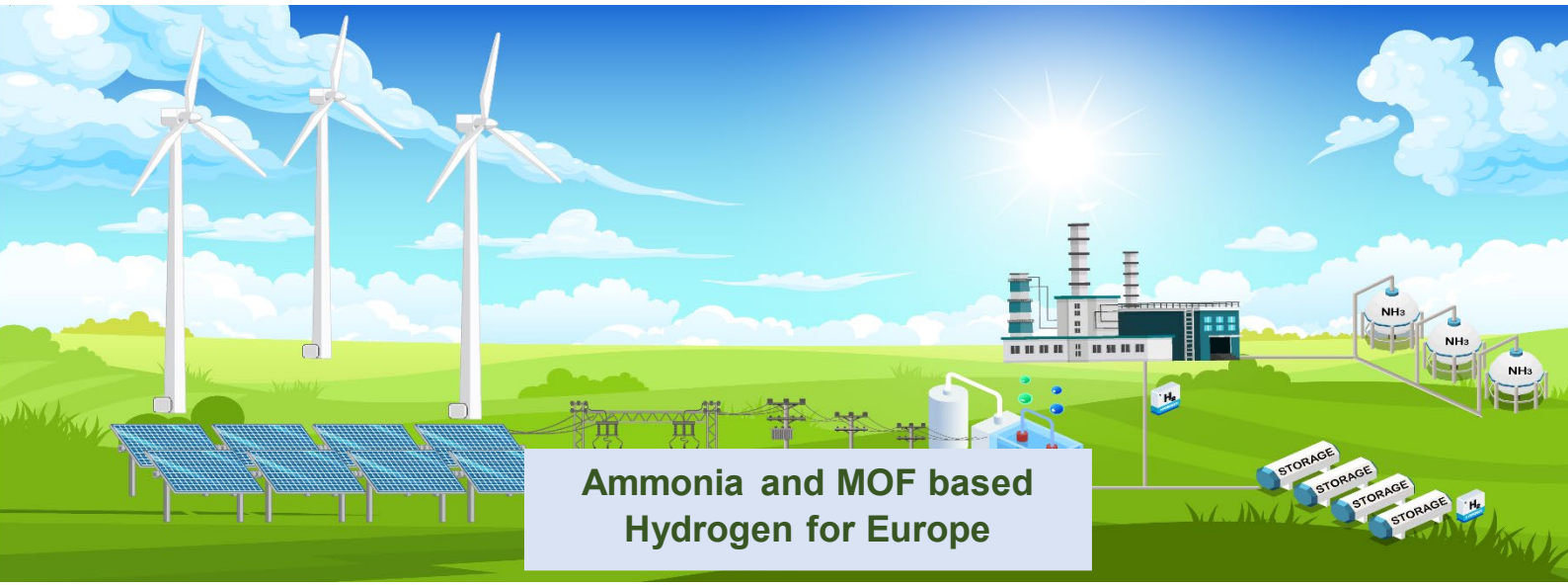


Welcome to this third AMBHER newsletter. AMBHER is a four-year project targeting the development of high-performance, cost-effective hydrogen storage technologies. Two different technologies are addressed: novel nanoporous metal organic frameworks (MOFs) for the short time hydrogen storage in vessels 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 third 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!

In this number:

Funded by the European Union

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 m^2/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.

Looking back to the last months, the partners of AMBHER project were very busy on their work and activities.

- ✓ We started the Year 2024 with a PR1 review meeting, that was a productive and vey intense full day!

- ✓ End of February, the WP leaders had an on line meeting M21 PTC, where they discussed about the Review Meeting and satisfied and happy for the forst positive report received, they looked ahead for the next months and to set up the next goals.

- ✓ First article was published in May at the "Chemical Engineering Journal" about Comparison of thermo-hydraulic performance among different 3D printed periodic open cellular structures (find here: https://www.ambherproject.eu/article-papers/).

Within the European AMBHER project, a screening analysis based on sustainability pillars and circularity analysis – first LCA, LCC, and S-LCA was performed by RINA-C Sustainability Management Consulting team. This first iteration aimed to identify the most promising key component from a sustainability perspective. The focus was on the following system key components developed within AMBHER project for new hydrogen storage technologies for both short- and long-term hydrogen storage: Metal Organic Frameworks (MOFs), Catalysts, and Carbon Molecular Sieves Membrane (CMSM).

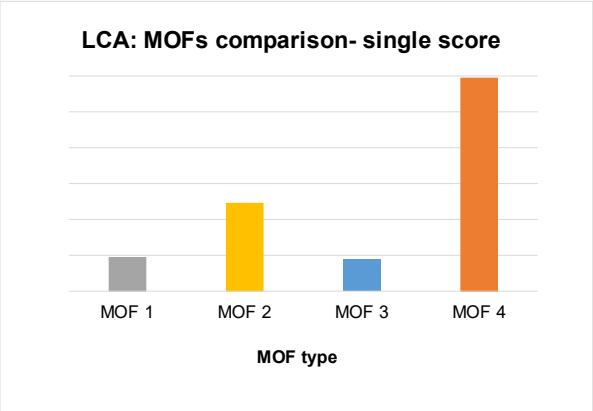
The study evaluates the sustainability performances of the AMBHER systems in terms of environmental, economic, and social impacts. For each above-mentioned category, different components were developed by the technical partners of the project: JM, CNRS, ITQ-CSIC and TECNALIA.

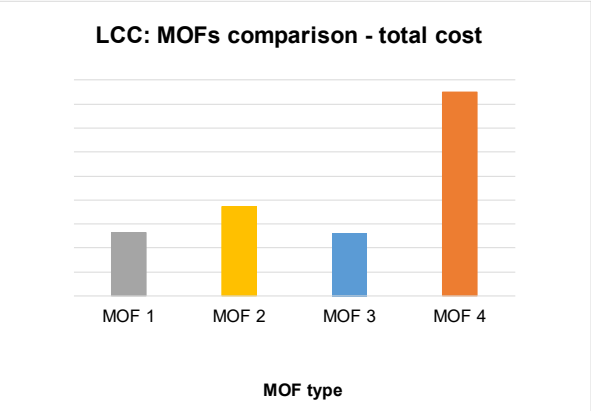
A comprehensive comparative analysis was conducted on Metal-Organic Frameworks (MOFs) based on lab-scale data, considering environmental, economic, and social perspectives. For the two catalysts analysed within this study, the comparison was feasible only from economic and social perspectives. However, each catalyst underwent a self-assessment from an environmental standpoint. In contrast, the molecular carbon membrane was subjected to a thorough self-assessment covering all three perspectives: environmental, economic, and social.

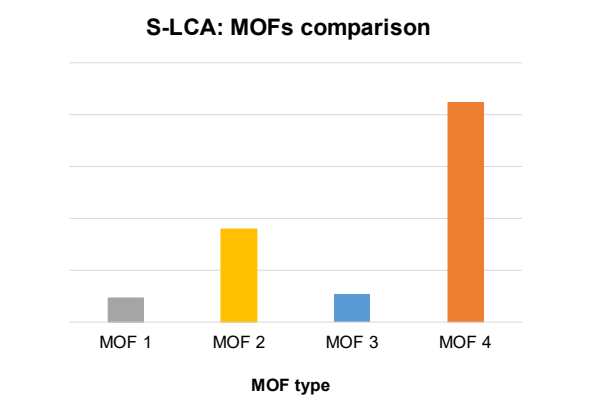
The analyses were conducted following the main regulatory framework (ISO 14040, ISO 14044, ILCD Handbook, SETAC Guidelines, ISO 15686-5 and Geen Delta) and the developed activities were carried out following the four phases of the LCA framework: goal and scope of the study, Life Cycle Inventory (LCI), Life Cycle Impact Assessment (LCIA) and results and interpretation. A cradle -to-gate approach was considered and both primary and secondary data input were gathered to feed the system modelled in SimaPro (Ecoinvent Database) and OpenLca (Psilca Database) software calculations.

MOFs

Above the four MOFs analysed, MOF 3 is the cheapest MOF and demonstrate the lowest environmental impact. The hot spot in the MOF 3 analysis is related to the electricity consumption that has the greatest impact. S-LCA results show the lowest social impact for MOF 1, followed by the MOF 3, which has almost equal score. The study shows that organic linker has the greatest impact with respect to total social risk.



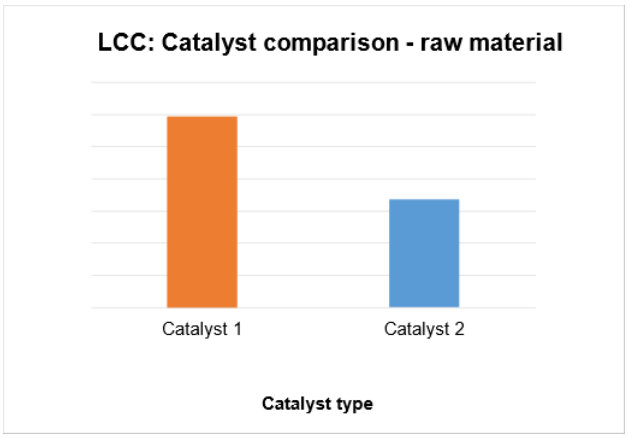


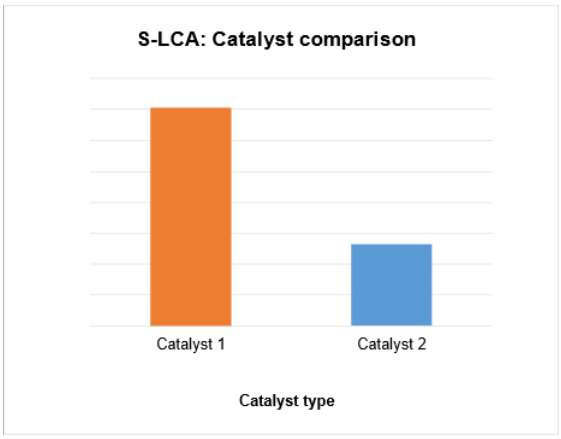


- **MOF 1:** cheapest MOF
- **MOF 2:** benchmark
- **MOF 3:** possible candidate
- **MOF 4:** benchmark

Catalysts

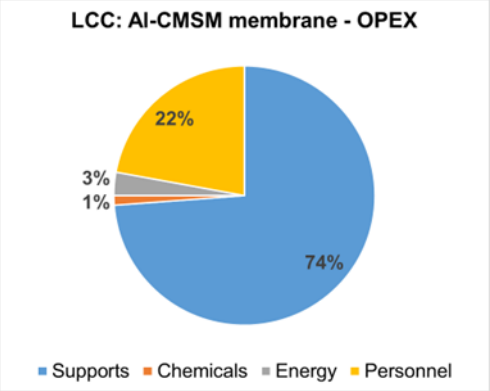
From an economic perspective the Catalyst 2 results cheaper than the Catalyst 1 when considering only raw materials. Also, from a social perspective Catalyst 2 shows the lowest total social impact when considering only raw materials. The most impactful sectors are related to the metals production value chains for both catalysts. From an environmental perspective, both catalysts influence several impact categories (e.g. Eutrophication, terrestrial, Eutrophication, marine, Acidification, Particulate matter and Photochemical ozone formation) that account for 10% of total impacts, due to the direct emission in air of greenhouse gases during the synthesis process.





Membrane

The environmental impact assessment calculated through the LCA analysis shows that energy consumption accounts for almost 70% of total impacts. The synthesis process itself shows major contribution in eutrophication, particulate matter and photochemical ozone formation impact categories. LCC results show that the membrane supports account for 74% of total cost, followed by the personnel cost (22%). S-LCA results show that the alumina porous support value chain production cover about 80% of total social risk.

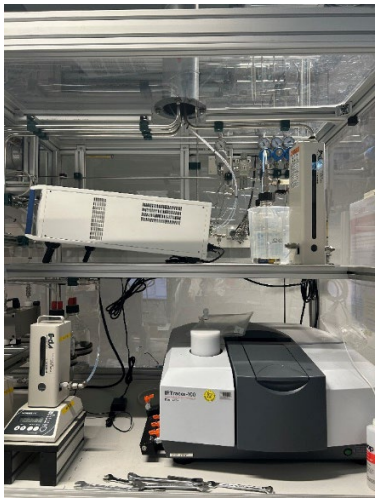


These three analyses have been aimed at:

- gaining a better understanding of the environmental, economic and social performance of the synthesis methods and the raw materials used as well as identifying areas for improvement.
- compare the relative burdens between them in each component category.

The content of this study is a screening analysis, a first iteration aimed to identify the most promising key component from a sustainability perspective, and it will be finalised in a further deliverable, generated by the end of the project (M48).

In TUE a new formulation of metal doped carbon membranes developed by Tecnalia partner is being tested. The idea of integrating transition metals such as Co, Ni, Zn, Zr is to study their interaction with ammonia for the successive separation in a membrane reactor for ammonia synthesis. The pictures below shows the setup used to test by performing the single and mixed gas permeation tests carried out in a wide range of temperature up to 350°C and Pressure up to 7 bar, with the aim of studying possible physical and chemical interactions between ammonia and the metal incorporated into the carbon layer. In the pictures the membrane reactor is connected to the analysis part consisting of a gas chromatography, and a bubble flow meter used to quantify the amount of gas (H_2, N_2, NH_3) that has been separated by the membrane.



In May J. Verschoot from Materials Chemistry and Catalysis, Debye Institute for Nanomaterials Science, Utrecht University participated at MH2024, held Saint Malo (France) from 26th to 31st May 2024 (https://mh2024.org/). She talked about "Metal hydride nanocomposites as transition metal free catalysts for ammonia synthesis" related to our project Ambher.

Her presentation is in our website, just following this link:

https://www.ambherproject.eu/wp-content/uploads/2024/05/MH-conference-Juliette-Verschoor-2024-Final-Version-1.pptx

1 Cube BV, that is in charge of the Dissemination task, organized at the end of January (29TH and 30TH), in Eindhoven a "Winter School on Membrane reactors" with a collaboration of our partner Tu/e and another european project MACBETH.

There were two full days where we could discuss about membrane preparation, scale up, catalyst development for membrane reactors, demonstration at lab scale and large scale.

The speakers were international so as the students.

We remind you to have a look on their impressions, looking at the recup video's:

Feedback from the students

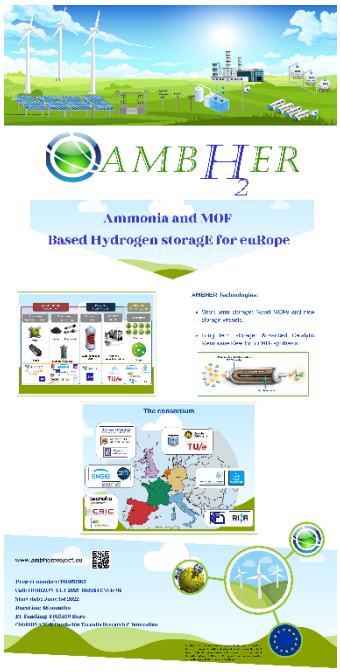
Feedback from the speakers

Moreover all the students and speakers had a nice moment at Fling Restaurant where they had a good social dinner.

All the presentations of the speakers you find them in our website:

List of presentations

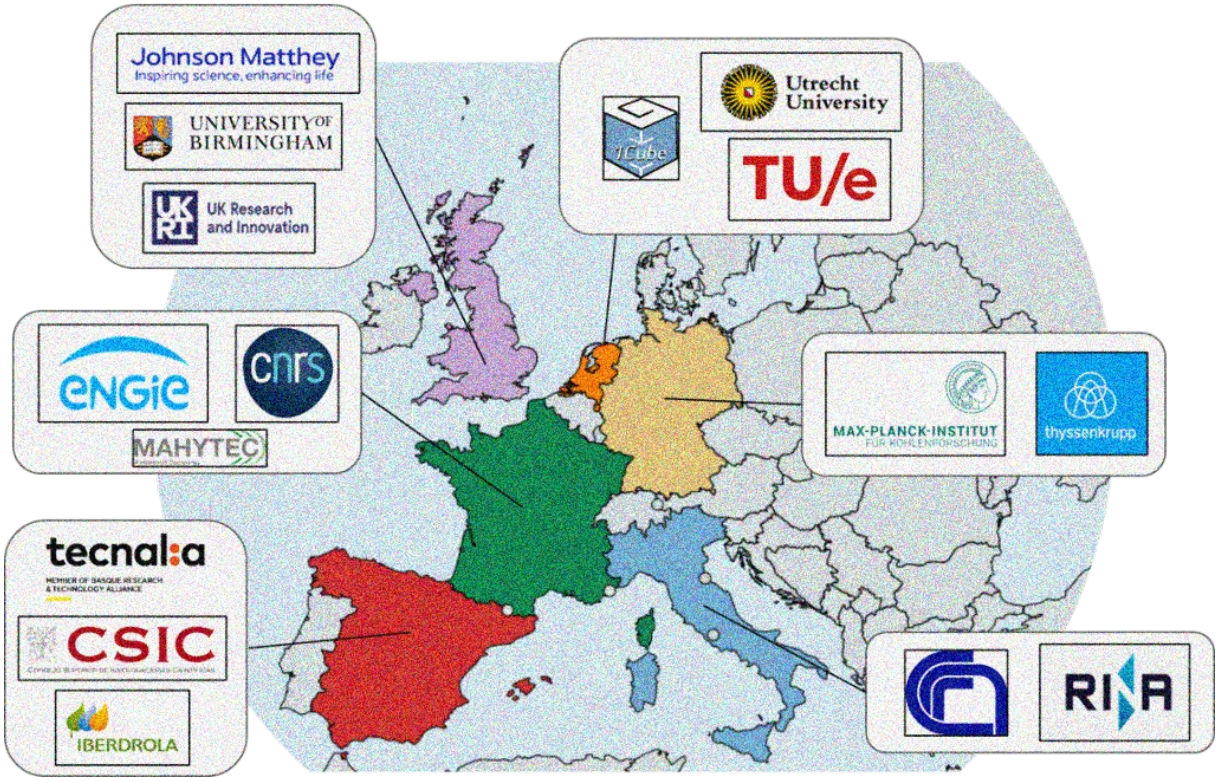
In the following months, 1 Cube was busy on getting ready to be part at the big event in Milazzo (Sicily), where AMBHER project proudly participated as a Gold Sponsor at the IX Symposium on Hydrogen, Fuel Cells, and Advanced Batteries, (HYCELTEC) held from June 30th to July 3rd 2024.



Rollup: Ambher project

This prestigious event brought together leading experts, researchers, and industry professionals from around the world to discuss the latest advancements and innovations in the field of hydrogen energy and related technologies.

More about this fantastic event is going to be written in the next newsletter.



Project details:
Project number: 101058565
Project name: Ammonia and MOF Based Hydrogen storagE 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 Tecnalia Research & Innovation
Project Coordinator: José-Luis Viviente

Funded by the European Union

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