INNOMEM

Open Innovation Test Bed
for nano-enabled Membranes

Role of the research organizations involved in the project

For a project like INNOMEM, whose goal is the creation of a sustainable Open Innovation Test Bed (OITB) on nano-enabled membranes, the research activity is a really central topic.

For this reason, the second issue of the INNOMEM newsletter is focused on the research organizations involved in the project and their main activities performed and to be performed in order to achieve the initiative's scope.

Remember to **subscribe** to the INNOMEM newsletter and to follow the project progresses on **LinkedIn** and **Twitter** accounts!

WE INTRODUCE YOU THE RESEARCH ORGANIZATION IN OUR CONSORTIUM!

Fundacion Tecnalia Research & Innovation

TECNALIA is the largest centre of applied research and technological development in Spain, a benchmark in Europe and a member of the Basque Research and Technology Alliance. We collaborate with companies and institutions to improve their competitiveness, people's quality of life and achieve sustainable growth. We do it thanks to people who are passionate about technology and committed to building a better society.

Our Mission: to transform technological research into prosperity.

Our vision: To be agents of transformation of companies and society for their adaptation to the challenges of a changing future.

We work with an increasingly strategic business relationship model based on trust, collaboration, and a shared technological approach, whereby our main scopes of action are: smart manufacturing, digital transformation, energy transition, sustainable mobility, Personalised health, and the urban ecosystem. We are the first private Spanish organisation in contracting, participation, and leadership in the European Commission's Horizon 2020 programme and we are ranked third in European patent applications.

Automatized and upscaled Pilot Lines 1 and 2 (Spinning system and Plating system)

Regarding INNOMEM, TECNALIA, through its Membrane Technology and Process Intensification department, coordinates the project with Jon Zuñiga and Jose Luis Viviente acting as Project managers. Moreover, TECNALIA is in charge of Upgrading and Upscaling two advanced membrane manufacturing pilot lines: PL1 - Mixed Matrix Hollow fibers. (Dual Layer Mixed Matrix hollow fiber spinning system for gas separation membrane development and, PL2 - Palladium-based membranes (Electroless plating system for Pd-based membrane development onto porous tubular supports).

Both pilot lines are in the final stage of validation and once this phase has finished, the membranes developed will be integrated into two different Showcases: SC3 - Mixed matrix membrane for gas separation leaded by POLYMEM and SC4 - Advanced membranes for pure hydrogen purification leaded by H2SITE.

Eindhoven University of Technology

Eindhoven University of Technology (TUE) is a young university, founded in 1956 by industry, local government and academia. Today, their spirit of collaboration is still at the heart of the university community. We foster an open culture where everyone feels free to exchange ideas and take initiatives.

TUE offers academic education that is driven by fundamental and applied research. Our educational philosophy is based on personal attention and room for individual ambitions and talents. Our research meets the highest international standards of quality. We push the limits of science, which puts us at the forefront of rapidly emerging areas of research.

TUE combines scientific curiosity with a hands-on mentality. Fundamental knowledge enables us to design solutions for the highly complex problems of today and tomorrow. We understand things by making them and we make things by understanding them. Our campus is in the centre of one of the most powerful technology hubs in the world: Brainport Eindhoven. Globally, we stand out when it comes to collaborating with advanced industries. Together with other institutions, we form a thriving ecosystem with one common aim – to improve quality of life through sustainable innovations.

The research group Sustainable Process Engineering is part of the faculty of Chemical Engineering and Chemistry at the Eindhoven University of Technology. The main objective of the research group is the development of novel integrated reactor concepts (such as Membrane Reactors, micro reactors, structured catalysts, and reactors) based on improved fundamental knowledge using validated advanced (multi-phase) reactor models. This is achieved by employing a combination of state-of-the-art numerical models (at different levels of detail using the multi-level modelling approach), advanced (non-invasive) experimental techniques and experimental demonstration of novel reactor concepts (proof of concept).

TUE is responsible for the creation of a virtual lab and an expert system for modelling of membranes and membrane reactors within the INNOMEM project. The virtual lab will connect potential clients with modelling requests to capable modelling partners within the INNOMEM consortium. This virtual lab will be used to develop an expert system on membrane and membrane reactor modelling which will be able to do preliminary calculations on these systems to provide a more rigorous and advanced user experience. A promising PhD researcher named Zançat Sahin has been hired for these tasks, having the necessary skillset and experience with regards to modelling. He will oversee the development of this virtual lab and expert system. He is working with Task Leader Fausto Gallucci within the group of Sustainable Process Engineering/Inorganic Membranes and Membrane Reactors at Eindhoven University of Technology.

In the previous months, a dedicated modelling database has been created through collaboration between all modelling partners. The information on the available models obtained within this database has been used to design an optimal set of heuristics and procedures. To accommodate the procedures that are meant to select the correct partner according to client wishes, an in-house function has been developed. This function cross-checks all available partners and models as available in the models' database in order to select and output the most appropriate one. This is then fed back to the client. A webpage

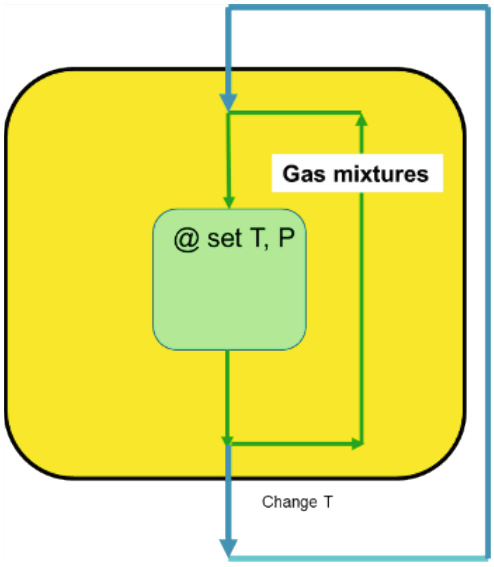
has been created for this virtual lab (https://www.innomem.eu/virtual-lab-modelling/). Clients can reach the dedicated team that runs the in-house code per modelling request and connects these clients to the most appropriate partner.

Institute on Membrane Technology

The Institute on Membrane Technology (CNR-ITM) is a research Institute of the National Research Council of Italy (CNR, www.cnr.it) including 40 persons as permanent staff and around 50-60 persons as research fellows, post-docs, PhD students, master students, visiting professors, visiting researchers, etc.

One of the main missions of the Institute on Membrane Technology is the research and development in the field of membrane science and engineering. The research activities aim to promote knowledge, innovation and high-level training in the field of membranes and their application in, gas separation, energy, hydrogen production, water treatment, bioartificial organs, biotechnology, food and agriculture. The ITM is internationally recognized for its peculiar skills in the membrane preparation (organic, inorganic, mixed matrix, biohybrid), transport phenomena, selective separations at molecular level, catalytic membranes, catalytic membrane reactors, membrane contactors, integrated membrane processes, membrane in regenerative medicine and tissue engineering. As part of national, European and international research projects, other than bilateral agreements, ITM has established collaborations with Research Institutes, Universities and Companies located in Italy, Europe, China, South Korea, Japan, Saudi Arabia, Brazil, United States, etc.

Thanks to the wide experience in disseminating and communicating research, CNR-ITM is responsible of the Dissemination Activities of INNOMEM.



Furthermore, CNR-ITM is the leader of the Virtual testing and characterization lab in INNOMEM.

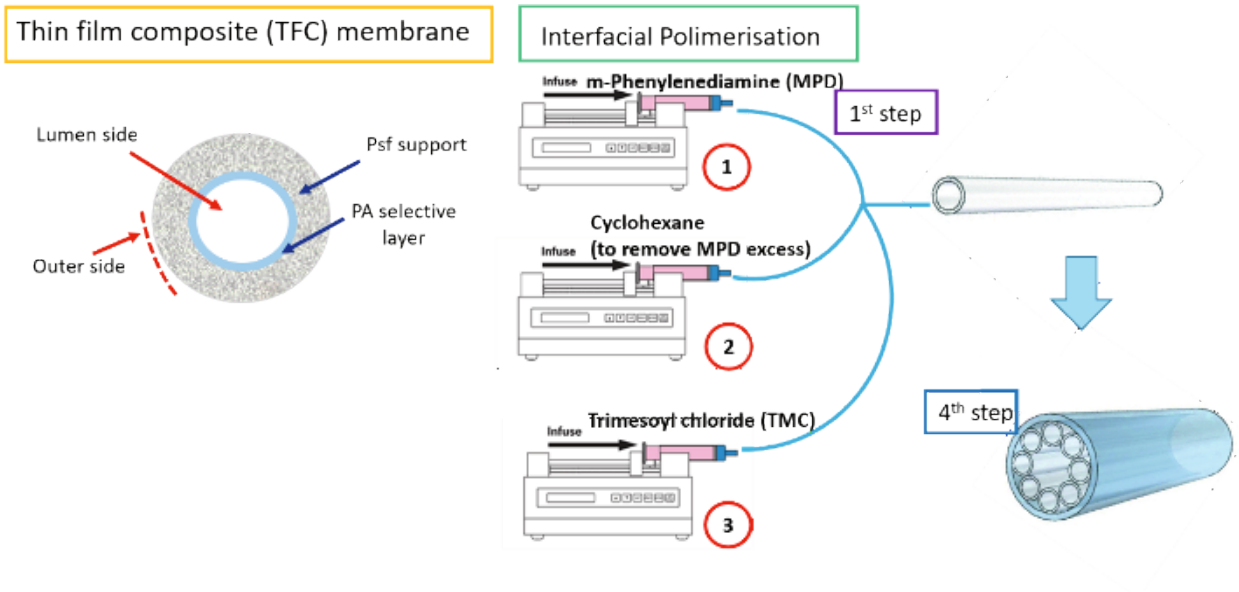
The virtual characterization lab is fully dedicated for characterizing and testing membranes developed in the various showcases. In addition, the role of this Virtual Lab is to collect through the SEP the external requests, manage them and assign any single request to the most appropriate partner. The facilities and apparatus of this lab are not located physically at one place and CNR-ITM coordinates and harmonizes the activities performed by the various partners, defining set procedures for testing and characterizing the membranes, with standard operating procedures. Appropriate testing protocols, reports layout, excel datasheet are developed and shared among the partners to make easier and immediate the results exchange and common understanding.

University of Zaragoza

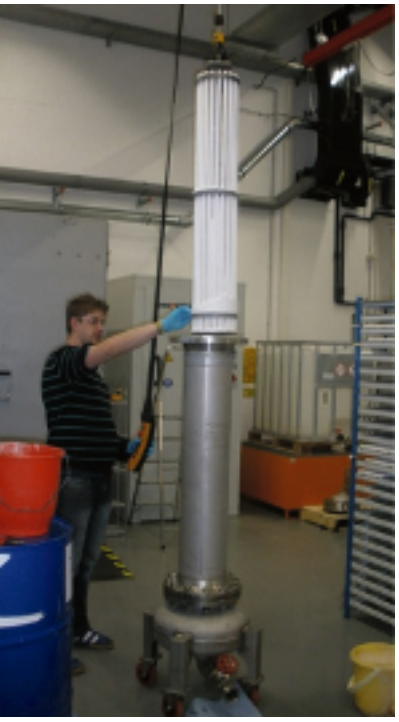
University of Zaragoza (UNIZAR), founded in 1542, presently consists of 17 faculty/school of engineering, 51 departments and 6 research institutes. The execution of the INNOMEM project is being developed within the installations of the Institute of Nanoscience and Materials of Aragon (INMA, https://inma.unizar-csic.es/), which was founded in 2020 at the request of the University of Zaragoza and the Spanish National Research Council (CSIC).

UNIZAR is involved in Pilot Line 9 and Showcase 3. This showcase deals with the fabrication of mixed matrix membranes (MMMs) for liquid and gas separation. In UNIZAR´s case such fabrication consists of an improved hollow fibre (HF) membranes preparation, eventually including MOFs (metal organic frameworks in their synthesis, for water treatment by nanofiltration (NF) and gas separation.

Through microfluidic methods, NF membranes and gas separation membranes were fabricated, by modifying the lumen side of the HF (see figure below). The aim was to upscale the fabrication procedure from 1 hollow fibre to several fibres at the same time. Moreover, the length of the module was also increased by a determined factor and currently the fabricated membranes are being tested for NF and gas separation.



Fraunhofer IKTS



Fraunhofer is Europe's largest application-oriented research organization. The Fraunhofer Institute of Ceramic Techniques and Systems (IKTS) performs applied research in the field of technical ceramics. The research field of Environmental and Process Engineering with the department Nanoporous Membranes is one of the biggest European research groups in the field of ceramic membranes. The research includes support, intermediate and separating top layers development as well as process investigation, optimisation and modelling.

Fraunhofer IKTS is responsible for scaling-up the fabrication of gas separating zeolite membranes (MFI, CHA) into industrial size in terms of membranes geometry and production method including in-line quality control.

MFI-membranes were successfully stepwise scaled up from single to multy channel geometry and up to 0.5 m long membrane elements. For first time up to 20 MFI of a length of 0.5 m were synthesized in on batch. CHA-membranes were scaled-up to 0.25 m. Highest selectivity of 200 were found in 50/50 mixtures of CO2/CH3 allowing separation of > 99% CO2 in only on membrane step.

Ceramic supports of different geometries for MFI scaling-up (l.) and synthesis of 20 MFI-membranes in one batch (r.)

Helmholtz-Zentrum Hereon

Helmholtz-Zentrum Hereon is part of the Helmholtz Association, Germany's largest scientific organization. The research center's approximately 1,100 employees make substantial contributions to clarifying major and pressing issues in key scientific, economic and social topics. Hereon's Institute of Membrane Research is developing innovative membranes and membrane processes to address global challenges as water shortages, climate change and energy transition. This involves a holistic, interdisciplinary approach: it includes developing new materials, processing these materials into membranes as well as constructing pilot plants in which these systems are made ready for implementation. Environmentally friendly manufacturing processes are at the forefront of all of our activities. All steps are accompanied by comprehensive computer simulations. With the help of these digital twins, developing modern membrane systems can be considerably accelerated. The core of Hereon's activities in INNOMEM is the improvement and operation of a pilot line for the

production of thin film composite membranes for the separation of CO2 and supplying the membranes installed in advanced membrane modules to project partners. The improved membrane production infrastructure will be made assessable to interested parties via INNOMEM's Single Entry Point.

Institute of Chemical Engineering Sciences

The Institute of Chemical Engineering Sciences (ICE-HT) is one of the founding Institutes of FORTH (Foundation for Research and Technology, Hellas). FORTH reports directly to the General Secretariat for Research and Innovation (GSRI) of the Hellenic Ministry of Development and Investments. During its operation ICE-HT has evolved to a leading center for the advancement of scientific knowledge in the fields of chemical engineering sciences.

The role of the Institute in INNOMEM involves (a) contribution to the creation of the virtual labs for modeling and characterization, (b) support of the development work for selected pilot lines through model scale-up, (c) support the network activities for services to companies and research organizations. The expertise of the lab that participates in INNOMEM involves multi-scale modeling, simulation of flow, transport and sorption in membranes, 3D reconstruction of mixed-matrix and multi-layered membranes from SEM images, prediction of separation, purification and barrier properties.

ICE-HT has already advanced during the project its state-of-the-art in software development for porous membranes and nanofluids, through the implementation of in-house codes for the prediction of transport properties in membranes with nano- and micro-inclusions. Special attention was paid to the computer-aided generation of particle aggregates and their interaction with surfaces and porous substrates using electron microscopy images. The software can be employed for the prediction of the performance of membranes in gas separation and filtration of suspensions and aerosols. An indicative image of three-dimensional reconstructions of particle suspensions in a porous membrane sample is shown below.

Universität Duisburg-Essen

Universität Duisburg-Essen (UDE), Germany, has been formed in 2003 by the merger of the Universities Duisburg and Essen. The university has a broad spectrum of fields, with a strong focus on the sciences, engineering and medicine. Nanotechnology and water science are two of the core areas, and the interdisciplinary activities are organized in the Centre of Nanointegration Duisburg-Essen (CENIDE) as well as the Center for Water and Environmental Research (ZWU).

The in this project involved Chair "Technische Chemie II" (TCII), led by Prof. Ulbricht (www.uni-due.de/tech2chem), has a key position within research and teaching in the

Chemistry Department of UDE, and it is an active member of CENIDE and ZWU. The research of the Ulbricht group is devoted to functional polymeric materials with a focus on membranes and particular emphasis on membrane applications in water purification, bioseparation or energy technologies.

In INNOMEM we take part as one of the key facilities providing a pilot line set-up for flat sheet membranes. Located in Duisburg at the NanoEnergieTechnikZentrum (NETZ), a roll-to-roll coating system (COATEMA Click&Coat®) is used to manufacture flat sheet membranes in a continuous process with a membrane width of up to 60 cm and a production rate of up to 2 m/min. Together with EVONIK, we form one of the showcases and successfully illustrated the chances this project offers to industrial partners to increase the TRL of their research. Starting with a novel polymer and lab-based membrane synthesis from EVONIK, we transferred this process to our pilot line to show the feasibility of the commercial production of a new anion-exchange membrane with improved properties for water electrolysis compared to other state of the art membranes.

Roll-to-roll coating system (COATEMA Click&Coat®)

H2SITE

H2SITE is a company focused on-site hydrogen production by advanced membrane reactors. H2SITE's mission is to manufacture these advanced membrane reactors that can provide industrial hydrogen at small to medium scale, with high purity at small to medium scale, helping our clients to reduce their costs. Our technology is based on compact, efficient and secure systems with a low environmental impact, thanks to one-step reactors (hydrogen production and purification by advanced membranes) based on intensification process, where different feedstock as natural gas, methanol, ethanol (or their "bio-alternatives" for renewable generation) and/or ammonia can be the starting raw material.

In the frame of INNOMEM project, H2SITE's role is to lead showcase 4. At the same time, we have our own task as membrane integrator in the hydrogen production system, giving support in the validation of this system at the biogas plant of ENGIE too.

Prior to membrane integration and later validation of the technology, H2SITE has already performed several tasks related with the setup of the reactor. Specifically, conversion of the fixed bed configuration into a fluidized bed one and the assembly of the entire balance of plant (BoP) have been carried out. Besides, the electrical installation (Programmable Logic Controller) of the has also been done. In the coming months, other tasks such as isolation of the entire system (to avoid heat losses) and safety procedure validation will be performed in order to be ready to integrate membranes when needed.

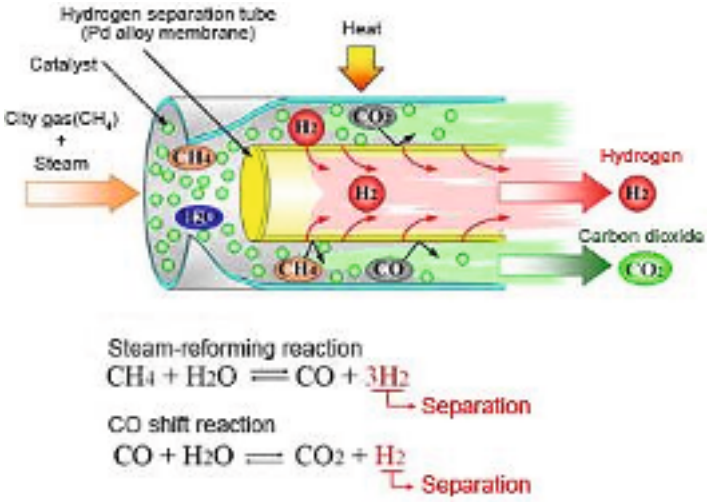
By means of this Open innovation test bed frame and in relation with the upgrade of pilot line

#2, the showcase #4 will deal with advanced membranes for pure hydrogen production and characterization.

As you may know, hydrogen is mainly produced by reforming of natural gas at industrial scale. This is a endothermic system which takes place at high temperature followed by high and low temperature WGS processes and finally, hydrogen purification steps. This conventional system is only efficient at very large scale when heat integration is optimized.

By means of membrane reactor technology, efficiency can be improved with the integration of catalytic reaction and separation in one single vessel. Full conversion and hydrogen separation is achieved thanks to Pd membranes. Chemical equilibrium is shifted towards products, when conversion takes place at lower temperature.

Here you have a close picture of hydrogen production and separation process. Hydrogen is produced by SMR and this hydrogen is separated by palladium alloy membranes thanks to their unique solution-diffusion separation model. These membranes are extremely selective and in a fluidized bed reactor high hydrogen purities and yields can be achieved.



Thanks to this innovative technology, we are able to make a compact system while reducing costs both capex and opex.

This showcase technology is based on Pd membranes and process intensification where the manufacture of advanced membranes will be validated.

Partners are TECNALIA, TUe, ENGIE, RKV and us (H2SITE). This means that industrials, academics, and research centers are here bringing their expertise together.

Main contents of show case 4 are:

- Membrane manufacturing
- Characterization of advance membranes
- Material and process design
- Integration of membrane reactor

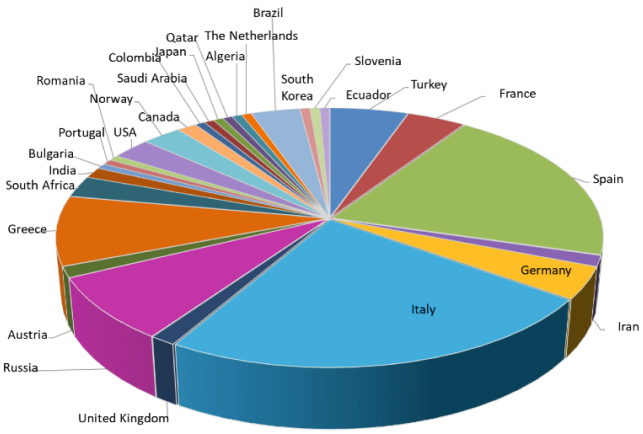
INNOMEM special session in the frame of the International Conference on Hydrogen Production

Dr. Adolfo Iulianelli (CNR-ITM) Chaired with Dr. Antonio Vita (CNR-ITAE) the 12th edition of the **International Conference on Hydrogen Production (ICH2P-2021)**, which was held online between September 19-23, 2021 (https://www.ich2p-2021.org).

The event was organized by the CNR-ITM and CNR-ITAE and under the patronage of the International Association for Hydrogen Energy (IAHE) and was focused on the scientific developments on the sustainable H2 generation, purification, storage and utilization, further enriched by a number of parallel side-events under the conference motto "**Hydrogen for a green future**".

In brief, **ICH2P-2021 conference** has dealt with 8 plenary speakers (Dr. Bart Biebuyck (NL) & Dr. Nikolaos Lymperopoulos (GR), Executive Director and Project Manager of the Fuel Cells and Hydrogen Joint Undertaking (FCH-JU), respectively; Prof. Ibrahim Dincer (TR), founding Chair of ICH2P conference and President of the Turkish National Association for Hydrogen; Em. Prof. John Sheffield (USA), President of the International Association for Hydrogen Energy; Em. Prof. Enrico Drioli (IT), Founding Director of CNR-ITM and Honorary President of the European Membrane Society; Dr. Antonino Aricò (IT), Director of the CNR-ITAE; Prof. Bruno G. Pollet (Canada), President of the Green Hydrogen Division of the International Association for Hydrogen Energy; Dr. Camel Makhloufi (FR), R&D Program Leader at Hydrogen Lab of ENGIE Industry), more than **200 attendees** coming from 27 Countries all of around the World and **170 contributors** as oral and poster presentations, **5 side events**.

Among these, the **INNOMEM Special Session**, organized by Dr. Adele Brunetti (CNR-ITM), Dissemination manager of the project, was aimed at promoting the project activities in the field of hydrogen treatment and production as well as gas separation. After an overall introduction to the project done by the Coordinator (TECNALIA), the session included nine presentations provided by some of the leaders of the pilot lines development (TECNALIA, HEREON, UNIZAR, UDE, H2SITE, FORTH-ICEHT), of the Virtual testing (CNR-ITM) and modelling (TUE) labs and by the responsible of exploitation activities (CiaoTech – PNO).



INNOMEM Consortium

Project details

Start date:	**01-05-2020**
Duration:	**48 months**
Project cost:	**16.001.766.25 euro**
Project funding:	**14.716.872.26 euro**

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This project has received funding from the European Union's Horizon 2020 Research & Innovation programme under Grant Agreement No 862330.