

Ammonia and MOF based Hydrogen storage for Europe



Welcome to this first AMBHER newsletter. AMBHER is a four-year project targeting the development of high-performance, cost-effective hydrogen storage technologies. Two different technologies are addressed: novel nanoporous Metal Organic Frameworks (MOFs) for the short time hydrogen storage in vessels for transport applications and membrane reactors integrating new catalysts and membranes for ammonia synthesis for long term hydrogen storage media.

The present newsletter is the first release of the biannual letter that will be published by AMBHER presenting the progress on the project and highlighting information related to the R&D fields addressed. Hope you will find the info in this newsletter interesting. On our website www.ambherproject.eu you will find public presentations, all the public deliverables of the project and many other interesting news. Stay tuned!

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About the Project

AMBHER (Ammonia and MOF based Hydrogen for Europe) is a European project providing a holistic approach to tackle the short and long term energy storage challenges raised by the high degree of electrification our society is aiming for. Firstly, AMBHER is addressing the main societal, economic and technological questions coming together with the use of green ammonia as seasonal renewable energy storage. Simultaneously, AMBHER is developing and demonstrating innovative and cheaper compressed hydrogen storage potentially solving the gap toward local and economically relevant power-to-hydrogen hub.

AMBHER will thus increase the number of applications in the energy and transport sectors and the possibilities for success and industrial adoption by key players. For short-term hydrogen storage, novel nanoporous MOFs (Metal Organic Frameworks) of high surface area ($>2.500 \text{ m}^2/\text{g}$) and low cost synthesis will be developed following an original shaping process (3D printing). Furthermore, AMBHER will develop a conformable cryo-vessel that can accommodate stacks of MOF bodies of tailored-made shape.

A capacity of 40 g/L of usable space at 100 bar is achieved at competitive cost with respect to current high pressure cylinders. For long-term storage, advanced materials (both catalysts and membranes) and their combination in an intensified 3D-printed intensified periodic open cell structured reactor will be developed to allow hydrogen storage in the form of ammonia (NH_3) in a cost-efficient and resource-effective process at lower temperatures and pressures compared to conventional systems. AMBHER project is validating both solutions at TRL 5 addressing the positioning of the solutions developed in relevant business cases.

Impacts

AMBHER project will contribute to the objectives of the European Green Deal towards making the European Union (EU) climate neutral in 2050. It will play an important role in addressing some of the key challenges facing today's global society, such as the cost of energy, energy security and climate change. It will not only reduce the EU's energy dependence, but also make its energy system more resilient by balancing the energy generation and consumption curve facilitating the integration of the renewable energy in the grid through long-term storage hydrogen technologies.

The use of renewable energy storage solutions in the short and long term enables the decarbonisation of many sectors that would otherwise be difficult to decarbonise, such as transport sector. These innovations will have an impact on the entire value chain of these sectors and improve the overall competitiveness of the European economy. AMBHER will also contribute to the generation of wealth by creating around 20,000 jobs (direct, indirect and induced) accumulated (2030-2035). It will connect material developers with key players in the hydrogen economy, additive manufacturing companies, chemical companies and end-users of ammonia, matching existing needs and new products with the essential link provided by innovative organizations that are capable of developing advanced technologies that will meet the challenges of the coming years.



Partners of AMBHER

The Consortium of the AMBHER project includes 16 partners from 6 Countries, and puts together both Universities and Research centers as well as SME and large Industries. The project is coordinated by Tecnalía. Below a short description of the AMBHER partners.

TECNALIA



Fundación TECNALIA Research & Innovation (<https://www.tecnalia.com>) is the largest private, non-profit applied research centre in Spain, a benchmark in Europe, and member of the [Basque Research and Technology Alliance \(BRTA\)](#). We collaborate with companies and institutions to improve their competitiveness, people's quality of life and achieve sustainable growth. Our main areas of action are fully aligned with the Sustainable Development Goals

(SDGs): smart manufacturing, digital transformation, energy transition, sustainable mobility, personalised health, and urban ecosystem. TECNALIA employs around 1,472 people (266 PhDs) with an income of 113, 5 million € in 2020. It has been granted over 777 patents and promote more than 30 spin-off companies.

TECNALIA is a key agent in the European Research Area. TECNALIA actively participates in the governing bodies of several European Technology Platforms, PPPs and JTIs (EEB, FOF, SPIRE, ARTEMIS...) and associations. TECNALIA has participated in 252 H2020 projects, coordinating 73 of them, and on 35 HORIZON EUROPE projects under negotiation by April 2022 coordinating 6 of them.

The [Membrane Technology and Process Intensification](#) group of the Material and Processes Dept. in the Energy, Climate and Urban Transition Unit will be involved in the project. The group develops advanced membranes and membrane reactors for Industrial Gas and liquid Separation demands. Aiming at increasing the efficiency, reducing the operating and capital costs as well as physical and environmental footprint in different applications. Some examples, H₂ purification and production, CO₂ Capture and conversion, natural gas processing, biogas upgrading and olefin/paraffin separation among others. We have extensive testing and membrane manufacturing capabilities, and we have experience on working from proof-of-concept to relevant industrial scale.

Eindhoven University of Technology



Eindhoven University of Technology (TU/e) is a research university specializing in engineering science & technology. Our education, research and knowledge valorization contribute to: science for society:



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- solving the major societal issues and boosting prosperity and welfare by focusing on the Strategic Areas of Energy, Health and Smart Mobility
- science for industry: the development of technological innovation in cooperation with industry
- science for science: progress in engineering sciences through excellence in key research cores and innovation in education

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).

CNR – ITAE



Consiglio Nazionale
delle Ricerche



Consiglio Nazionale delle Ricerche (National Council of Research, Italy) (CNR), <http://www.cnr.it>, is a public research organisation; its duties are to carry out, promote, spread, transfer and improve research activities in the main sectors of knowledge growth and the application of this research for the scientific, technological, economic and social development of the country. The scientific network of the National Research Council of Italy consists of more than 100 Institutes, divided into 7 Departments. The Institute for Advanced Energy Technologies “Nicola Giordano” (ITAE), headquartered in Messina, operates within the Department of “Engineering, ICT and Energy and Transport Technologies”, being one out of a total of 21 research institutes grouped according to similar competencies and strategic priorities of the reference macro-area. ITAE develops and promotes energy-efficient, innovative technologies with low environmental impact through the use of fossil and renewable energy sources. The scientific expertise of ITAE is related to developing and optimising materials and chimica/technological processes for producing electric and/or thermal energy along with new fuels with specific reference to hydrogen. Approx. 100 people are employed at ITAE.

University of Utrecht

Utrecht University (UU): A world leading University in the heart of the Netherlands. Our ambition to achieve a better future for everyone motivates our scientists in executing their world leading research and inspiring teaching. At Utrecht University, the various



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disciplines collaborate intensively towards four major societal themes; Dynamics of Youth, Institutions for Open Societies, Life Sciences and Sustainability. This lively and inspiring academic environment attracts professors, researchers, and PhD candidates from all over the globe, making both the University and the Faculty of Science a vibrant international community and wonderfully diverse.

At the **Faculty of Science** there are 6 departments to make a fundamental connection with: Biology, Chemistry, Information and Computing Sciences, Mathematics, Pharmaceutical Sciences and Physics.

At the **Debye Institute for Nanomaterials Science**, chemistry and physics meet to study the properties of materials at the nanoscale. We specifically focus on three themes: catalysis, colloids and nanophotonics.

The group of **Materials Chemistry and Catalysis (MCC)**, who is a partner in this project, focuses on the synthesis, characterization and performance of well-defined solid catalysts and related functional materials for energy storage and physicochemical conversion processes. The aim is to establish a relationship between structure and materials functionality at length scales ranging from the single atomic and molecule level over the micro-, meso- and macroscopic scale up to the level of small reactor set-ups.



Universiteit Utrecht

CSIC



INSTITUTO DE
TECNOLOGÍA
QUÍMICA



CSIC
CONSEJO SUPERIOR DE INVESTIGACIONES CIENTÍFICAS



UNIVERSITAT
POLITÀCNICA
DE VALÈNCIA

The Spanish National Research Council (CSIC) is the largest public research institution in Spain and one of the most renowned institutions in the European Research Area. It is affiliated to the Ministry of Science and Innovation. The Institute of Chemical Technology (CSIC-ITQ) jointly belongs to CSIC and to the Polytechnic University of Valencia (UPV). CSIC-ITQ has led activities regarding development of electrocatalytic materials, gas separation membranes and solid oxide fuel cells. Moreover, CSIC-ITQ is responsible of key activities on synthesis of nanomaterials, mesoporous materials and different functional architectures in several European consortia. CSIC-ITQ also has a long experience in the design and own fabrication of fully-automated laboratory reactor prototypes operating at high pressures, temperatures and production rates as well as excellent facilities for performing characterisation and transport measurements in realistic operation conditions. ITQ has a leading position in the design, fundamental characterization and kinetic study of heterogeneous catalysts. Within AMBHER project, CSIC-ITQ will contribute to the objective dedicated to the long-term hydrogen storage. CSIC-ITQ will work on the design and development of new catalysts for the ammonia synthesis at milder conditions than those encountered in the energy intensive Haber-Bosch process. In close



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collaboration with AMBHER partners, the designed catalysts will be fully characterised, modelled and optimized to be used in a breakthrough catalytic membrane reactor further intensifying the ammonia synthesis process.

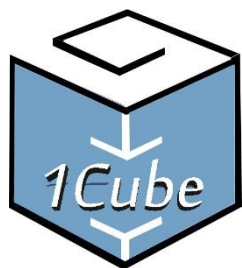
Max Planck



MAX-PLANCK-INSTITUT FÜR KOHLENFORSCHUNG

The Max-Planck-Institut für Kohlenforschung, founded in 1912 as the Kaiser Wilhelm Institute für Kohlenforschung is a foundation of private law controlled by a Board of Directors and integrated, as one of the 86 institutes, in the Max-Planck-Gesellschaft. It pursues basic research in all fields of catalysis. The central theme of all Departments is basic research in the catalytic transformation of compounds and materials with the highest degree of chemo-, regio- and stereoselectivity under conditions which maximize efficient use of natural resources. Researchers at the institute perform basic research in the fields of organic and organometallic chemistry, homogeneous and heterogeneous catalysis, as well as in theoretical chemistry. Five departments, each one headed by one scientific director, form the scientific backbone of the institute. The research departments are supported by service groups that provide state-of-the-art analytics, efficient IT, and excellent hardware from specialized workshops.

1 CUBE BV



1CUBE BV is a Dutch based SME specialized in support for research projects management and dissemination. We organize, write, submit, manage research and development projects.

We also act as Partners for EU project, above all on business planning, exploitation, dissemination and management.

RINA



With almost 160 years of experience across a wide range of industries, RINA is a multinational company that helps clients build strong, successful businesses. Through a global network of 3,900 talented professionals operating out of 200 offices in 70 countries,



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we support market operators across the entire lifecycle of their projects, whilst assisting them in renewing their products, technologies and services.

CNRS



CNRS is a public organisation for scientific and technological research and is under the authority of the French Ministry for Research. It is also the largest fundamental research organisation in Europe. Measured by the amount of human and material resources it commits to scientific research or by the great range of disciplines in which its scientists carry on their work, the CNRS is clearly the hub of research activity and technological innovation.

IRCELYON (Research Institute for Catalysis and Environment of Lyon) was founded in 2007 and is the largest national department devoted to the development of catalytic and environmental remediation processes. The “Engineering from material to process” (ENG) team (~10 permanent staffs and 20-25 students) at the center of this project has already gained a large experience of materials and process development in the frame of European projects

The development of MOF as adsorbent for CO₂ capture from Natural Gas was initiated in 2005 in the frame of the Integrated Project “TopCombi” (FP7). Synthesis Upscaling and Shaping technologies have been developed in the EU H2020 project ProDia which lead to the successful demonstration of HKUST-1 and UiO-66 pilot manufacture. This experience and expertise in MOF synthesis, functionalization, characterization and adsorption ideally matches the work proposed within the AMBHER project. In addition, the background in Chemical Engineering and pilot testing will allow designing suitable materials from start for real process conditions, thus ensuring key issues such as scale-up, shaping and conditioning among others. Finally, the consortium will benefit of numbers of testing facilities for adsorption measurements and characterization.

Thyssenkrupp



Thyssenkrupp comes with an over hundred-year experience in chemical plant technology as a leading EPC (Engineering, Procurement, Commissioning) company. With a long reference list of large capacity Ammonia plants and a focus on future green ammonia energy future, thyssenkrupp will exploit the results of a successful Ambher project.



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With a history of over 170 years, today IBERDROLA is a global energy leader, the number-one producer of wind power and one of the world's biggest electricity utilities by market capitalisation. The units supply energy to almost

100 million people in dozens of countries, has more than 600,000 shareholders, a workforce comprising more than 35,000 employees and assets worth more than €122 billion. Thanks to its commitment to clean energy, IBERDROLA is currently one of the companies with the lowest emissions and an international benchmark for the contribution to the fight against climate change and to sustainability. The company has set itself the target of achieving global carbon neutrality by 2050 and it expects its emissions intensity to be almost zero in Europe by 2030. In fact, its CO2 emissions are two thirds lower than those of our EU competitors.

IBERDROLA is leading the transition towards a sustainable energy model through investments in renewable energy, smart grids, large-scale energy storage and digital transformation, offering the most advanced products and services to its customers. IBERDROLA units are present today in the several countries and geographical areas, leading energy utility and a benchmark, thanks to its sustainable energy model. In the H2 production field, IBERDROLA, in its mission to lead the energy transition, is spearheading the development of green H2 with over 60 projects in eight countries (Spain, the United Kingdom, Brazil, the United States, among others) to meet the demand for electrification and decarbonisation in sectors such as industry and heavy transport, with a portfolio that will require investments of more than €3 billion by 2030 to produce 400,000 tonnes per year. The company has created a new green H2 business unit with the aim of becoming the world leader in this technology. The group is addressing the technological challenge of producing and supplying green H2 from clean energy sources, powering the electrolytic process with 100% renewable electricity. The green H2 is a new growth opportunity for IBERDROLA.

MAHYTEC



MAHYTEC is a French company specialized in hydrogen storage, working on two technologies of storage: compressed hydrogen storage as well as solid hydrogen

through metal hydrides. In the project, MAHYTEC will be in charge of the design and the manufacturing of a conformable vessel for the MOF. Due to the relatively low pressure (up to 100 bars), various shapes of vessels with higher space occupancy will be considered, while taking into consideration the heat exchanger





CRIGEN is ENGIE's corporate R&D center devoted to green gases (hydrogen, biogas and liquefied gases), new energy uses in cities and buildings, industry and emerging technologies (digital technology and artificial intelligence, drones and robots, nanotechnologies and sensors).

ENGIE Lab CRIGEN conducts operational R&D projects and develops pilots, and implements innovative offers to boost and speed up the energy transition.

ENGIE Lab CRIGEN brings together in its premises key skills and testing resources unique in Europe to prepare tomorrow's energy solutions. It is also an enabler to accelerate and strengthen collaboration between the French and International R&D ecosystems.

The Hydrogen Lab, representing CRIGEN within AMBHER project, assesses technologies and develops a systemic approach for supporting green hydrogen developments all along the value chain: hydrogen production, transportation and storage, markets (industry, mobility) and Power-to-X.

University of Birmingham



UNIVERSITY OF
BIRMINGHAM

Founded in 1900, the University of Birmingham is one of the leading research-based universities in the United Kingdom; the breadth of research expertise is a distinctive characteristic of the University. The last UK Research Excellence Framework in 2014 confirmed that

87% of the University's research has global reach, meaning it is recognised internationally in terms of its originality, significance and rigour. Birmingham is 90th in the 2022 QS World University Rankings, cementing our position in the top 100 universities globally and placing us 14th out of the 24 Russell Group universities to feature in the ranking.

Johnson Matthey



Johnson Matthey's vision is for a world that's cleaner and healthier, today and for future

generations. As a global leader in sustainable technologies, we apply our cutting-edge science to create solutions with our customers that make a real difference to the world around us. Today one in three cars is fitted with a JM catalyst which prevents 40ton/min of pollutants to be released to the atmosphere.



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We aim to have 95% of our sales contributing to four priority UN SDGs by 2030 and to achieve net zero by 2040. And we help other businesses to achieve their sustainability targets with our science, technology and products. We've been leaders in our field for more than 200 years, applying unrivalled scientific expertise to enable cleaner air, improved health and the more efficient use of our planet's natural resources.

And now, as the world faces the challenges of climate change and resource scarcity, we have an even bigger role to play. Johnson Matthey will be central in accelerating the big transitions needed in transport, energy, chemicals production and creating a circular economy.

UKRI



Science and Technology Facilities Council

STFC is part of UKRI (UK Research and Innovation), which convenes, catalyzes and invests in close collaboration with others to build a thriving, inclusive research and innovation system and whose overarching vision is for that outstanding research and innovation system in the UK giving everyone the opportunity to contribute and to benefit, enriching lives locally, nationally and internationally. STFC's mission is to deliver world-leading national and international research and innovation capabilities and, through those, discover the secrets of the Universe. Our major research and innovation campuses at Harwell, Daresbury and research facilities across the UK support fundamental research in astronomy, physics and space science. UKRI/STFC's role within the AMBHER project is to use our expertise in the characterization of ammonia synthesis (and decomposition) catalysts to develop advanced in-situ and ex-situ techniques to reveal catalyst mechanisms along with structural changes and even potential degradation pathways.

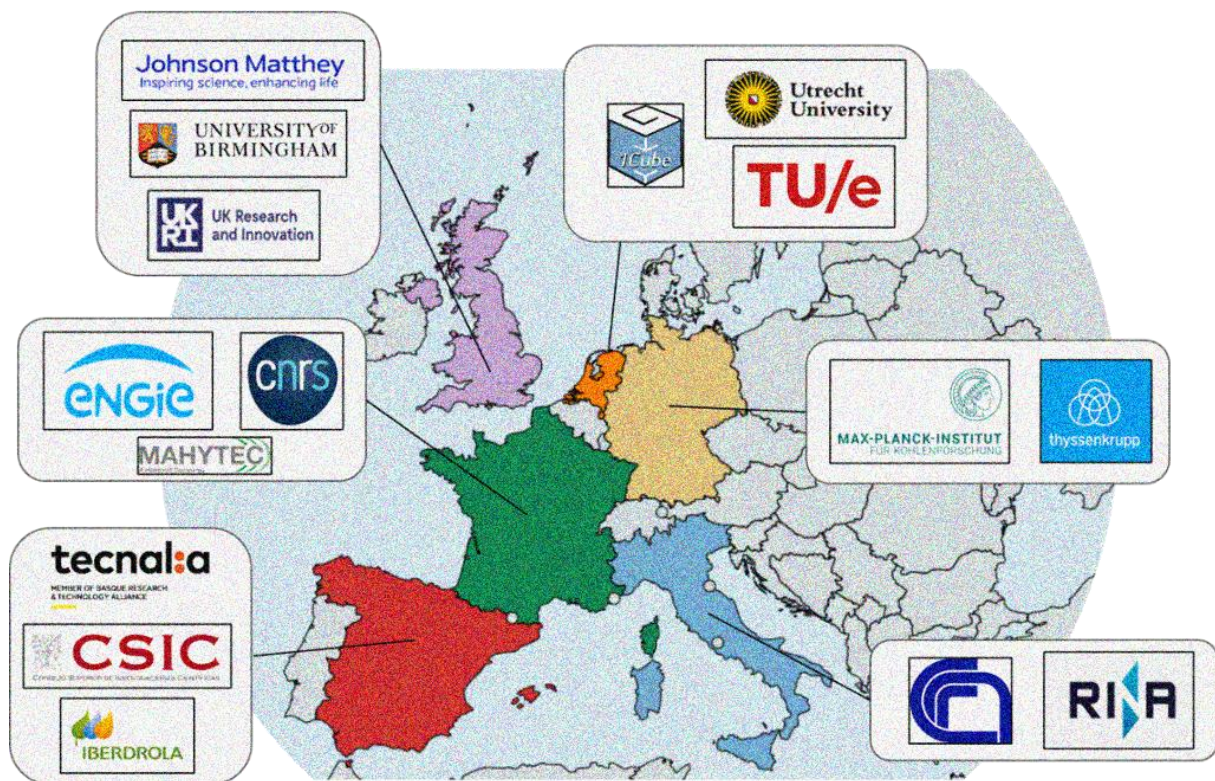
Dissemination

The AMBHER project has been presented by our project coordinator at the International Conference on Catalysis in Membrane Reactors, held in Japan (Tokyo), 1-4th August 2022.

This was the 15th edition of the conference. The next edition, the ICCMR16, will be organized by Tecnalia in October 2023 in San Sebastian. AMBHER will be present with the new PhD students hired within the project in the last months.



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Project name: Ammonia and MOF Based Hydrogen storageE for euRope

Project acronym: AMBHER

Call: HORIZON-CL4-2021-RESILIENCE-01

Topic: HORIZON-CL4-2021-RESILIENCE-01-17

Starting date: June 1st 2022

Duration: 48 months

UE funding: 4,915,870 Euro

COORDINATOR: Fundación Tecna:ia Research & Innovation

Project Coordinator: José-Luis Viviente



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