on the receiving Partner's own responsibility. The receiving Partner may not, in any way or in respect of any situation, bring a claim against the providing Partner based on such use. The Partners acknowledge that Work Results and Background is provided 'as is' and without any representation or warranty, express or implied, as to its accuracy or completeness, including, without limitation, any implied warranty of merchantability or fitness for a particular purpose or any warranty that the use of Work Results and Background will not infringe or violate any patent or other proprietary rights of any Third-Party.

9.3 No Partner shall be responsible to any other Partner for any indirect or consequential loss or similar damage, such as, but not limited to, loss of profit, loss of revenue, or loss of contracts.

A Partner's aggregate liability towards the other Partner's collectively shall be limited to once the Partner's share of the total costs of the Joint Project.

A Partner's liability shall not be limited under either of the two foregoing paragraphs to the extent such damage was caused by a wilful act or gross negligence or to the extent that such limitation is not permitted by law.

9.4 For the avoidance of doubt, a Partner that enters into a Third-Party contract for the purposes of this Agreement (employment of staff, subcontract, etc.) shall be solely responsible for carrying out its part of the Joint Project and the Third-Party's compliance with this Agreement.

9.4 In the context of the collaboration, the Partners will undertake to share information with the degree of care they would apply to their own information. The Partners do not accept any liability for the accuracy, fitness for purpose, and completeness of the information shared by them in the context of this Agreement or for damage of whatever kind resulting from the application of such information either during the term of the collaboration or following the end of the Agreement. This is without prejudice to the provisions of Clauses 9.1 and 9.2.

10. Personal data

If the Joint Project involves research data containing personal data transfer of such personal data between the Partners or processing of such personal data by one Partner on behalf of another Partner, the relevant Partners will enter into separate agreements regarding such transfer or processing in accordance with applicable law on the protection of personal data and each Partner's privacy policy.

11. Final provisions

11.1 This Agreement replaces all oral or written agreements between the Partners with regard to the Joint Project entered into prior to its signature.

11.2 Should a provision of this Agreement be or become invalid, this is without prejudice to the validity of the remaining provisions of this Agreement. Rather, the provision should be replaced retrospectively with such provision as is legally permissible and, in terms of its content, comes closest to the original intention. The same applies to unforeseen lacuna in the Agreement.

11.3 No Partner is entitled to undertake obligations binding the other Partners without their express prior written consent.

11.4 The Partners agree that this Agreement may be executed by means of either (i) generally accepted and available software (e-signature including a digital certificate for independent identity validation), e.g. Adobe Sign, DocuSign or similar electronic signature technology, or (ii) a scan of a blue wet ink signature, which shall be considered as an original wet ink signature for all purposes and shall have the same force and effect as an original wet ink signature.

11.5 In the event of any dispute that may arise between the Partners relating to the interpretation and/or performance of this Agreement, they shall attempt to reach an amicable solution to such dispute. In the event that the Partners are unable to come to an amicable solution, the dispute shall be submitted to the competent court of the defendant Partner, and the Agreement shall be interpreted in accordance with the laws of the country of the defendant. The language to be used in court proceedings shall be English if allowed by the competent court defined in this Agreement. The contractual language is also English.

11.6 Provisions of this Agreement which contravene a higher-ranking law (in particular EU law on state aid or provisions of the Grant Agreements) are invalid. Nothing in this Agreement shall be deemed to require a Partner to breach any mandatory statutory law or Grant terms and conditions under which the Party is operating.

11.7 Rights and obligations under this contract may not be transferred to third Partners without the prior written consent of the other Partners to the contract.

12. Annexes

Attached to this Agreement:

Annex 1: Project Proposal

Warsaw University of Technology

(place) (date) , Mariusz Malinowski .... Digitally signed by Mariusz Malinowski Date: 2025.05.19 12:02:00 +02'00'

VSB - Technical University of Ostrava

(place) (date) , ..prof. Václav Snášel CSc. .... Digitálně podepsal prof. Václav Snášel CSc. Datum: 2025.05.22 12:01:26 +02'00'

[redacted]

Taipei Medical University

(place) (date) , [redacted] ... 2025.05.23

M-ERA.NET Call 2024

Full-Proposal

Project Acronym: AH-Nano-Cat

Project Coordinator:

(Organisation and Country):

Warsaw University of Technology POLAND

Each partner is requested to contact the respective national/regional funding organisation before Full-Proposal submission

To be submitted by the Project Coordinator only.
The Full-Proposal form has a technical limit of 40 pages.
Refer to Guide for Proposers when filling out this form.

The following formatting conditions apply:
Do not change the formatting of this template. The font to be used in the main body of text is Arial, size 11 points. Standard character spacing and a minimum of single line spacing is to be used. Text elements other than the body text, such as headers, foot/end notes, captions, formulas, may deviate, but must be legible. The page size is A4, and left and right margins should be at least 15 mm. The top and bottom margins (including header and footer with page number) must not be changed. Any changes to the template that would result in effectively bypassing the 40-page limit will not be accepted.

Attention:
The structure, the order of chapters and the formatting conditions of the proposal form must not be changed to ensure the fairness of the evaluation. The evaluation will be done solely on the information provided within the mandatory templates (no links to external sources will be considered).
<u>Any restructuring and change of the proposal form will result in a formal rejection of the proposal.</u>

Content

Colour Code:
Black: text in black must be kept
Blue: text in blue is for information purpose and can be deleted.

1. SUMMARY

Project Acronym	AH-Nano-Cat				
Proposal Long Title	Advanced Hybrid Nanomaterials for Efficient Photo(electro)catalytic Water Purification and Hydrogen Production				
Project Coordinator	Name:	[redacted]			
	E-mail:	[redacted]			
Coordinator Organisation (full name in original language / name in English)	Original Language: Politechnika Warszawska English: Warsaw University of Technology		Country/ Region	Poland	
Address	Plac Politechniki 1		Tel:	[redacted]	
	Postal code (CEDEX)	00-661	Fax:		
	City	Warsaw	www:	www.pw.edu.pl	
Total Project Costs (Euro)	**871 713**	**Requested Funding (Euro)**	**818 962**		
Planned starting date	01.07.2025	Duration (in months)	**36**	Total person months	259
Call Topic (only one topic must be chosen)	☐	Sustainable advanced materials for energy			
	☐	Innovative surfaces, coatings and interfaces			
	☐	High performance composites			
	☐	Functional materials			
	☒	Materials addressing environmental challenges			
	☐	Next generation materials for advanced electronics			

Publishable Abstract

Publishable Abstract for funded projects, including: *specific innovation objectives and results, needs addressed, impact and potential benefits (up to 1000 characters)*

Please use these headlines for structuring the publishable abstract

- Rationale / Needs to be addressed

Since water is one of the most important resources, it is crucial to keep it free from chemicals and pathogens to increase clean water accessibility. Simultaneously, water is a source of green hydrogen, which may replace fossil fuels, helping to keep the environment clean.

- Objectives

The main objective of the project is the preparation of novel hybrid materials based on g-C_3N_4 with the addition of carbon nanomaterials and transition metal oxides (e.g. TiO_2, Fe_2O_3) or sulfides (e.g. MoS_2) that can be used for photo- and photoelectrocatalytic water purification and hydrogen production.

- Potential applications

The project results, i.e., g-C_3N_4-based efficient photo- and photoelectrocatalysts, will be used for water purification to remove organic dyes and bacteria, and in green hydrogen production via solar-driven water splitting.

- Impact and potential benefits

The catalysts will facilitate water reuse and increase the accessibility of both clean water and renewable energy, which are critical factors for human health and environmental sustainability.

Publishable Contact Details

I agree that the coordinators contact details (name and e-mail address) will be published

Yes ☒
No ☐

Project Summary

Project Summary, including: *specific innovation objectives and results, needs addressed, impact and potential benefits (up to 4000 characters).*
Whenever appropriate, indicate the TRL[1] position in the beginning of the project and after the project is finished (not mandatory).

Water is a source of life, so it is of utmost importance to keep it clean and usable for everyone. Due to anthropogenic activities, water sources are becoming more contaminated with different pollutants, such as organic and inorganic chemicals or microorganisms. Photo- and photoelectrocatalytic methods recently gained more interest in water purification due to their low cost, sustainability, high efficiency, and low environmental impact. Additionally, water can be the source of hydrogen, which is considered the fuel of the future. Also, in this case, photo- and photoelectrocatalytic water-splitting processes are gaining popularity because green hydrogen can be obtained using these methods. However, in both cases, the proper photo- and photoelectrocatalysts must be used for efficient processes. However, these materials still have some water purification and hydrogen production limitations. The disadvantages of the commonly used catalysts include low photoabsorption efficiency, high electron-hole recombination, susceptibility to photocorrosion, high cost, limited sunlight utilization, poor separation efficiency of charge carriers, and specific band gaps and their positions. Hence, designing novel photo- and photo(electro)catalysts, addressing most of the mentioned drawbacks, might help obtain efficient, eco-friendly, and sustainable processes for water purification and hydrogen production.

Since its discovery, graphitic carbon nitride (g-C_3N_4) has gained much attention in photocatalysis. It has excellent chemical and thermal stability and good visible light absorption ability. This material is also non-toxic and eco-friendly and can be obtained from easily available compounds. Unfortunately, its use for water purification and hydrogen production processes has limitations due to low specific surface area,

[1] TRL: Technology Readiness Level; https://ec.europa.eu/research/participants/data/ref/h2020/other/wp/2018-2020/annexes/h2020-wp1820-annex-g-trl_en.pdf

rapid recombination of charge carriers, low transport efficiency, and wide band gap. However, through the formation of heterojunctions, interactions with other materials (such as transition metal oxides, sulfides, or carbon nanomaterials), and structure modifications, the band gap can be easily tuned, and the efficiency of the photo- and photoelectrocatalysis can be significantly increased.

The main objective of the project is the preparation of novel hybrid materials based on g-C_3N_4 with the addition of carbon nanomaterials and transition metal oxides (e.g. TiO_2, Fe_2O_3) or sulfides (e.g. MoS_2) that can be used for photo- and photoelectrocatalytic water purification and hydrogen production. Joining g-C_3N_4 with those materials can increase its specific surface area, enhance its light absorption and charge separation, and increase its stability, durability, and reusability.

In this project, novel approaches to the synthesis of hybrid materials will be proposed. The synthesis techniques that will be used are easily scalable, more sustainable, and less complicated than the commonly used preparation methods. Graphitic carbon nitride will be prepared using various chemical approaches e.g. polymerization method developed at VSB - Technical University of Ostrava. Modification of g-C_3N_4 with MoS_2 and carbon nanomaterials will be carried out by using a method developed at the Warsaw University of Technology. Transition metal oxides will be prepared at Taipei Medical University. The combination of the g-C_3N_4 with transition metal oxides or sulfides and carbon nanomaterials has not been studied widely. The prepared materials will be tested for their photocatalytic ability to remove organic and microbial impurities from water and their photoelectrocatalytic properties for water splitting, producing green hydrogen.

The planned research will result in obtaining materials with better efficiency and stability for photoelectrocatalytic water treatment, ensuring clean water, and using hydrogen for energy applications, priority areas in the battle against climate change.

2. CONSORTIUM OVERVIEW

Attention: PIC is mandatory

CONSORTIUM OVERVIEW						
Organisation	**Partner name (Full name)**	**Coordinator (P1) Warsaw University of Technology (WUT)**	**Partner 2: VSB - Technical University of Ostrava (VSB-TUO)**	**Partner 3: Taipei Medical University (TMU)**		
	Participation Identification Code (PIC) [2]	**999884052**	**999868144**	**950325879**		
	TRL[3] at project start	**2**	**3**	**2**		
	TRL at project end	**4**	**5**	**4**		
	Organisation Type[4]	HE	HE	HE		
	Website (http:…)	www.pw.edu.pl	www.vsb.cz	www.tmu.edu.tw		
	Region / Country	Poland	Czech Republic	Taiwan		
	Organisation registration number[5]	VAT [redacted]	VAT [redacted]	VAT [redacted]		
	Size (Employees) [6]	[redacted]	[redacted]	[redacted]		
	Turnover (K€) [6]	[redacted]	[redacted]	[redacted]		
	Contact person's title / name	[redacted] Pawlicka	Dr. Eng. Monika Michalska	Dr. Chung-Kwei Lin		
	Contact person's telephone	+48607601809	+420596994301	+886920124923		
	Contact person's e-mail	ma[redacted]pw.edu.pl	monika.kinga.michalska@[redacted]	[redacted]tmu.edu.tw		
Funding Organisation (FO)	Name of FO +Contact person in in FO [7]	National Science Centre, Poland Anna Kotarba	Technology Agency of the Czech Republic (TA CR)	National Science and Technology Council (NSTC), Taiwan Ms. Ching-Mei Tang		

[2] Insert Participant Identification Code (PIC) of your organisation as used for participating on Horizon Europe. Information on how to find / get your PIC see FAQs on the Call page.
[3] Technology Readiness Level (see Annex 2 in the Guide for Proposers)
[4] HE-University, RES-Research organisation, SME-Small and Medium sized Enterprise, IND-Large Company, OTH-Others. (according to national rules)
[5] VAT number or other Registration number
[6] Only for companies
[7] **It is strongly recommended to contact M-ERA.NET contact person in your region/country** for further information about funding rules, prior to the submission of a Full-Proposal (see Participating countries & regions Call 2024)

		[redacted] tel. +48 538 185 453	[redacted]	[redacted] nstc.gov.tw		
	Funding Programme (full name[8])	M-ERA.NET	Programme SIGMA	M-ERA.NET		

[8] Name of the funding programme for which the partner is applying

3. EXCELLENCE

3.1 Objectives of the project and expected results

The project focuses on developing novel hybrid materials that can be used for photo- and photoelectrocatalytic water purification and hydrogen production. **The main objective is the preparation of novel hybrid materials based on g-C_3N_4 with the addition of:**

1. **carbon nanomaterials,**
2. **transition metal oxides (e.g. TiO_2, Fe_2O_3),**
3. **and sulfides (e.g. MoS_2).**

Combining g-C_3N_4 with the proposed materials will enhance its specific surface area, light absorption, charge separation, stability, durability, and reusability. It is anticipated that novel hybrid materials with outstanding photo- and photoelectrocatalytic properties will be developed. Hybrid materials based on g-C_3N_4 with the addition of carbon nanomaterials and transition metal oxides or sulfides were not widely reported in the literature. Hence, the research on the properties of these materials is also very important.
The novelty of this project is also connected to the synthesis method of the proposed materials. **One of the project's objectives will be to develop a synthesis protocol for the hybrid materials.** Compared to commonly used methods, the ones developed at partners' institutions are less complicated, more sustainable, and easily scalable. The synthesis protocol will involve choosing the proper method (e.g., synthesis using a microwave reactor, an impinging jet reactor, polymerization method, etc.) and optimizing the quantities of each component of the hybrid material. This approach will allow us to obtain the materials with desired photo(electro)catalytic properties for water purification and hydrogen production.

3.2 Ambition

- *Current state of art and progress beyond the state-of-the-art*

In recent years, clean water and sustainable energy sources have become increasingly urgent due to population growth and climate change. As a result, the development of novel methods for water purification and hydrogen production has received considerable attention. Photo- and photoelectrocatalytic processes are now considered the most promising due to their low cost, sustainability, high efficiency, and low environmental impact. However, the efficiency of these processes is still not satisfying, so one of the solutions to this problem is the design of novel materials that can act as catalysts. Recently, graphitic carbon nitride (g-C_3N_4) emerged as one of the promising materials in this area due to its unique properties, such as high stability, visible light absorption, and excellent photoactivity.
However, it suffers from the low specific surface area, rapid recombination of charge carriers, and low transport efficiency [1,2]. These drawbacks can be overcome by surface modification of g-C_3N_4, formation of heterojunctions, and interactions with other materials (such as carbon nanomaterials, metal oxides, or sulfides) that can alter the band gap, increase its surface area, charge transport, and result in overall increased catalytic activity and stability of these materials [3,4].
The hybrid structures of g-C_3N_4 modified with oxides, such as TiO_2, Fe_2O_3, sulfides, or carbon nanomaterials, showed efficient photocatalytic activity for water treatment, especially for removing organic dyes, pharmaceuticals or pesticides, and microbial contaminants [5-8]. It has also shown promising activity for photoelectrocatalytic water splitting [4,9-11].
A few papers showed that combining g-C_3N_4 with carbon nanomaterials and oxides/sulfides has better efficiency than pure g-C_3N_4 and its hybrid structures with only one additional material [12-14]. Hence, we decided to focus on preparing hybrid materials based on g-C_3N_4 with the addition of carbon nanomaterials and metal oxides/sulfides. However, these materials are often obtained by complicated synthesis techniques that are time- and energy-consuming (such as hydrothermal or calcination methods), so their practical applications are limited [14,15]. Also, the properties of the obtained materials strongly depend on the synthesis method used. Hence, one of the project aims is to obtain hybrid structures involving g-C_3N_4 with novel, easily scalable, and more sustainable methods than the ones currently used. This will lead to materials suitable for water purification and hydrogen production technologies.
Our research team has recently developed novel photocatalysts based on surface-modified g-C_3N_4 nanosheets and bulk materials incorporating silver nanoparticles (Ag NPs) [16]. This low-temperature,

eco-friendly wet synthesis method led to materials with significantly enhanced photocatalytic activity, achieving up to 98% efficiency in photodegradation under visible light. Our study demonstrated that increasing the silver content reduces nanoparticle size, which in turn improves photocatalytic performance. Optimized photocatalytic activity was observed at 1.5 wt% Ag under visible light and 3 wt% Ag under UV light, indicating strong potential for wastewater treatment applications.
In prior work [17], we modified TiO_2 and melem/g-C_3N_4 materials with Ag NPs, where even a minimal Ag content (0.5 wt%) substantially boosted photocatalytic activity. Achieving over 95% photodegradation of acid orange 7 dye under UV light for TiO_2 and melem/g-C_3N_4, and up to 98% under visible light for melem/g-C_3N_4, these modifications proved effective for environmental applications.
More recently [18], our team demonstrated a scalable, cost-effective method to synthesize metal-free g-C_3N_4-based photocatalysts using melamine and thermal treatment in nitrogen or air atmospheres at 400–550°C. This method resulted in photocatalysts with up to 99% efficiency under visible light, providing a sustainable alternative with lower energy requirements. Additionally, our preliminary studies indicate that g-C_3N_4 produced through this method [16] shows promising photoelectrocatalytic activity in hydrogen generation, with illumination resulting in increased cathodic current and hydrogen output (Figure 1).

[redacted]

Figure 1. Chronoamperometry measurements with cyclically illuminated g-C_3N_4-based photocathode at the potential of 0 vs. RHE, in 0.5M H_2SO_4 aqueous solution with FTO glass as an electrode substrate.

The team has also developed a variety of photocatalytic materials using advanced fabrication techniques such as spray pyrolysis, spin coating combined with sol-gel methods, and ink-jet printing with UV-curing procedures [19-21]. These approaches have been tailored to optimize the performance of transition metal oxides for photocatalytic applications. Complementary techniques like scanning electrochemical microscopy have been employed to screen and fine-tune the potential photocatalysts, ensuring effective performance under various operational conditions [22,23]. In parallel, we have studied Zn- and Ag-doped bioactive glasses as antibacterial biomaterials, showcasing enhanced biocompatibility and antimicrobial efficiency [24,25]. Building on this foundation, our research aims to integrate synchrotron-reduced nanocatalysts (e.g., Ag, Pd) with transition metal oxides (e.g., TiO_2, Fe_2O_3) using g-C_3N_4 as a template. These hybrid materials are anticipated to significantly enhance catalytic and photocatalytic abilities, supporting applications in water purification, hydrogen generation, antibacterial performance, and medical waste management.
These efforts align with our previous studies demonstrating high-efficiency photocatalytic systems, particularly g-C_3N_4-based materials modified with Ag nanoparticles, achieving remarkable degradation efficiencies and hydrogen generation capabilities under visible and UV light. This integrated approach offers scalable, eco-friendly solutions for pressing environmental and biomedical challenges.

- *Originality and/or innovation of the proposed approach*

The project aims to prepare novel hybrid materials based on g-C_3N_4 with the addition of carbon nanomaterials and transition metal oxides (e.g., TiO_2, Fe_2O_3) or sulfides (e.g., MoS_2), which can be employed for the photo- and photoelectrocatalytic purification of water and the production of hydrogen. Graphitic carbon nitride (g-C_3N_4) offers a promising platform for developing advanced water purification and hydrogen production materials. Combining g-C_3N_4 with other materials can lead to synergistic effects that enhance the overall performance of the hybrid catalysts.

Since the properties of the materials strongly depend on the preparation method, the project will utilize novel synthesis techniques developed at partners' institutions, which are easily scalable and more sustainable than the commonly used methods. One of the methods will involve the use of an impinging jet reactor for the preparation of semiconductors. This novel technique is simple and scalable, involves low-cost reagents, can be easily controlled, and can be performed continuously [26]. Other techniques will involve using a microwave reactor, which can be used to obtain the material with desired properties in a significantly shorter time than hydrothermal techniques [27,28]. At each project stage, the materials will be thoroughly studied and characterized to understand the relationship between the synthesis conditions and photo(electro)catalytic properties of the hybrid structures. This approach will allow the future design of efficient catalysts for water purification and hydrogen production. The project partners' extensive experience and expertise will be used to propose the most suitable conditions for synthesizing the advanced hybrid materials and identify the most suitable materials from those available for the aforementioned applications. These materials should possess optimal properties, ensuring their functionality and applicability.

- *Key results of the project and innovation potential*

The AH-Nano-Cat project focuses on the development of innovative hybrid materials with strong potential for photo- and photoelectrocatalytic applications in water purification and hydrogen production. By combining partners from three different countries, each with distinct starting and ending TRLs, the project will bridge basic and applied research. Specifically, understanding the relationship between synthesis methods and material properties will enable the design of a sustainable and scalable synthesis process, resulting in materials with optimal properties suitable for commercial applications. Additionally, the project will lay the groundwork for future studies into hybrid photocatalytic materials, offering valuable insights into material interactions, photocatalytic mechanisms, and synthesis techniques. The knowledge generated will benefit both academic research and industrial applications, supporting advances in sustainable environmental technologies.

3.3 Concept and approach

- *Overall concept*

The synthesis of novel hybrid materials based on g-C_3N_4 will involve the creation of a facile chemical approach to obtain pristine g-C_3N_4 material and its composites. This will include the addition of carbon nanomaterials, transition metal oxides (eg. TiO_2, Fe_2O_3) or sulfides (eg. MoS_2) which may help us to achieve improved efficiency and durability in photo- and photoelectrocatalytic processes for water purification and hydrogen production. The synthesis protocol will involve the use of novel, sustainable and easily scalable methods developed at partner institutions (e.g. wet chemical synthesis with the use of an impinging jet reactor). These methods require less energy compared to the traditional synthesis techniques and can be performed without the use of harmful chemicals. During the project, the obtained materials will be thoroughly studied, so it will be possible to choose the most efficient catalysts for water purification and hydrogen production, and most importantly propose a synthesis method that could be used in the future for big-scale production.

- *Start and target TRL*

All project Partners are from different universities. Depending on the country and the funding agency requirements, the project will start with TRL 2 or TRL 3 and end with TRL 4 or TRL 5.

The Warsaw University of Technology part of the project on green hydrogen production will start at TRL 2 and conclude at TRL 4, focusing on foundational research to develop and validate novel materials for photoelectrocatalytic hydrogen production. Beginning at TRL 2, WUT will explore innovative synthesis methods to create materials with improved photo(electro)catalytic properties, combining components that have shown individual potential in hydrogen generation but have not yet been extensively studied as integrated systems. The research will investigate how synthesis techniques affect the materials' catalytic efficiency, aiming to optimize their structure and properties. As the project advances to TRL 4, the materials will undergo testing under laboratory conditions to evaluate their photoelectrocatalytic performance in generating green hydrogen. This testing phase will validate the scalability and effectiveness of the synthesis methods, establishing a foundation for future application and potential scale-up in sustainable hydrogen production processes.

For the VSB – Technical University of Ostrava part of the project, the research will start at TRL 3 and progress to TRL 5. VSB-TUO will be responsible for the preparation and surface modification of graphitic carbon nitride (g-C_3N_4), focusing on improving its photocatalytic properties for wastewater treatment. The initial phase at TRL 3 will involve optimizing the synthesis methods and surface modifications to enhance the catalytic activity and stability of the material. As the project advances toward TRL 5, VSB-TUO will conduct more extensive testing of the modified g-C_3N_4 materials in photocatalytic wastewater treatment systems. This stage will assess the scalability of the materials and their real-world applicability in environmental applications, ensuring their performance is maintained under practical conditions.

For the Taipei Medical University part of the project, the research will start at TRL 2 and end at TRL 4. Beginning at TRL 2, TMU will explore innovative synthesis methods to create materials with the addition of metal oxides (such as TiO_2 or Fe_2O_3) with enhanced properties for both photocatalytic applications in hydrogen production and their antibacterial effectiveness. At the TRL 2 stage, TMU will conduct basic research on the synthesis and modification of these materials, investigating how different preparation methods affect their photocatalytic efficiency and antibacterial properties. As the project progresses to TRL 4, TMU will focus on characterizing the antibacterial properties of the prepared materials and testing their performance in laboratory settings. This phase will include refining the materials' structure and ensuring their safety and efficacy for practical applications, particularly in environmentally sustainable technologies.

- *Approach to Responsible Research & Innovation*

Several strategies from Responsible Research & Innovation (RRI) will be integrated into the project. The aim is to ensure that the project's outcomes have a significant impact on both the environment and society. This will be achieved through the development of materials suitable for water purification and hydrogen production. The synthesis approach will prioritize proposing more sustainable preparation techniques that are easily scalable, require minimal energy consumption, and avoid the use of harmful chemicals and processes.

The project aims to create hybrid materials for water purification and hydrogen production with a focus on sustainability, responding to societal needs for clean water and renewable energy. The environmental impact is carefully considered through the use of eco-friendly synthesis methods that minimize energy consumption, avoid harmful chemicals, and prioritize scalable production techniques.

Stakeholder engagement is central to the project, allowing diverse perspectives to shape the research direction and outcomes. Regular consultations with industry partners, regulatory bodies, and end-users ensure that the developed materials are safe, effective, and aligned with real-world applications. This collaboration fosters transparency and public trust, as the project openly communicates its progress and findings.

Ethical considerations are also embedded in the project's framework, ensuring compliance with legal and social standards for safety, data protection, and environmental impact. Additionally, the project promotes inclusivity by encouraging diverse input and ensuring the accessibility of results to the broader research community. By aligning with RRI principles, AH-Nano-Cat aims not only to advance innovative materials for environmental applications but also to contribute positively to society, supporting sustainable and responsible technological development.

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4. IMPACT

4.1 Contribution at the European or international level to the expected impacts listed under the selected call topic

The United Nations Agenda 2030 for Sustainable Development, particularly Goal 6: „Ensure availability and sustainable management of water and sanitation for all“, and Goal 7: „Ensure access to affordable, reliable, sustainable and modern energy for all“ align with the main aims of the project that falls within the **Materials addressing environmental challenges** topic. The AH-Nano-Cat aligns perfectly with broader sustainability objectives, given the critical importance of clean water and green hydrogen in achieving sustainability goals. The project contributes to the transition towards a more sustainable and resilient future by promoting developing and deploying cleaner and more efficient technologies.

- **Scientific impacts**

The AH-Nano-Cat consortium comprises researchers with expertise in diverse fields, including chemical engineering, materials science, surface chemistry, and physical chemistry. Our interdisciplinary approach will facilitate scientific excellence, enabling us to achieve the ambitious objectives in this proposal. Throughout the project, the properties of the materials based on g-C_3N_4 will be examined to propose the best synthesis method, resulting in the most efficient photo(electro)catalysts for water purification and hydrogen production. This all-inclusive strategy, which covers sustainable material preparation, surface modification, physicochemical characterization, and photo(electro)catalytic testing, will yield an in-depth and useful result. The results obtained in this project will be published in prestigious journals (including Open Access options to ensure a better availability to the wider audience), presented at international conferences, and will be available on a project website.
The project will provide the researchers involved in the Consortium with access to a collaborative international environment, enabling the exchange of knowledge and expertise with leading institutions. This collaboration will enhance all the involved partners' research capacity, strengthen their position in the global scientific community, and increase the visibility of their research outputs. In addition to advancing knowledge, the project will support the training of young scientists and graduate students, equipping them with valuable skills in nanomaterials synthesis, characterization, and application. The insights gained from the project will not only contribute to academic research but also pave the way for future collaborations and applications in industrial and technological innovations.

Partner 1 (Coordinator): WUT will strengthen its research capacity in photoelectrocatalytic processes by exploring novel synthesis methods and understanding the interplay between material properties and catalytic performance. This will position WUT as a leader in basic research on advanced hybrid nanomaterials while supporting the training and development of young scientists.

Partner 2 (VSB-TUO): VSB-TUO will focus on scaling up the materials and validating their performance in near-real-world conditions. This contribution will enhance VSB-TUO's expertise in translating laboratory-scale innovations to pilot-scale applications, bridging the gap between fundamental research and practical implementation.

Partner 3 (TMU): TMU will benefit by integrating its experience in material characterization and biological safety into the consortium's efforts. TMU's involvement will ensure that the developed materials are safe for environmental applications, adding a unique dimension to the project's interdisciplinary approach.

- **Economic impacts** *(for low TRLs present the visions for potential industrial use)*

The AH-Nano-Cat project focuses on preparing novel efficient photo(electro)catalysts for water purification and hydrogen production, which carries significant economic benefits. Because partners from three different countries are involved, international cooperation will be strengthened, which might lead in the future to technology and knowledge transfer, as well as innovation exchange between the participating countries, and enhancing their global competitiveness. The materials planned to be obtained in the project have a very high potential for industrial use. Many companies are now focusing on using novel methods for clean hydrogen production and water purification, so they might widely use g-C_3N_4-based photo(electro)catalysts in these technologies. Initial interest in the project's outcomes has already been expressed by two companies, Hydrogen Taiwan Co., Ltd., and GUS Technology Co., Ltd. (see attached Letters of Intent), both specializing in hydrogen technologies and novel materials for clean energy production. This indicates a strong potential for collaboration in developing and commercializing the project's innovative materials for green hydrogen production and sustainable energy solutions. Proposing a scalable and sustainable synthesis method for these materials will be crucial for their commercialization. However, further investments and research will be needed to bring these materials to market, requiring skilled professionals to support research, development, manufacturing, and implementation, which will contribute to the creation of new job opportunities. Throughout the project, the AH-Nano-Cat consortium members will actively seek additional companies and investors interested in commercializing the materials. This will be achieved by engaging with industry stakeholders through conferences, workshops, and networking events, as well as utilizing existing connections in the hydrogen, water treatment, and clean energy sectors. Additionally, the consortium will explore strategic partnerships, joint ventures, and licensing agreements to accelerate the commercialization process and attract investment for scaling up production.

Partner 1 (Coordinator): The involvement of WUT in the AH-Nano-Cat project will attract industry interest, boosting collaboration opportunities with both local and international companies, including the two companies that have already shown interest. This engagement will provide opportunities for research commercialization, knowledge transfer, and new collaborations, potentially leading to increased funding, new projects, and industry partnerships.

Partner 2 (VSB-TUO): The participation of VSB-TUO in the AH-Nano-Cat project is expected to drive industrial collaborations by developing innovative materials for water purification and clean energy applications. These advancements have the potential to attract interest from European and international companies, creating opportunities for research commercialization and knowledge transfer. The expertise gained will position VSB-TUO to secure additional funding and strengthen its role in industry-academic partnerships. This collaboration may also lead to economic benefits in the region through the commercialization of project outcomes and the development of new technologies.

Partner 3 (TMU): The success of the enterprises in Taiwan is based on the innovative leading technologies that are supported by the Government and a strong combination from the industries, officials, and academics. The novel hybrid materials developed by the AH-Nano-Cat project will be beneficial not only to the Taiwanese economics (two companies already show their interests) but also the team members in Europe. TMU encourages faculties to spin-off companies with innovative technology. With the help from the partners in Europe, we believe it will be much easier to have an impact worldwide.

4.2 Significance of the project results and user benefit

- *Innovation capacity and integration of new knowledge*

The AH-Nano-Cat project demonstrates significant innovation capacity by combining the expertise of partners from three different countries, each contributing their unique knowledge and skills. WUT will contribute with their expertise in carbon nanomaterials, sulfides and photoelectrocatalytic water splitting processes. VSB-TUO will contribute with their expertise in g-C_3N_4 synthesis and photocatalytic water purification processes. TMU will contribute with their expertise in metal oxide and metallic nanoparticles synthesis and defining the antibacterial properties of materials. The project aims to develop novel hybrid materials with a focus on their application in water purification and hydrogen production, both of which are critical areas for sustainable development. Through this collaboration, the consortium will integrate cutting-edge research in materials science, catalysis, and environmental technologies, pushing the boundaries of current understanding. The integration of new knowledge will occur through a continuous exchange of research findings and data across the partners. By focusing on scalable and sustainable synthesis methods, the project will generate valuable insights into how material properties can be optimized for specific applications, such as photo(electro)catalytic water purification and hydrogen production. This research will not only advance the academic understanding of these materials but also offer practical solutions to real-world challenges. The knowledge generated will directly benefit both the scientific community and industry stakeholders, particularly in the development of new materials for clean energy and environmental technologies. The project results will contribute to the creation of new intellectual property and patents. This innovation capacity is expected to lead to the commercialization of novel technologies, potentially transforming current practices in water purification and hydrogen production.

- *Competitiveness and growth of companies (market analysis where relevant)*

The materials and methods proposed in the AH-Nano-Cat project are highly competitive compared to current technologies for water purification and hydrogen production. Compared to conventional water purification methods like reverse osmosis or chemical disinfection, which are energy-intensive and require frequent maintenance, photocatalysis offers a more sustainable and lower-maintenance alternative. Similarly, while current hydrogen production methods such as steam methane reforming (SMR) or water electrolysis are either carbon-intensive or costly, photo(electro)catalysis offers a cleaner and potentially cheaper method by utilizing solar energy. However, these technologies still have some significant challenges to overcome. The main issue hindering the widespread use of the innovative hybrid materials based on g-C_3N_4, enhanced with carbon nanomaterials and transition metal oxides (e.g., TiO_2, Fe_2O_3) or sulfides (e.g., MoS_2), is their relatively limited efficiency and stability under real-world conditions. While these materials have shown promise in controlled laboratory settings, scaling them up for practical applications faces efficiency constraints, such as low light absorption, high electron-hole recombination rates, and limited light spectrum utilization. Additionally, their stability under harsh environmental conditions—such as photocorrosion and wear—can reduce their performance and lifespan. The AH-Nano-Cat project seeks to address these challenges by incorporating strategic modifications, such as doping with metals, creating nanocomposites, and incorporating protective coatings to enhance the efficiency, stability, and longevity of the materials. Another challenge is the scalability and economic viability of the materials. While the components are abundant, the key to market success lies in minimizing production costs through sustainable, scalable, and cost-effective synthesis methods. Innovations in green synthesis and low-cost precursors are essential for bridging the gap between laboratory-scale research and industrial-scale applications. The development of these materials holds significant potential for transforming water purification and green hydrogen production technologies, addressing global challenges such as water scarcity and the need for renewable energy. Furthermore, the successful implementation of these materials can drive market growth in the green chemistry and renewable energy sectors, attracting interest from companies focused on clean technologies and sustainable infrastructure. This project lays the foundation for future academic and industrial collaborations, developing further research and commercial interest, and catalyzing the transition to eco-friendly solutions.

Partner 1 (Coordinator): For WUT, the project will strengthen its position as a leading research institution in the field of advanced nanomaterials and green hydrogen technologies. Through the development of new hybrid nanomaterials, WUT researchers will gain valuable knowledge and skills in materials science, catalysis, and sustainable hydrogen production. This will enhance WUT's innovation capacity, enabling it to integrate cutting-edge scientific advances into its curriculum and research programs. Quantitatively, the project is expected to result in a significant increase in high-impact publications, patents, and academic partnerships, reinforcing WUT's reputation globally. By proposing innovative solutions in photoelectrocatalytic hydrogen production, WUT stands to attract new research funding and strengthen collaborations with industry partners in the clean energy sector. These advancements could lead to licensing opportunities for proprietary nanomaterials or spin-offs that commercialize lab-scale innovations.

Partner 2 (VSB-TUO): Participation of VSB-TUO in the AH-Nano-Cat project will enhance its expertise in the development of advanced hybrid nanomaterials for environmental and energy applications, especially in photocatalysis and water treatment. The project will boost the university's reputation in sustainable material science and increase its visibility through high-impact publications and potential patents. Collaboration with industrial partners will open opportunities for technology transfer, commercialization, and future joint ventures. The project's results will also strengthen the ability to secure funding for further research and start new international partnerships in the fields of clean energy and environmental technologies.

Partner 3 (TMU): For TMU, this project investigates the novel hybrid materials not only for environmental and energy applications but also for medical waste treatment and antibacterial applications concerning public health issues. TMU team will deepen their expertise in materials science, antibacterial, photo- and photoelectrocatalysis, laying the foundation for future technological breakthroughs. The Taiwanese government emphasizes research on water purification and green energy technologies. TMU team with its industrial partners (please see LoIs for details) can play an important role concerning this issue. The strong AH-Nano-Cat team can extend the impact to Asian countries and worldwide.

4.3 Sustainability and RRI

The AH-Nano-Cat project addresses urgent environmental issues: water purification and clean energy production. Both topics will be resolved using a sustainable photo(electro)catalysis approach, so the energy source used for these processes will be renewable. Also, an important factor that will be addressed during research in the project is developing a sustainable synthesis method. In this case we propose a synthesis protocol without harmful chemicals, based on aqueous solutions, and with limited energy consumption. This approach aligns with goals 6 and 7 of the UN Sustainable Development Goals: „Ensure availability and sustainable management of water and sanitation for all", and "Ensure access to affordable, reliable, sustainable and modern energy for all". Since the project will be carried out in an international consortium, it can become a platform for exchanging ideas and experiences between researchers with different scientific and cultural backgrounds. In the project, a wide diversity of people will be engaged, including researchers with different cultural backgrounds (involving Central European and Asian countries) and stages of their experience (ranging from early-stage to senior researchers). Women will be involved in conducting the proposed research at each project partner, and the Project Coordinator is a woman. These are the factors for reassuring gender, ethnicity, and intersectional equality, diversity, and inclusivity. The consortium will have regular online and in-person (at least once per year) meetings to discuss the results obtained and plan further development. This will be a great opportunity to extend research networks and become the base for future funding applications. During the meetings, an exchange of ideas will occur. It will be an excellent space for early-stage researchers to demonstrate their findings to an international audience. One of the outcomes of the meetings will be scientific publications, which are planned to be published in Open Access journals to assure access to the gained knowledge for the public.

Circularity and Environmental Dimensions: The AH-Nano-Cat project strongly emphasizes circularity and environmental sustainability through the design of innovative materials and processes that prioritize waste minimization, recyclability, and resource efficiency. By employing easily scalable, more sustainable, and less complicated synthesis methods and using abundant, eco-friendly materials such as graphitic carbon nitride (g-C_3N_4), the project minimizes the environmental footprint associated with material production. The photo(electro)catalysts developed are designed to be durable and recyclable, promoting a closed-loop lifecycle that reduces reliance on non-renewable resources and aligns with circular economy principles. The project's water purification processes reclaim contaminated water for reuse, addressing water scarcity while minimizing waste. Additionally, hydrogen production via photo(electro)catalysis relies on water as a renewable resource, generating green hydrogen with zero carbon emissions, further contributing to climate action targets. Through life cycle-oriented design and renewable energy integration, the project delivers sustainable solutions that align with global environmental goals.

Ethical, Political, Social, and Cultural Dimensions: AH-Nano-Cat considers the ethical implications of resource use, ensuring that production and deployment of the technology adhere to safety and non-toxicity standards. Socially, the project will contribute to the well-being of communities by providing clean water solutions and sustainable energy alternatives. The work will be inclusive and respectful of the diverse socio-political contexts of its international partners, promoting collaboration that bridges cultural divides. The project's collaborative framework will encourage mutual learning and knowledge sharing among researchers from Central Europe and Asia, promoting cultural inclusivity and innovation that respects the social norms of the involved regions. This approach underscores the commitment to Responsible Research and Innovation (RRI), ensuring that the outcomes are ethically sound, socially beneficial, and politically neutral.

Gender Relevance and Balance: The project is committed to the advancement of gender equality, with a particular emphasis on providing an inclusive environment within the consortium. Among the key personnel, women are strongly represented, including the Project Coordinator, ensuring gender balance at leadership levels. The project encourages the participation of researchers at different career stages, supporting the development of female leaders in science. This commitment to gender balance aligns with broader goals of enhancing diversity and equity in STEM fields and academia.

4.4 Dissemination and exploitation strategy

Describe for each partner measures to disseminate and exploit the project results and to maximise the impact.

The AH-Nano-Cat consortium has devised a comprehensive dissemination and exploitation strategy that takes advantage of each partner's strengths to increase the project's impact. This includes joint publications, conference presentations, a dedicated project website, and outreach via social media or events. To exploit project outcomes, the consortium will pursue patents, licensing agreements, and industry partnerships, particularly in water purification and renewable energy. This strategy ensures that the knowledge gained is shared with the scientific community, industry, and broader public, aligning with sustainability and Responsible Research and Innovation (RRI) principles.

4.4.1 Management of intellectual property rights (IPR)

The AH-Nano-Cat project will implement a comprehensive intellectual property rights management strategy to ensure the fair protection and use of intellectual property within the consortium. This strategy will align with each partner's internal guidelines and local regulations, and will be formalized in a Consortium Agreement (CA). The CA will outline ownership of both Background IP (pre-existing IP) and Foreground IP (new IP generated during the project), with each partner retaining ownership of their Background IP while granting others provisional access on a need-to-use basis. For Foreground IP, ownership will be shared based on each partner's contribution, with provisions for joint ownership. The CA will also cover confidentiality, publication terms, and the commercialization of project outcomes. While there are currently no industry partners involved, two companies have provided Letters of Intent (LOI), and additional industry partners will be sought throughout the project to explore commercialization opportunities. Licensing and revenue-sharing terms will be established in advance to ensure transparency and equitable benefit distribution once industry partners are onboard. Regular reviews will ensure ongoing alignment with the project's goals, enabling smooth collaboration and maximizing the scientific and commercial impact of the project's results.

4.4.2 Dissemination activities of project results

The AH-Nano-Cat project will undertake a wide range of dissemination activities to ensure that its results reach diverse audiences and maximize impact. These activities will include joint publications in high-impact scientific journals (e.g., *Journal of Materials Chemistry A, Applied Materials & Interfaces, Applied Catalysis B: Environmental*, etc.) with Open Access feature, presentations at international conferences (e.g., *MRS and E-MRS* spring or autumn meetings, *Materials Week, Euromat,* etc.), and contributions to specialized workshops to engage the scientific community and stakeholders in relevant fields such as water purification, hydrogen production, and materials science. The project will also create and maintain a dedicated project website to provide regular updates, share key findings, and highlight the progress of the research. Social media campaigns, and outreach events will be organized to increase visibility and engage with a broader public, including policymakers, environmental organizations, and industry representatives. To drive the knowledge transfer, the project will collaborate with relevant stakeholders, including universities, research institutions, and industry partners, to showcase the potential applications of the research. Additionally, materials and results will be shared through open access platforms, ensuring accessibility and facilitating the exchange of knowledge. Through these activities, the AH-Nano-Cat project aims to contribute to scientific advancement, raise awareness of its findings, and promote the adoption of its technologies in water treatment and renewable energy sectors. The respective provisions in the Consortium Agreement will regulate the procedure for the presentation of project results.

Partner 1 (Coordinator): WUT is planning to publish at least two papers related to hybrid materials based on g-C_3N_4, carbon nanomaterials, and MoS_2 in top journals (e.g., *Carbon Energy, Carbon*, etc.) and present project results at least once per year at key events like *Carbon* conference.

Partner 2 (VSB-TUO): VSB-TUO will focus on publishing at least two joint research papers on scalable synthesis methods for g-C_3N_4 and hybrid materials in high-impact journals (e.g., *Green Chemistry, Applied Surface Science, etc.)* and present findings at leading international conferences such as *MRS Spring Meeting.*

Partner 3 (TMU): TMU will disseminate research results on the hybrid materials through joint publications in high-ranking (Q1) journals (e.g., *Materials Today Energy*, *Chemical Engineering Journal*, etc.), conference presentations (e.g., *E -MRS*, *Materials Today conferences*, etc.), and workshops. At least two SCI papers and one international presentation are planned.

4.4.3 Plans for the commercialisation of results

The AH-Nano-Cat project will pursue commercialization strategies aimed at transforming scientific advancements into real-world applications, with a focus on water purification and renewable energy sectors. Although there are no industry partners involved in the project consortium, two companies have provided Letters of Intent (LOIs), and additional collaborations will be sought as the project progresses. The commercialization plans include the exploration of licensing agreements with industry stakeholders in the water treatment and energy sectors, which will allow for the commercial exploitation of key technologies developed during the project. These licensing agreements will enable companies with the necessary resources to scale and implement the technologies in industrial settings.
If the project results demonstrate strong innovation potential, the consortium may also consider establishing spin-off companies or joint ventures to commercialize the technologies. These spin-offs would focus on translating research outcomes, particularly in the area of photocatalysis, into practical, commercial solutions for industrial-scale water treatment and hydrogen production. The consortium will also pursue technology transfer opportunities with universities, research institutions, and industry players, facilitating the transition of the project's findings from the research phase to commercial production. This could involve licensing patents and sharing expertise with partners interested in applying the developed technologies.
Patent protection will be a key part of the commercialization strategy, with the consortium planning to file patents on key innovations arising from the project to secure intellectual property rights. This will be managed through the Consortium Agreement, ensuring fair distribution of patent ownership among partners. By building a robust IP portfolio, the consortium will create opportunities for licensing or selling the patents to interested parties for commercialization. Furthermore, small and medium-sized enterprises (SMEs) working in materials science, environmental technologies, and clean energy will be targeted for collaboration. These SMEs may be interested in the novel materials and technologies developed, providing an avenue for rapid commercialization and integration into existing products or services.
To support these efforts, the consortium will conduct market assessments and feasibility studies to identify the most promising applications and market opportunities for the developed technologies, ensuring that commercialization efforts align with market demand. Through these strategies, the AH-Nano-Cat project aims to deliver tangible, sustainable solutions to the water purification and renewable energy sectors while maximizing the commercial potential of its innovations.

Partner 1 (Coordinator): The works planned in the project aim to advance the green hydrogen production technology by photoelectrocatalytic processes from TRL 2 (basic research) to TRL 4 (laboratory validation of components). This will allow to undertake actions that will demonstrate core feasibility, establishing the technology's fundamental principles and unique benefits over current hydrogen production methods, as well as testing the prototype components in controlled lab settings, leading to reliability assessment, scalability and integration potential. Additionally, a preliminary market analysis will be conducted to identify high-potential applications and industry stakeholders interested in sustainable hydrogen solutions. IP protection will be established for the developed technology, ensuring future commercialization rights.

Partner 2 (VSB-TUO): The objective is to prepare and modify the surface of graphitic carbon nitride, and to conduct further studies of the proposed materials in photocatalysis for wastewater treatment - TRL 5. The results will be shared with companies for industrial testing. The materials can be used in wastewater treatment, medical applications, or the energy industry, among other applications. VSB-TUO plans to file at least 2 functional samples (Gfunk - funkční vzorek) from obtained project results.

Partner 3 (TMU): With the novel catalysts and photocatalysts (nanocatalysts-transition metal oxides decorated on g-C_3N_4) developed within the project, in addition to its application in hydrogen energy, the antibacterial performance for water purification and medical waste management will be investigated. At the end of the project, the as-prepared materials can reach TRL 5 and share with industrial partners (two companies have already agreed). During the project, we will continue to seek suitable industrial partners and might even start a spin-off company that is highly encouraged by TMU.

4.4.4 Management of research data

The AH-Nano-Cat project will implement a streamlined research data management strategy to ensure efficient, secure, and ethical handling of data across all partners. Adhering to the FAIR principles (Findable, Accessible, Interoperable, Reusable), the consortium will maintain a shared data repository for storing and managing datasets, metadata, and documentation. Access to the repository will be governed by the Consortium Agreement, ensuring transparency and safeguarding sensitive or proprietary information. Standardized protocols for data collection, analysis, and sharing will be followed, and datasets intended for publication will be made available on open access platforms whenever possible, in compliance with EU data protection and open science guidelines. Regular backups, encryption, and controlled access will safeguard data integrity, and long-term preservation strategies will ensure the availability of key datasets for future research and innovation.

Partner 1 (Coordinator): Data generated at WUT will be stored on secure university servers integrated with a local repository, ensuring compliance with FAIR principles and EU data protection standards. While project-wide datasets will be shared through the consortium's repository, WUT will additionally host high-impact results on publicly accessible platforms like *OpenAIRE* or *Zenodo* to enhance dissemination and visibility. Institutional guidelines on ethical and secure data handling will ensure both proprietary data protection and open access publication where applicable.

Partner 2 (VSB-TUO): VSB-TUO will handle data using its university infrastructure, employing standardized protocols for data collection, storage, and sharing while ensuring security and accessibility for consortium partners.

Partner 3 (TMU): TMU will utilize its institutional systems for managing research data, focusing on secure storage, effective collaboration, and compliance with the consortium's guidelines for sharing and publication.

5. IMPLEMENTATION

5.1 Work plan

5.1.1 Overview

Describe briefly the overall structure of the work plan.

The project is divided into four work packages, where each partner of the consortium will be responsible for one work package connected to the application of materials and tasks in the work package connected to the preparation of the materials. The responsibilities for the tasks and work packages are connected to the expertise of each project partner. This will allow for the effective achievement of the established goals.

Table: Work package list

WP no.	Work package title	Work package leader	Participating project partners	Start [month]	End [month]
1	**Synthesis of hybrid nanomaterials based on g-C_3N_4**	Warsaw University of Technology (Partner 1, WUT)	VSB-TUO (Partner 2), TMU (Partner 3)	1	36
2	**Testing the prepared materials for photoelectrocatalytic hydrogen production**	Warsaw University of Technology (Partner 1, WUT)	0	7	36
3	**Testing the prepared materials for photocatalytic removal of organic dyes from water**	VSB - Technical University of Ostrava (Partner 2, VSB-TUO)	0	7	36
4	**Testing the antibacterial properties for water purification and managing medical waste of the prepared materials**	Taipei Medical University (Partner 3, TMU)	0	7	36

5.1.2 Detailed description of work package

WP number:	1
WP title:	**Synthesis of hybrid nanomaterials based on g-C_3N_4**
Leader:	Warsaw University of Technology (Partner 1, WUT)
Partners involved:	VSB-TUO (Partner 2), TMU (Partner 3)
Start date:	Month 1
End date:	Month 36
Objectives:	The objective of Work Package 1 is the development of facile synthesis methods to obtain pristine g-C_3N_4 material and its composites. This will include the incorporation of carbon nanomaterials (e.g., carbon dots, carbon nanotubes, reduced graphene oxide, etc.), transition metal oxides (e.g., TiO_2, Fe_2O_3), or sulfides (e.g., MoS_2) to achieve enhanced efficiency and durability in photo- and photoelectrocatalytic water purification and

	hydrogen production processes. The produced materials will be made available to other work packages for further investigation and assessment of their suitability for specific applications.
Type of activities:	WP1 is connected to the development of preparation methods for novel hybrid materials based on g- C_3N_4 with the addition of carbon nanomaterials and metal oxides or sulfides. The activities taken in this WP are connected to low TRLs and focus on fundamental research to establish scalable, reproducible synthesis protocols and thoroughly characterize the physicochemical properties of the materials. These activities lay the groundwork for subsequent testing and application in higher TRL-focused work packages, ensuring the transition from basic material development to applied technologies. Due to thorough material characterization it will be possible to understand the connection between the synthesis technique and the catalytic and antibacterial activity of the obtained materials.
Description of content:	The WP1 will be divided into the following tasks: Task 1.1: Preparation of g-C_3N_4 using various chemical approaches (months: 1–24) The partner responsible for this task will be VSB-TUO. The synthesis of g-C_3N_4 material will be conducted, i.e., via thermal condensation from carbon precursors, including melamine, dicyanamide, and urea. The synthesis process will involve the analysis of process conditions, such as temperature and heating time, to obtain organic carbon materials based on g-C_3N_4 with relevant photo- and photoelectrocatalytic properties. In the next step, the as-synthesized bulk g-C_3N_4 material will be used to prepare the nano-g-C_3N_4 material. Task 1.2: Preparation of g-C_3N_4 with the addition of carbon nanomaterials (carbon dots, carbon nanotubes, rGO, GO) (months: 1–24) The partner responsible for this task will be WUT. The addition of carbon nanomaterials to g-C_3N_4 prepared in task 1.1 will be carried out using various methods. One of the approaches will be based on the sonochemical method, where the proper materials (carbon nanotubes, rGO) will be added to g-C_3N_4 and mixed with the assistance of ultrasounds. The other approach assumes the preparation of carbon dots on g-C_3N_4 using an arc discharge method developed at WUT. The carbon nanomaterials will be used in their raw and functionalized forms. The quantity and type of the carbon nanomaterial added to g-C_3N_4 will be the subject of investigation. The influence of the added carbon nanomaterials on the photo- and photoelectrocatalytic properties of g-C_3N_4 will be studied. These hybrid materials will be used for additional functionalization with transition metal sulfides or oxides. Task 1.3: Preparation of g-C_3N_4 with the addition of carbon nanomaterials and sulfides (e.g. MoS_2) (months: 13–36) The partner responsible for this task will be WUT. Transition metal sulfides will be prepared using methods developed at WUT using different reactors (e.g., impinging jet reactor and microwave reactor). The addition of transition metal sulfides (e.g. MoS_2) to the materials obtained in task 1.2 will be carried out using either a sonochemical approach or a direct precipitation method using the aforementioned techniques. The amount and type of the transition metal sulfides will be investigated, and the proper synthesis technique will be proposed. The influence of the added transition metal sulfides on the photo- and photoelectrocatalytic properties of hybrid structures based on g-C_3N_4 and carbon nanomaterials will be studied. Task 1.4: Preparation of g-C_3N_4 with the addition of carbon nanomaterials and TiO_2 (months: 1–24)

	The partner responsible for this task will be TMU. Titanium dioxide (TiO_2) will be prepared using chemical wet synthesis methods, including sol-gel, spray pyrolysis, hydrothermal, and co-precipitation, on the materials obtained in task 1.2. To enhance the photocatalytic properties of TiO_2 additional doping with metallic elements (e.g. Ag, Pt, Pd, etc.) might be conducted. Screening of optimal doping elements will be performed by scanning electrochemical microscopy. The effect of doping transition metal oxide and synthesis techniques on the properties of the hybrid materials will be evaluated. The photo(electro)catalytic and antibacterial properties and their performance for medical waste treatment of these hybrid materials will be investigated. Task 1.5: Preparation of g- C_3N_4 with the addition of carbon nanomaterials and Fe_2O_3 (months: 13–36) The partner responsible for this task will be TMU. Ferric oxide (Fe_2O_3) with optimal doping will be prepared using the aforementioned chemical synthesis methods on the materials obtained in task 1.2. Synchrotron X-ray reduction technique will be used to decorate hybrid materials with nano-sized catalysts (Ag, Pd, and Pt). The effect of doping transition metal oxide and decorating nanocatalysts on these hybrid materials' photo(electro)catalytic and biomedical performance will be investigated.
Milestones:	*M 1.1.1 (month: 12): Methodology for the scalable synthesis of bulk* g-C_3N_4 *materials as a function of temperature and time with physicochemical properties of the obtained materials.* *M 1.1.2 (month: 24): Methodology for the scalable synthesis of nano-*g-C_3N_4 *materials as a function of temperature and time with physicochemical properties of the obtained materials.* *M 1.2.1 (month: 18): Methodology for the scalable synthesis of hybrid materials based on* g-C_3N_4 *and carbon nanomaterials using the sonochemical method with physicochemical properties of the obtained hybrid structures.* *M 1.2.2 (month: 24): Methodology for the scalable synthesis of hybrid materials based on* g-C_3N_4 *and carbon nanomaterials using the arc discharge method with physicochemical properties of the obtained hybrid structures.* *M 1.3.1 (month: 30): Methodology for the scalable synthesis of hybrid materials with the addition of transition metal sulfides using the sonochemical method with physicochemical properties of the obtained hybrid structures* *M 1.3.2 (month: 36): Methodology for the scalable synthesis of hybrid materials with the addition of transition metal sulfides using the direct precipitation method with physicochemical properties of the obtained hybrid structures.* *M 1.4.1 (month: 12): Methodology for the scalable synthesis of* TiO_2 *with optimal doping.* *M 1.4.2 (month: 24): Methodology for the scalable synthesis of hybrid materials based on* g-C_3N_4 *and carbon nanomaterials with the addition of optimal transition metal oxides.* *M 1.5.1 (month: 24):* Methodology for the scalable synthesis of hybrid materials based on g-C_3N_4 and carbon nanomaterials with the addition of transition metal oxide doped-Fe_2O_3. *M 1.5.2 (month: 36):* Methodology for the scalable synthesis of hybrid materials with synchrotron X-ray reduced nanocatalysts.
Expected results and deliverables:	The main expected results are: scalable syntheses of bulk and nano-g-C_3N_4 materials, hybrid materials based on g-C_3N_4 and carbon nanomaterials,

	hybrid materials, TiO_2 with optimal doping with the addition of transition metal sulfides, hybrid materials based on g-C_3N_4 and carbon nanomaterials with the addition of optimal transition metal oxides, and the methods of their fabrication with the whole details about their physicochemical characterizations. The materials will be tested for photoelectrocatalytic hydrogen production (WP2), photocatalytic removal of organic dyes from water (WP3), and the antibacterial properties (WP4) of the prepared materials for water purification processes. The biomedical performance (WP4) of the obtained materials will also be considered. *D 1.1.1 (VSB-TUO, month 24): report on the scalable synthesis of bulk and nano-g-C_3N_4 materials.* *D 1.2.1 (WUT, month 24): report on the scalable synthesis of hybrid materials based on g-C_3N_4 and carbon nanomaterials.* *D 1.3.1 (WUT, month 36): report on the scalable synthesis of hybrid materials with the addition of transition metal sulfides.* *D 1.4.1 (TMU, month 12): report on the scalable synthesis of TiO_2 with optimal doping* *D 1.4.2 (TMU, month 24): report on the scalable synthesis of hybrid materials based on g-C_3N_4 and carbon nanomaterials with the addition of optimal transition metal oxides.* *D 1.5.1 (TMU, month 24): report on the scalable synthesis of g-C_3N_4 based hybrid materials with optimal Fe_2O_3 doping.* *D 1.5.2 (TMU, month 36): report on the scalable synthesis of hybrid materials decorated with nano-sized catalysts (Ag, Pd, and Pt).*

WP number:	**2**
WP title:	**Testing the prepared materials for photoelectrocatalytic hydrogen production**
Leader:	Warsaw University of Technology (Partner 1, WUT)
Partners involved:	0
Start date:	Month 7
End date:	Month 36
Objectives:	The objective of Work Package 2 is to study the materials prepared in WP1 for their photoelectrocatalytic water splitting properties. During water splitting, two reactions occur on the electrodes: oxidation of water on the anode and reduction on the cathode. Both reactions are very important and must be efficient in obtaining green hydrogen from water splitting. Hence, in this WP, the materials obtained in WP1 will be tested as catalysts for hydrogen (HER) and oxygen evolution reactions (OER) in a photoelectrochemical process.
Type of activities:	In WP2, the materials prepared in WP1 will be tested for their photoelectrocatalytic water-splitting capabilities. The research activities will include the development of photoelectrodes and the establishment of a robust measurement protocol to ensure reproducible results and effectively demonstrate the application potential of the obtained materials for photoelectrocatalytic water splitting. The prepared electrodes will be studied for their activity and stability The measurements will be conducted under controlled laboratory conditions, aligning with TRL 4.
Description of content:	The WP2 will be divided into the following tasks: Task 2.1: Design of photoelectrodes used for photoelectrocatalytic cells (months 7–30)

	The photoelectrodes that are used in photoelectrocatalytic water splitting have a huge impact on the efficiency of the process. For the photoelectrodes the catalytic materials are deposited on conducting substrates that can enhance the charge transfer and collection throughout the reaction. In this task, photoelectrodes will be prepared on different conducting substrates (e.g., FTO glass, metal mesh, or carbon paper) by deposition of the catalytic ink using various techniques (e.g., spin-coating, doctor blade, drop-casting, spray coating). The catalytic ink composition (used solvent, binder, and catalyst concentration) will also be tested. The obtained electrodes will be studied using microscopic techniques to evaluate the uniformity of the surface coverage by the catalytic particles on the surface and gravimetric methods to evaluate the loading of the catalyst in the electrode. Based on these measurements, the photoelectrode preparation method will be chosen and used for further tests in water splitting. <u>Task 2.2: Testing the prepared materials for photoelectrocatalytic HER (months: 7–30)</u> The materials prepared in WP1 will be used to prepare photocathodes using the methodology developed in task 2.1 and will be tested for hydrogen evolution reaction. The setup will consist of a photoelectrochemical cell in which the photocathode based on the materials from WP1 will be used, as well as a metal anode. The measurements will be performed in different aqueous electrolytes (e.g. acidic, neutral, alkaline) and under different light irradiation (specific wavelengths and sunlight simulation) to determine which conditions will be the best for hydrogen generation. The tests will be carried out in bulk photoelectrocatalytic and flow cells. Gas chromatography or mass spectrometry methods will evaluate the amount of hydrogen generated. Factors such as photocurrent density, solar-to-hydrogen (STH) conversion efficiency, incident photon-to-current conversion efficiency, Faradaic efficiency, and operational stability will be determined for all the materials. <u>Task 2.3: Testing the prepared materials for photoelectrocatalytic OER (months: 13–36)</u> The materials prepared in WP1 will be used to prepare photocathodes using the methodology developed in task 2.1 and will be tested for oxygen evolution reaction. The setup will consist of a photoelectrochemical cell in which the photoanode based on the materials from WP1 will be used, as well as a metal cathode. The measurements will be performed in different aqueous electrolytes (e.g. acidic, neutral, alkaline) and under different light irradiation (specific wavelengths and sunlight simulation) to determine which conditions will be the best for oxygen generation. The tests will be carried out in bulk photoelectrocatalytic and flow cells. Gas chromatography or mass spectrometry methods will evaluate the amount of oxygen generated. Factors such as photocurrent density, solar-to-hydrogen (STH) conversion efficiency, incident photon-to-current conversion efficiency, Faradaic efficiency, and operational stability will be determined for all the materials.
Milestones:	*<u>M 2.1.1 (month: 24):</u> Composition of the catalyst ink for the preparation of photoelectrodes.* *<u>M 2.1.2 (month: 30):</u> Methodology for photoelectrode preparation for photoelectrocatalytic water splitting.* *<u>M 2.2.1 (month: 24):</u> A series of photoelectrocatalytic measurements in different electrolytes and under different light irradiation to better understand the mechanisms for hydrogen evolution reaction.* *<u>M 2.2.2 (month: 30):</u> An efficient and stable photoelectrocatalyst for hydrogen evolution reaction and reaction conditions.*

	<u>M 2.3.1 (month: 30):</u> A series of photoelectrocatalytic measurements in different electrolytes and under different light irradiation to better understand the mechanisms for oxygen evolution reaction *<u>M 2.3.2 (month: 36):</u> An efficient and stable photoelectrocatalyst for oxygen evolution reaction and reaction conditions*
Expected results and deliverables:	The main expected results are: complete methodology for preparing photoelectrodes for water splitting, efficient and stable photoelectrocatalysts for HER and OER. The benchmark for the prepared photoelectroctrodes would be 300 mV and 400 mV of overpotential (at 10 mA/cm2) for HER and OER, respectively. *<u>D 2.1.1</u> (WUT, month 24): Report on the methodology for catalyst ink preparation.* *<u>D 2.1.2</u> (WUT, month 30): Report on the photoelectrode preparation technique.* *<u>D 2.2.1</u> (WUT, month 24): Report on the photoelectrochemical characterization of the water splitting photocathodes.* *<u>D 2.2.2</u> (WUT, month 30): Publication about the obtained photoelectrocatalyst for hydrogen evolution reaction.* *<u>D 2.3.1</u> (WUT, month 30): Report on the photoelectrochemical characterization of the water splitting photoanodes.* *<u>D 2.3.2</u> (WUT, month 36): Publication about the obtained photoelectrocatalyst for oxygen evolution reaction.*

WP number:	**3**
WP title:	**Testing the prepared materials for photocatalytic removal of organic dyes from water**
Leader:	VSB - Technical University of Ostrava (Partner 2, VSB-TUO)
Partners involved:	0
Start date:	Month 7
End date:	Month 36
Objectives:	The objective of Work Package 3 is to examine the prepared materials in WP1 for their photocatalytic removal of organic dyes from water. This analysis aims to examine the effect of removing selected organic dyes from water by the photocatalyst employed (as determined in WP1) under the influence of light and time. For the most promising samples measurements in real-life conditions will be performed.
Type of activities:	On the TRL scale, the above work is classified as experimental proof of concept of the proposed materials and their application validation technology at the laboratory scale (TRL 3-5). According to the Technology Agency of the Czech Republic (TACR) rules, the expected results are: - 2 functional samples (Gfunk - funkční vzorek). It is expected to achieve high-value results that could later be used by industrial partners interested in commercialization of the obtained materials in their research area of application. - 2 scientific articles (O - ostatní výsledky). It is expected to achieve high-value results and publish articles with all the included Partners in high-rank international journals. Later, the idea of creating such materials could find potential readers and be used to scale it up from laboratory to industry.
Description of content:	The WP3 will be divided into the following tasks: <u>Task 3.1: Testing the materials from Task 1.1 (months: 7–30)</u> The synthesized various types of g-C_3N_4 materials from Task 1.1 will be characterized using Mott-Schottky analysis (valence and conduction bands)

	and current-voltage (CV) electrochemical measurements in three electrode systems in the liquid electrolyte. This will provide additional support for other physicochemical analyses and information about the degradation mechanism of organic dyes in water. Finally, the photocatalyst will be examined in the presence of selected dyes (e.g. acid orange 7, rhodamine B, phenol, methylene blue) under ultraviolet (UV) or visible (VIS) light irradiation. For the most promising samples measurements in real-life conditions will be performed. Task 3.2: Testing the materials from Task 1.2 (months: 10–30) The achieved materials from Task 1.2 will be electrochemically tested using Mott-Schottky and CV analyses to complete information received from other physicochemical techniques and the degradation mechanism of selected dyes in water solution. The photocatalysis process will be realized in two periods of time. The first period will be done in the dark to estimate the adsorption equilibrium, and the second will be done under light irradiation (UV, VIS). For the most promising samples measurements in real-life conditions will be performed. Task 3.3: Testing the materials from Task 1.3 (months: 19–36) The materials obtained in Task 1.3 will be subjected to electrochemical testing using Mott-Schottky and CV analyses. This will provide additional information obtained from other physicochemical methods and enable the elucidation of the degradation mechanism of selected dyes in water solutions. The photocatalysis process will be conducted over two distinct periods. The initial phase will be conducted without light to estimate the equilibrium adsorption. The subsequent phase will be carried out under light irradiation, encompassing UV and visible light. For the most promising samples measurements in real-life conditions will be performed. Task 3.4: Testing the materials from Task 1.4 and Task 1.5 (months: 13–36) The materials from Task 1.4 and Task 1.5 will be subjected to electrochemical testing using Mott-Schottky and CV analyses. This will provide supplementary data obtained from other physicochemical methods, thus enabling the mechanism of degradation of selected dyes in water solutions to be identified. Finally, the photocatalyst will be subjected to examination in the presence of a selection of dyes (e.g. acid orange 7, rhodamine B, phenol, methylene blue) under the irradiation of ultraviolet (UV) or visible (VIS) light. For the most promising samples measurements in real-life conditions will be performed.
Milestones:	*M.3.1.1 (month 30): Photocatalysts tested over various dyes and light and the knowledge about the whole mechanism that occurs in water solution.* *M.3.2.1 (month 30): A series of photocatalyst tests conducted on selected dyes and under different light conditions, to better understand the overall mechanism that occurs in water solutions.* *M.3.3.1 (month: 36): A series of photocatalyst tests performed on selected dyes under different light conditions. The purpose of these tests is to gain a deeper understanding of the overall mechanism that occurs in water solutions.* *M.3.4.1 (month: 36): A series of photocatalyst tests will be conducted on a selection of dyes under different light conditions. These tests aim to gain a more comprehensive understanding of the overall mechanism that occurs in water solutions.*
Expected results and deliverables:	The main expected results are physicochemical and electrochemical results and photocatalysis tests in wastewater treatment with 70 - 80% relative efficiency as a function of reactor, light intensity, etc. after 2 h of irradiation.

	D 3.1.1 (VSB-TUO, month 24): Report on the photocatalytic properties of the obtained materials used for removal of organic dyes from water in controlled laboratory conditions *D 3.1.2 (VSB-TUO, month 30): Report on the photocatalytic properties of the obtained materials used for removal of organic dyes from water in real-life conditions* *D 3.2.1 (VSB-TUO, month 24): Report on the photocatalytic properties of the obtained materials used for removal of organic dyes from water in controlled laboratory conditions* *D 3.2.2 (VSB-TUO, month 24): Publication about the photocatalytic properties of g-C_3N_4 materials modified with carbon nanomaterials for removal of organic dyes from water* *D 3.2.3 (VSB-TUO, month 30): Report on the photocatalytic properties of the obtained materials used for removal of organic dyes from water in real-life conditions* *D 3.3.1 (VSB-TUO, month 30): Report on the photocatalytic properties of the obtained materials used for removal of organic dyes from water in controlled laboratory conditions* *D 3.3.2 (VSB-TUO, month 36): Report on the photocatalytic properties of the obtained materials used for removal of organic dyes from water in real-life conditions* *D 3.4.1 (VSB-TUO, month 30): Report on the photocatalytic properties of the obtained materials used for removal of organic dyes from water in controlled laboratory conditions* *D 3.4.2 (VSB-TUO, month 36): Report on the photocatalytic properties of the obtained materials used for removal of organic dyes from water in real-life conditions* *D 3.4.3 (VSB-TUO, month 36): Publication about the photocatalytic properties of g-C_3N_4 materials modified with carbon nanomaterials and metallic oxides/sulfides for removal of organic dyes from water*

WP number:	**4**
WP title:	**Testing the antibacterial properties for water purification and managing medical waste of the prepared materials**
Leader:	Taipei Medical University (Partner 3, TMU)
Partners involved:	0
Start date:	Month 7
End date:	Month 36
Objectives:	The objective of Work Package 4 is to examine the materials prepared in WP1 concerning their antibacterial properties for water purification and their performance in medical waste management. The as-prepared various hybrid materials with optimal oxide doping and nanocatalyst decoration will undergo a series of antibacterial examinations for different human pathogens, such as E. Coli, S. aureus, B. subtilis, etc., to reveal the effects of sunlight, the addition of hybrid material, temperature, and time. Detailed consideration for medical waste management to improve the safety and clearness of the environment will be proceeded.
Type of activities:	Though started from TRL 2, the synthesized hybrid materials is expected to reach TRL 4 or 5 at the end of this project. The expected outcomes are: 1. Evaluation of the hybrid materials concerning the antibacterial performance and their ability for medical waste management. The results will be used with industrial Partners for potential marketing investigation.

	2. Demonstration of prototypes in conference exhibition that can extend its potential in various applications. 3. Publication in high-ranked scientific journals to widen its visibility in publics.
Description of content:	The WP4 will be divided into the following tasks: <u>Task 4.1: Testing the materials for antibacterial performance (months: 7–24)</u> The materials prepared in WP1 will be used to prepare antibacterial agents against human pathogens such as E. Coli, S. aureus, B. subtilis, etc. Various amounts of as-prepared hybrid materials (powder type) will be added to a solution containing human pathogens. The antibacterial performance with and without simulated sunlight irradiation as a function of time will be evaluated. Bulk hybrid materials will be made into discs, and the size of the bacterial inhibition zone will be examined. <u>Task 4.2: Testing the materials for medical waste management (months: 13–36)</u> The materials prepared in WP1 will be used to manage the medical waste. Medical waste management is getting increasing attention due to human health and environmental issues. The application of nanocatalysts in medical waste management is an efficient and affordable approach. The hybrid materials prepared in WP1 will be used to neutralize medical waste chemicals and solutions. Deposition of selected hybrid materials on medical devices will be attempted. Antibacterial performance and antibiofilm formation of surface-modified medical devices will be investigated.
Milestones:	*<u>M 4.1.1 (month: 12):</u> A series of antibacterial tests for powdered hybrid materials will be performed for selected human pathogens under different concentrations and simulated sunlight irradiations.* *<u>M 4.1.2 (month: 24):</u> A series of antibacterial tests for bulk hybrid materials will be performed for selected human pathogens under different concentrations and simulated sunlight irradiations.* *<u>M 4.2.1 (month: 24):</u> Powdered hybrid materials will be added to medical waste chemicals and solutions. Degradation of hazardous species under different concentrations and simulated sunlight irradiations for different durations will be evaluated.* *<u>M 4.2.2 (month: 36):</u> Deposition of selected hybrid materials on medical devices will be performed. Antibacterial performance and antibiofilm formation of surface-modified medical devices using simulated sunlight irradiations will be examined.*
Expected results and deliverables:	The main expected results are: The as-prepared series hybrid materials (g-C_3N_4 with additional carbon, g-C_3N_4 based MoS_2, g-C_3N_4 based hybrid materials with optimal Fe_2O_3 and/or TiO_2 doping and decorated with nano-sized catalysts) in optimal conditions (which will be obtained from WP1) will be evaluated concerning the antibacterial abilities in human pathogens. The antibacterial performance of the hybrid materials will be compared with the results from WP2 and WP3. The whole detail related to the used amount/size, the types (powder/bulk), and the antibacterial stability with or without light irradiation will be reported. The performance of the hybrid materials in the management of medical waste chemicals and solutions and coating on medical devices will be investigated. *<u>D 4.1.1 (TMU, month 12):</u> Examination of the antibacterial ability on powdered hybrid materials in various concentrations of human pathogens.* *<u>D 4.1.2 (TMU, month 24):</u> Examination of the antibacterial ability on bulk hybrid materials in various concentrations of human pathogens.*

	D 4.2.1 (TMU, month 24): Evaluation of hazardous species degradation with powdered hybrid materials under different durations of UV/VIS irradiation. *D 4.2.2 (TMU, month 36): Evaluation of antibiofilm formation and antibacterial performance of medical devices coated with the optimal hybrid materials. The performance will be investigated under different durations of UV/VIS irradiation.*

5.1.3 Time schedule

Describe the timing of the different work packages and their components.
Please provide a clearly arranged and detailed time schedule (Gantt chart).

The AH-Nano-Cat project is divided into four Work Packages (WPs).

WP1 focuses on developing novel photo(electro)catalytic materials based on g-C_3N_4 combined with carbon nanomaterials, metal oxides (TiO_2, Fe_2O_3), and sulfides (MoS_2). All Consortium members are involved in WP1, which spans the entire project duration (months 1–36). VSB-TUO will initially synthesize g-C_3N_4 (Task 1.1, months 1–24) and distribute the samples. WUT will modify g-C_3N_4 with carbon nanomaterials (Task 1.2, months 1–24) and later incorporate MoS_2 (Task 1.3, months 13–36). TMU will prepare doped TiO_2 for modification of materials from Task 1.2 (Task 1.4, months 1–24) and later focus on Fe_2O_3 synthesis (Task 1.5, months 13–36). The overlapping tasks and extended duration of WP1 allow for iterative feedback and material design optimization to achieve desired properties.

WP2, conducted by WUT, evaluates the photoelectrochemical properties of the synthesized materials for water splitting. It begins in month 7 and continues until project completion. The first materials from WP1 will be used to prepare photoelectrodes (Task 2.1, months 7–30) for hydrogen evolution reaction (Task 2.2, months 7–30) and, for the most promising electrodes, oxygen evolution reaction (Task 2.3, months 12–36). The overlapping tasks facilitate iterative improvements in both electrode design and material synthesis.

WP3, conducted by VSB-TUO, assesses the photocatalytic properties of the materials for purifying water from organic dyes. Starting in month 7 and lasting through the project, initial tests will focus on g-C_3N_4 (Task 3.1, months 7–30), followed by g-C_3N_4 modified with carbon nanomaterials (Task 3.2, months 10–30). Later stages will evaluate g-C_3N_4 modified with metal sulfides (Task 3.3, months 19–36) and metal oxides (Task 3.4, months 13–36). Overlapping tasks enable refinement of photocatalysts and adjustments in WP1 synthesis protocols. Promising materials will also be tested under real-life conditions.

WP4, conducted by TMU, tests the antibacterial properties and medical waste management potential of the materials. Starting in month 7, Task 4.1 (months 7–24) focuses on antibacterial testing, followed by Task 4.2 (months 13–36) for medical waste management applications. Task overlap facilitates feedback to improve material properties and synthesis methods.

The overlapping task timelines in the project are a strategic approach that enhances collaboration and efficiency. This structure allows for continuous feedback between partners, enabling real-time adjustments to synthesis and testing procedures, which improves the quality and performance of the developed materials. By integrating efforts across WPs, consortium members can use their expertise to optimize material properties and address challenges more effectively. Additionally, overlapping timelines enable iterative improvement, ensuring that knowledge gained in earlier tasks informs subsequent activities. This collaborative and dynamic workflow accelerates progress and ensures a cohesive and innovative project outcome.

WP1	Task 1.1				M 1.1.1 (12)				M 1.1.2 (24)				
	Task 1.2						M 1.2.1 (18)		M 1.2.2 (24)				
	Task 1.3										M 1.3.1 (30)		M 1.3.2 (36)
	Task 1.4				M 1.4.1 (12)				M 1.4.2 (24)				
	Task 1.5								M 1.5.1 (24)				M 1.5.2 (36)
WP2	Task 2.1												
	Task 2.2												
	Task 2.3												
WP3	Task 3.1										M 3.1.1 (30)		
	Task 3.2										M 3.2.1 (30)		
	Task 3.3												M 3.3.1 (36)
	Task 3.4												M 3.4.1 (36)
WP4	Task 4.1												
	Task 4.2												

5.1.4 Risk management

Identify the critical risks and describe the mitigation measures.

The following risks might occur during realization of the project:

1. **Scientific and Technical Risks**: Failure to synthesize materials based on g-C_3N_4 with the desired photo(electro)catalytic and antibacterial properties for water treatment or hydrogen production or inferior performance metrics and insufficient characterization of materials, leading to gaps in understanding their properties.
   Risk Mitigation: Diversify synthesis approaches, optimize experimental parameters, and leverage the expertise of consortium partners to address specific challenges. Collaboration with external experts or institutions will be considered if necessary. A comprehensive suite of analytical techniques will be employed, and results will be cross-validated among consortium partners to ensure reliability.
2. **Integration and Interdependence Risks**: Delays in one Work Package or Task impacting subsequent tasks, particularly the transition from synthesis to testing and evaluation.
   Risk Mitigation: Maintain regular communication and coordination through periodic meetings to ensure alignment across work packages. Develop contingency plans to adjust schedules or reallocate resources promptly to address potential bottlenecks.
3. **Data Management Risks**: Poor organization or loss of research data, leading to compromised project outcomes.
   Risk Mitigation: Implement centralized data storage aligned with FAIR principles, conduct regular data backups, and provide training for consortium members on data management practices.
4. **Scalability and Application Risks**: Challenges in scaling up materials or processes for real-world applications.
   Risk Mitigation: Incorporate scalability considerations during the initial design phase of synthesis and testing protocols. Collaborate with potential industry stakeholders early to align the project's outputs with industrial needs and explore their practical applications.

5. **Dissemination Risks**: Limited dissemination or ineffective communication of project results, reducing their impact and visibility.
   Risk Mitigation: Implement a structured dissemination plan, including joint publications, conference presentations, and public outreach activities. Regularly review dissemination progress and adjust strategies as necessary to maximize reach and engagement.
6. **Intellectual Property Risks**: Disputes or ambiguities regarding ownership and usage rights of intellectual property generated during the project.
   Risk Mitigation: Clearly define intellectual property management policies in the Consortium Agreement, covering ownership, access rights, and conflict resolution. Regular reviews will monitor IP developments, and mediation mechanisms will address disputes efficiently.
7. **Environmental and Societal Risks**: Potential adverse environmental or societal impacts from project activities or materials.
   Risk Mitigation: Perform environmental impact assessments and adopt sustainable synthesis methods where possible. Regularly engage with societal stakeholders to ensure alignment with ethical and environmental standards.
8. **Resource Risks**: Limited access to necessary human, financial, or material resources, potentially hindering project activities.
   Risk Mitigation: Identify and secure resource needs at the proposal stage, with contingency plans to reallocate resources or seek additional funding if required. Establish collaborations with external institutions to share expertise and equipment and ensure efficient utilization of available resources.

5.2 Management structure and procedures

Describe the organisational structure and the decision-making procedure, including conflict resolution. If appropriate, describe the constitution of the external advisory board.

In order to guarantee the effective coordination, clear communication, and sound decision-making required for the successful completion of the AH-Nano-Cat project, a management structure has been established. This comprises the appointment of a project leader (PI), work package leaders (WPLs), and a steering committee (SC), with an additional input from an external advisory board (EAB) to provide impartial guidance. The PI is responsible for the overall progress of the project, ensuring that all agreed milestones are met and that the research remains aligned with the strategic goals of the project. This role also entails coordinating activities across all partners, managing resources, and acting as the primary point of contact for external stakeholders and funding bodies. The work package leaders oversee the management of each major aspect of the project through the implementation of distinct work packages (WPs). These WPs are directed by dedicated WPLs, who are responsible for ensuring the completion of tasks within their respective work packages in a timely and high-quality manner, and for reporting to the PI. The SC is tasked with overseeing the activities of the partnership and is composed of representatives from each partner institution. The committee is chaired by the PI and holds meetings on regular basis (quarterly or as needed) to discuss progress, address potential risks, and make key strategic decisions. Additionally, the SC is responsible for the allocation of financial resources and the distribution of resources among partners. The External Advisory Board (EAB) is formed of experts in materials science, environmental engineering, and industry stakeholders. The EAB provides external oversight and impartial advice. Its functions include the review of project outcomes, the offering of constructive feedback, and the suggestion of adjustments to enhance project impact and applicability. The following section outlines the decision-making procedures that will be employed throughout this process: (i) The process of consensus-based decision-making is one that is founded upon the collective input and agreement of all parties involved. The convening of regular meetings, both in person and via virtual platforms, enables an inclusive approach to decision-making, whereby decisions are reached through the process of consensus. Each partner is afforded the opportunity to contribute to discussions, thereby fostering transparency and collaborative input. (ii) A tiered approval process is employed. Significant decisions pertaining to the project's trajectory, budgetary modifications, or strategic pivots are presented by the PI to the SC for approval. Minor operational decisions are the responsibility of WPLs, thereby facilitating the streamlining of day-to-day management. In the event of a conflict, the following procedures are in place: (i) Internal Dispute Mechanism: Conflicts are resolved at the lowest possible level, with initial mediation by the PI. If unresolved, the issue is escalated to the SC for further deliberation., (ii) Arbitration by EAB: For significant disputes or strategic impasses, the EAB acts as an impartial arbitrator, providing expert recommendations to maintain project alignment and prevent delays.

The advancement of the project deliverables will be presented and discussed at the project meetings, which occur three times in person and at least every sixth month, or more frequently if necessary, via the available online platforms. The inaugural meeting of the project is scheduled to take place in late 2025 or early 2026 at WUT (Poland). This meeting will mark the commencement of the project's work on two main areas: "Synthesis of hybrid nanomaterials based on g-C_3N_4" (WP1) and "Testing the prepared materials for photoelectrocatalytic hydrogen production" (WP2). The second meeting is scheduled to take place in 2027 at VSB-TUO in the Czech Republic, marking the commencement of the project's work on "Testing the prepared materials for photocatalytic removal of organic dyes from water" (WP3). The final meeting is scheduled to take place in 2028 at TMU (Taiwan), marking the commencement of the project's work on WP4, which will investigate the antibacterial properties of the prepared materials for water purification and medical waste management. The purpose of these meetings will be to provide a comprehensive overview of the project's progress. Consortium members are expected to attend all project meetings and provide updates on the status of their respective contributions. Additionally, written annual project reports are required. These reports will be submitted to the Project Coordinator, who will disseminate them to other partners and request necessary amendments. It will be the responsibility of the Project Coordinator to ensure effective communication and data exchange between all parties involved. In order to facilitate this, a dedicated website will be created and maintained by the project team, where updates will be posted in a regular, timely manner. The detailed terms and conditions of cooperation, communication and data exchange, as well as the responsibilities and rights of all partners involved, and all issues related to intellectual property rights, commercialisation and other commercial aspects of the project will be regulated by a formal Consortium Agreement, which will be signed by all relevant project partners.

This structured and collaborative management approach guarantees the efficient progression of the AH-Nano-Cat project, enabling it to adapt to challenges and achieve its research and innovation goals while maintaining high standards of inclusivity and cooperation.

5.3 Quality of the individual participants

Describe briefly the role and expertise of each partner team in the project. Explain the added value for each partner resulting from the transnational cooperation. Describe also the benefit for the project derived by the participation of each of the partners.

Partner 1 (Coordinator): Warsaw University of Technology (WUT), Poland

Role in the project: Preparation and modification of carbon nanomaterials (such as graphene oxide, reduced graphene oxide, carbon nanotubes, carbon dots), and molybdenum disulfide. Studies of the proposed materials in photoelectrocatalytic water splitting processes.

Relevant expertise: People from Warsaw University of Technology involved in the project (PI [redacted] have experience in the topic of carbon nanomaterials - preparation, modification, and their applications, especially in the field of catalysts for water splitting and low-temperature fuel cells. The team has also experience in the preparation of molybdenum disulfide using an innovative synthesis method in an impinging jet reactor. In the last 5 years, researchers from WUT were the PIs of several projects, two of them involving the production of hybrid materials based on MoS_2 and carbon nanomaterials for hydrogen production, and one of them focusing on the preparation of carbon dots.

The laboratories of WUT that will be used throughout the project have the proper equipment to perform the planned research, including high-pressure microwave reactor, impinging-jet reactor, ultrasonic homogenizers, scanning electron microscopes (SEM), spin coater, X-ray fluorescence spectrometer (XRF), UV-Vis spectrophotometer, FT-IR spectrometer, X-ray diffractometer (XRD), thermogravimetric analyzer (TGA), mass spectrometer (MS), gas chromatograph (GC), potentiostats with the possibility to perform electrochemical impedance spectroscopy (EIS) measurements and equipped with a rotating disc electrode (RDE) setup. It is planned to buy a rotating ring-disc electrode (RRDE) setup to study the mechanisms of the reactions in order to better understand the effect of the preparation method on the electrochemical properties of the obtained materials. Additionally, a LED solar simulator and a switchable LED light source will be bought to better control the irradiation of the samples and study their photoelectrocatalytic properties. A photoelectrochemical cell and a photoelectrochemical flow cell are also

planned to ensure reproducible measurements of water splitting efficiency in static and dynamic (resembling real-life) conditions.
Added value: The participation of WUT in the AH-Nano-Cat project will bring additional benefits through enhanced international collaboration, building on the existing partnerships among the involved teams. Staff and students from WUT will have access to exchange opportunities, as well as advanced equipment and expertise across the consortium. This collaboration will be crucial for understanding the link between synthesis methods and material properties, facilitating the development of more efficient and stable photoelectrocatalysts for water splitting and other applications. The knowledge exchange across institutions will further support the creation of new materials, elevate WUT's research profile, and pave the way for future industrial collaborations.

Partner 2: VSB-Technical University of Ostrava (VSB-TUO), Czech Republic

Role in the project: Preparation and surface modification of graphitic carbon nitride. Studies of the proposed materials in photocatalysis in wastewater treatment.
Relevant expertise: The VSB-TUO research team, led by [redacted], has considerable experience in the synthesis of a range of semiconductor nanomaterials, including pristine, doped and surface-modified nanocomposites, which are suitable for photocatalytic applications. The expertise provided by the team is well documented by publications in high-profile international journals. Additionally, Dr. Michalska has experience acting as the Principal Investigator (PI) in the management of national and international research projects.
The laboratories of VSB-TUO that will be utilized throughout the project are equipped with the requisite apparatus to undertake the planned research, including an X-ray diffractometer (XRD), UV-Vis and photoluminescence (PL) emission spectrophotometers, FT-IR and Raman spectrometers, and a thermogravimetric analyzer with a differential scanning calorimeter. The laboratories also contain a thermal gravimetric analyzer (TG-DSC), N_2 adsorption-desorption isotherms BET, elemental and zeta potential analyzers, potentiostats with the capability of performing Mott-Schottky (valence and conduction bands), current-voltage (CV) in three electrode systems, and electrochemical impedance spectroscopy (EIS) measurements. Moreover, the laboratories are fully equipped with the necessary apparatus to conduct photodegradation experiments under UV or visible light irradiation.
Added value: The additional benefit for VSB-TUO is the extension of experience in transnational collaboration and the acquisition of novel experience in the context of industrial engagement (two companies have shown their interest in the project results - see Letters of Intent). Furthermore, collaboration with WUT will facilitate a more profound understanding of photoelectrocatalytic hydrogen production. TMU will contribute to the investigation of the antibacterial properties of the prepared materials for water purification and medical waste management. A comprehensive insight into these processes and the necessity for hydrogen production and water purification will be instrumental in advancing material synthesis by VSB-TUO beyond the AH-Nano-Cat project.

Partner 3: Taipei Medical University (TMU), Taiwan

Role in the project: Preparation and modification of transition metal oxides (Fe_2O_3, TiO_2). Studies of the antibacterial properties of the prepared materials.
Relevant expertise: TMU team includes [redacted] (a materials scientist with 30 years of experience), TMU team members (with two other faculties from chemical engineering) are experts in materials preparation and characterization of functional oxide materials for catalytic, electrochromic, supercapacitor, and biomedical applications. Various combinations of transition metal oxide, nanosized catalysts, and antibacterial agents have been developed and examined concerning the aforementioned applications. Equipment for the preparation (spray pyrolysis, sol-gel, hydrothermal, etc.) and characterization (UV-VIS, Raman, FT-IR, Scanning electrochemical microscopy, etc.) of the required materials are well established in the TMU team. XRD, TEM, XPS, BET surface analyzer, etc. are available in the core facility laboratories at three universities. In addition, Profs. Lin and Chiou have long experience in using synchrotron X-ray reduction for nano-sized catalyst preparation. The required hybrid materials are expected to be prepared and optimized successfully for this AH-Nano-Cat project.
Added value: TMU team has strong collaborations with WUT in research projects, scientific publications, and mutual international visits. Not only the faculties but also students and post-docs can greatly benefit from this AH-Nano-Cat consortium. TMU team can collaborate on the novel materials developed within

this project with industrial partners (two LoIs already signed and more are expected during the project) starting from the energy field to biomedical applications, from the lab side to a large-scale pilot test is expected at the end of the project.

5.4 Consortium as a whole

- **Complementarity and balance of the consortium including gender aspects**

The AH-Nano-Cat Consortium comprises a well-balanced team of universities with complementary expertise in nanotechnology, catalysis, and hydrogen generation. Each partner brings specialized skills, ensuring a comprehensive approach to addressing the project's challenges and driving innovation. The diversity of the consortium is reflected in its geographic distribution and the range of disciplines represented. Gender balance is an integral aspect, with women holding key leadership and research roles, including Dr. Marta Mazurkiewicz-Pawlicka as the project coordinator, Dr. Monika Michalska as the PI from VSB-TUO, and Dr. Yuh-Ching Chiou and Dr. Yu-Ching Weng as Co-PIs from TMU. Initiatives such as mentorship programs and workshops promote inclusivity, enhancing the consortium's creativity and strengthening its collaborative efforts.

- **Inter- and transdisciplinarity character of the consortium**

To obtain all the objectives of the AH-Nano-Cat project, it is necessary to engage an inter- and transdisciplinary team with expertise in chemical engineering, materials science, surface chemistry, biomaterials, and physical chemistry. The partner institutions involved in the project possess the expertise needed to obtain the assumed goals for the planned tasks. The different expertise of the project partners can be seen in the work packages they are responsible for - the team from VSB-TUO specializes in the preparation of g-C_3N_4 and photocatalytic degradation of organic dyes from water, the team from WUT specializes in carbon nanomaterials and metal sulfides preparation and photoelectrocatalytic hydrogen generation, the team from TMU specializes in synthesis of metal oxides and their biomedical applications. Furthermore, regular discussions and knowledge exchange meetings will facilitate communication and collaboration among team members, ensuring alignment with project goals and objectives. These interactions will strengthen the synergy between chemistry, physics, and materials science, paving the way for groundbreaking discoveries and advancements in the field.
The transdisciplinary approach, in conjunction with the collaboration within the AH-Nano-Cat consortium and the synergy of the work plan, will result in an advantage in the field of novel hybrid materials based on g-C_3N_4, which would not be possible to achieve through the contributions of individual laboratories.
The AH-Nano-Cat consortium comprises scientific research partners from various countries, including Poland, the Czech Republic, and Taiwan. It is clearly visible that the partners represent diverse ethnic backgrounds and collectively possess the necessary complementary competencies to fulfill the various roles required for the project. The consortium's research component comprises experts in materials science and engineering, processing technologies, and chemistry. Identifying world-class scholars with this specific expertise within a single country is challenging. Therefore, transnational cooperation is essential to achieve the objectives of the project. The teams involved in the project have a history of previous collaborations in mutual projects (i.e. Polish-Taiwanese projects) or scientific publications. The proposed scientific research will be conducted in a manner that respects linguistic and cultural heritage while simultaneously benefiting from them. Our students and colleagues will have many opportunities to gain confidence in presenting their findings in English through oral presentations and posters. The consortium will facilitate collaboration between the respective university partners from different countries, paving the way for more extensive transnational cooperation, not only in the field of science but also in the broader context of cultural exchange and mutual understanding.

5.5 Cost calculation and resources

5.5.1 Personnel cost

Partner 1 (Coordinator): 169 800 EUR (requested: 169 800 EUR), estimated number of person-months: 96; other costs for Principal Investigator (18 person-months), additional salary for co-

investigator (12 person-months), student and PhD student scholarships and salaries (66 person-months)
Partner 2: 150 174 EUR (requested: 120 138 EUR): estimated numbers of person-months 79; remuneration for project members.
Partner 3: 145 000 EUR (requested: 145 000 EUR), estimated number of person-months: 84; other costs for Principal Investigator, additional salary for co-investigator, and student scholarships and salaries.

5.5.2 Equipment

Partner 1 (Coordinator): 51 653 EUR (requested funding: 51 653 EUR): rotating ring disc electrode (RRDE) setup, LED solar simulator, switchable LED light source, photoelectrochemical flow cell, photoelectrochemical cell, computers, software
Partner 2: 0 EUR (All the facilities necessary for VSB-TUO tasks are available).
Partner 3: 0 EUR (All the facilities necessary for TMU tasks are available).

5.5.3 Consumables

Partner 1 (Coordinator): 23 008 EUR (requested funding: 23 008 EUR): chemicals, electrodes for electrochemical measurements, single use containers, glassware, gasses: Ar, N_2, He, other laboratory materials: membranes, pipettes, paper
Partner 2: 9 300 EUR (requested funding; 7 440 EUR): Chemicals and materials, technical gases, small laboratory equipment such as Teflon cups for autoclave, magnetic stirrers, stirring elements, crucibles, electrodes, laboratory glassware, etc.).
Partner 3: 20 000 EUR (requested funding: 20 000 EUR): precursors and chemicals for oxide synthesis, gasses: Ar, N_2, He, cytotoxicity and antibacterial kits, laboratory materials: single use containers, glassware, plate, membranes, pipettes, paper, Stationery, and Computer Usage Fees.

5.5.4 Travel

Partner 1 (Coordinator): 34 512 EUR (requested funding: 34 512 EUR): Travel and accommodation costs for conferences and consortium meetings.
Partner 2: 31 065 EUR (requested: 24 852 EUR): Travel costs for conferences and consortium meetings.
Partner 3: 30 000 EUR (requested: 30 000 EUR): Travel costs for conferences and consortium meetings.

5.5.5 Subcontracting

Partner 1 (Coordinator): 7 823 EUR (requested funding: 7 823 EUR): X-Ray photoelectron spectroscopy (XPS) analysis, mass spectrometer maintenance, calibration and training, the cost of catering during the consortium members' meeting at WUT, courier/postal services.
Partner 2: 0 EUR
Partner 3: 6 000 EUR (requested funding: 6 000 EUR): X-ray diffraction (XRD) analysis, Scanning electron microscope(SEM), Scanning-Transmission electron microscope (STEM), training and operating costs and courier/postal services.

5.5.6 Other costs *(i.e. for seminars, etc)*

Partner 1 (Coordinator): 5 736 EUR (requested funding: 5 736 EUR): Open access publication costs.
Partner 2: 20 460 EUR (requested: 16 368 EUR): Open access publication and conference fees.
Partner 3: 5 460 EUR (requested funding: 5 460 EUR): Open access publication costs and conference fees.

5.5.7 Indirect costs

Partner 1 (Coordinator): 57 359 EUR (requested funding: 57 359 EUR): 20% of direct eligible costs
Partner 2: 52 748 EUR (requested: 42 198 EUR) 25 % of the direct cost.
Partner 3: 51 615 EUR (requested: 51 615 EUR) 20 % of the direct cost.

Table: Total project costs (only integer)

Describe costs of all project partners in EURO.

Please refer to eligible costs for each partner at national/regional level. For TOTAL COSTS each category must be filled in the first line and for REQUESTED FUNDING must be filled in the second line according to specific national/regional rules.

Partner	Person months	Personnel cost	Equipment	Consum-ables	Travel	Sub-contracting	Other costs	Indirect costs	Total costs	Total requested funding
		Euro	Euro	Euro	Euro	Euro	Euro	Euro	Euro	Euro
Partner 1 (Coordinator) WUT	96	169800	51653	23008	34512	7823	5736	57359	**349891**	
		169800	51653	23008	34512	7823	5736	57359		**349891**
Partner 2 VSB-TUO:	79	150174	0	9300	31065	0	20460	52748	**263747**	
		120138	0	7440	24852	0	16368	42198		**210996**
Partner 3 TMU:	84	145000	0	20000	30000	6000	5460	51615	**258075**	
		145000	0	20000	30000	6000	5460	51615		**258075**
Partner 4:										
Partner 5:										
Total:	**259**	**464974**	**51653**	**52308**	**95577**	**13823**	**31656**	**161722**	**871713**	**0**
		434938	**51653**	**50448**	**89364**	**13823**	**27564**	**151172**	**0**	**818962**

6. ETHICAL ISSUES

Please fill YES or NO.

ETHICAL ISSUES[9]		YES / NO	Page
HUMAN EMBRYOS/FOETUSES			
Does your research involve Human Embryonic Stem Cells (hESCs)?		NO	
Does your research involve the use of human embryos?		NO	
HUMANS			
Does your research involve human participants?		NO	
Does this activity involve interventions (physical also including imaging technology, behavioural treatments, etc.) on the study participants?		NO	
Does this activity involve conducting a clinical study as defined by the Clinical Trial Regulation (EU 536/2014[10])? (using pharmaceuticals, biologicals, radiopharmaceuticals, or advanced therapy medicinal products)		NO	
HUMAN CELLS / TISSUES (not covered by section 1)			
Does your research involve human cells or tissues?		NO	
PERSONAL DATA			
Does your research involve processing of personal data?		NO	
Does it involve the processing of special categories of personal data (e.g. sexual lifestyle, ethnicity, genetic, biometric and health data, political opinion, religious or philosophical beliefs)?		NO	
If YES	Does it involve processing of genetic, biometric or health data?	NO	
Does it involve profiling, systematic monitoring of individuals, or processing of large scale of special categories of data or intrusive methods of data processing (such as, surveillance, geolocation tracking etc.)?		NO	
Does this activity involve further processing of previously collected personal data (including use of pre-existing data sets or sources, merging existing data sets)?		NO	
ANIMALS			
Does your research involve animals?		NO	
ENVIRONMENT, HEALTH and SAFETY			
Does this activity involve the use of substances or processes that may cause harm to the environment, to animals or plants (during the implementation of the activity or further to the use of the results, as a possible impact)?		NO	
Does this activity deal with endangered fauna and/or flora / protected areas?		NO	
Does this activity involve the use of substances or processes that may cause harm to humans, including those performing the activity (during the implementation of the activity or further to the use of the results, as a possible impact)?		NO	
ARTIFICIAL INTELLIGENCE			
Does this activity involve the development, deployment and/or use of Artificial Intelligence?		NO	
OTHER ETHICS ISSUES			
Are there any other ethical issues that should be taken into consideration?		NO	
Please specify (max. 1000 characters)			

I CONFIRM that I have taken into account all ethics issues above. ☒

[9] Table assembled based on EC Horizon Europe Guidance: https://ec.europa.eu/info/funding-tenders/opportunities/docs/2021-2027/common/guidance/how-to-complete-your-ethics-self-assessment_en.pdf
[10] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32014R0536

7. CHECKLIST FOR PROPOSERS (must not be deleted)

The proposal conforms to the call guidelines.	☒
The provided proposal forms have not been changed in structure, order of chapters and formatting conditions.	☒
Every project partner has been in direct contact with his/her national / regional funding agency and has checked that their collaboration and their project contributions are eligible for funding.	☒
All project partners have checked the national/regional programme procedures and regulations. All project partners are aware of documents requested by the national/regional funding organisations. ***IMPORTANT REMINDER: All consortium partners must check if applications (at Pre-Proposal and/or Full-Proposal stage) have to be submitted also to their national/regional funding organisations.***	☒
All partners who are not eligible for 100% funding are able to provide financial resources for their own contribution.	☒
The consortium is aware that a duly signed and stamped consortium agreement (CA) between the project partners is recommended for funded projects based on national/regional funding rules, including agreements on intellectual property rights (IPR) and agreements on scientific publications. At the time of proposal submission, it is recommended to provide the principles ruling the CA but not the CA itself.	☒

Please go to https://www.m-era.net/joint-call-2024 to submit this Full-Proposal form and the Annex 1 to the Full-Proposal form online.

Deadline for submission: 20 November 2024, 12:00 noon Brussels time

For further information on M-ERA.NET, please go to: http://www.m-era.net