ANDREAH

AMMONIA BASED MEMBRANE REACTOR FOR GREEN HYDROGEN PRODUCTION

Project ID	101112118
PRR 2024	Pillar 2 – H_2 storage and distribution
Call topic	HORIZON-JTI-CLEANH2-2022-02-04: Ammonia to green hydrogen: efficient system for ammonia cracking for application to long distance transportations
Project total cost	EUR 2 980 361.25
Clean H_2 JU max. contribution	EUR 2 980 361.25
Project period	1.7.2023–30.6.2027
Coordinator	Fundacion Tecnalia Research and Innovation, Spain
Beneficiaries	1 Cube BV, Consiglio Nazionale delle Ricerche, Iberdrola Clientes SA, KIC InnoEnergy SE, RINA Consulting SpA, Technische Universiteit Eindhoven, Umicore Denmark ApS, VTTI BV

https://www.andreahproject.eu/

PROJECT AND GENERAL OBJECTIVES

The Andreah Horizon Europe project aims to effect a quantum leap in the development of advanced ammonia decomposition technologies to produce ultra-pure hydrogen (> 99.998 %) by developing an innovative system based on a catalytic membrane reactor for the cracking of ammonia.

The system will be based on the design, construction and testing of an advanced ammonia cracker for ultra-pure hydrogen production (10 kgH_2/day) based on a catalytic membrane reactor in order to intensify the process of hydrogen production through the integration of cracking and purification. The advance cracker will include:

- an innovative and environmentally friendly structured catalyst constructed with few critical materials that can be used at much lower temperatures than in the state-of-the-art (SOA) process;
- innovative membranes for the selective separation of H_2 during the production process.

The project will also involve developing novel sorbents for polishing the H_2 recovered by the membranes. In addition, it will include the design and optimisation of all the subcomponents of the balance of plant with particular attention to optimising thermal integration.

NON-QUANTITATIVE OBJECTIVES

- Designing and setting up a broad and complete network of value chains with world-class universities, research centres and industrial partners to develop the key building blocks for ammonia cracking.
- Developing a full life-cycle assessment, life-cycle costing and health and safety analysis of Andreah.
- Developing a set of flexible, cost-effective and environmentally friendly technologies that can be easily tailored for the decomposition of ammonia into green H_2 for different applications (energy, transport, etc.).
- Paving the way for the future exploitation of Andreah's key exploitable results, by laying the foundations for new business opportunities related to the development of new catalysts and membranes integrated into membrane reactors to provide huge process intensification, enabling the distributed generation of hydrogen from NH_3 as a long-term storage media.
- Promoting the dissemination and communication of Andreah's results and expanding its impact.

FUTURE STEPS AND PLANS

- Conduct of a market and stakeholder analysis.
- Development of a novel catalyst and structured catalyst for application onto open cell foams and 3D-printed periodic open cellular structures and catalyst kinetic modelling.
- Development of sorbents for sorbent kinetics sorption modelling.
- Development of carbon molecular sieve membranes selective for H_2 in an H_2, N_2 and NH_3 mixture and membrane modelling.
- Conduct of a preliminary integrated analysis of the new technologies based on sustainability pillars and circularity analysis, including a preliminary life-cycle assessment, life-cycle costing and a social life-cycle assessment.

PROJECT TARGETS

Target source	Parameter	Unit	Target	Target achieved?	SOA result achieved to date (by others)	Year for reported SOA result
Project's own objectives	Amount of Pd per membrane	g	< 0.1	⚙	2.6	2023
	OPEX of the ammonia-cracking system	k € / year	209.5		282.42	2020
	Decentralised cost of H_2 production	€/kg	4.27		5.51	2020
	Amount of Ru in the catalyst for low-temperature (< 500 °C) cracking	wt%	< 1		2–8	2021
	CAPEX of the ammonia-cracking system	k €	211.74		384.72	2020
SRIA (2021–2027)	H_2-carrier-specific energy consumption	kWh input / kgH_2 recovered	16		20	2020

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CANDHY

COMPATIBILITY ASSESSMENT OF NON-STEEL METALLIC DISTRIBUTION GAS GRID MATERIALS WITH HYDROGEN

Project ID	101111893
PRR 2024	Pillar 2 – H_2 storage and distribution
Call topic	HORIZON-JTI-CLEANH2-2022-02-01: Compatibility of distribution non-steel metallic gas grid materials with hydrogen
Project total cost	EUR 2 607 481.25
Clean H_2 JU max. contribution	EUR 2 607 481.00
Project period	1.9.2023–31.8.2026
Coordinator	Fundación para el Desarrollo de las Nuevas Tecnologias del Hidrógeno en Aragón, Spain
Beneficiaries	Fundacion Tecnalia Research and Innovation, Groupe Européen de Recherches Gazières, GRTgaz, Redexis Gas Servicios SL, Redexis SA, RINA Consulting – Centro Sviluppo Materiali SpA, Sumnistros Industriales Diversos SA, Università degli studi di Bergamo

http://candhy.eu/

PROJECT AND GENERAL OBJECTIVES

- Performing a full review of the state of art of the European gas distribution grids, the standards and codes for testing regarding material compatibility with hydrogen, and hydrogen embrittlement mechanisms to collect information for the development of useful testing protocols to derive the properties of the classes of materials studied in Candhy in their relevant operating conditions.
- Designing, developing and performing an experimental campaign to test the most relevant non-steel metallic materials found in Candhy under different hydrogen levels to assess their tolerance of this gas in the operating conditions usual for the distribution grid.
- Documenting and analysing the effect of hydrogen gas on the non-steel metallic materials tested in the experimental campaign mentioned previously.
- Developing models for the prediction of hydrogen embrittlement mechanisms.
- Proposing guidelines, procedures and areas of development to support the future standardisation of the testing and qualification of materials in the distribution network in the presence of H_2 / natural gas blends.
- Developing a technical database on the hydrogen compatibility of metals as a tool to aid in the selection of materials for use in hydrogen gas distribution.

PROGRESS AND MAIN ACHIEVEMENTS

- A questionnaire has been created and distributed among European distribution system operators and gas associations to collect data that will allow the determination of the current status of the grid, regarding the materials involved and other relevant parameters, and the operating conditions.
- The state-of-the-art development of relevant standards useful for studying embrittlement phenomena in non-steel metallic material is under progress. These standards will allow the definition of the conditions of the experimental campaign that will be developed next year.

FUTURE STEPS AND PLANS

- Completing an inventory of the gas grid.
- Extrapolating results of the review on current standards to define those relevant to the experimental campaign.
- Starting an experimental campaign on non-steel metallic materials with a round robin test.

PROJECT TARGETS

Target source	Parameter	Unit	Target	Target achieved?
Project's own objectives	Study of impact of hydrogen on non-steel metallic materials	number of materials analysed	Cover at least five types of material	⚙
	Inventory of materials of the distribution grid	–	Collect as much information as possible from European DSOs	
	Review of state-of-the-art standards related to hydrogen embrittlement tests	number of standards	Review as many standards as possible	
	Database of compatible non-steel metallic materials	number	Create one database	
	Semi-empirical model to predict hydrogen embrittlement mechanisms	number	Construct one model to anticipate embrittlement	
	Harmonised guidelines	number	Propose harmonised guidelines for future standardisation	

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COSMHYC DEMO

COMBINED SOLUTION OF METAL HYDRIDE AND MECHANICAL COMPRESSORS: DEMONSTRATION IN THE HYSOPARC GREEN H_2 MOBILITY PROJECT

Project ID	101007173
PRR 2024	Pillar 2 – H_2 storage and distribution
Call topic	FCH-01-8-2020: Scale-up and demonstration of innovative hydrogen compressor technology for full-scale hydrogen refuelling station
Project total cost	EUR 3 773 858.75
Clean H_2 JU max. contribution	EUR 2 999 637.13
Project period	1.1.2021–31.12.2024
Coordinator	Europäisches Institut für Energieforschung EDF KIT EWIV, Germany
Beneficiaries	Communauté de Communes Touraine Vallée de l'Indre, EIFHYTEC, MAHYTEC SARL, Nel Hydrogen AS, Steinbeis Innovation gGmbH

https://cosmhyc.eu

PROJECT AND GENERAL OBJECTIVES

To meet the demands of a growing hydrogen economy, new technologies in the hydrogen refuelling infrastructure – including those for hydrogen compression – are necessary. In Cosmhyc DEMO, the innovative Cosmhyc compression solution, which combines a metal hydride and mechanical compressor, has been shown to be ready for commercial deployment. At the test site in France, a public hydrogen refuelling station (HRS) will be installed for a variety of vehicles (e.g. fleet vehicles and garbage trucks). The hybrid compressor will be used to supply hydrogen at both 350 bar and 700 bar.

NON-QUANTITATIVE OBJECTIVES

- The project aims to increase public acceptance of hydrogen mobility. Integrating the new compressor in a community in which there have been previous hydrogen mobility activities and demonstration projects is likely to increase overall acceptance.
- It also aims to include a smart gas hub for switching between storage, the HRS and the filling centre. A new gas panel has been designed and will allow for smart switching between the filling centre for trailers, on-site hydrogen supply storage and the HRS.

PROGRESS AND MAIN ACHIEVEMENTS

The main achievement is the installation of the new HRS on the demonstration site and the start of refuelling operations, mainly involving the garbage truck of Interreg North-West Europe's Hector project.

Other major areas of progress and achievements are as follows:

- A new membrane mechanical compressor was designed and manufactured. In addition, the design of an innovative metal hydride compressor was set and its assembly and certification process is in the advanced stages.
- The compositions of the metal hydrides for all stages of compression were selected, without rare earth materials. These hydrides are currently produced in high quantities (approximately 1 000 kg per compression stage). Furthermore, compressive reactors have been manufactured, including a brand new heat exchanger specifically developed as part of the project.
- Significant progress has been made in the permit-issuing process related to the installation of the metal hydride compressor on the demonstration site.
- The filling centre gas panel was completed, involving safety studies. The Communauté de Communes Touraine Vallée de l'Indre refuelling demonstration site will also be capable of green hydrogen production, funded as part of the Hy'Touraine initiative. The Cosmhyc DEMO metal hydride compressor and filling centre gas panel will also be used to compress hydrogen produced at Hysoparc.

FUTURE STEPS AND PLANS

- The refuelling operations are starting at the newly built HRS at the demonstration site in Sorigny, France.
- The integration of a metal hydride compressor is planned for mid 2024.
- Long-term tests of the demonstration unit will be conducted with the on-site vehicle fleet.
- Final exchanges about safety studies and authorisation are taking place.
- An opening event for the launch of the HRS and compressor will be organised to gather local stakeholders and the general public, including EU officials, at the demonstration site.

PROJECT TARGETS

Target source	Parameter	Unit	Target	Target achieved?
Project's own objectives	Nominal pressure of the on-site storage tank	bar	950	⚙
	Storage capacity	kg	125	
	Refuelling protocol	–	SAE J2601 (light-duty vehicles) SAE J2601–2 (heavy-duty vehicles)	
	Noise	dBA	60	
	Daily capacity	kg/day	200	
	Dispensing pressure	bar	200/350/700	✓

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DELHYVEHR

DELIVERY OF LIQUID HYDROGEN FOR VARIOUS ENVIRONMENT AT HIGH RATE

Project ID	101137743
PRR 2024	Pillar 2 – H_2 storage and distribution
Call topic	HORIZON-JTI-CLEANH2-2023-02-05: Demonstration of LH_2 HRS for heavy duty applications
Project total cost	EUR 5 064 971.25
Clean H_2 JU max. contribution	EUR 3 711 901.13
Project period	1.1.2024–31.12.2026
Coordinator	ENGIE, France
Beneficiaries	Absolut System SAS, ArianeGroup SAS, Asociatia Energy Policy Group, Benkei, Cesame-Exadébit SA, DEKRA Services SA, Elengy SA, European Research Institute for Gas and Energy Innovation, Fives Cryomec AG, Trelleborg Clermont-Ferrand SAS, Trelleborg Sealing Solutions UK Limited, University of Ulster

https://cordis.europa.eu/project/id/101137743

PROJECT AND GENERAL OBJECTIVES

The European research project Delhyvehr, coordinated by ENGIE, will develop a liquid hydrogen (LH_2) high-rate bunkering station with a refuelling flow rate of > 5 TPH and zero boil-off losses, dedicated to maritime, aviation and railway applications. The project is expected to complete its demonstration by 2026. Along with market maturity, the cost of distribution is expected to be halved by 2030.

Delhyvehr will drive the maturation of each main system constituting the large-scale refuelling station, with a specific focus on pumping (Fives Cryomec AG), metering (Cesame-Exadébit SA), loading (Trelleborg) and boil-off gas management systems (Absolut System SAS) of the full demonstration apparatus (ArianeGroup SAS). Throughout the project, H_2 safety management activities (University of Ulster) will support the maturation plan and de-risk design and operation. Technology, economic and environmental (policy and governance) studies will allow the assessment and replication of the performance of the demonstration.

NON-QUANTITATIVE OBJECTIVES

- Facilitate the industrialisation of high-rate refuelling station for aviation, maritime and railway applications.
- Reduce helium consumption, which may be a showstopper in LH_2 development, by using gaseous nitrogen for sanitation.
- Provide harmonised guidelines and recommendations for the deployment of bunkering stations.
- Decarbonise heavy-duty vehicle transport and dedicated infrastructure to deliver a hydrogen-related carbon footprint aligned with the second edition of the renewable energy directive (less than $3.38 kgCO_2/kgH_2$).

FUTURE STEPS AND PLANS

The project will first define the high-level requirements of each application based on a functional design analysis with the support of end users from the advisory board.

Through modelling, design, manufacturing and functional testing, the project will increase the technological maturity of each key component of the refuelling line in a dedicated track.

Those developments will feed into the integrated design and associated protocols specification to form components that can be assembled into a demonstration unit built at ArianeGroup SAS's unique European facility in Vernon, France.

PROJECT TARGETS

Target source	Parameter	Unit	Target	Target achieved?
Project's own objectives	LH_2 flowmeter calibration uncertainty on the mass flow rate	wt%	0.8	⚙
	Flow rate at which liquid hydrogen is delivered	kg/h	5 000	✓
	Cryogenic pump design's hydraulic efficiency	%	45	⚙

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EUH$_2$STARS

EUROPEAN UNDERGROUND H$_2$ STORAGE REFERENCE SYSTEM

Project ID	101137798
PRR 2024	Pillar 2 – H$_2$ storage and distribution
Call topic	HORIZON-JTI-CLEANH2-2023-02-01: Large-scale demonstration of underground hydrogen storage
Project total cost	EUR 27 228 904.25
Clean H$_2$ JU max. contribution	EUR 19 655 460.13
Project period	1.1.2024–30.9.2029
Coordinator	RAG Austria AG, Austria
Beneficiaries	Austrian Gas Grid Management AG, Axiom angewandte Prozesstechnik GmbH, Axiom Polska Sp z.o.o., Energie Beheer Nederland BV, Energieinstitut an der Johannes Kepler Universität Linz Verein, Linz Strom Gas Wärme GmbH für Energiedienstleistungen und Telekommunikation, Magyar Földgáztároló Zrt., Montanuniversität Leoben, Nederlandse Organisatie voor toegepast-natuurwetenschappelijk onderzoek, Shell Global Solutions International BV, Trinity Capital SL

http://euh2stars.eu

PROJECT AND GENERAL OBJECTIVES

Euh$_2$stars's mission is to demonstrate best practice for a competitive, complete and qualified large-scale hydrogen storage system using a porous subsurface reservoir to enable the integration of European renewable energy sources.

The overall aim of the project is to demonstrate underground hydrogen storage in depleted porous natural gas reservoirs at technology readiness level (TRL) 8. RAG Austria AG is in a unique position, starting with an existing pilot facility developed as part of the Underground Sun Storage 2030 project (www.uss-2030.at) to TRL 6. Euh$_2$stars will bring the pilot to TRL 8 using results of several relevant projects (Hydrogen underground storage in porous reservoirs (Hyuspre), Hydrogen storage in European subsurface (Hystories), Underground Sun Storage, Underground Sun Conversion, etc.). To achieve the overall aim and maximise the exploitation of the project's results for replication in other regions of Europe, the following specific objectives and outcomes are planned.

- Provide recommendations to best manage all environmental, legal and (future) regulatory, societal and market-related aspects to ensure the successful implementation of an underground hydrogen storage facility in Europe.
- Provide recommendations on the topic of health, safety, environment and quality, including a monitoring plan to ensure that the level of risk is as low as reasonably practicable when operating the demonstration site and future commercial storage sites.
- Run four cycles of seasonal operation with different characteristics and usage profiles to demonstrate their ability to be integrated with different energy infrastructure systems to achieve the highest hydrogen purification levels.
- Show transformation pathways to replicate findings from the demonstration in full-scale commercial settings at existing underground gas storage facilities and storage sites to be developed in depleted natural gas reservoirs in Europe located in Austria (RAG Austria), Hungary (Hungarian Gas Storage), the Netherlands (Shell Global Solutions International) and Spain (Trinity Capital SL).
- Show how to integrate hydrogen storage facilities into the local, national and European energy infrastructures and markets by showcasing specific use cases in Austria, Hungary, the Netherlands and Spain, and other use cases including integration into the European hydrogen backbone.
- Establish a sound interactive process for stakeholder involvement to maximise replication potential and the exploitation of the results of the demonstration.

PROJECT TARGETS

Target source	Parameter	Unit	Target	Achieved to date by the project	Target achieved?	SOA result achieved to date (by others)	Year for reported SOA result
Project's own objectives	H$_2$ purification achieved at exit of hydrogen purification unit	%	98 – Grade A according to ISO 14687	Unknown (novel purification configuration)	⚙	N/A	N/A
SRIA (2021–2027)	Hydrogen recovery factor of H$_2$ purification unit	%	95	Unknown (novel purification configuration)		80	2030

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H2REF-DEMO

HYDRAULIC COMPRESSION FOR HIGH CAPACITY HYDROGEN REFUELLING STATION DEMONSTRATION

Project ID	101101517
PRR 2024	Pillar 2 – H_2 storage and distribution
Call topic	HORIZON-JTI-CLEANH2-2022-02-08: Development of novel or hybrid concepts for reliable, high capacity and energy-efficient H_2 compression systems at real-world scale
Project total cost	EUR 5 786 712.50
Clean H_2 JU max. contribution	EUR 4 617 384.88
Project period	1.1.2023–30.6.2026
Coordinator	Centre technique des industries mécaniques, France
Beneficiaries	Faber Industrie SpA, H2Nova, HYDAC Technology GmbH, Hydrogen Refueling Solutions, Università degli Studi di Modena e Reggio Emilia, Université de Technologie de Compiègne

https://heavy-v.h2ref.eu/about-us/

PROJECT AND GENERAL OBJECTIVES

H2REF-DEMO aims to further develop and quintuple the innovative compression concept developed in H2REF in order to address large vehicle refuelling applications requiring hydrogen to be dispensed at rates of hundreds of kilograms per hour, such as refuelling bus fleets every evening at bus depots, refuelling trucks and refuelling trains. The concept is particularly suited to scaling up, thanks to the scalability of fluid power technology and composite pressure vessel technologies.

As it incorporates the intrinsic modularity of fluid power technology together with that of pressure vessel technology, this disruptive solution will allow the different expected hydrogen supply configurations to be addressed in a cost-effective and reliable manner, in particular those that are the most suitable for large-scale refuelling applications for which daily consumption exceeds 1 t:

- on-site production;
- road delivery with high-pressure trailers (e.g. 500 bar, in carbon composite), as these have an effective payload of around 1 t.

Large-scale hydrogen refuelling involves two distinct types of compression.

- **Compression of hydrogen production for storage.** As production is the supply chain function with the highest cost, it tends to be performed through continuous (24/7) operation of production devices sized on the basis of daily consumption. Storage of the hydrogen produced requires compression at the same rate in order to keep storage size and footprint within acceptable limits.
- **Compression of stored hydrogen for high-capacity dispensing.** This compression function brings hydrogen from storage – that is, a fixed vessel storing hydrogen produced on site, a fixed vessel into which hydrogen has been delivered by trailer or a trailer – maintaining the pressure required for dispensing at the rate required when dispensing takes place, for example at any time of the day when vehicles pull in to refuel, or almost continuously during a certain time frame (e.g. 4–6 h per day at a bus depot). The feed pressure of compression for dispensing is typically higher than that of compression for storage; however, the required throughput is also higher (as dispensing takes place only part of the time).

NON-QUANTITATIVE OBJECTIVES

The main goal of the project is to develop and test at full scale a high-capacity compression module (HCCM) capable of either hydrogen compression for storage prior to dispensing (1.2 t/day) or hydrogen compression for high-capacity (35 MPa) dispensing (150 kg/h–2.5 kg/min), with 1 year's demonstration of use for the high-capacity refuelling of heavy-duty vehicles in a commercially operated refuelling station. Particular attention will be given to optimising design to minimise costs.

PROGRESS AND MAIN ACHIEVEMENTS

In the first year of the H2REF-DEMO project, the following results were achieved:

- multiphysical modelling and simulation of the HCCM process and initial sizing and estimation of potential performance;
- functional specification of the HCCM based on a bladder accumulator and an elementary compression unit;
- functional specification and material selection for bladder and tests on material;
- design of the shell of the accumulator;
- development of an initial safety plan;
- specification and simulation of the global refuelling system;
- specification and simulation of the hydraulic power pack;
- review of existing regulations, codes and standards and identification of gaps with the project activities.

FUTURE STEPS AND PLANS

- Selection of bladder material / manufacture of bladders.
- Manufacture of shells.
- Development of the accumulator and performance of the first tests.
- Development of the hydraulic power pack.
- Start of the development of the gas skid.

PROJECT TARGETS

Target source	Parameter	Unit	Target	Target achieved?
Project's own objectives	CAPEX	k€/(kg/day)	3.5	⚙
	Availability	%	97	
	Mean energy to 350 bar	kWh/kg	3.5	
	MTBF	days	47	
	HRS contribution to H_2 price	€/kg	2.5	
	Bladder durability	cycles	20 000	

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HIGGS

HYDROGEN IN GAS GRIDS: A SYSTEMATIC VALIDATION APPROACH AT VARIOUS ADMIXTURE LEVELS INTO HIGH-PRESSURE GRIDS

Project ID	875091
PRR 2024	Pillar 2 – H_2 storage and distribution
Call topic	FCH-02-5-2019: Systematic validation of the ability to inject hydrogen at various admixture level into high-pressure gas networks in operational conditions
Project total cost	EUR 2 107 672.50
Clean H_2 JU max. contribution	EUR 2 107 672.50
Project period	1.1.2020–31.12.2023
Coordinator	Fundación para el Desarrollo de las Nuevas Tecnologías del Hidrógeno en Aragón, Spain
Beneficiaries	Deutscher Verein des Gas- und Wasserfaches – Technisch-Wissenschaftlicher Verein EV, European Research Institute for Gas and Energy Innovation, Fundacion Tecnalia Research and Innovation, OST – Ostschweizer Fachhochschule, Redexis SA

www.higgsproject.eu/

PROJECT AND GENERAL OBJECTIVES

HIGGS aimed to fill in the gaps in knowledge of the impact that high levels of hydrogen could have on high-pressure natural gas infrastructure, its components and its management. To reach this goal, the project has developed a mapping of technical, legal and regulatory barriers and enablers; tested materials/components; completed techno-economic modelling; and finally concluded preparing a set of conclusions as a pathway towards enabling the injection of hydrogen into high-pressure gas grids.

NON-QUANTITATIVE OBJECTIVES

- Compile recommendations for regulations, codes and standards according to current and future regulation/standardisation.
- Forge a pathway for the stepwise integration of hydrogen into the EU gas network, to improve the potential of hydrogen injection by 2030 and 2050.
- Create a techno-economic model and study of the roles of technologies for integrating H_2/CH_4 and sector coupling at the EU level.

PROGRESS AND MAIN ACHIEVEMENTS

- The testing platform has enabled dynamic and static tests to be carried out with blends of 20 mol % H_2, 30 mol % H_2 and 100 % H_2.
- The project has adopted the techno-economic model, and several scenarios have been modelled.
- A system has been created for separating low concentrations of hydrogen in natural gas. The experimental campaign with the gas separation prototype was successful.
- The gas tightness of valves of different natures and joints has been proved for hydrogen blends and 100 % hydrogen. The equipment of the gas grid behaved the same way as when natural gas was transported.
- The tested carbon steels showed no signs of embrittlement due to hydrogen exposure.
- A complete set of findings has been provided to predict what will be expected from gas grids until 2050.

FUTURE STEPS AND PLANS

The project has finished.

PROJECT TARGETS

Target source	Parameter	Unit	Target	Target achieved?
Project's own objectives	Blending percentage of H_2 compatible with existing gas transmission networks	%	100	✓
	Readiness of gas transmission networks for H_2 distribution	%	Complete inventory	
	Techno-economic approach to grid repurposing	%	Model scenarios	

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HQE

HYQUALITY EUROPE

Project ID	101101447
PRR 2024	Pillar 2 – H_2 storage and distribution
Call topic	HORIZON-JTI-CLEANH2-2022-02-09: Sampling methodology and quality assessment of HRS
Project total cost	EUR 3 453 685.00
Clean H_2 JU max. contribution	EUR 3 453 685.00
Project period	1.1.2023–31.12.2025
Coordinator	SINTEF AS, Norway
Beneficiaries	Air Liquide France Industrie, Deutsches Zentrum für Luft- und Raumfahrt EV, Europäisches Institut für Energieforschung EDF KIT EWIV, EMCEL GmbH, ENGIE, ENGIE Energie Services, L Air Liquide SA, LINDE GmbH, NPL Management Limited, Orlen Laboratorium SA, Toyota Motor Europe NV, Zentrum für BrennstoffzellenTechnik GmbH, Zentrum für Sonnenenergie- und Wasserstoff-Forschung Baden-Württemberg

http://hyqualityeurope.eu

PROJECT AND GENERAL OBJECTIVES

The goal of the project is to increase the reliability of hydrogen refuelling stations (HRSs) and the confidence of investors, operators and consumers in them. The project's objectives are to:

- collect representative data on the quality of hydrogen in European HRSs (300 spot samples in 100 HRSs);
- develop an occurrence class and promote an approach involving risk assessment;
- establish an open-source database to compile the results to allow HRS operators to take an approach involving risk assessment to ensure hydrogen quality;
- test a network of six hydrogen analysis laboratories in order to certify them at the EU level;
- demonstrate the effectiveness of online analysis;
- standardise hydrogen quality sampling and analysis methodologies for EU HRSs;
- aid future research by defining the occurrence class of at least four new impurities beyond those listed in EN 17124:2022 and the International Organization for Standardization (ISO) 21087:2019.

PROGRESS AND MAIN ACHIEVEMENTS

The project has extensively contributed to the development of ISO 14687, 19880–9 and 19880–8.

The work to collect information from HRS operators and perform sampling and analysis started. The first laboratory comparison was completed, with nine laboratories taking part. All impurities listed in ISO 14687 were present in the comparison, and this is the first comparison to be conducted of this type.

A hydrogen quality workshop was hosted by ISO, ASTM International and the National Renewable Energy Laboratory to disseminate some of the early results of the project.

FUTURE STEPS AND PLANS

The project will continue the sampling and analysis work, working towards a target of collecting 300 samples. Further laboratory comparisons will be conducted. The project will also install online quality-monitoring facilities in three HRSs.

PROJECT TARGETS

Target source	Parameter	Unit	Achieved to date by the project	Target achieved?
Project's own objectives	Standards affected by project	number	3	⚙

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HYCARE

AN INNOVATIVE APPROACH FOR RENEWABLE ENERGY STORAGE BY A COMBINATION OF HYDROGEN CARRIERS AND HEAT STORAGE

Project ID	826352
PRR 2024	Pillar 2 – H_2 storage and distribution
Call topic	FCH-02-5-2018: Hydrogen carriers for stationary storage of excess renewable energy
Project total cost	EUR 2 024 230.00
Clean H_2 JU max. contribution	EUR 1 999 230.00
Project period	1.1.2019–31.7.2023
Coordinator	Università degli Studi di Torino, Italy
Beneficiaries	Centre national de la recherche scientifique, ENGIE, Fondazione Bruno Kessler, GKN Powder Metallurgy Engineering GmbH, Helmholtz-Zentrum Hereon GmbH, Institutt for energiteknikk, Parco Scientifico Tecnologico per l'Ambiente Environment Park Torino SpA, Stuehff GmbH (now SMasch), Tecnodelta SRL, Stühff Maschinen- und Anlagenbau GmbH

http://www.hycare-project.eu/

PROJECT AND GENERAL OBJECTIVES

The main objective of the Hycare project was to develop a prototype hydrogen storage tank using a solid-state hydrogen carrier on a large scale. The tank was based on an innovative concept combining hydrogen and heat storage to improve the energy efficiency of the whole system. The tank developed was joined with a proton exchange membrane electrolyser, as the hydrogen provider, and a proton exchange membrane fuel cell, as the hydrogen user, at the ENGIE Lab Crigen, located in Île-de-France. Hycare's integrated system was commissioned in spring 2023, and system testing and validation was performed up to October 2023.

NON-QUANTITATIVE OBJECTIVES

- **Safety.** The project aims to achieve low temperatures and pressures for storing hydrogen using carriers.
- **Energy efficiency.** The project aims to improve the energy efficiency of hydrogen storage using heat storage through phase change materials.

PROGRESS AND MAIN ACHIEVEMENTS

Those involved in the Hycare project were able to create a pilot plant with the capacity to store up to 46 kg of hydrogen at less than 50 bar and less than 100 °C in a 20 ft container. The pilot plant demonstrates that efficient energy storage by a solid-state hydrogen carrier is possible at a large scale and provides insights for further research and development and technology implementation at the societal level.

FUTURE STEPS AND PLANS

The project has finished.

The hydrogen storage tank will be available at SMasch's premises in Germany. SMasch will give potential customers and partners the opportunity to visit the Hycare hydrogen storage tank and its system, adding value to the project's results and the future development of the apparatus.

PROJECT TARGETS

Target source	Parameter	Unit	Target	Achieved to date by the project	Target achieved?	SOA result achieved to date (by others)	Year for reported SOA result
Project's own objectives	Hydrogen storage capacity of the system	kgH_2	–	35.0 measured; 46.3 estimated	✓	260	2021
	Cyclability	number of full cycles until a 2 % reduction in the gravimetric capacity of the H_2 carrier is reached	250	250		N/A	N/A
	Volumetric capacity of H_2 carrier	kgH_2 per unit of volume of carrier	–	Reversible capacity at 55 °C between 1 and 25 bar of less than 70 (69.3)		N/A	2021
	Gravimetric capacity of H_2 carrier	wt% of H_2 in the carrier	–	Reversible capacity at 55 °C between 2 and 20 bar of 1.1		N/A	
	Maximum pressure of the H_2 carrier tank	bar	< 50	40		N/A	2021

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HYGHER

HYDROGEN HIGH PRESSURE SUPPLY CHAIN FOR INNOVATIVE AND COST EFFICIENT DISTRIBUTION

HIGH PRESSURE HYDROGEN VALUE CHAIN

Project ID	101137867
PRR 2024	Pillar 2 – H_2 storage and distribution
Call topic	HORIZON-JTI-CLEANH2–2023-02-04: Demonstration of high pressure (500–700 bar) supply chain
Project total cost	EUR 6 769 096.25
Clean H_2 JU max. contribution	EUR 4 991 009.88
Project period	1.1.2024–31.12.2026
Coordinator	Europäisches Institut für Energieforschung EDF KIT EWIV, Germany
Beneficiaries	EIFHYTEC, Fraunhofer-Gesellschaft zur Förderung der Angewandten Forschung EV, Hype, Hype Assets, RE.CO.MA SRL, Steinbeis Innovation gGmbH, Univerza v Ljubljani

https://cordis.europa.eu/project/id/101137867/fr

PROJECT AND GENERAL OBJECTIVES

Hygher is an EU project funded by the Clean Hydrogen Partnership and coordinated by the European Institute for Energy Research (in Germany). It aims to demonstrate the maturity of an innovative high-pressure hydrogen distribution value chain. This will include the installation of an innovative filling centre able to compress hydrogen at high pressure, and the operation of two new high-pressure trailers to supply the fleet of taxis operated by HYPE in Île-de-France. With a total budget of over EUR 6.7 million, the seven consortium partners are working on improving and integrating all components along the new value chain. Through specific efforts on innovative compression, circularity and safety, the project will allow sustainable and cost-efficient hydrogen distribution, removing one of the main barriers to the wider deployment of hydrogen mobility. The project started in 2024 and has an expected duration of 3 years.

NON-QUANTITATIVE OBJECTIVES

The main objective of Hygher is to demonstrate the feasibility of an innovative, cost-efficient and reliable high-pressure value chain, by combining various innovative technologies ready for large-scale demonstration.

The main progress expected beyond the state of the art (SOA) and the results of Hygher is as follows:

- build an innovative filling centre equipped with a metal hydride compressor, a mechanical booster and cascade storage, enabling the efficient distribution of > 2 t/day at 500 bar;
- build two innovative trailers, with a capacity of 1.25 t of hydrogen each at an operating pressure of 500 bar, equipped with innovative control, monitoring and communication devices to ensure efficiency and interoperability;
- adapt a standard hydrogen refuelling station by integrating 500-bar trailers into smart storage cascade management and thereby significantly improve efficiency and demonstrate a capacity increase;
- install and operate the overall value chain in Île-de-France, close to trans-European transport network corridors, and thus reinforce the EU H_2 infrastructure network and prepare for its replication and massification;
- demonstrate the new value chain under real commercial conditions, by operating the equipment with HYPE's fleet of fuel cell electric vehicles (taxis) and other 350-bar and 700-bar fuel cell electric vehicles;
- validate the safety of the overall concept at 500 bar and prepare for a 700-bar upgrade by screening the framework of regulations, codes and standards, and performing safety analyses of parts of the system, from single components to the overarching value chain.

FUTURE STEPS AND PLANS

The main first steps of the project to be conducted in 2024 are:

- the preparation of the initial project safety plan, including a review of the regulations, codes and standards, and the planning of safety studies for individual systems and for the demonstration;
- the setting of specifications at the value chain level and determination of the optimised design of subsystems;
- the preparation of the construction phase of all subsystems (ordering components and planning construction in workshops);
- the definition of scenarios and collection of existing data for a techno-economic assessment study, life-cycle analysis and scale-up analysis;
- the preparation of the promotional toolbox, launch of the communication campaign, determination of the initial exploitation and intellectual property strategy, the delivery of a webinar for experts and stakeholders to introduce them to the project and the validation of techno-economic specifications.

PROJECT TARGETS

Target source	Parameter	Unit	Target	Target achieved?	SOA result achieved to date (by others)	Year for reported SOA result
Project's own objectives	Trailers filled at high pressure (500–700 bar)	number	2	⚙	N/A	N/A
	Filling centres at high pressure (500–700 bar)	t/day	2.15		N/A	N/A
	HRS quantities delivered	kg/day	2 500 in 2 HRSs		N/A	N/A
SRIA (2021–2027)	Tube trailer CAPEX	€/kg	450		650	2 000
	Operating pressure of tube trailer	bar	500		300	2 000
	Tube trailer payload	kg	1 250		850	2 000

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HYLICAL

DEVELOPMENT AND VALIDATION OF A NEW MAGNETOCALORIC HIGH-PERFORMANCE HYDROGEN LIQUEFIER PROTOTYPE

Project ID	101101461
PRR 2024	Pillar 2 – H_2 storage and distribution
Call topic	HORIZON-JTI-CLEANH2-2022-02-03: Validation of a high-performance hydrogen liquefier
Project total cost	EUR 4 677 848.75
Clean H_2 JU max. contribution	EUR 4 677 848.75
Project period	1.1.2023–31.12.2027
Coordinator	Institutt for energiteknikk, Norway
Beneficiaries	Asociatia Energy Policy Group, Danmarks Tekniske Universitet, ENGIE, Fives Cryo, Helmholtz-Zentrum Dresden-Rossendorf EV, Iberdrola Clientes SA, Magnotherm Solutions GmbH, Shell Global Solutions International BV, SUBRA A/S, Technische Universität Darmstadt, Universidad de Sevilla, Università di Pisa, Universityof European Parliament and Council of the European Union

https://www.hylical.eu

PROJECT AND GENERAL OBJECTIVES

Hylical will contribute to (i) reaching an energy demand of 8 kWh/kg and a reduction in liquefaction cost of 20 % for small liquefaction volumes of 1–5 t/day; (ii) reducing capital expenditure and operating expenditure by at least 20 % in addition to the targeted energy savings; (iii) decentralising the (local) production of liquid hydrogen (LH_2), thus reducing the need for distribution and transport across long distances; (iv) coupling magnetocaloric hydrogen liquefaction (MCHL) technology to hydrogen production from renewables (green hydrogen) for off-grid configurations; (v) integrating into conventional liquefaction plants to increase their overall energy efficiency; and (vi) applying the processes for the liquefaction of hydrogen and for the management of boil-off from LH_2 tanks.

NON-QUANTITATIVE OBJECTIVES

Hylical aims to provide an alternative solution to the conventional vapour compression technology that offers several advantages.

- Reduced complexity will lead to less risk of failure, reduced requirement for regular maintenance and less downtime.
- The MCHL technology developed will be less noisy and will suffer significantly less from the ‘economy of scale’ than the currently employed vapour compression technology. It will also be more adaptable to fluctuations in loads and demands.

PROGRESS AND MAIN ACHIEVEMENTS

- Prediction of new materials/compositions for MCHL.
- Updated state of the art (SOA) for LH_2 safety provisions.
- Performance of initial simulations for heat transfer in an active magnetic regenerator (AMR) in cryogenic conditions.
- Starting construction of a cryochamber to host the AMR and testing heat transfer and pressure drops in ambient conditions.

FUTURE STEPS AND PLANS

- Synthesis of promising new materials predicted by computational material design.
- Characterisation of magnetic/structural properties and optimisation of materials for targeted applications.
- Upscaling of material production from grams to kilograms to suit the needs of the planned demonstration.
- Detailed simulation of heat flow, inleak and losses in cryogenic conditions.
- Testing of a cryochamber hosting the AMR and assessment of its properties in cryogenic conditions.

PROJECT TARGETS

Target source	Parameter	Unit	Target	Target achieved?	SOA result achieved to date (by others)	Year for reported SOA result
Project’s own objectives and SRIA (2021–2027)	H_2 liquefaction energy intensity	kWh/kg	8	⚙	10	2020
SRIA (2021– 2027)	H_2 liquefaction cost	€/kg	< 1.5		1.5	2020

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HYPSTER

HYDROGEN PILOT STORAGE FOR LARGE ECOSYSTEM REPLICATION

Project ID	101006751
PRR 2024	Pillar 2 – H_2 storage and distribution
Call topic	FCH-02-7-2020: Cyclic testing of renewable hydrogen storage in a small salt cavern
Project total cost	EUR 15 514 301.73
Clean H_2 JU max. contribution	EUR 4 999 999.00
Project period	1.1.2021–31.12.2024
Coordinator	Storengy SAS, France
Beneficiaries	Association pour la Recherche et le Développement des Méthodes et Processus Industriels, Axelera – Association Chimie-Environnement Lyon et Rhone-Alpes, École polytechnique, Element Energy Limited, Environmental Resources Management Limited, Equinor Energy AS, ERM France, ESK GmbH, Inovyn Chlorvinyls Limited, Institut national de l'environnement industriel et des risques SAS, Brouard Consulting, Storengy France

https://hypster-project.eu/

PROJECT AND GENERAL OBJECTIVES

Hypster aims to demonstrate the industrial-scale operation of cyclical hydrogen storage in salt caverns to support the emergence of the hydrogen energy economy in Europe in line with Hydrogen Europe's overall roadmap. The cavern is located in Etrez in Auvergne-Rhône-Alpes, France. For the production of green hydrogen, the Etrez storage site will rely on local renewable energy sources and a 1 MW proton exchange membrane electrolyser. In the long run, this facility will produce 400 kg of hydrogen per day (equivalent to the hydrogen consumption of 16 hydrogen-powered buses). The objective of the project is to test industrial-scale green hydrogen production and storage in salt caverns and the technical and economic reproducibility of the process in other sites throughout Europe.

NON-QUANTITATIVE OBJECTIVES

- Assessment of the economic feasibility of the process.
- Measurement of risk and environmental impacts.
- Definition of guidelines for regulation and normative adaptation in Europe.
- Study of its techno-economic replicability in Europe.
- Microbiological analysis.

PROGRESS AND MAIN ACHIEVEMENTS

- The workover of the EZ53 well was successfully completed in 2023.
- All works (civil, piping, electrical, instrumentation, automation) have been carried out and all equipment procured has been installed and connected, except the electrolyser stacks.
- Numerical simulation models for hydrogen storage in the salt cavern have been adapted.
- A risk analysis of underground hydrogen storage in the salt cavern has been performed.
- Commercial and microbiological analyses have started.
- The cold commissioning of the electrolyser has started (without hydrogen).
- The opening of the site was held in September 2023.

FUTURE STEPS AND PLANS

- Delivery of stacks in April 2024.
- Conduct of hydrogen tightness tests in April–May 2024.
- Conduct of hydrogen cycling tests, starting in June 2024.
- Production of hydrogen, starting in June–July 2024.
- Delivery of final workshop and wrapping up of the project in August–December 2024.

PROJECT TARGETS

Target source	Parameter	Unit	Target	Target achieved?
MAWP addendum (2018–2020)	OPEX	€/kg	1	⚙
	Power	MW	1	
	H_2 mass	kg	2 000	
	CAPEX	€/kg	450	

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HYSTORIES

HYDROGEN STORAGE IN EUROPEAN SUBSURFACE

Project ID	101007176
PRR 2024	Pillar 2 – H_2 storage and distribution
Call topic	FCH-02-5-2020: Underground storage of renewable hydrogen in depleted gas fields and other geological stores
Project total cost	EUR 2 499 911.75
Clean H_2 JU max. contribution	EUR 2 499 911.75
Project period	1.1.2021–30.6.2023
Coordinator	Geostock SAS, France
Beneficiaries	Consejo Superior de Investigaciones Científicas, Bureau de Recherches Geologiques et Minieres, Česká geologická služba, Réseau d'excellence européen sur le stockage géologique de CO_2, Ethniko Kentro Erevnas Kai Technologikis Anaptyxis, Fundación para el Desarrollo de las Nuevas Tecnologías del Hidrógeno en Aragón, Geoinženiring družba za geološki inženiring d.o.o., Geological Survey of Denmark and Greenland, Geologische Bundesanstalt, Geosphere Austria – Bundesanstalt für Geologie, Geophysik, Klimatologie und Meteorologie, Główny Instytut Górnictwa, Helmholtz-Zentrum Potsdam Deutsches GeoForschungsZentrum GFZ, Institut royal des Sciences naturelles de Belgique, Instituto Geológico y Minero de España, Institutul Naţional de Cercetare – Dezvoltare pentru Geologie și Geoecologie Marin –GeoEcoMar, Instytut Gospodarki Surowcami Mineralnymi i Energia PAN, Istituto Nazionale di Oceanografia e di Geofisica Sperimentale, Ludwig-Bölkow-Systemtechnik GmbH, Micropro GmbH, Middle East Technical University, Montanuniversität Leoben, NORCE Norwegian Research Centre AS, Sveučilište u Zagrebu Rudarsko-geološko-naftni fakultet, Tallinna Tehnikaülikool, UK Research and Innovation, Universidade De Évora

https://hystories.eu/

PROJECT AND GENERAL OBJECTIVES

The Hystories project, explored underground hydrogen storage in Europe from 1 January 2021 to 30 June 2023. Led by Geostock, it involved key partners across Europe and gathered geological data from 23 countries. The project focused on salt caverns and porous media (depleted liquid or gaseous hydrocarbon reservoirs, saline aquifers).

The current industrial experience of pure hydrogen storage is limited, with only a few projects in Europe and the United States. While the storage of town gas (a mixture containing hydrogen) in porous media has a historical precedent, the storage of pure hydrogen presents new challenges, particularly due to Hydrogen's reactivity, its ability to embrittle steels and its low viscosity and volumetric energy density.

The main objectives of the Hystories project were to bring technical developments to large-scale renewable hydrogen storage in depleted fields or aquifers and to assess how underground hydrogen storage could facilitate the transition to a CO_2-emission-neutral energy system in the EU by 2050.

PROGRESS AND MAIN ACHIEVEMENTS

The project identified potential underground hydrogen storage sites in porous media and estimated their total hydrogen storage capacity at 6 850 TWh (19 000 TWh including offshore sites) in the EU and neighbouring countries. A risk analysis method associated with microbial activity in future underground hydrogen storage was proposed, and hydrogen consumption was modelled. The results showed hydrogen consumption of 0.06 % at the laboratory scale and 0.004 % at the storage scale after five seasonal hydrogen injection and withdrawal cycles. A dozen common steel grades for oil tubing were tested in the presence of hydrogen, and recommendations were issued on the type of steel to be used in storage.

In conclusion, underground hydrogen storage has significant potential to contribute to the decarbonisation of energy networks and societies, especially in Europe. Storage in salt caverns is considered technically mature. No major technical impediments of storage in depleted fields or aquifers were identified, although questions remain regarding the quality of the gas released and the potential costs of treatment required to enable its reinjection into hydrogen distribution networks. The project also highlighted the importance of the regulatory framework and business models for the deployment of storage sites, and the need for further investigation into cost estimation and the role of underground hydrogen storage in the energy value chain.

FUTURE STEPS AND PLANS

The project has finished.

PROJECT TARGETS

Target source	Parameter	Unit	Target	Achieved to date by the project	Target achieved?
MAWP addendum (2018–2020)	Large-scale H_2 storage / capital cost	€/kg	0.6	0.017 (salt); 0.011 (porous)	✓
	Energy used in large-scale H_2 storage / release	MWh/kg	9.3	1.7 (salt); 2.5 (porous)	
	Large-scale H_2 storage / chain efficiency	%	72	95 (salt); 92.5 (porous)	

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HYUSPRE

HYDROGEN UNDERGROUND STORAGE IN POROUS RESERVOIRS

Project ID	101006632
PRR 2024	Pillar 2 – H_2 storage and distribution
Call topic	FCH-02-5-2020: Underground storage of renewable hydrogen in depleted gas fields and other geological stores
Project total cost	EUR 3 714 850.00
Clean H_2 JU max. contribution	EUR 2 499 850.00
Project period	1.10.2021–30.6.2024
Coordinator	Nederlandse Organisatie voor toegepast-natuurwetenschappelijk onderzoek, Netherlands
Beneficiaries	Centrica Storage Limited, Energie Beheer Nederland BV, Energieinstitut an der Johannes Kepler Universität Linz Verein, Equinor Energy AS, Fondazione Bruno Kessler, Forschungszentrum Jülich GmbH, Magyar Földgáztároló Zrt., NAFTA AS, Neptune Energy Hydrogen BV, RAG Austria AG, Shell Global Solutions International BV, SNAM SpA, Technische Universität Clausthal, University of Edinburgh, Uniper Energy Storage GmbH, Wageningen University

https://www.hyuspre.eu/

PROJECT AND GENERAL OBJECTIVES

Hyuspre studied the potential of large-scale hydrogen storage in porous reservoirs in Europe. This includes the identification of suitable geological storage reservoirs and a techno-economic feasibility assessment for hydrogen storage in these reservoirs. Hyuspre addressed specific technical challenges regarding storage, and involved the conduct of an economic analysis to facilitate the decision-making process to develop a portfolio of potential field pilots. The techno-economic assessment enabled the development of a roadmap for widespread hydrogen storage towards 2050.

NON-QUANTITATIVE OBJECTIVES

- Hyuspre aimed to conduct a study assessing potential matches between hydrogen supply and demand sites, including the need for hydrogen to buffer time-varying renewable energy demands.
- The project aimed to conduct a study on the potential of European underground hydrogen storage to facilitate the achievement of a zero-emission energy system by 2050.

PROGRESS AND MAIN ACHIEVEMENTS

After the extension of Hyuspre by 6 months until June 2024, the project operated according to plan. Laboratory experiments were concluded in March 2024, and results were subsequently analysed and reported. The hydrogen scenario studies (on the EU-scale H_2 system, guidelines for decision-making on reservoir suitability, levelised cost of hydrogen and hydrogen roadmap for Europe) were developed in close cooperation with the project's industrial partners.

FUTURE STEPS AND PLANS

Hyuspre is in its concluding phase. The consortium concluded all planned activities and delivered all planned deliverables by the end of June. A fifth webinar was offered on the European hydrogen roadmap in June. The final conference was held on 19 June in the Netherlands.

PROJECT TARGETS

Target source	Parameter	Target achieved?
Project's own objectives	Develop future scenario roadmaps for EU-wide implementation	⚙
	Evaluate the amount of renewable energy that can be buffered versus time-varying demands	
	Establish a cost estimate and identify the business case for H_2 storage in porous reservoirs	
	Visualise suitable H_2 underground stores and their H_2 storage potential based on GIS	✓
	Establish geochemical, microbial, flow and transport, and geomechanical processes for H_2 in porous reservoirs	
	Map the proximity of hydrogen stores to large renewable energy infrastructures	

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LH2CRAFT

SAFE AND EFFICIENT MARINE TRANSPORTATION OF LIQUID HYDROGEN

Project ID	101111972
PRR 2024	Pillar 2 – H_2 storage and distribution
Call topic	HORIZON-JTI-CLEANH2-2022-02-06: Development of large scale LH_2 containment for shipping
Project total cost	EUR 5 627 595.94
Clean H_2 JU max. contribution	EUR 5 627 595.94
Project period	1.6.2023–31.5.2027
Coordinator	Hydrus Anotati Synektiki Michaniki Etaireia Symvoulon Anonymi Etaireia, Greece
Beneficiaries	American Mpiro of Siping Hellenic Monoprosopi Etaireia Periorismenis Evthinis, Bureau Veritas Marine & Offshore – registre international de classification de navires et de plateformes offshore, Cegelec NDT-PSC, EASN Technology Innovation Services BVBA, Ethnicon Metsovion Polytechnion, Foundation Wegemt – A European Association of Universities in Marine Technology and Related Sciences, Gabadi SL, HD Korea Shipbuilding & Offshore Engineering Co., Ltd, Panepistimio Patron, RINA Services SpA, Technische Universität Dresden, TWI Limited, University of Strathclyde

https://lh2craft.eu/

PROJECT TARGETS

Target source	Parameter	Unit	Target	Target achieved?
SRIA (2021–2027)	LH_2 ship tank CAPEX	€/kg	< 10	⚙
	Boil-off	%/day	< 0.5	
	LH_2 ship tank capacity	t	2 900 per tank	

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NICOLHY

NOVEL INSULATION CONCEPTS FOR LH_2 STORAGE TANKS

Project ID	101137629
PRR 2024	Pillar 2 – H_2 storage and distribution
Call topic	HORIZON-JTI-CLEANH2-2023-02-03: Novel insulation concepts for LH_2 storage tanks
Project total cost	EUR 1 999 628.75
Clean H_2 JU max. contribution	EUR 1 999 585.00
Project period	1.1.2024–31.12.2026
Coordinator	Bundesanstalt für Materialforschung und -prüfung, Germany
Beneficiaries	Alma Mater Studiorum – Università di Bologna, Deutsches Zentrum für Luft- und Raumfahrt EV, Norges teknisk-naturvitenskapelige universitet, Ethnicon Metsovion Polytechnion

http://nicolhy.eu

PROJECT AND GENERAL OBJECTIVES

The Nicolhy project aims to develop a novel insulation concept based on vacuum insulation panels that enables the safe and cost- and energy-efficient storage of large quantities of liquid hydrogen (LH_2). Such large-scale LH_2 storage technology is necessary for establishing a hydrogen storage facility with dimensions from 40 000 m³ to more than 200 000 m³ of LH_2. However, new design concepts are needed because the currently available technologies used in small and medium-sized storage facilities today are not suitable for upscaling. The main problems preventing upscaling are the long time required to produce the storage facilities due to the process for their manufacture, their low tolerance for failure and their spherical shape, which reduces the payload in technical applications by up to 50 % compared with other shapes. The novel concept will change these conditions by using a system that is modular, open and time- and cost-efficient while ensuring multifailure-tolerant production, operation and service and has onshore and offshore applications. The Nicolhy consortium is ideally suited to this ambitious project. It brings together experts from the fields of cryothermodynamics, and marine, chemical, process and safety engineering.

The project's technical objectives are to:

- design a tank, along with its thermal insulation and supporting structure, that is suitable for the large-scale storage of LH_2, scalable, energy-efficient and sustainable, with low construction and operation costs, and that ensures improved safety standards;
- define materials and predict overall thermal insulation performance;
- test the novel insulation concept at laboratory scale;
- perform safety and risk analyses during operational and fire scenarios;
- perform circularity, sustainability and scalability assessments of the concept developed.

FUTURE STEPS AND PLANS

- Design and produce a test rig.
- Design and test diverse novel insulation concepts for the storage of LH_2.
- Perform manufacturing, assembly, safety, circularity, sustainability and scalability studies.

PROJECT TARGETS

Target source	Parameter	Unit	Target	Target achieved?	SOA result achieved to date (by others)	Year for reported SOA result
SRIA (2021–2027)	Onshore LH_2 containment tank CAPEX	€/kg	< 20	⚙	100	2020
Project's own objectives	LH_2 boil-off	mass-%/day	< 0.1		0.3	2020

OPTHYCS

OPTIC FIBRE-BASED HYDROGEN LEAK CONTROL SYSTEMS

Project ID	101101415
PRR 2024	Pillar 2 – H_2 storage and distribution
Call topic	HORIZON-JTI-CLEANH2-2022-02-02: Hydrogen and H2NG leak detection for continuous monitoring and safe operation of HRS and future hydrogen/H2NG networks
Project total cost	EUR 2 499 428.75
Clean H_2 JU max. contribution	EUR 2 499 428.75
Project period	1.1.2023–31.12.2025
Coordinator	Enagás Transporte SA, Spain
Beneficiaries	FEBUS Optics, Fundación para el Desarrollo de las Nuevas Tecnologías del Hidrógeno en Aragón, Fundacion Tecnalia Research and Innovation, Groupe Européen de Recherches Gazières, GRTgaz, Lumiker Aplicaciones Tecnológicas SL

https://opthycs.eu/

PROJECT AND GENERAL OBJECTIVES

The Opthycs project aims to develop a new system for continuous leak detection based on optic fibre sensor technologies, ensuring the safety and sustainability of a hydrogen-based energy system.

Acknowledging the critical need for effective leak detection methods in light of the environmental impact of hydrogen emissions, Opthycs introduces an innovative approach by developing a solution that includes cutting-edge coating materials for fibre Bragg gratings (FBGs) and the creation of a combined detection system merging FBGs with distributed acoustic and temperature-based detection technologies.

PROGRESS AND MAIN ACHIEVEMENTS

In the first year, the project enabled the determination of the design specifications and requirements of the system from the technical, environmental and economical perspectives.

Progress has also been made in the development of sensor solutions. Coating materials for FBG sensors are developed using advanced plasma techniques, ensuring properties such as coating adhesion and increased hydrogen sensitivity.

The first tests for the development of the combined system (merging three different technologies), and the development of the interrogator and interpretative software have taken place in recent months.

FUTURE STEPS AND PLANS

Coating materials for FBG sensors will continue to be developed using advanced plasma techniques. A test bench will evaluate sensor responses under different environmental conditions during laboratory testing, controlling variables such as temperature, humidity and hydrogen concentration.

The development of FBG interrogators is another critical element of the project, involving advancements such as the integration of optical components for signal amplification and the testing of configurations allowing the measurement of a large number of sensors with a single interrogator. This breakthrough significantly increases the scalability of the system while maintaining accuracy and response time.

The final stage of Opthycs includes validating the combined H_2 detection system in predefined use cases, such as pipelines, hydrogen refuelling stations and gas grid installations.

PROJECT TARGETS

Target source	Parameter	Unit	Target	Target achieved?
Project's own objectives	Minimum leak concentration detected	%	0.4	⚙
	Time of response	seconds	30, with a maximum response time of 1 s at a concentration of 0.4 % volume	
	Detection threshold	l_n/min	0.4 (blending operation); 1.2 (pure H_2)	
	Time of recovery	seconds	60/20 depending on application	

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PILGRHYM

PRE-NORMATIVE RESEARCH ON INTEGRITY ASSESSMENT PROTOCOLS OF GAS PIPES REPURPOSED TO HYDROGEN AND MITIGATION GUIDELINES

Project ID	101137592
PRR 2024	Pillar 2 – H_2 storage and distribution
Call topic	HORIZON-JTI-CLEANH2-2023-02-02: Pre-normative research about the compatibility of transmission gas grid steels with hydrogen and development of mitigation techniques
Project total cost	EUR 3 999 073.75
Clean H_2 JU max. contribution	EUR 3 999 073.75
Project period	1.1.2024–31.12.2027
Coordinator	GRTgaz, France
Beneficiaries	Commissariat à l'Énergie Atomique et aux Énergies Alternatives, Enagás Transporte SA, Fluxys Belgium SA, Fraunhofer-Gesellschaft zur Förderung der Angewandten Forschung EV, Fundación para el Desarrollo de las Nuevas Tecnologías del Hidrógeno en Aragón, Fundacion Tecnalia Research and Innovation, Groupe Européen de Recherches Gazières, Onderzoekscentrum voor Aanwending van Staal NV, Sintef AS, Snam SpA, Universidad de Burgos

http://pilgrhym.eu/

PROJECT AND GENERAL OBJECTIVES

The main goal of Pilgrhym is to provide a European roadmap for safely and efficiently integrating pure H_2 into existing natural gas infrastructure, contributing to the decarbonisation of the energy sector. To achieve this goal, Pilgrhym has set forth an ambitious objective of providing transmission system operators with comprehensive guidelines to assess the feasibility of using pure H_2 in existing natural gas pipelines.

To reach the previously stated goals, Pilgrhym has established seven technical and non-technical specific objectives (SOs), interconnected with the project's results, key performance indicators and work packages.

- Develop a database of material characterisation testing on representative steel grades of the EU gas grids, including tensile properties, fracture toughness and fatigue crack growth properties.
- Establish a harmonised testing protocol to support the repurposing of natural gas lines to accommodate hydrogen.
- Develop a numerical modelling approach for simulating and predicting hydrogen-assisted fracture and fatigue.
- Produce a more realistic fatigue crack growth rate master curve for the purpose of assessing fitness for service, in particular for low K values corresponding to the actual operating domain of the EU gas grids.
- Identify existing and/or innovative technologies for mitigation compatible with operational constraints.
- Engage with stakeholders to ensure cooperation and awareness.
- Facilitate the uptake and exploitation of Pilgrhym results by the academic community, technology developers and end users.

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RHEADHY

REFUELLING HEAVY DUTY WITH VERY HIGH FLOW HYDROGEN

Project ID	101101443
PRR 2024	Pillar 2 – H_2 storage and distribution
Call topic	HORIZON-JTI-CLEANH2-2022-02-10: Implementing new/optimised refuelling protocols and components for high flow HRS
Project total cost	EUR 4 734 730.00
Clean H_2 JU max. contribution	EUR 3 999 381.50
Project period	1.2.2023–31.1.2027
Coordinator	ENGIE, France
Beneficiaries	Alfa Laval Vicarb SAS, Benkei, Emerson Process Management Flow BV, ENGIE Energie Services, Faurecia Systèmes d'Echappement SAS, Hydrogen Refueling Solutions, Lauda DR. R. Wobser GmbH & Co. KG, Tescom Europe GmbH & Co. KG, Zentrum für BrennstoffzellenTechnik GmbH

https://rheadhy.eu/

PROJECT AND GENERAL OBJECTIVES

Rheadhy's main goal is to develop components and refuelling stations able to fully implement and test new – very-high-flow – refuelling protocols for heavy-duty vehicles and bring them to the market.

NON-QUANTITATIVE OBJECTIVES

- **Design and assemble a very-high-flow hydrogen refuelling line.** The main goal is to provide components and refuelling lines designed for the required performance and operating conditions (very high flow rate, pressure, temperature, dynamic behaviour), with optimal trade-off between constraints and performance and constraint repartitioning among components.
- **Develop new components needed for high-flow refuelling.** The main goals are to develop new very-high-flow components and make them ready to commercialise (cooling technology, flow meters, valves, heat exchangers), to develop an advanced bidirectional communication interface, and to test, optimise and adapt components already in the prototype phase of their development (breakaway, hose, nozzle and receptable assembly).
- **Develop and demonstrate a new protocol for refilling storage systems.** The main goal is to demonstrate new standardised refuelling protocols for heavy-duty vehicles developed in ISO TC 197 WG24 or by other standardisation bodies.
- **Ensure the fast and efficient refilling of storage systems with H_2 at a low cost.**
- **Standardise and certify components of hydrogen refuelling stations to ensure the fast deployment of the components.** The main goals are to contribute to the development of standards through participation in the development of ISO TC 197 and CEN 268 WG5 and to obtain certifications for all the components in accordance with the relevant standards (ISO TC 197, CEN 268 WG5, OIML R139).

PROGRESS AND MAIN ACHIEVEMENTS

- All partners (product manufacturers) have completed the design of the concept for their product (including mechanical design, electrical design, communication, first 3D model, first draft of piping and instrumentation diagram or layout, etc.) and are now starting the detailed design phase.
- More than 250 simulations have already been done in order to aid the design of the different components.

FUTURE STEPS AND PLANS

The components for the Rheadhy project (cooling unit, by Lauda; heat exchanger, by Alfa Laval; flow sensor, by Emerson Micro Motion; control valve and safety valves, by Emerson Tescom; transport storage testing system, by Forvia) will be developed.

Then, the high-flow distribution line will be integrated into two hydrogen refuelling stations (the Hydrogen Refueling Solutions site and the ZBT site).

Afterward, tests will be performed on these two stations in order to validate the key performance indicators of the project.

PROJECT TARGETS

Target source	Parameter	Unit	Target	Target achieved?
Project's own objectives	Time to refill a 100 kg HD truck storage test system	minutes	10	⚙
	Time to refuel a heat exchanger and cooling system for hydrogen dispensed below – 30 °C	minutes	10	
	Pressure regulator and shut-off valve compatible with very high flow rate and high pressure (1 000 bar)	g/s	170 (mean flow rate); 300 (peak flow rate)	
	Peak flow for prototype's breakaway, nozzle and hose	g/s	300	
	Refuelling events demonstrated for the fully integrated chain	number	300	
	Refuelling simulations performed	operations	1 000	
	Flow rate determined by measuring device compatible with very high flow rate, targeting > 100 kg total mass per refuelling	g/s	170 (mean flow rate); 300 (peak flow rate)	

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ROAD TRHYP

ROAD TRAILER DESIGN: USE OF TYPE V THERMOPLASTIC TUBE WITH LIGHT COMPOSITE STRUCTURE FOR HYDROGEN TRANSPORT

Project ID	101101422
PRR 2024	Pillar 2 – H_2 storage and distribution
Call topic	HORIZON-JTI-CLEANH2-2022-02-07: Increased hydrogen capacity of GH 2 road trailers
Project total cost	EUR 2 642 912.59
Clean H_2 JU max. contribution	EUR 2 499 999.50
Project period	1.1.2023–31.12.2025
Coordinator	Air Liquide SA, France
Beneficiaries	Arkema France SA, Centre national de la recherche scientifique, Covess NV, École Nationale Supérieure de Mécanique et d'Aérotechnique, Efectis France, Envitest J. Pacholski Sp J, Politechnika Wrocławska, Segula Engineering, Segula Slovensko s.r.o., Université de Poitiers

http://road-trhyp.eu/

PROJECT AND GENERAL OBJECTIVES

The overall ambition of the ROAD TRHYP project is to demonstrate that using a trailer made out of thermoplastic composite tubes (type V) is a suitable solution to maximise the amount and the quantity of H_2 transported while satisfying end-user requirements (safety, ability to be decontaminated) and enforced regulations with a low TCO.

The main objectives are to:

- design type V 700-bar tubes according to EN 17339 and key performance tests;
- elaborate a decontamination methodology to ensure H_2 purity;
- demonstrate the safety of type V tubes;
- demonstrate that a trailer made with type V tubes will achieve the expected key performance indicators in 2030 and improved environmental impact;
- formulate the regulatory recommendations aimed at accelerating the deployment of the technology.

PROGRESS AND MAIN ACHIEVEMENTS

- Type V cylinders have been developed and preliminary testing is ongoing.
- Raw material to be processed to make type V cylinders has been developed and optimised with a carbon fibre content of 57 % by volume.
- The methodology for carrying out a design of experiments analysis and the bench test to enable testing to find the optimised parameters for a type V cylinder are ready.
- A safety study has shown that the three main accident scenarios for a trailer are hose rupture, leakage of the filling hose and leakage of the piping. An assessment of the severity of H_2 flammable cloud ignition consequences in the case of no mitigation measures has been carried out.
- The initial trailer design work done so far has shown that the target of 1.5 t of H_2 stored in a trailer is achievable.
- An assessment of the regulation of H_2 cylinders and ancillary components, H_2 fuelling stations and H_2 transport has been carried out.
- Life-cycle analyses carried out on a type I and a type IV trailer show that there is a benefit in terms of reducing CO_2 emissions, the use of fossil and mineral resources, and particle emission, among other things.

FUTURE STEPS AND PLANS

The next steps are:

- finalise preliminary type V cylinder testing;
- carry out decontamination tests on one cylinder;
- start ambient extreme temperature cycling tests and bonfire tests;
- conduct permeation tests;
- recommend regulations for operating trailers with type V cylinders in hydrogen refuelling stations;
- determine barriers to the safe operation of a trailer with type V cylinders;
- determine thermophysical properties of the processed material and study the mechanical behaviour of the cylinder in response to fire;
- finalise the trailer design and design a demonstration unit;
- manufacture the demonstration unit;
- model temperature when filling and defueling, then fill and defuel the demonstration unit to calibrate the prediction tool developed;
- carry out a bonfire test on a demonstration unit to simulate the behaviour in response to fire of a cylinder and a set of cylinders;
- finalise the life-cycle assessment with a trailer equipped with type V cylinders;
- assess the TCO.

PROJECT TARGETS

Target source	Parameter	Unit	Target	Target achieved?
Project's own objectives	Operating pressure	bar	700	⚙
	Tube trailer payload	kg	1 500	
	Tube trailer CAPEX	€/kg	400	

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SHERLOHCK

SUSTAINABLE AND COST-EFFICIENT CATALYST FOR HYDROGEN AND ENERGY STORAGE APPLICATIONS BASED ON LIQUID ORGANIC HYDROGEN CARRIERS: ECONOMIC VIABILITY FOR MARKET UPTAKE

Project ID	101007223
PRR 2024	Pillar 2 – H_2 storage and distribution
Call topic	FCH-02-1-2020: Catalyst development for improved economic viability of LOHC technology
Project total cost	EUR 2 563 322.50
Clean H_2 JU max. contribution	EUR 2 563 322.50
Project period	1.1.2021–30.6.2024
Coordinator	Commissariat à l'Énergie Atomique et aux Énergies Alternatives, France
Beneficiaries	Evonik Operations GmbH, Friedrich-Alexander-Universität Erlangen-Nürnberg, Hydrogenious LOHC Technologies GmbH, Kuwait Petroleum Research & Technology BV, Noordwes-Universiteit, Universidad del País Vasco / Euskal Herriko Unibertsitatea

https://sherlohck.eu/

PROJECT AND GENERAL OBJECTIVES

Liquid organic hydrogen carriers are attractive owing to their ability to safely store large amounts of hydrogen (up to 7 wt% or 2 300 kWh/t) for a long time and to release pure hydrogen on demand. The project targets the development of (i) highly active and selective catalysts with partial/total substitution of platinum group metals (PGMs); (ii) a novel catalytic system architecture, with components ranging from the catalyst to the heat exchanger, to minimise internal heat loss and to increase the space–time yield; and (iii) novel catalyst testing, system validation and demonstration through the demonstration unit (> 10 kW, > 200 h).

PROGRESS AND MAIN ACHIEVEMENTS

Requirements have been defined for the hydrogenation and dehydrogenation catalyst, the type and quality of liquid organic hydrogen carriers, hydrogen quality, the testing routine and energy consumption; these are compatible with all the objectives of the project. This initial work has laid the foundation for the whole project. Benzyltoluene was chosen as the reference molecule, and Pt-based catalysts from Clariant were selected as the catalysts' benchmark.

The design of a catalyst through density functional theory predictive analysis has reduced the use of PGM catalysts. Calculations were applied to the dehydrogenation of methylcyclohexane (to toluene) as a reference molecule, as benzyltoluene was too complex for the calculation. The overall dehydrogenation energies calculated for the various alloys considered showed that alloys such as Co, Co_3Pt, SnPt, Sn_3Pt_2, Sn_2Pt and Sn_4Pt could be potential low-Pt-based catalytic materials. Catalyst materials have been synthesised and tested on a laboratory scale with a standardised test protocol. Some Pt-X (X = Fe, Zn, Co or Cu) catalysts supported by alumina outperform the benchmark catalyst in terms of activity. Pt-Co, with a cobalt content of 0.5 wt%, achieved almost the same dehydrogenation activity and selectivity as catalysts with 1 wt% Pt but with half the amount of this noble metal. PGM-free catalysts have very low activity. Furthermore, through experiments with model substances simulating by-product formation, it was possible to gain better insights into the dehydrogenation reaction and catalyst deactivation. Promising results were initially obtained for the first catalyst reactivation by oxidative regeneration with synthetic air procedures executed in batch operations.

In parallel, to explore the advantages of structured heat-exchanger reactors combined with improved catalysts, models were constructed and simulations were performed to support the choice of possible reactor geometries, in particular to define suitable heat-conductive reactor structures. The results indicated that, for both reactions, foam structure, catalyst activity, mass and operating conditions are first-order parameters. 3D monolith structures were prepared to integrate catalyst materials, and a long-term testing campaign was launched, which ran up to June 2024.

FUTURE STEPS AND PLANS

- Sherlohck has integrated the catalyst into the thermally conductive support structure.
- Long-term testing in continuous operation (> 200 h) was ongoing until June 2024.
- Testing of the resistance of catalysts to different poisons is ongoing.
- The modelling of the reaction kinetics for the design of new reactors has started for the dehydrogenation reaction.

PROJECT TARGETS

Target source	Parameter	Unit	Target	Achieved to date by the project	Target achieved?	SOA result achieved to date (by others)	Year for reported SOA result
Project's own objectives	Catalyst selectivity	%	99.8	99.4	⚙	Around 100	2022
	Degree of conversion	%	90	88	⚙	Around 100	2022
	Catalyst productivity in dehydrogenation	gH2 / g catalyst / min	3	0.85	✓	0.85	2022

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SINGLE

ELECTRIFIED SINGLE STAGE AMMONIA CRACKING TO COMPRESSED HYDROGEN

Project ID	101112144
PRR 2024	Pillar 2 – H_2 storage and distribution
Call topic	HORIZON-JTI-CLEANH2-2022-02-04: Ammonia to green hydrogen: efficient system for ammonia cracking for application to long distance transportations
Project total cost	EUR 2 989 671.25
Clean H_2 JU max. contribution	EUR 2 989 671.25
Project period	1.5.2023–30.4.2026
Coordinator	CoorsTek Membrane Sciences AS, Norway
Beneficiaries	Consejo Superior de Investigaciones Científicas, Fondazione ICONS, Gea Energia Crio SL, SINTEF AS, Universitat Politècnica de Catalunya, Univerza v Ljubljani

https://singleh2.eu/

PROJECT AND GENERAL OBJECTIVES

Single will enable ammonia to be used as an energy carrier in the hydrogen value chain through the demonstration of a proton ceramic electrochemical reactor that integrates the ammonia dehydrogenation reaction, hydrogen separation, heat management and compression in a single stage. The combination of the four steps in a single reactor allows the technology to achieve unprecedented energy efficiencies and deliver purified, pressurised hydrogen (20 bar). Single will demonstrate the technology at a 10 kgH_2/day scale that will provide a pathway for future scaled-up systems, ranging from small (fuelling stations) to large, centralised (at harbours) structures.

NON-QUANTITATIVE OBJECTIVES

Single aims to disseminate information to relevant communities and maximise the outcomes and reach of the project.

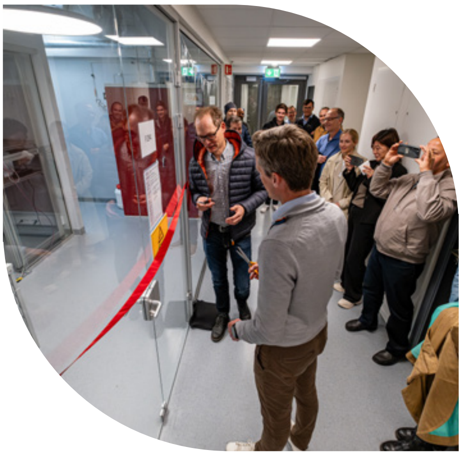
Those involved in implementing the project collaborate with standardisation organisations to valorise project results by contributing to the creation or revision of standards. To achieve this goal, Single has used HSbooster.eu's consultancy services to guide the project consortium to ensure the adoption of the right strategic approach and efficient contribution to the standardisation process.

PROGRESS AND MAIN ACHIEVEMENTS

- Ni and barium zirconium yttrium cerate support catalytic activity, and their stability has been studied to enable optimisation by infiltrating the active metal and changing the morphology of Ni and its interaction with the barium zirconium yttrium cerate support.
- Candidate alloy materials have been identified for constructing and safely operating reactor housing in the presence of ammonia.
- Cells, KETs and stacks have been manufactured.
- Single collaborated with Hsbooster.eu for 3 months to perform standardisation activities.

FUTURE STEPS AND PLANS

- The proton ceramic electrochemical reactor cell will be further optimised to improve its catalytic activity and electrochemical performance under relevant conditions.
- Stacks for 10 kgH_2/day module will be fabricated.
- The 10 kgH_2/day module will be designed, assembled, constructed and tested.
- The life cycle, value chain economics and critical raw materials of the system will be assessed.



PROJECT TARGETS

Target source	Parameter	Unit	Target	Target achieved?	SOA result achieved to date (by others)
SRIA (2021–2027)	Hydrogen-carrier-specific energy consumption	kWh input / kgH_2 recovered	17	⚙	20
	Hydrogen carrier delivery cost (for 3 000 km ship transfer)	€/kg	2.5		4

UNLOHCKED

UNLOCKING THE POTENTIAL OF LOHCS THROUGH THE DEVELOPMENT OF KEY SUSTAINABLE AND EFFICIENT SYSTEMS FOR DEHYDROGENATION

Project ID	101111964
PRR 2024	Pillar 2 – H_2 storage and distribution
Call topic	HORIZON-JTI-CLEANH2-2022-02-05: Efficient system for dehydrogenation of liquid organic hydrogen carriers for application to long distance transportations
Project total cost	EUR 2 941 312.75
Clean H_2 JU max. contribution	EUR 2 941 312.75
Project period	1.6.2023–31.5.2026
Coordinator	Universidad del País Vasco / Euskal Herriko Unibertsitatea, Spain
Beneficiaries	Centre national de la recherche scientifique, Commissariat à l'Énergie Atomique et aux Énergies Alternatives, Framatome GmbH, Heraeus Deutschland GmbH & Co. KG, HyGear BV, HyGear Fuel Cell Systems BV, HyGear Hydrogen Plant BV, HyGear Operations BV, HyGear Technology And Services BV, Noordwes-Universiteit

https://unlohcked.cnrs.fr/

PROJECT AND GENERAL OBJECTIVES

By advancing breakthrough research on liquid organic hydrogen carrier (LOHC) technologies, Unlohcked aims to develop a radically disruptive, versatile and scalable LOHC dehydrogenation plant. Firstly, highly active and stable catalysts not containing critical raw materials (CRMs) will be developed to reduce LOHC dehydrogenation at moderate temperatures. Secondly, a solid oxide fuel cell system will be developed to be thermally integrated in the dehydrogenation process. The heat demand of the dehydrogenation unit will be fully covered by the fuel cell, while generating electric power. The surplus of hydrogen will be exported. These innovative systems, when fully integrated, will significantly increase the overall efficiency (> 50 %) of hydrogen and electric power production from LOHCs.

The main objectives of this project are:

- to develop a CRM-free or low-CRM catalyst with a high conversion rate, selectivity and productivity for dehydrogenation;
- to scale up one of the catalysts developed, from a gram at laboratory scale to multiple kilograms for the demonstration unit;
- to develop a breakthrough integrated system in which the reactor is thermally coupled to a solid oxide fuel cell, simplifying the dehydrogenation plant and improving its thermal efficiency;
- to demonstrate the feasibility of producing H_2 and generating renewable electricity from LOHC-stored hydrogen by heat integration between endothermic hydrogen release and exothermic fuel cell operation.

NON-QUANTITATIVE OBJECTIVES

- To reduce capital expenditure (i.e. owing to the use of less expensive materials, no chemical reagents and no cleaning cycles, and the extended lifetime of materials) and operational expenditure (i.e. owing to a continuous mode of operation and optimised process controls).
- To decrease the cost of transporting H_2, including by demonstrating the feasibility and cost-effectiveness of using LOHC technologies to transport H_2 from on-shore tanks to on-shore tanks all-inclusive.
- To develop a scale-up plan through techno-economic analysis in order to improve techno-economic viability, to include, in particular, comparisons with alternative H_2 technologies for long-distance transport.
- To put the EU at the forefront of H_2 technologies, to ensure a competitive and commercial advantage in Europe to incentivise future investments.
- To reduce the environmental impact of H_2 technologies, by reducing the use and release of toxic substances and CRMs with a huge environmental impact.
- To contribute to the European Green Deal goals through developing a fully CO_2-free dehydrogenation system.

PROGRESS AND MAIN ACHIEVEMENTS

After the first year of the project, we are in the middle of developing CRM-free and low-CRM catalysts; so far, we have created catalysts with conversion rates, selectivity and productivities close to those of the SOA catalysts.

FUTURE STEPS AND PLANS

- Continue developing catalysts at a laboratory scale to improve their conversion, selectivity and productivity, but mainly their stability, in order to reach the project's targets.
- Start designing the reactor to be integrated in the dehydrogenation unit.

PROJECT TARGETS

Target source	Parameter	Unit	Target	Achieved to date by the project	Target achieved?	SOA result achieved to date (by others)	Year for reported SOA result
Project's own objectives	KPI 1: grade of conversion of CRM-free or low-CRM catalysts	%	95	86	⚙	85	2022
	KPI 2: catalyst selectivity	%	> 99.8	98.8		82	2022
	KPI 3: catalyst productivity in dehydrogenation	gH_2/gcat/min	> 0.02	8		0.0212	2022

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WINNER

WORLD CLASS INNOVATIVE NOVEL NANOSCALE OPTIMIZED ELECTRODES AND ELECTROLYTES FOR ELECTROCHEMICAL REACTIONS

Project ID	101007165
PRR 2024	Pillar 2 – H$_2$ storage and distribution
Call topic	FCH-03-1-2020: HT proton conducting ceramic materials for highly efficient and flexible operation
Project total cost	EUR 2 931 788.75
Clean H$_2$ JU max. contribution	EUR 2 931 788.75
Project period	1.1.2021–31.3.2024
Coordinator	SINTEF AS, Norway
Beneficiaries	Consejo Superior de Investigaciones Científicas, Alleima Tube AB, CoorsTek Membrane Sciences AS, Danmarks Tekniske Universitet, ENGIE, Shell Global Solutions International BV, Universitetet i Oslo

https://www.sintef.no/projectweb/winner/

PROJECT AND GENERAL OBJECTIVES

The Winner project is contributing to the shift towards a future with more sustainable energy by developing an efficient and durable technology platform based on electrochemical proton ceramic conducting (PCC) cells designed to unlock a path towards commercially viable production, extraction, purification and compression of hydrogen at a small to medium scale through three process chains:

- cracking of ammonia to produce pressurised hydrogen or power, where PCC reactors provide an innovative solution for the flexible, secure and profitable storage and utilisation of energy in the form of green ammonia;
- dehydrogenation of ethane to produce ethylene and pressurised hydrogen, where PCCRs provide new sustainable pathways for electrically driven processes in the chemical industry;
- reversible steam electrolysis (using reversible protonic ceramic electrochemical cells), where PCC reactors allow the shifting of electric power generation to hydrogen production, enabling grid balancing, improved matching of the demand and supply of electricity, and more efficient use of renewable energy sources.

NON-QUANTITATIVE OBJECTIVES

Winner is developing a multiscale, multiphysics modelling platform integrating various disciplines (atomistic, electrochemical, mechanical, fluid flow, reactor engineering, electric, heat), with the goal of establishing the rate-determining steps at a meso scale in the electrochemical cell, and the most efficient dimensioning and arrangement of the cells in the multitube reactor design. The work is supported by relevant experimental data and enhanced experimentation methodologies applied in the project.

PROGRESS AND MAIN ACHIEVEMENTS

The project developed novel tubular cells using a production line established by CoorsTek Membrane Sciences, consisting of a Ni-BZCY72 electrode with BZCY81-dense electrolyte. The cells met performance criteria for reversible electrolysis of ammonia to hydrogen cells, with a cell area-specific resistance below 1 ohm.cm^2 at 650 °C, a faradaic efficiency of 80–90 % and a degradation rate below 1.2 %/kh under reversible operation. A tubular cell was successfully in reversible operation for over 4 000 h at 4 bar at 650 °C. The results of these research and development activities are reported in several public deliverables. A communication platform was established to link various models and competencies developed from the atomistic scale to the process scale. An engineering model was created for each of the Winner applications, which is now functioning alongside multiple other models integrated together. The construction of a computational fluid dynamics model has been initiated, with outputs including energy demand in relation to balance of plant and for the overall process for selected input parameters. A life-cycle assessment of three applications was conducted, showing the benefits of proton ceramic technologies in comparison with benchmark cases. In 2023, a multitube testing unit within Consejo Superior de Investigaciones Científicas was prepared, and upgrades and commissioning were initiated.

FUTURE STEPS AND PLANS

The project was finalised at the end of March 2024 with the delivery of techno-economic analysis and life-cycle assessment results. A results exploitation workshop was also organised in March 2024.

PROJECT TARGETS

Target source	Parameter	Unit	Target	Achieved to date by the project	Target achieved?	SOA result achieved to date (by others)	Year for reported SOA result
Project's own objectives	Round-trip efficiency of reversible steam electrolysis	% at 650 °C	> 75	N/A	⚙	Unclear as this is not well documented in the literature	2019
	Faradaic efficiency	%	> 95	> 90	✓	> 90	2021
	Durability	hours	3 000	> 4 000		< 1 000	2021
	Area-specific resistance of cell	ohm.cm^2 at 650 °C	< 1	< 1		2.5	2022
Project's own objectives and MAWP (2018–2020)	Levelised cost of hydrogen produced	€/kg	5	N/A	⚙	> 6, based on GAMER technology with several scaling up assumptions	2022

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