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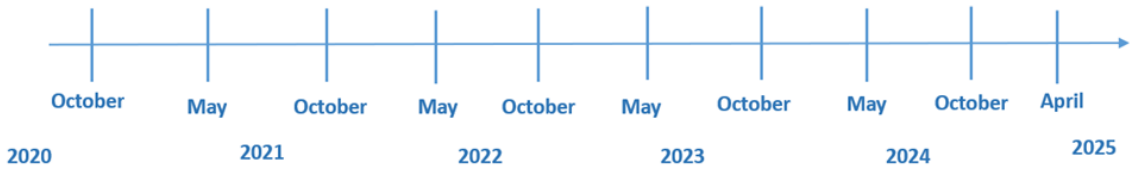
Advanced material and Reactor for ENergy storage tHrough Ammonia

Newsletter – March 2025



Editorial

Welcome to this 9th ARENHA project newsletter. ARENHA is a five-year European project with global impact seeking to develop, integrate and demonstrate key material solutions enabling the use of ammonia for flexible, safe and profitable storage utilization of energy. Ammonia is an excellent carrier due to its high energy density, carbon-free composition, industrial know-how and relative ease of energy storage. ARENHA demonstrates the feasibility of ammonia as a dispatchable form of large-scale energy storage.

The present newsletter is the final release, and it is 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.arenha.eu you will find public presentations, all the public information of the project and many other interesting news.

In this Issue:

What is ARENHA?

The concept

For decades, utility-scale energy storage has been used to balance load and demand within an energy generation system composed mainly of base load power sources enabling thus to large nuclear or thermal generating plant to operate at peak efficiencies. Energy storage has contributed over the time to meet peak demand and regulate frequency beside peak fossil fuel power plants that usually provided the bulk of the required energy. In the aforementioned context where inherent variability of the power generation asset was mainly a minor issue, energy storage capacity remains nevertheless limited for economic reasons storing electricity during low electricity demand and releasing it back into the grid during high demand, typically over a daily cycle.

In the current context of global momentum in favour of renewable electricity catalysed by spectacular levelized production cost decrease, higher storage capacity is required to ensure security and flexibility providing a portfolio of services from grid services to the decarbonization of energy intensive sectors like the transport, industry or heating and cooling sector.

For that purpose, hydrogen produced from electrolysis reveals to be a key pathway to unlock the full potential of renewable and especially for seasonal energy storage of large energy quantity and more specifically for all situations dealing with a large energy-to-power ratio situation. Hydrogen having a low volumetric energy density, it has to be compressed to high pressure, liquefied or combined as hydrogen carrier. Among all possibilities, ammonia is a carbon-free and dispatchable energy carrier allowing storing large quantities of renewable electricity. It is a primary candidate to allow a secure and clean supply of renewable energy for various stationary or mobile applications and with ability to provide a wide range of energy storage services using existing infrastructures and both well-defined regulation and acceptable safety history for over 75 years. If state-of-the-art ammonia production plants produce between 3,000 and 6,000 ton NH_3/day, its well-known process involves H_2 production from natural gas reforming. Technical challenges remain to be overcome in order to ensure a flexible and cost comparable production of ammonia from intermittent renewable electricity sources. In addition to that, efficient energy discharge processes from NH_3 must be developed in order to best leverage the clean energy produced upstream by the renewable asset.

The ARENHA project aims at using ammonia as a green hydrogen carrier and for that purpose it develops its main activities around the green hydrogen production, ammonia synthesis, storage and dehydrogenation (Figure 1). Innovative materials are developed and integrated into ground-breaking systems in order to demonstrate a flexible and

profitable power-to-ammonia value chain but also several key energy discharge processes. Specifically, ARENHA is developing advanced SOEC for renewable hydrogen production, catalysts for low temperature/pressure ammonia synthesis, solid absorbents for ammonia synthesis intensification and storage, catalysts and membrane reactors for ammonia decomposition for pure hydrogen (>99.99%) production. Energy discharge processes studied in ARENHA tackle various applications from ammonia decomposition into pure H_2 for FCEV, direct ammonia utilization on SOFCs for power and ICEs for mobility.

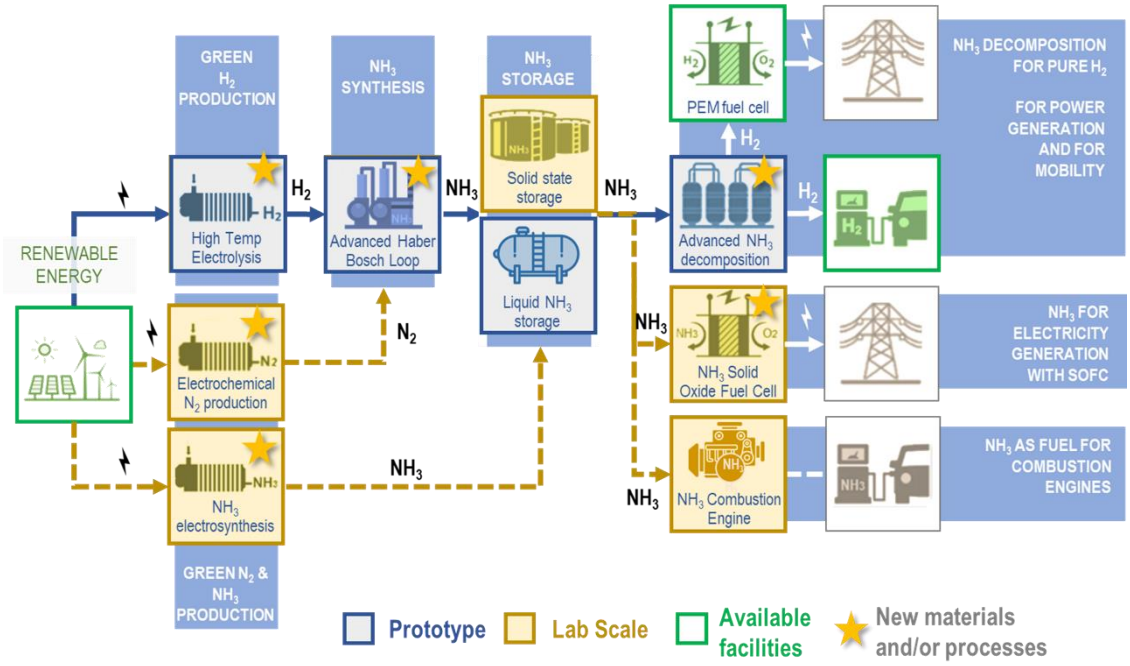


Figure 1. Power-to-ammonia-to-usage value chain in ARENHA

Project objectives

ARENHA will demonstrate the full power-to-ammonia-to-usage value chain at TRL 5 and the outstanding potential of green ammonia to address the issue of large-scale energy storage through LCA, sociological survey, techno-economic analysis deeply connected with multiscale modelling. For this purpose, breakthrough technologies will be developed and integrated along the overall value chain. The main technical objectives on material and system level are the following:

- To develop and integrate innovative solid oxide cell materials into a flexible high temperature electrolysis demonstration unit producing 1.5 Nm^3/hr hydrogen at ambient pressure to be connected on a real PV plant.

- To develop and integrate innovative materials into a synthesis loop enabling to operate a flexible Haber Bosch production unit of 10 kgNH_3/day at lower pressure (<50 bar) and temperature (<450 °C).
- To develop and integrate innovative materials into a decomposition reactor able to generate 10 Nm^3/hr of pure hydrogen (>99.99%) from green ammonia.
- To develop and test innovative materials and solutions for the alternative direct synthesis and utilization of next-generation green ammonia.
- To demonstrate ammonia as a flexible energy carrier through the development of a fully integrated prototype for green ammonia synthesis and decomposition.
- To assess the social acceptance, techno-economic-environmental feasibility, and replication potential of the developed value chains.

Latest news from the project

SOEC electrolyser prototypes

Both Elcogen and Fraunhofer-IKTS electrolyser prototypes have been built. FhG-IKTS has completed the integration and operation of the SOEC electrolyser in co-electrolysis mode. Furthermore, they have created a strategic partnership with ThyssenKruppNucera.

Ammonia synthesis prototype

The Ammonia synthesis prototype has been completed by PROTON VENTURES and will be tested in the coming months.

Ammonia cracking prototype

The Ammonia cracking prototype was designed, built and commissioned by H2SITE and successfully operated by CNH2 at Fertiberia demo site.

LCA, technoeconomic assessment and roadmap

A roadmap for the deployment of ARENHA technologies has been developed by ENGIE, together with a life cycle analysis and a technoeconomic assessment.

Footprinter

A footprinter to inform the general public in a user-friendly web-based platform has been developed by CNH2 with data obtained by ENGIE. Through a comparison based on the mobility and electricity consumption of ammonia in different scenarios, the aim is to enable an evaluation on the most cost-effective and sustainable solutions.

It can be accessed via this link: https://footprinter.arenha.eu/

Highligths

ARENHA Consortium Meeting (25th March 2025)

This face-to-face meeting of the ARENHA project took place during March the 25th of 2025 and was held in Puertollano (Spain). This meeting was the sixth face-to-face meeting and once more boosted the cooperation between partners.

Final Workshop (26th March 2025)

A workshop to share the outcomes of the ARENHA project with the general public was organised during March the 26th of 2025 and was held in Puertollano (Spain). It took place also online and was recorded for wider dissemination. A total of 85 people registered for the event, with nationalities from Europe, Australia and Latinamerica. The agenda and presentations can be found here: https://arenha.eu/content/consortium-workshops/. In addition, the video of the event has been uploaded in YouTube: https://youtu.be/tp_1YFn8CI4 and it is also accessible at the ARENHA public website.

Visit to Fertiberia demo-site (25th March 2025)

The project partners went to Fertiberia demo-site to see the ammonia cracker in operation. It has reached 1000 hours total.

ARENHA in the press

The project has been highlighted in the following media: Innovation News Network, H2Tech, Cryospain and UreaKnowHow.com.

ARENHA final public presentation

A final public presentation showing the main activities and achievements in the frame of the ARENHA project has been released. The presentation can be downloaded at the public website: https://arenha.eu/content/presentations/.

ARENHA final video

A final video of the project has been produced and can be accessed at the ARENHA public website.

Dissemination activities, publications and presentations

ARENHA public presentations as well as open access articles and public reports are available online in the dissemination section of the project website: www.arenha.eu.

Peer Reviewed Articles

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4. Freddy Kukk, Sergii Pylypko, Enn Lust and Gunnar Nurk, Influence of Active Layer Thickness of Reversible Solid Oxide Cells on the Electrochemical Performance of Water Electrolysis, *ECS Transactions,* **2021**, *103*(1), 511. https://doi.org/10.1149/10301.0511ecst.
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10. Valentina Cechetto, Luca Di Felice and Fasuto Gallucci, Advances and Perspectives of H_2 Production from NH3 Decomposition in Membrane Reactors. Energy Fuels **2023**, 37, 15, 10775–10798; https://doi.org/10.1021/acs.energyfuels.3c00760.
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Conference proceedings or presentations.

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10. L. Viviente, F. Gallucci, R. Campana, X. Sun, S. Megel, W.I.F. David, G. van Zee, S. Pylypko, J.A. Medrano, C. Dumand, C. Rouselle and A. Ramirez-Santos. Advanced materials and Reactors for ENergy storage tHrough Ammonia (ARENHA). European Hydrogen Energy Conference 2022 (EHEC2022). Madrid (Spain), May 18th-20th, 2022. Oral presentation.
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12. J. L. Viviente. Advanced materials and Reactors for ENergy storage tHrough Ammonia (ARENHA). 15th International Conference on Catalysis in Membrane Reactors (ICCMR15), Tokyo (Japan). July 31st-August 4th, 2022. Keynote Lecture.
13. V. Cechetto, L. Di Felice, F. Gallucci. Adsorbent materials for residual ammonia removal from hydrogen produced via ammonia decomposition in a catalytic reactor. 15th International Conference on Catalysis in Membrane Reactors (ICCMR15), Tokyo (Japan). July 31st-August 4th, 2022. Oral presentation. https://research.tue.nl/en/publications/adsorbent-materials-for-residual-ammonia-removal-from-hydrogen-pr
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15. V. Cechetto, L. Di Felice, F. Gallucci, Hydrogen production and purification via ammonia decomposition in a catalytic membrane reactor, 1st Symposium on Ammonia Energy, 1-2 September 2022 Cardiff, UK.
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24. ELCOGEN. Providing a platform for the state-of-the-art presentations and information exchange on the cutting-edge ceramic and composite technologies. 47th International Conference and Exposition on Advanced Ceramics and Composites, Daytona Beach (Florida, USA), 22-27 January 2023.
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Patents

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2. Patent application by TUE: V. Cechetto, L. Di Felice, F. Gallucci, “System to produce ultrapure hydrogen from ammonia”. Application number: PCT/NL2022/050128., application date: March 9th, 2022 (NL). International Publication Number: WO 2022/191702 A1.

3. Patent by PV: Gerard Van Zee “Ammonia separation system for an ammonia synthesis loop”, Patent Granted on November 13th (2023). Reference number: NL2031757B1.

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16. Amoniaco verde, la solución al transporte y almacenamiento de hidrógeno renovable. Cryospain. https://cryospain.com/es/amoniaco-verde
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PhD Thesis

1. Valentina Cechetto (2024). Ultra-pure hydrogen production via ammonia decomposition in packed bed membrane reactors. Technische Universiteit Eindhoven, ISBN: 978-90-386-6030-1

ARENHA in figures:

11 partners (6RES, 2 IND, 3 SME)

7 countries

5,684,325 € project

Start: April 2020

Duration: 60 months

Key milestones:

March 2025 - Ammonia decomposition prototype installed and validated

March 2025 - Ammonia synthesis prototype finished.

Projet Coordinator

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More information about ARENHA (including a non-confidential presentation of the project) is available at the project website: https://arenha.eu/

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