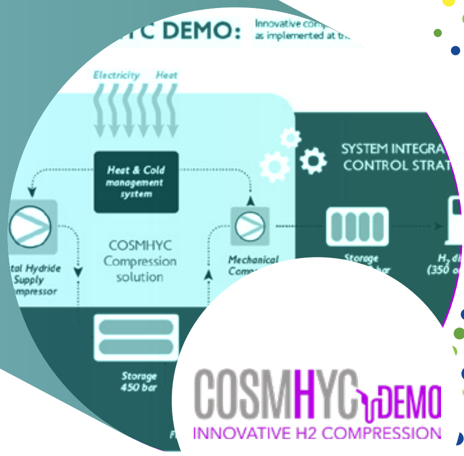

COSMHYC DEMO

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

Project ID:	101007173
PRD 2023:	Panel 2 – H2 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 costs:	EUR 3 773 858.75
Clean H_2 JU max. contribution:	EUR 2 999 637.13
Project period:	1.1.2020–31.12.2024
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/cosmhyc-project

PROJECT AND OBJECTIVES

To meet the demands of a growing hydrogen economy, new technologies in the hydrogen refuelling infrastructure – including that of hydrogen compression – are necessary. In COSMHYC DEMO, the innovative COSMHYC compression solution, which combines a metal hydride compressor and a 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. vehicle fleets and refuse 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 HRS.

PROGRESS AND MAIN ACHIEVEMENTS

- The HRS has been fully constructed and is ready to ship.
- The metal hydride composition has been decided upon for all compression stages.
- Site integration and filling centre gas panel design, including safety studies, have been completed.

FUTURE STEPS AND PLANS

- The HRS is due to be installed in summer 2023.
- The metal hydride compressor is due to be integrated in early 2024.
- Long-term tests of the demonstrator will be conducted with the on-site vehicle fleet.
- Final discussions regarding safety studies will take place, before authorisation is granted.
- An opening event for the launch of the HRS and compressor will be organised to bring together local stakeholders, the general public and EU officials at the demonstration site.

QUANTITATIVE TARGETS AND STATUS

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

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COSMHYC XL

COMBINED HYBRID SOLUTION OF METAL HYDRIDE AND MECHANICAL COMPRESSORS FOR EXTRA LARGE SCALE HYDROGEN REFUELLING STATIONS

Project ID:	826182
PRD 2023:	Panel 2 – H2 storage and distribution
Call topic:	FCH-01-7-2018: Improvement of innovative compression concepts for large scale transport applications
Project total costs:	EUR 2 749 613.75
Clean H_2 JU max. contribution:	EUR 2 749 613.75
Project period:	1.1.2019–30.06.2023
Coordinator:	Europäisches Institut für Energieforschung EDF–KIT EWIV, Germany
Beneficiaries:	Ludwig-Bölkow-Systemtechnik GmbH, Mahytec SARL, Nel Hydrogen AS, Steinbeis 2i GmbH

https://cosmhyc.eu/cosmhyc-xl-project

PROJECT AND OBJECTIVES

Hydrogen mobility is one of the most promising solutions for a sustainable energy transition in large-scale transport modes, including trucks, buses, trains and professional vehicle fleets. For these applications, a well-functioning hydrogen refuelling infrastructure is necessary, including hydrogen compressors able to meet challenging constraints in terms of flow rate and availability. COSMHYC XL aims to develop an innovative compression solution for extra-large hydrogen refuelling stations, based on the combination of a metal hydride compressor and a mechanical compressor.

NON-QUANTITATIVE OBJECTIVES

- The project aims to create a hybrid system allowing for different configurations. Ludwig-Bölkow-Systemtechnik will show that only small adaptations for different refuelling applications and intermediate storage capacities are required to minimise total costs.
- The project aims to increase reliability. The results of COSMHYC and the preliminary results of COSMHYC XL show that reliability can be strongly improved compared with that of SoA mechanical compressors.
- The project aims to undertake a cost-of-ownership assessment. Activities dedicated to this are ongoing. The results of the previous COSMHYC project show that the target total cost of ownership can be achieved.

PROGRESS AND MAIN ACHIEVEMENTS

- A prototype of a dual-head mechanical compressor has been assembled and is operational; the compressor reaches 120 kg/h in two-stage configuration and 240 kg/h in duplex configuration (listed in the European Commission's Innovation Radar).
- Metal hydrides without rare-earth elements were produced for all three compression stages (listed in the Innovation Radar).
- The metal hydride compressor prototype is assembled in a 20-foot container, including all subsystems (e.g. thermal integration, control and monitoring system) (listed in the Innovation Radar).
- The test site has been in commission for the metal hydride compressor prototype. All risk assessments were successfully performed, and pre-certification is complete. The long-term test started in Q4 2022.

FUTURE STEPS AND PLANS

- The project is conducting long-term tests of the prototypes. The tests of the mechanical compressor are complete; the metal hydride compressor tests started in late 2022. The testing protocol validates the combination of the compression technologies.
- The consortium is collecting and analysing all data generated during the tests. Based on these data, a techno-economic analysis will be conducted and the project's final exploitation roadmap will be set.

QUANTITATIVE TARGETS AND STATUS

Target source	Parameter	Unit	Target	Target achieved?	SoA result achieved to date (by others)	Year of SoA target
Project's own objectives	Energy consumption	kWh/kg	6.18		8	2018
	Degradation	%/1 000 h	0.8		N/A	N/A
	Specific costs	k€/kg*day	1.47		3.7	2021
	Noise levels	dB	< 60		53.9	2021

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HIGGS

HYDROGENINGASGRIDS:ASYSTEMATICVALIDATION APPROACH AT VARIOUS ADMIXTURE LEVELS INTO HIGH-PRESSURE GRIDS

Project ID:	875091
PRD 2023:	Panel 2 – H2 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 costs:	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 & Innovation, OST – Ostschweizer Fachhochschule, Redexis SA

https://higgsproject.eu/

PROJECT AND OBJECTIVES

HIGGS aims to fill in the gaps in knowledge regarding the impact that high levels of H_2 could have on high-pressure natural gas infrastructure, its components and its management. To reach this goal, the project is mapping technical, legal and regulatory barriers and enablers; testing materials/components; completing techno-economic modelling; and preparing a set of conclusions as a pathway towards enabling the injection of hydrogen into high-pressure gas grids. The inventory of materials/equipment and the mapping of regulations, codes and standards (RCS) are mostly complete, tests are ongoing and the techno-economic model is under development.

NON-QUANTITATIVE OBJECTIVES

- The project aims to draw up recommendations on regulations, codes and standards. The first screening has been completed, and the work is ongoing.
- A pathway for stepwise integration of hydrogen into the EU gas network is being drafted.
- The project aims to develop a techno-economic model and study of the roles of technologies for integrating H_2/CH_4 and sector coupling at the EU level. This work has started with the Trans Europa Naturgas Pipeline and the Mittel-Europäische-Gasleitung.

PROGRESS AND MAIN ACHIEVEMENTS

- The testing platform has enabled dynamic and static tests to be carried out with blends of up to 20 % H_2.
- The project has adapted the techno-economic model, and initial scenarios have been modelled.
- A system has been created for hydrogen separation in natural gas blends with low concentrations of hydrogen. The gas separation prototype experimental campaign has been completed, with promising results.

FUTURE STEPS AND PLANS

- The project will complete all experimental campaigns in the testing platform and characterisation of materials before and after hydrogen exposure, using a 30 % H_2 blend and 100 % H_2, to evaluate the effect of the injection of hydrogen.
- Data from the RCS review at the European and national levels were collected, reviewed and compiled in a comprehensive report comprising diagrams and graphs that are to be presented on the project website and used for presentations and papers. The first review was shared publicly, and is due to be updated in 2023.
- The simulation of the initial scenarios on the Trans Europa Naturgas Pipeline and the Mittel-Europäische-Gasleitung and analysis of techno-economic aspects are ongoing and are due to be completed in late 2023. This work will finish with the publication of four publicly available reports.
- The main and final report will be the pathway description, due to be delivered by the end of 2023. The results are intended to be used beyond the project period.

QUANTITATIVE TARGETS AND STATUS

Target source	Parameter	Target	Achieved to date by the project	Target achieved?
Project's own objectives	Blending percentage compatible with existing gas transmission networks	Technical compatibility of materials and equipment in transmission networks	Trials have been conducted with blends with 20 % hydrogen content, with and without trace impurities	⚙
	Readiness of gas transmission networks for H_2 distribution	Identify existing assets and their readiness for hydrogen transport	First inventory of the European grid	✓
	Techno-economic approach for grid repurposing	Start modelling	First scenarios modelled	⚙

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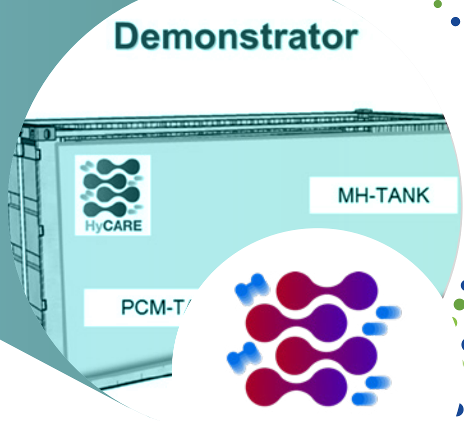
HYCARE

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



Project ID:	826352
PRD 2023:	Panel 2 – H2 storage and distribution
Call topic:	FCH-02-5-2018: Hydrogen carriers for stationary storage of excess renewable energy
Project total costs:	EUR 2 039 230.00
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:	Stühff Maschinen- und Anlagenbau GmbH, Stühff GmbH, Tecnodelta SRL, GKN Sinter Metals Engineering GmbH, Parco Scientifico Tecnologico per l'Ambiente SpA, Institutt for Energiteknikk, Helmholtz-Zentrum Hereon GmbH, Fondazione Bruno Kessler, Engie, Centre national de la recherche scientifique

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

PROJECT AND OBJECTIVES

The main objective of HyCARE is the development of a prototype hydrogen storage tank using a solid-state hydrogen carrier on a large scale. The tank will be based on an innovative concept, joining hydrogen and heat storage, to improve the energy efficiency of the whole system. The tank will be joined to a proton-exchange membrane (PEM) electrolyser as the hydrogen provider and a PEM fuel cell as the hydrogen user at the Engie Crigen laboratory, located in Île-de-France. As of 2023, the system is undergoing testing.

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 through the use of heat storage using phase change materials.

PROGRESS AND MAIN ACHIEVEMENTS

- Finalisation of the tank's assembly – using metal hybrid and phase change material tanks and pumping system components – was achieved. Pre-commissioning tests (i.e. FAT tests) were concluded in November 2022, enabling the tank transfer.
- The tank was moved to the installation site at the beginning of December 2022.
- At the installation site, fuel cells genset were received in September 2022 and the final commissioning was performed (assembly with the tank and partial SAT) in mid December 2022.
- System integration procedures were concluded in terms of long-term shutdown and control logic. The activation procedure and testing are under way.
- Following the progress with the tank system, techno-economic analysis is under way. Dissemination and exploitation of the project results are also being conducted.

FUTURE STEPS AND PLANS

- Finalisation of system activation was planned for March 2023. Testing of the demonstrator will take at least 4 months.
- A final exploitation event was planned for 21 April 2023 to showcase the project's tank and results.
- Techno-economic analysis, life cycle analysis and a market deployment plan will be finalised at the end of the project, in July 2023. The project is receiving support from the Horizon Results Booster platform for business plan development.

QUANTITATIVE TARGETS AND STATUS

Target source	Parameter	Unit	Target	Achieved to date by the project	Target achieved?
Project's own objectives	Volumetric capacity of H_2 carrier	kg of H_2 per unit of volume of carrier	N/A	Reversible capacity at 55 °C at 1–25 bar of less than 70	⚙
	Gravimetric capacity of H_2 carrier	% of H_2 weight in the carrier	N/A	Reversible capacity at 55 °C at 2–20 bar is equal to 1.1	⚙
	Hydrogen storage capacity	Maximum amount of H_2 in kg that can be stored in the system	N/A	Estimated reversible capacity of 44 at 55 °C, 1–25 bar	⚙
	Max. tank pressure	Pressure rating of the H_2 carrier tank in bar	< 50	40	✓
	Cyclability	Number of full cycles until reaching a 2 % reduction in the gravimetric capacity of the H_2 carrier	250	250	✓

HYPSTER

HYDROGEN PILOT STORAGE FOR LARGE ECOSYSTEM REPLICATION

Project ID:	101006751
PRD 2023:	Panel 2 – H2 storage and distribution
Call topic:	FCH-02-7-2020: Cyclic testing of renewable hydrogen storage in a small salt cavern
Project total costs:	EUR 21 158 886.73
Clean H_2 JU max. contribution:	EUR 4 999 999.00
Project period:	1.1.2021–31.12.2023
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, Ecole Polytechnique, Element Energy Limited, Equinor Energy AS, ERM France, ESK GmbH, Inovyn ChlorVinyls Limited, Institut national de l'environnement industriel et des risques, Brouard Consulting SAS, Storengy SA

https://hypster-project.eu/

PROJECT AND OBJECTIVES

HyPSTER aims to demonstrate the industrial-scale operation of cyclic hydrogen storage in salt caverns to support the emergence of the hydrogen energy economy in Europe in line with Hydrogen Europe's overall roadmapping. The cavern is located in Étrez in Auvergne-Rhône-Alpes in France. For the production of green hydrogen, the Étrez storage site will rely on local renewable energy sources and a 1 MW PEM electrolyser. In the long run, this facility will produce 400 kg of hydrogen per day (the equivalent of the daily consumption of 16 hydrogen buses).

PROGRESS AND MAIN ACHIEVEMENTS

- The subsurface materials for hydrogen salt cavern storage were ordered and are now in place.
- The surface materials have been selected and ordered. The civil works necessary to install the facilities have been carried out.
- 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.

FUTURE STEPS AND PLANS

- The hydrogen production platform facilities (electrolyser, compressor, etc.) will be received in Q2 and Q3 2023.
- The workover of the EZ53 well is ongoing and was expected to finish in April 2023. The project will build surface facilities so that the cavern can be operational before the planned tightness tests, which will take place in Q3 2023.

QUANTITATIVE TARGETS AND STATUS

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

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HYSTORIES

HYDROGEN STORAGE IN EUROPEAN SUBSURFACE

Project ID:	101007176
PRD 2023:	Panel 2 – H2 storage and distribution
Call topic:	FCH-02-5-2020: Underground storage of renewable hydrogen in depleted gas fields and other geological stores
Project total costs:	EUR 3 024 631.68
Clean H_2 JU max. contribution:	EUR 2 499 911.75
Project period:	1.1.2021–30.6.2023
Coordinator:	Geostock SAS, France
Beneficiaries:	Agencia Estatal Consejo Superior de Investigaciones Cientificas, Bureau de Recherches Géologiques et Minières, Česká Geologická Služba, CO2GeoNet – Reseau d'Excellence Européen sur le Stockage Geologique de CO2, Ethniko Kentro Erevnas Kai Technologikis Anaptyxis, Fundación para el Desarrollo de las Nuevas Tecnologías del Hidrógeno en Aragón, Geoinženiring Druzba Za Geoloski Inzeniring DOO, Geological Survey of Denmark and Greenland, Geologische Bundesanstalt, Główny Instytut Górnictwa, Helmholtz Zentrum Potsdam – Deutsches GeoForschungsZentrum, Institut royal des Sciences naturelles de Belgique, Institutul National de Cercetare-Dezvoltare Pentru Geologie si Geoecologie Marina – 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 OBJECTIVES

Although storing pure hydrogen in salt caverns has been practised in Europe since the 1970s, no pure hydrogen storage in depleted fields or aquifers has been undertaken. Hystories will deliver technical developments applicable to a vast range of future aquifer or depleted field sites, conduct techno-economic feasibility studies and provide insights into underground hydrogen storage for decision-makers in government and industry. The project started on 1 January 2021 and is now 60 % complete.

PROGRESS AND MAIN ACHIEVEMENTS

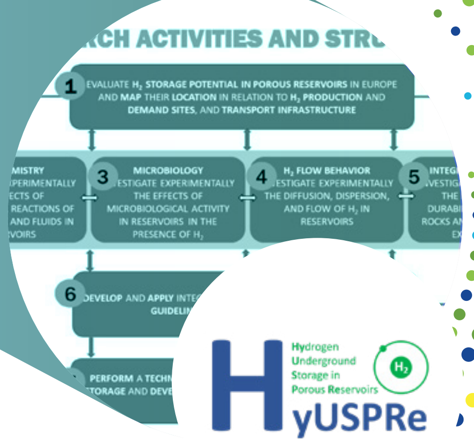
- The project has attained technological developments for pure hydrogen storage in depleted fields and aquifers.
- It has gained techno-economic insights into the development of underground storage of hydrogen.

FUTURE STEPS AND PLANS

- Hystories will proceed with the implementation of the work, which has been delayed; the focus is on completing this ambitious project on time.
- The main technical development analyses are complete: the key preliminary results have been obtained and the hydrogen storage needed by the European energy system has been identified. The remaining tasks related to the techno-economic assessments are ready to be carried out.
- The techno-economic analyses are complete; the focus is on elaboration of the final implementation plan.

QUANTITATIVE TARGETS AND STATUS

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)	✓
	Large-scale H_2 storage / release energy use	MWh/kg	9.3	1.7 (salt) 2.5 (porous)	
	Large-scale H_2 storage chain efficiency	%	72	95 (salt) 92.5 (porous)	



HYUSPRE

HYDROGEN UNDERGROUND STORAGE IN POROUS RESERVOIRS

Project ID:	101006632
PRD 2023:	Panel 2 – H2 storage and distribution
Call topic:	FCH-02-5-2020: Underground storage of renewable hydrogen in depleted gas fields and other geological stores
Project total costs:	EUR 3 714 850.00
Clean H_2 JU max. contribution:	EUR 2 499 850.00
Project period:	10.1.2021–31.12.2023
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 Foldgaztarolo Zartkoruen Mukodo Reszvenytarsasag, 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 OBJECTIVES

HyUSPRe studies 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. The project is addressing specific technical challenges regarding storage, and conducting an economic analysis to facilitate the decision-making process for the development of a portfolio of potential field pilots. The techno-economic assessment will allow for the development of a roadmap for widespread hydrogen storage towards 2050.

NON-QUANTITATIVE OBJECTIVES

- HyUSPRe aims to conduct a study assessing the potential matching of hydrogen supply and demand sites, including the necessity of hydrogen to buffer time-varying renewable energy demands.
- The project aims to conduct a study on the potential of European hydrogen underground storage to facilitate a zero-emission energy system by 2050.

PROGRESS AND MAIN ACHIEVEMENTS

HyUSPRe recently completed the first periodic reporting period, covering months 1–15; overall, the project is on track. Nearly all projected research activities were carried out, and related deliverables realised and published on the project website. Several activities and reports have been delayed – these are all related to the experimental work programme and show that laboratory experiments often do not proceed exactly as planned and need flexibility in execution. Part of the projected output and key exploitable results were able to be achieved by the end of the first reporting period.

FUTURE STEPS AND PLANS

It is expected that HyUSPRe will be executed in line with the project plan. The technical work is ongoing. For the laboratory experiments, agreements have been made with industrial partners, and rock and fluid samples and data have been collected from them. All but two deliverables planned in the first reporting period (months 1–15) were achieved. The consortium will continue to execute the research programme in the second period (months 16–27; ends in December 2023) and is optimistic that all activities, evaluations and reporting will be finalised within the originally agreed project timescales.

QUANTITATIVE TARGETS AND STATUS

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

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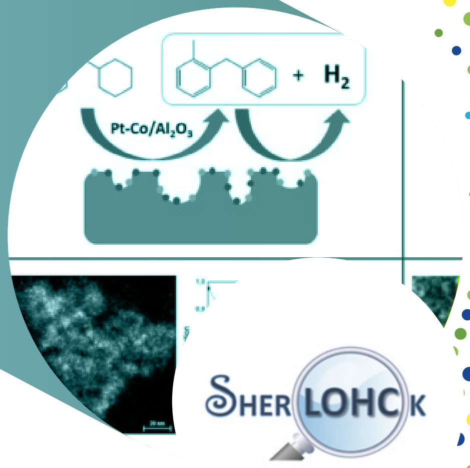

SHERLOHCK

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
PRD 2023:	Panel 2 – H2 storage and distribution
Call topic:	FCH-02-1-2020: Catalyst development for improved economic viability of LOHC technology
Project total costs:	EUR 2 563 322.50
Clean H_2 JU max. contribution:	EUR 2 563 322.50
Project period:	1.1.2021–31.12.2023
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 OBJECTIVES

Liquid organic hydrogen carriers (LOHCs) are attractive due 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, including the catalyst and the heat exchanger, to minimise the internal heat loss and to increase the space−time yield; and (iii) novel catalyst testing, system validation and demonstration in the demonstration unit (> 10 kW, > 200 hours).

PROGRESS AND MAIN ACHIEVEMENTS

Requirements in line with the objectives of the project have been defined for the hydrogenation and dehydrogenation catalysts; liquid organic hydrogen carrier type and quality; hydrogen quality; testing routine; and energy consumption. This initial work has enabled the foundations to be laid for the whole project. Benzyltoluene was chosen as the reference molecule, and Pt-based catalysts from Clariant were selected as catalysts' benchmark.

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

In parallel, to explore the advantages of structured heat exchanger reactors combined with improved catalysts, models and simulations were used to support the choice of possible reactor geometries, in particular to define suitable heat-conductive reactor structures. The results indicate that, for both reactions, foam structure, catalyst activity, mass and operating conditions are first-order parameters. Initial three-dimensional monolith structures have been prepared to integrate catalyst materials.

A communication and dissemination plan was developed at the beginning of the project. The communication activities carried out involve:

- the project website;
- diffusion of activities on LinkedIn (https://www.linkedin.com/in/sherlohck/?originalSubdomain=es) and Twitter, now known as X (https://twitter.com/SherlohckProj);
- participation in promotional events (conferences, workshops);
- distribution of newsletters and press releases.

The project has standardised the test protocol.

FUTURE STEPS AND PLANS

- SherLOHCk will integrate the catalyst into the thermal conductive support. The design of the first conductive support is ongoing.
- Long-term testing in continuous operation (> 200 hours) has not started yet.
- Testing of the resistance of catalysts to different poisons has not started yet.
- The modelling of the reaction kinetics for the design of new reactors has started for the dehydrogenation reaction.

QUANTITATIVE TARGETS AND STATUS

Target source	Parameter	Unit	Target	Achieved to date by the project	Targetachieved?	SoA result achieved to date (by others)	Year of SoA target
Project's own objectives	Catalyst productivity in dehydrogenation	g of H_2/g of catalyst/min	3	5.3	✓	0.85	2022
	Degree of conversion	%	90	74	⚙	~ 100	
	Catalyst selectivity	%	99.8	99.04	⚙	~ 100	

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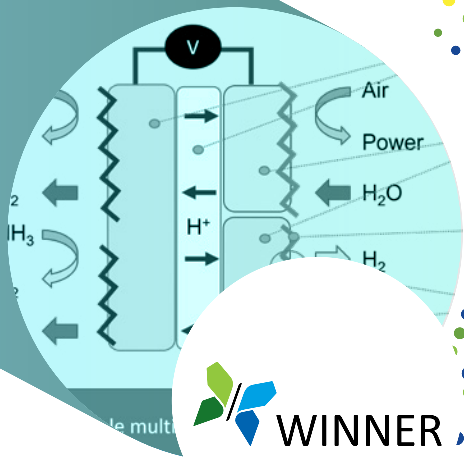

WINNER

WORLD-CLASS INNOVATIVE NOVEL NANOSCALE OPTIMISED ELECTRODES AND ELECTROLYTES FOR ELECTROCHEMICAL REACTION

Project ID:	101007165
PRD 2023:	Panel 2 – H2 storage and distribution
Call topic:	FCH-03-1-2020: HT proton conducting ceramic materials for highly efficient and flexible operation
Project total costs:	EUR 2 931 788.75
Clean H_2 JU max. contribution:	EUR 2 931 788.75
Project period:	1.1.2021–31.12.2023
Coordinator:	Sintef AS, Norway
Beneficiaries:	Agencia Estatal Consejo Superior de Investigaciones Cientificas, Alleima, CoorsTek Membrane Sciences AS, Danmarks Tekniske Universitet, Engie, Shell Global Solutions International BV, Universitetet i Oslo

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

PROJECT AND OBJECTIVES

WINNER is contributing to the shift towards a more sustainable energy future by developing an efficient and durable technology platform based on electrochemical proton-conducting ceramic cells designed to unlock a path towards commercially viable production, extraction, purification and compression of hydrogen, at small or medium scale, using three process chains:

- cracking of ammonia to produce pressurised hydrogen or power, where proton-conducting ceramic reactors (PCCRs) provide an innovative solution for 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 open new sustainable pathways for electrically driven processes in the chemical industry;
- reversible steam electrolysis, where PCCRs allow for a shift from 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.

NON-QUANTITATIVE OBJECTIVES

WINNER is developing a multiscale multiphysics modelling platform integrating all disciplines (atomistic, electrochemical, mechanical, fluid flow, reactor engineering, electric, heat) with the goal of establishing rate-determining steps at 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

State-of-the-art (SoA) cell development. The project has developed novel tubular cells based on the production line established using the software CTMS. The half-tubular cells consist of a Ni-BZCY72 electrode with a BZCY81 dense electrolyte. Various electrode materials and architectures have been screened for the multiple applications of the project. The following performance criteria were successfully met for the reversible electrolysis cells and ammonia-to-hydrogen cells: cell area-specific resistance of below 1 Ωcm^2 at 650 °C, faradaic efficiency of 80–90 % and a degradation rate below 1.2 % per 1 000 hours under reversible operation. For the conversion of ammonia to hydrogen, the NH_3 conversion is above 99 % with H_2 extraction of > 98 %. Current work on dehydrogenation application is focusing on materials/electrode research. Results will be presented in the next period.

A tubular cell was successfully operating in reversible operation for more than 4 000 hours at 4 bar at 650 °C. The cell shows high faradaic efficiency at the end of the testing period (above 80 %). Post-characterisation analysis is currently being performed.

Engineering model. The results of these research and development activities are reported in several public deliverables (31–34). The partners initially worked on establishing a communication platform (i.e. defining common nomenclature, parameters and models) to put in place a link between the different models and competences developed from the atomistic scale to the process scale. An engineering model has been defined for each of the WINNER applications; these models are available in Excel format and in converted Aspen files. The models are built based on the definition of the process flowsheet with necessary balance of plant, operating conditions, electrochemistry, kinetic and heat balance, etc. The tool is now functioning with multiple integrated models (e.g. integrated atomistic + kinetics + electrochemistry models at the cell level; CFD + engineering tool + Aspen models at the cell, reactor and process levels; mechanical model to be integrated with CFD). The outputs of this tool include the energy demand per balance of plant and for the overall process for the selected input parameters (temperature, selectivity, conversion efficiency, cell voltage, faradaic efficiency, etc.).

Life cycle assessment. Life cycle assessment evaluation of the three applications is currently in progress, with user cases and benchmark cases defined for all applications.

FUTURE STEPS AND PLANS

WINNER is currently preparing for the multitube module demonstration, which will focus on reversible electrolysis operating at 600 °C with pressure ranging from 4 bar to 20 bar. Twelve cells will be tested in parallel. The production for this cell has started, as have all activities around the test unit (plant and analytic coupling, hazard and operability analysis, definition of operational protocols, commissioning).

QUANTITATIVE TARGETS AND STATUS

Target source	Parameter	Unit	Target	Achieved to date by the project	Target achieved?	SoA result achieved to date (by others)	Year of SoA target
Project's own objectives and MAWP addendum (2018–2020)	Levelised cost of the produced hydrogen	€/kg	5	N/A	⚙	> 6 based on GAMER technology with several scaling-up assumptions	2022
Project's own objectives	ASR of the cell	Ωcm^2 at 650 °C	< 1	< 1	✓	2.5	
	Round-trip efficiency of reversible steam electrolysis	% at 650 °C	> 75	N/A	⚙	N/A	2019
	Faradaic efficiency	%	> 95	> 90	⚙	> 90	2021
	Durability test	hours	3 000	> 4 000	✓	< 1 000	

Clean Hydrogen Partnership
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