ADVANCEPEM

ADVANCED HIGH PRESSURE AND COST-EFFECTIVE PEM WATER ELECTROLYSIS TECHNOLOGY

Project ID	101101318
PRR 2026	Pillar 1 - H_2 Production
Call Topic	HORIZON-JTI-CLEANH$_2$-2022-01-03
Project Total Costs	1 631 066.56
Clean H_2 JU Max. Contribution	1 607 330.00
Project Period	01-02-2023 - 31-01-2027
Coordinator Beneficiary	CONSIGLIO NAZIONALE DELLE RICERCHE, IT
Beneficiaries	SYENSQO SPECIALTY POLYMERS ITALY S.P.A., RWE GENERATION SE, IRD FUEL CELLS A/S, HSSMI TRADING LIMITED, RHODIA OPERATIONS, SYENSQO LABORATOIRE DU FUTUR SAS, SPECIALTY OPERATIONS FRANCE, HSSMI Consulting Ltd, OORT ENERGY LTD, RWE POWER AKTIENGESELLSCHAFT

https://advancepem.eu/

PROJECT AND GENERAL OBJECTIVES

Direct production of highly pressurised hydrogen via electrolytic water splitting can save significant energy compared with downstream gas compression. ADVANCEPEM aims to develop a set of breakthrough solutions at materials, stack, and system levels to increase hydrogen pressure and current density while maintaining nominal energy consumption < 50 kWh/kg H_2. Reinforced Aquivion® polymer membranes with enhanced conductivity, a high glass transition temperature, increased crystallinity, and the ability to withstand high differential pressure have been developed for this application. To mitigate hydrogen permeation to the anode and related safety issues, efficient recombination catalysts are integrated in both the membrane and the anode structure. The new technology has been validated by demonstrating a 50-kW nominal-capacity high-pressure electrolyser in an industrial environment. The consortium comprises an electrolyser manufacturer, a membrane and catalyst supplier, a membrane electrode assembly developer, and an end-user for system demonstration.

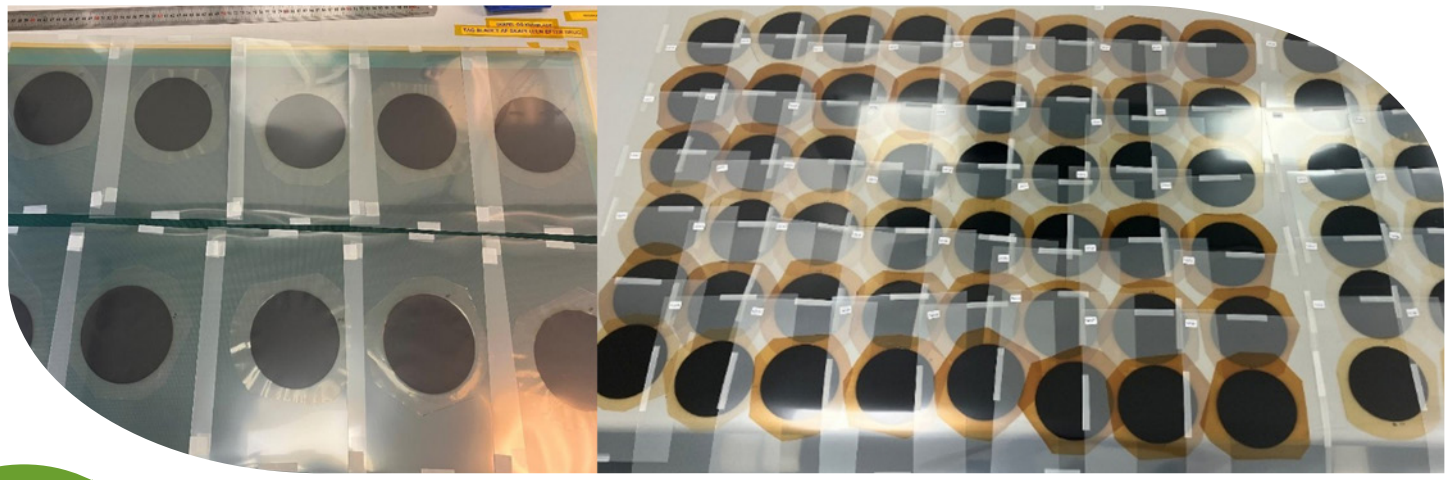
NON-QUANTITATIVE OBJECTIVES

- Develop a novel polymer electrolyte membrane (PEM) electrolyser able to produce hydrogen at very high pressure, thus reducing the post-compression energy consumption.
- Develop a cost-effective technology allowing for the large-scale application of PEM electrolysers.
- Achieve a significant reduction of capital costs by minimising the use of critical raw materials, developing cheap coated bipolar plates and operating the electrolyser at a high production rate while assuring high efficiency and safe operation.

PROGRESS, MAIN ACHIEVEMENTS AND RESULTS

The project is progressing well towards its planned objectives. Functional components have been developed, and stack development activities are advancing as planned. The design phase for PEM electrolyser validation has started, with key technical, health, safety, environmental standards, operational parameters, and boundary conditions defined for the installation, commissioning, and testing of the newly developed technology.

The project website and visual identity were established during the first project period, and dissemination activities began with the publication of a paper in an international open-access journal. The Data Management Plan and the Communication, Dissemination, and Exploitation Plan have also been completed and delivered.



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Initial technical results include:

- Development of thin (90 µm) Aquivion membranes containing radical scavengers, achieving conductivities of approximately 200 mS cm^{-1}.
- Achievement of cumulative IR-free O_2 and H_2 evolution overpotentials of 120 mV versus the thermoneutral potential at 5 A cm^{-2}, using an IrRu-oxide solid-solution anode and Pt/C cathode catalyst with a PGM loading of 1.2 mg cm^{-2}.
- Achievement of a performance of 5 A cm^{-2} at 1.83 V/cell and 90 °C, with a total PGM loading per MEA of 1.2 mg cm^{-2}, combining Aquivion membrane/ionomer technology with advanced PGM catalysts.

FUTURE STEPS AND PLANS

Future activities will follow the project implementation plan, with a particular focus on stack assembly using the newly developed reinforced membranes, as well as on system assessment and testing.

Specific efforts will include:

- Further development of the Life Cycle Assessment (LCA) process.
- Continued optimisation and scale-up of the most promising reinforced membrane selected during the first project phase, with emphasis on large-scale manufacturing.
- Scaling up production of OER, HER, and recombination catalysts for MEA manufacturing.
- Production of large-area MEAs for stack integration.
- Continued procurement of components according to the established schedule.
- Kick-off of construction site activities.
- Delivery of the ADVANCEPEM demonstrator.
- Launch of the operational trial phase.
- Continuation of dissemination and communication activities.

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	Low Electrode Overpotentials	mV vs. Etn @ 5 A cm^{-2}	200	120	✓	N/A	N/A
	Cell performance	V@ 5 A cm^{-2}	1.85	1.83		2.2	2020
	Degradation	%/1000h	0.25	0.1		0.19	2020
	Nominal Current Density	A/cm^2	5	5		2.2	2020
	Cell/Stack operating temperature	°C	90	90		90	2021
	Membrane conductivity	mS cm^{-1}	200	> 200		200	2024

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AEMELIA

ANIONIC EXCHANGE MEMBRANE WATER ELECTROLYSIS FOR HIGHLY EFFICIENTCY SUSTAINABLE, AND CLEAN HYDROGEN PRODUCTION

Project ID	101137912
PRR 2026	Pillar 1 - H_2 Production
Call Topic	HORIZON-JTI-CLEANH$_2$-2023-01-01
Project Total Costs	2 764 927.00
Clean H_2 JU Max. Contribution	2 764 926.75
Project Period	01-01-2024 - 28-02-2027
Coordinator Beneficiary	COMMISSARIAT À L'ÉNERGIE ATOMIQUE ET AUX ÉNERGIES ALTERNATIVES, FR
Beneficiaries	CONSIGLIO NAZIONALE DELLE RICERCHE, SINTEF AS, SYENSQO SPECIALTY POLYMERS ITALY S.P.A., IMPERIAL COLLEGE OF SCIENCE TECHNOLOGY AND MEDICINE, SPECIALTY OPERATIONS FRANCE, SYENSQO LABORATOIRE DU FUTUR SAS, FUNDACION TECNALIA RESEARCH and INNOVATION, MATGENIX, CLAIND SRL, CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE CNRS

https://aemelia.eu/

PROJECT AND GENERAL OBJECTIVES

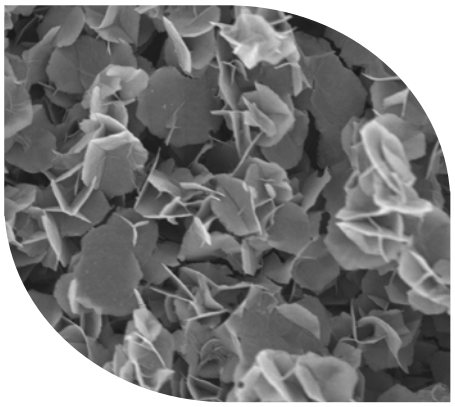
AEMELIA accepts the challenge of designing and prototyping an anion-exchange membrane electrolysis (AEMEL) method that meets and exceeds Hydrogen Europe's 2030 targets for performance, durability, safety, and cost. For example, AEMELIA targets:

- A current density of 1.5 A cm-2 at low voltage (1.72 V).
- An energy efficiency of 46.2 kWh/kg, or 86% of the maximum theoretical efficiency, to increase H_2 production while reducing energy consumption, compared with CLAIND's actual product (1.76 V (47.1 kWh/kg) at 0.5 A/cm^2 in 0.2 M KOH at 42°C and 10 bar).
- A levelised cost of hydrogen of 2.5 €/kg H_2 (17% lower than the 2030 target).
- A degradation rate enabling a 10-year lifetime.
- Capital expenditure is expected to reach the 2030 targets through upscaling.

NON-QUANTITATIVE OBJECTIVES

AEMELIA intends to introduce new technology for anion-exchange membrane WE based on the following:

- An innovative route for electrode preparation without an ionomer.
- Implementation of a recombination catalyst and electrodes without any platinum-group metals in the stack.
- Increased cell efficiency through the use of pulsed supply current, due to short time periods for oxygen bubble release.
- Design of an optimal membrane backbone and side chain to sustain high hydroxide conductivity, despite high operating temperature (t > 60°C), through a machine-learning approach.
- Machine-learning investigation of low-environmental-impact solvent use to dissolve polymer for preparing ionomer dispersion solution.



PROGRESS, MAIN ACHIEVEMENTS AND RESULTS

- Development of a data-driven methodology to support membrane optimisation using deep learning.
- Analysis of SYSENQO's Beion membrane showing high hydroxide conductivity (236 mS/cm at 50 °C), but its use is limited due to fluorination.
- Investigation of Ni2P as the first non-PGM recombination catalyst, targeting promising activity for oxygen reduction reaction (ORR) and hydrogen evolution reaction (HER).
- Development of ionomer-free electrodes, using NiMo and NiFeB coatings with thermal treatments showing enhanced activity.
- Investigation of NiMoS catalysts for HER, targeting overpotential reduction.
- Preliminary cell testing highlights temperature-dependent performance differences among membranes, with Fumatech and Piperion excelling under different conditions.
- Optimised stack design through computational fluid dynamics.
- Development of an environmental assessment method.

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FUTURE STEPS AND PLANS

Ionomer-free electrodes:

- Adhesion improvement of physical vapour deposition (PVD) based anode.
- Testing of PVD-based cathode and electrodeposited anode at the single cell level.
- Testing of electrode prepared with chemically activated porous transport layer (PTL) fibers at single cell level.
- Establishing cell performance and ageing tests.

Classical route of electrodes preparation, avoiding fluorinated ionomer, such as Nafion:

- Testing of molybdenum sulfide-based cathode catalyst with an alternative to Nafion.
- Thermal treatment of NiFeO allows electron conductivity enhancement of the OER catalyst.

The development of polymers should enable the down-selection of a fluorine-free polymer capable of sustaining high hydroxide conductivity at 80°C. This polymer should be soluble in an eco-friendly solvent. To find out this compound, the machine learning already in use needs to be fed with more data, which may come from the literature.

In addition to the stack design and the importance of the manifold position, the influence of the flow design will be investigated. A final design for the full stack will be finalised to start manufacturing.

PROJECT TARGETS

Target source	Parameter	Unit	Target	Target achieved?
Project's own objectives	Safe and sustainable: Fluorine-free ionomers and membranes prepared with green and safe solvents via a cost-effective process	-	No fluorine polymer and a safe solvent for the ionomer dissolution	
	TEA shows low-cost hydrogen towards	€/kg	3	
	To ensure market entry by 2031 and ~750MW capacity by 2036 (Number of companies willing to test AEMELIA development)	Number	6	

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CARMA-H_2

CARBON-NEGATIVE PRESSURIZED HYDROGEN PRODUCTION FROM WASTE USING AN ENERGY EFFICIENT PROTONIC MEMBRANE REFORMERCARMA-H_2

Project ID	101137756
PRR 2026	Pillar 1 - H_2 Production
Call Topic	HORIZON-JTI-CLEANH$_2$-2023-01-05
Project Total Costs	12 818 293.75
Clean H_2 JU Max. Contribution	9 954 418.76
Project Period	01-10-2024 - 30-09-2028
Coordinator Beneficiary	ASOCIACIÓN DE LA INDUSTRIA NAVARRA, ES
Beneficiaries	HAFFMANS BV, SERVICIOS DE LA COMARCA DE PAMPLONA SA, HERA HOLDING HABITAT, ECOLOGÍA Y RESTAURACIÓN AMBIENTAL S.L., SINTEF AS, COORSTEK MEMBRANE SCIENCES AS, SHELL GLOBAL SOLUTIONS INTERNATIONAL BV, AGENCIA ESTATAL CONSEJO SUPERIOR DE INVESTIGACIONES CIENTÍFICAS, NAVARRA DE INFRAESTRUCTURAS LOCALES SOCIEDAD ANÓNIMA (NILSA), SNAM SPA, FONDAZIONE ICONS, UNION ENGINEERING AS

https://carma-h2.eu/

PROJECT AND GENERAL OBJECTIVES

CARMA-H_2 aims to develop and demonstrate an innovative modular reactor at the Arazuri wastewater treatment plant in Navarra, Spain. The project integrates multiple technologies to convert biogas from organic waste into pressurised hydrogen (500 kg/day) and CO_2 (over 4 000 kg/day) with high energy efficiency.

At the core of CARMA-H_2 is the Protonic Membrane Reformer (bioPMR), a breakthrough technology that enables direct separation of high-purity hydrogen and capture-ready CO_2 in a single, continuous step. The bioPMR will be deployed alongside three key sub-systems: a biogas pre-treatment unit, a CO_2 liquefaction system, and the existing waste-to-biogas plant at Arazuri. This fully integrated setup ensures a streamlined, highly efficient production process.

To optimise performance and scalability, CARMA-H_2 will develop a digital twin that leverages advanced computational models and control systems to enhance real-time monitoring and process efficiency.

A life cycle assessment will evaluate the project's environmental impact, considering waste streams, biogas sources, and energy inputs. Additionally, CARMA-H_2 will assess critical raw material (CRM) usage to ensure compliance with sustainability and regulatory standards. By combining cutting-edge hydrogen production, circular economy principles, and digital innovation, CARMA-H_2 paves the way for decentralised, cost-effective hydrogen generation, supporting Europe's clean energy transition.

NON-QUANTITATIVE OBJECTIVES

CARMA-H_2 is more than a technological project; it is a step towards a sustainable hydrogen ecosystem through:

- Fostering strong collaboration with industry stakeholders and regulatory bodies across the biogas, hydrogen, and CO_2 sectors to ensure alignment with market needs and evolving policies.
- Creating synergies with European research initiatives, particularly EURAMET's EMPIR programme and the European Partnership on Metrology, to enhance hydrogen quality assurance.
- Implementing Guarantees of Origin (GOs) in Spain to certify the renewable nature of its hydrogen and reinforce its credibility.
- Engaging directly with end-users across mobility, industry, and energy.
- Exploring real-world hydrogen applications, ranging from urban transport and logistics to metallurgy and power generation.
- Strengthening a circular approach by minimising emissions and maximising resource efficiency through CO_2 utilisation in the agri-food and beverage sectors.

PROGRESS, MAIN ACHIEVEMENTS AND RESULTS

- Start of design and construction of auxiliary facilities at the Arazuri wastewater treatment plant in Navarra, setting the stage for the installation of the innovative bioPMR.
- Analysis of renewable electricity use to optimise energy costs and ensure a sustainable power supply for the demonstration phase.
- Ongoing efforts to enhance manufacturing capacity, with new equipment being installed at CTMS's pilot fabrication line to support the production of bioPMR components.
- Launch of CARMA-H_2's communication strategy, focusing on engaging multiple audiences through the website and social media.

FUTURE STEPS AND PLANS

- Optimising each stage of the process to maximise efficiency and performance.
- Conducting a comprehensive safety assessment of all subsystems, ensuring that every component meets the highest standards before full-scale implementation.
- Enhancing the waste-to-biogas conversion process to achieve higher efficiency and an

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- ideal composition for seamless integration with the bioPMR unit.
- Improving the hydrogen production system by recycling gaseous streams, thereby increasing yield while enhancing the value of the CO_2 captured through an upgraded liquefaction unit.
- Conducting technical evaluations, including testing the catalytic performance of the Protonic Membrane Reformer under real biogas conditions and verifying the reliability of individual engineering units before full-scale deployment. These steps are crucial to ensuring the robustness and long-term viability of CARMA-H_2's innovative technology.

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	System energy use	kWh/kg	59		64	2020
	System CAPEX	€/(kg/d)	900/2 000		1 250	2020
	System OPEX	€/kg	1.3		1.35	2020

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DELYCIOUS

DELYCIOUS: DIAGNOSTIC TOOLS FOR ELECTROLYSERS: COST-EFFICIENT, INNOVATIVE, OPEN, UNIVERSAL AND SAFE

Project ID	101192075
PRR 2026	Pillar 1 - H_2 Production
Call Topic	HORIZON-JTI-CLEANH$_2$-2024-01-04
Project Total Costs	4 189 735.18
Clean H_2 JU Max. Contribution	3 995 403.18
Project Period	01-01-2025 - 31-12-2027
Coordinator Beneficiary	FRAUNHOFER GESELLSCHAFT ZUR FÖRDERUNG DER ANGEWANDTEN FORSCHUNG E. V., DE
Beneficiaries	HORIBA FRANCE SAS, ETA - ENERGIA, TRASPORTI, AGRICOLTURA SRL, UNIVERSITEIT TWENTE, AIR LIQUIDE FORSCHUNG UND ENTWICKLUNG GMBH, OU STARGATE HYDROGEN SOLUTIONS, SIVONIC GMBH, DUMAREY SOFTRONIX SRL

https://www.delycious-project.eu/

PROJECT AND GENERAL OBJECTIVES

The overarching objective of the DELYCIOUS project is to enhance electrolysis technologies for industrial-scale renewable hydrogen production. To achieve this goal, we develop universal diagnostic tools for the commercial electrolyser technologies AEL, PEMEL, and SOEL. The diagnostic tools consist of hardware sensors, most notably electrochemical impedance spectroscopy (EIS) and Raman spectroscopy, together with physical model-based and data-driven algorithms. All hardware sensors and algorithms undergo rigorous laboratory-scale validation across all three electrolyser technologies. In addition, an electrolyser management system (EMS) is to be demonstrated in a large-scale AEL application (> 100 kW), combining sensor data and algorithms to meet key performance indicators (KPIs). The KPIs are for fault prediction, reliability, safety, lifetime extension and cost reduction.

NON-QUANTITATIVE OBJECTIVES

- Development of a flexible test platform that provides a laboratory-scale environment adaptable to multiple electrolysis technologies.
- Use of advanced hardware sensors (EIS and Raman spectroscopy) to monitor and detect degradation mechanisms in electrolysis systems.
- Development of advanced algorithms to enable a comprehensive understanding of degradation processes.
- Integration of sensors and algorithms into an open-access Electrolyser Management System (EMS) for deployment to end users.
- Validation of EMS functionality to demonstrate robustness and scalability in a large-scale AEL system (>100 kW).
- Definition of a commercialisation roadmap outlining the exploitation of DELYCIOUS results and supporting large-scale deployment by 2030.

PROGRESS, MAIN ACHIEVEMENTS AND RESULTS

- Successful availability and approval of the EIS and Raman devices for lab-scale electrolyser implementation.
- Completion of 13 project deliverables during the reporting period.
- The first lab-scale single-cell test campaign at Stargate Hydrogen (AEL) was successfully executed, demonstrating the integration and operation of EIS and Raman diagnostics.
- Selected results have been made publicly available via the project website, supporting dissemination to the wider community.



PRR 2026 PILLAR
H_2 Production

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- Significant progress in software and Electrolyser Management System (EMS) development, including system architecture, interfaces, and algorithm/HMI requirements.
- Ongoing development of physics-based models in collaboration between AL IFC and UT, with strong progress.
- Experimental data from the AEL test campaign are currently being post-processed for model parameterisation and further validation.

FUTURE STEPS AND PLANS

The next lab-scale test campaign will be conducted at UT for SOEL, followed by a campaign at AL ICF for PEMEL. In parallel, the advanced algorithms and the Electrolyser Management System (EMS) continue to be developed and refined.

By mid-2026, several key project outcomes are expected, including the development of a physical cell model and a database, the development of the condition monitoring scheme, and initial software testing. A key milestone in August 2026 will mark the successful completion of lab-scale hardware integration and the end of the lab-scale test campaigns.

The second year of DELYCIOUS will conclude with additional important developments, such as the scale-up of the EIS system from SIVONIC and the validation of the physical model at cell level by UT. Overall, the consortium is working in close collaboration and actively preparing for the next project phase, including the large-scale demonstration planned for 2027.

PROJECT TARGETS

Target source	Parameter	Unit	Target	Target achieved?
Project's own objectives	Degradation alkaline electrolysis (AEL)	% / 1 000h	0.1	
	Degradation of proton exchange membrane electrolysis (PEMEL)	% / 1 000h	0.12	
	Degradation of solid oxide electrolysis (SOEL)	% / 1 000h	0.5	
	Reliability for flexible electrolyser operation	%	> 90	
	Hydrogen detection	%	< 2	
	Fault detection and isolation (FDI)	%	> 95	
	Cost of monitoring system AEL	€/kW	12	
	Cost of monitoring system PEMEL	€/kW	15	
	Cost of monitoring system SOEL	€/kW	15.6	

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DJEWELS

DELFZIJL JOINT DEVELOPMENT OF GREEN WATER ELECTROLYSIS AT LARGE SCALE

Project ID	826089
PRR 2026	Pillar 1 - H_2 Production
Call Topic	FCH-02-1-2018
Project Total Costs	41 967 250.00
Clean H_2 JU Max. Contribution	10 999 999.00
Project Period	01-01-2020 - 30-06-2026
Coordinator Beneficiary	HYCC B.V., NL
Beneficiaries	NV NEDERLANDSE GASUNIE, MCPHY ENERGY ITALIA SOCIETA A RESPONSABILITA LIMITATA, MCPHY ENERGY, BIOMETHANOL CHEMIE NEDERLAND B.V., NOBIAN INDUSTRIAL CHEMICALS BV, INDUSTRIE DE NORA SPA-IDN, MCPHY ENERGY DEUTSCHLAND GMBH, HINICIO

http://www.djewels.eu

PROJECT AND GENERAL OBJECTIVES

Djewels demonstrates the operational readiness of a 20 MW electrolyser to produce green hydrogen and fuels under real-life industrial and commercial conditions. It will advance the technology from TRL 7 to TRL 8 and lay the foundation for the next scale-up step, 100 MW, on the same site. Djewels will enable the development of the next generation of pressurised alkaline electrolysers by developing more cost-efficient, higher-performance, high-current-density electrodes, and is preparing for the serial manufacturing of the stack and the scale-up of the balance of plant components.

NON-QUANTITATIVE OBJECTIVES

Project development phase:

Perform the engineering activities for setting up the water electrolysis system.

- Ensure safety performance: (i) completed design; (ii) completed hazard and operability analysis.
- Establish a business case for hydrogen for producing green hydrogen and develop a business plan for large-scale upscaling towards 2030.

Operations:

- Evaluate technical and business model performance regarding predictions through monitoring of system operation.
- Define the optimal operation conditions of the new high-density electrode package.
- Demonstrate the reduced footprint of high-pressure alkaline electrolysis versus low-pressure systems.
- Demonstrate the feasibility of high-pressure alkaline electrolysis to undertake primary grid balancing services.
- Formulate and disseminate project results.

PROGRESS, MAIN ACHIEVEMENTS AND RESULTS

Technical:

- Finalisation of Djewels basic engineering.
- Technology demonstration of 1 MW stack completed.
- Testing of advanced high current density electrodes on 1 MW stack completed.

Permits:

- Irrevocable environmental permit issued.
- Irrevocable water permit issued.

Financing:

- Wadden fonds subsidy for project development stage approved.
- Tailormade subsidy of 80 M Euros approved by the Dutch state.

Project management:

- Project execution and engineering plan for execution activities has been completed.

FUTURE STEPS AND PLANS

- Finalisation of project contractual agreements in the entire supply chain.
- Subsequent move to project execution.
- Start of operations; Q4 2027.

PROJECT TARGETS

Target source	Parameter	Unit	Target	Target achieved?
Project's own objectives	System nominal capacity	MW	20	
	Efficiency degradation @ rated power and considering 8 000 hours of operations/year	% increase in energy consumption every year	1.5	
	Energy consumption	kWh/kg	< 52.8	
	CAPEX @ rated power, including ancillary equipment and commissioning	M/(t/d)	5.5	
	Flexibility with a degradation <2% year	% of nominal power	3-110	
	Hot start from min to max power	%/secs	20 (ramp up) 100 (ramp down)	

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ENDURE

ALKALINE ELECTROLYSERS WITH ENHANCED DURABILITY

Project ID	101137925
PRR 2026	Pillar 1 - H_2 Production
Call Topic	HORIZON-JTI-CLEANH$_2$-2023-01-03
Project Total Costs	2 492 868.75
Clean H_2 JU Max. Contribution	2 492 868.75
Project Period	01-01-2024 - 31-12-2026
Coordinator Beneficiary	OU STARGATE HYDROGEN SOLUTIONS, EE
Beneficiaries	ZENTRUM FÜR SONNENENERGIE- UND WASSERSTOFF-FORSCHUNG BADEN-WURTTEMBERG, FUNDACIÓN PARA EL DESARROLLO DE LAS NUEVAS TECNOLOGÍAS DEL HIDRÓGENO EN ARAGÓN, UNIVERSITÉ CATHOLIQUE DE LOUVAIN, PERMASCAND AB, FRAUNHOFER GESELLSCHAFT ZUR FÖRDERUNG DER ANGEWANDTEN FÖRSCHUNG EV

https://endureh2.com/

PROJECT AND GENERAL OBJECTIVES

The main objective of ENDURE is to bring the performance and durability of alkaline electrolysers to a new level. More specifically, to drastically decrease the degradation rate and increase the efficiency of alkaline cells and stacks through the development of hierarchically structured flow-engineered monolithic porous transport electrodes, via design/material improvements on the stack level, and accelerated testing procedures. If the electrolyser degradation rate could be reduced, it would result in two-fold benefits:

- Lower operating expenditures through lower energy consumption over the electrolysers' lifetime.
- Lower capital expenditures through a lower level of oversizing of the balance-of-plant components needed.

Both would positively affect the levelised cost of hydrogen (LCOH).

NON-QUANTITATIVE OBJECTIVES

ENDURE aims to make alkaline electrolysers more durable by drastically reducing the degradation rate of alkaline electrolysis cells and stacks, to:

- Reduce carbon emissions and mitigate climate change by enabling the widespread adoption of hydrogen as a clean and sustainable fuel source.
- Reduce the cost of hydrogen production, making it a more competitive fuel source and driving the growth of the renewable energy sector.
- Contribute to the development of a more sustainable and resilient energy system that can balance intermittent renewable energy sources with the need for a stable and continuous energy supply.

PROGRESS, MAIN ACHIEVEMENTS AND RESULTS

Harmonised test protocols for cell- and stack-level testing were developed and shared with the European Commission's Joint Research Centre (JRC).

- A baseline 7-cell stack (≥1 000 cm² electrode area) was assembled and tested for ≥500 hours, providing reference performance data.
- Development of a new generation of porous transport electrodes, showing strong performance, particularly for pure Ni-based electrodes.
- Development and 100-hour testing of PGM-free HER and OER catalysts under industrial conditions, demonstrating high activity and durability.
- Cell- and stack-level simulation models were developed, providing insights into flow dis



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- tribution and identifying design limitations and efficiency improvements.
- Extensive testing of various gasket materials to ensure suitability for industrial applications.

FUTURE STEPS AND PLANS

- Scaling up the novel electrodes to ≥1 000 cm² while maintaining electrochemical performance.
- Assembling the ENDURE prototype stack, including novel electrodes and design improvements.
- Testing the ENDURE prototype stack, targeting a degradation rate of 0.1%/1 000 h over at least 500 hours of operation.
- Developing a Life Cycle Assessment (LCA) and a business case for the prototype stack.

PROJECT TARGETS

Target source	Parameter	Unit	Target	Target achieved?
Project's own objectives	Baseline degradation profile of a 10-kW electrolysis stack using pre-commercial electrodes at high current density	Number of cells cm^2 hours A/cm^2	≥ 5 cells with an electrode footprint of ≥1 000 cm^2 tested for ≥500 hours at a current density of 1 A/cm^2	⚙
	Developing high-performance and PGM-free catalyst coating for the HER and OER	mV A/cm^2 hours	HER < 150 mV OER < 250 mV at ±1 A/cm^2 after 100 hours of electrode testing	✓
	Hierarchically structured flow-engineered monolithic porous transport electrodes (PTE) with optimised bubble removal capacity	kWh/kg A/cm^2 V/cell temperature (°C) hours	47 kWh/kg at 1 A/cm^2 and 80°C for 100 hours ≥1.25 A/cm^2 at ≤1.95V/cell	
	Upscaling of porous transport electrodes (PTE)	cm^2	≥1 000 while maintaining electrochemical performance	⚙
	Low-cost high-performance 10-kW stack prototype	€/kW cm^2	150 €/kW for a prototype stack of ≥5 cells with ≥1 000 cm^2 electrode footprint	
	Testing and validation of innovative stack components	kWh/kg A/cm^2 number of cells	48 kWh/kg at 1 A/cm^2 for a laboratory stack of ≥10 cells with ≥100 cm^2 electrode footprint	

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ENDURION

EFFICIENT AND DURABLE PRESSURISED ANION EXCHANGE MEMBRANE ELECTROLYSER WITH NOVEL TRIPLE-BOUNDARY AND STACK DESIGNS

Project ID	101192485
PRR 2026	Pillar 1 - H_2 Production
Call Topic	HORIZON-JTI-CLEANH$_2$-2024-01-02
Project Total Costs	5 637 583.82
Clean H_2 JU Max. Contribution	3 977 952.94
Project Period	01-05-2025 - 31-10-2028
Coordinator Beneficiary	AIT AUSTRIAN INSTITUTE OF TECHNOLOGY GMBH, AT
Beneficiaries	DE NORA ITALY HYDROGEN TECHNOLOGIES SRL, ACONDICIONAMIENTO TARRASENSE ASOCIACIÓN, SCUOLA UNIVERSITARIA PROFESSIONALE DELLA SVIZZERA ITALIANA, ECOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE, CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE CNRS, UASABI INOVEYSHANS SLLC, INDUSTRIE DE NORA SPA-IDN, UNIVERSITÉ DE PAU ET DES PAYS DE L'ADOUR, POLITECNICO DI TORINO, ARKEMA FRANCE SA, INSTRUMENTACIÓN Y COMPONENTES SA, IOLITEC IONIC LIQUIDS TECHNOLOGIES GMBH

https://www.endurion.eu/

PROJECT AND GENERAL OBJECTIVES

ENDURION aims to develop an efficient, durable, and cost-effective pressurised anion exchange membrane electrolyser (AEMEL) through a cross-cutting strategy that combines an innovative three-phase boundary, a unique cell-stack design, earth-abundant CRM-free materials, and scalable manufacturing processes.

KEY OBJECTIVES:

- Develop a novel pressurised AEM electrolyser (AEMEL).
- Fabricate an innovative three-phase boundary to improve cell performance.
- Design a unique cell-stack architecture for pressurised operation.
- Use exclusively earth-abundant, critical raw material (CRM)-free materials.
- Apply scalable processing and manufacturing methods.
- Achieve energy consumption below 50 kWh/kg H_2.
- Achieve a degradation rate below 0.7% per 1 000 hours.
- Reach a capital cost of €450/kWe.

NON-QUANTITATIVE OBJECTIVES

- Demonstrate the use of machine learning for materials design, property–performance analysis, and optimisation in AEMEL development.
- Combine materials simulation with experimental datasets from OER and HER electrocatalyst compositional libraries to accelerate material discovery and validation.
- Develop data-driven approaches to support the design of high-performance AEMEL components.
- Harmonise pressurised AEMEL testing protocols in coordination with the European Commission's Joint Research Centre (JRC).



PROGRESS, MAIN ACHIEVEMENTS AND RESULTS

- Developed key components for a pressurised AEM electrolyser (AEMEL), supported by materials modelling and simulation.
- Developed low-overpotential, earth-abundant catalysts for the hydrogen evolution reaction (HER) and oxygen evolution reaction (OER).
- Developed a bio-based membrane for sustainable AEMEL operation.
- Designed a novel membrane-electrode assembly (MEA) incorporating ionic liquids to enhance electrolyser durability.

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- Developed a new bipolar plate design suitable for a future 50 kW stack.
- Combined experimental development with simulation-driven optimisation to accelerate component design and performance improvement.

FUTURE STEPS AND PLANS

- Develop exploitation and business plans to support the commercial implementation of ENDURION in climate-neutral data centre applications and IT energy infrastructure.
- Assess market opportunities, value chains, and deployment pathways for the ENDURION technology.
- Establish a roadmap for commercialisation and industrial adoption within five years after project completion.
- Support the transition of ENDURION from project outcomes to market-ready solutions through targeted exploitation activities.

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	Electrode area	cm^2	≥ 500	5		up to 100	2023
	Operating temperature	°C	up to 90	60		60	2023
	Stack unit size	kW	≥ 50			2	2021, 2023
	Cell pressure	bar	≥ 50	1		8	2023
	Operating voltage	Volt	1.7 - 1.8	1.86		1.85	2023
	Efficiency	kWh/kg H_2	≥ 50	-		57	2023
	Current density	A/cm^2	1.0 - 1.2	1		1	2023
	Alkaline concentration	mol/L	≥ 1	1		0.2	2023
	Degradation	%/1 000 h	> 0.7	-		0.5 (after 260 hours)	2023
	Use of CRM	mg/W	0	-			2023

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EPHYRA

ESTABLISHING EUROPEAN PRODUCTION OF HYDROGEN FROM RENEWABLE ENERGY AND INTEGRATION INTO AN INDUSTRIAL ENVIRONMENT

Project ID	101112220
PRR 2026	Pillar 1 - H_2 Production
Call Topic	HORIZON-JTI-CLEANH$_2$-2022-01-08
Project Total Costs	24 658 777.00
Clean H_2 JU Max. Contribution	17 757 002.50
Project Period	01-06-2023 - 31-05-2028
Coordinator Beneficiary	MOTOR OIL (HELLAS) DIILISTIRIA KORINTHOU A.E., EL
Beneficiaries	ENVIROMETRICS TECHNIKOI SYMVOULOI ANONYMI ETAIREIA, STICHTING NEW ENERGY COALITION, ORCAN ENERGY AG, SOLUFORCE B.V., ENERTIME SA, ETHNIKO KENTRO EREVNAS KAI TECHNOLOGIKIS ANAPTYXIS, DEUTSCHES ZENTRUM FUR LUFT - UND RAUMFAHRT EV, RINA CONSULTING S.P.A., SIEMENS PROCESS SYSTEMS ENGINEERING LIMITED, ETA - ENERGIA, TRASPORTI, AGRICOLTURA SRL, ETHNICON METSOVION POLYTECHNION, INSTITUTO TECNOLOGICO DE ARAGON

https://ephyraproject.eu/

PROJECT AND GENERAL OBJECTIVES

EPHYRA will demonstrate the integration of a first-of-its-kind renewable hydrogen production facility at an industrial scale in South-eastern Europe, employing improved electrolysis technology with a capacity of 30 MW. The large-scale electrolysis will be integrated into industrial operations at Motor Oil Hellas's Corinth Refinery, one of Europe's top refineries and the largest privately owned industrial complex in Greece. It will operate for at least two years under commercial conditions and supply renewable hydrogen to the refinery's processes and external end-users.

The industrially integrated renewable hydrogen production will be developed around a circular economy and industrial symbiotic approach, with the electrolyser coupled to (i) renewable electricity production, (ii) an innovative waste heat harvesting technology, (iii) environmental optimisation of water use, (iv) valorisation of produced oxygen in current Motor Oil Hellas's refinery operations, (v) a digital twin, and (vi) a dedicated energy management system. EPHYRA will contribute to all key performance indicators for electrolysis technology, as detailed in the objectives of the Clean Hydrogen Partnership's strategic research and innovation agenda. Therefore, EPHYRA will demonstrate the technology's reliability for green hydrogen production at the lowest possible cost, thus enabling the EU renewable hydrogen economy, industry decarbonisation, and uptake of zero-emission fuels.

NON-QUANTITATIVE OBJECTIVES

- Develop a detailed technology and integration concept for an enhanced electrolysis system.
- Optimise synergies among H_2 production, utilisation, complementary supply, and the valorisation of waste streams (waste heat, oxygen, water) within a circular economy framework.
- Develop a digital twin and controls and automation for the H_2 plant and its (symbiotic) environment.
- Set up and operate the integrated H_2 production plant and complementary supply and valorisation streams (local circular H_2 economy), including standardisation and safety aspects.
- Assess the techno-economic, environmental and societal sustainability of the H_2 production plant and the local circular H_2 economy.
- Achieve sustainable impact through stakeholder engagement, social acceptance and industrial replication (incl. business modelling and development).

PROGRESS, MAIN ACHIEVEMENTS AND RESULTS

- Major milestones, including electrolyser procurement, technical validation, and integration planning, have been completed.
- A tender process for procuring the electrolyser has been launched.
- A comprehensive evaluation of the proposed solutions resulted in METACON AB being selected as the vendor.
- A purchase order has subsequently been placed, and a solar Power Purchase Agreement (PPA) has been secured.
- A feasibility study by ENERTIME and MOH evaluated the integration of an Organic Rankine Cycle (ORC) system, identifying the most cost-efficient scenario as installing ORC in other refinery units rather than directly with the electrolyser.
- The economic feasibility of utilising oxygen in the refinery Claus unit and a desktop study of its use in the FCC unit were also conducted. The findings of these studies are critical in guiding investment decisions and ensuring the project's alignment with the overall business strategy.
- Significant activities on digital twin design include the development of a mathematical model of the electrolyser-separator block in gPROMS, the realisation of two configurations of the electrolyser-separator block and the integrated system model, and sensitivity analysis of the steady-state model to identify key performance variables affecting system performance.
- Additional models for optimising the hydrogen production system configuration to minimise cost, the ORC for waste-heat management, and the renewable energy supply are under development.
- A comprehensive market assessment for large-scale renewable hydrogen production, especially in refineries, has been conducted, identifying sig

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- nificant replication potential in industries such as steel and chemicals. The assessment also emphasised integrating green hydrogen into existing operations for decarbonisation.
- A comprehensive suite of communication and dissemination tools was developed to enhance project outreach and engagement.
- A dedicated project website was launched, serving as a central hub for project-related information and updates.
- Standardised document templates were created to ensure consistency and professionalism in project communications. A LinkedIn project account was established to facilitate networking with industry professionals and policymakers.

FUTURE STEPS AND PLANS

- Completion of the FEED study for the electrolyser, followed by detailed engineering for the integrated industrial green hydrogen production unit, to precisely define all the technical specifications of the system and its operational requirements.
- Conduction of an environmental study for the permitting process, as well as the necessary safety studies (HAZID, HAZOP, etc.), culminating in the final version of the draft safety plan.
- The GO/NO-GO decision is expected in tandem with the selection of the EPC contractor, followed by site preparation and the start of the construction phase, leading to the equipment's arrival.
- Conduction of basic and detailed engineering and procurement for the ORC system.
- Refinement of the models developed for the digital twin and the simulation of the auxiliary functions and the energy management system will proceed as planned.
- Further work towards the project's techno-economic, environmental and societal sustainability includes the development of a techno-economic framework and sustainability assessment, and a preliminary business plan to assess the project's theoretical feasibility and long-term sustainability.

PROJECT TARGETS

Target source	Parameter	Unit	Target	Target achieved?
Project's own objectives	O_2 production - Base Case	tons/year	19 322	
	Operating hours per year - Base Case	hours/year	3 945	
	O_2 production - Full Load	tons/year	39 184	
	CO_2 savings for project duration - Base Case	ktons/year	52.6	
	Availability - Full Load	%	91	
	H_2 production - Full Load	tons/year	4 898	
	H_2 production - Base Case	tons/year	2 415	
	CO_2 savings for project duration - Full Load	ktons/year	108.1	
	LCOH targeted - Full Load	€/kg H_2	2.6	
	LCOH targeted - Base Case	€/kg H_2	3.3	
	Availability - Base Case	%	45	
	Operating hours per year - Full Load	hours/year	8 000	
	Degradation	%/1 000h	≤0.11	
	Use of critical raw materials as catalysts	mg/W	< 0.6	
	Hot idle ramp time	sec	≤30	
	Cold start ramp time	sec	≤900	
	CAPEX	€/kW	≤ 480 ±10%	
	Current density	A/cm²	> 0.6	
	O&M cost	€/(kg/d)/y	≤ 43±10%	
	Electricity consumption @ nominal capacity	kWh/kg	≤ 49	

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EXSOTHYC

EXSOLUTION-BASED NANOPARTICLES FOR LOWEST COST GREEN HYDROGEN VIA ELECTROLYSIS

Project ID	101137604
PRR 2026	Pillar 1 - H_2 Production
Call Topic	HORIZON-JTI-CLEANH$_2$-2023-01-01
Project Total Costs	2 495 480.00
Clean H_2 JU Max. Contribution	2 495 480.00
Project Period	01-01-2024 - 31-12-2026
Coordinator Beneficiary	OU STARGATE HYDROGEN SOLUTIONS, EE
Beneficiaries	AGFA GEVAERT NV, THE UNIVERSITY COURT OF THE UNIVERSITY OF ST ANDREWS, FRAUNHOFER GESELLSCHAFT ZUR FÖRDERUNG DER ANGEWANDTEN FÖRSCHUNG EV, TECHNISCHE UNIVERSITÄT EINDHOVEN

https://exsothyc.com/

PROJECT AND GENERAL OBJECTIVES

The main objective of the EXSOTHyC is to develop and validate a next-generation alkaline electrolyser short-stack prototype with a novel cell design featuring disruptive sub-components and breakthrough materials to meet the future needs of GW-scale renewable energy storage.

NON-QUANTITATIVE OBJECTIVES

EXSOTHyC aims to contribute to scientific advances across and within disciplines such as materials science, membrane science and engineering, and electrochemistry. EXSOTHyC aims to enhance EU industrial leadership in hydrogen systems and components by developing new materials, catalysts, and production methods that can be applied to other areas of renewable energy and clean technology, thereby contributing to standards, wider adoption of green hydrogen through lower prices, and the growth of the renewable energy sector. EXSOTHyC aims to help achieve the Green Deal goals, including sustainable energy, energy security, no CO_2 emissions, cleaner air, and lower environmental impact by avoiding the use of platinum group metals and creating more green jobs.

PROGRESS, MAIN ACHIEVEMENTS AND RESULTS

- Development of a scalable coating technology and heat-treatment strategy for fabricating dimensionally stable electrodes incorporating exsolvable catalytic particles.
- Establishment of a new synthetic route to hybrid transition metal phosphide exsolution nanoparticles.
- Development of a membrane with reduced hydrogen transport (HTO).
- Development of a catalyst-coated diaphragm with good electrochemical performance and limited gas crossover.
- Development of a model describing shutdown behaviour in alkaline water electrolysis stacks.
- Development of a model describing reverse currents in alkaline electrolysers.
- Advanced cell characterisation using electrochemical impedance spectroscopy (EIS).

FUTURE STEPS AND PLANS

- Improved electrodes and membranes were manufactured at a scale enabling assembly of a prototype stack with 1 000 cm² active area per cell and 15 cells per stack.
- Development and application of an accelerated stress test protocol that simulates reverse currents during flexible operation, combined with advanced cell characterisation.
- Assembly and testing of a short-stack prototype demonstrating:
  - Electricity consumption below 48 kWh/kg at 1 A/cm².
  - Critical raw material usage of 0.3 mg/W (as defined in the SRIA roadmap).
  - Stable operation at 5% load (0.05 A/cm²) with hydrogen concentration in oxygen below 0.4%.

PROJECT TARGETS

Target source	Parameter	Unit	Target	Target achieved?
Project's own objectives	Development of novel perovskite powders with exsolved nanoparticles, a highly active catalyst for the hydrogen and oxygen evolution reaction	mV @ 10 mA/cm²	OER ≤ 250 mV HER ≤ 100 mV	
	Development of DSE (porous substrate coated with the novel catalyst) and CCS for AEL application exhibiting long-term stability and high electrochemical activity	mV @ 0.5 A/cm² % degradation/24h	HER < 100 at 0.5 A/cm², OER < 250 at 0.5 A/cm²	⚙
	Upscaling the prototype sub-components into stack level to be able to fabricate an alkaline electrolysis prototype stack	cm² per cell; number of cells	1 000 cm² per cell 15-cell stack assembled	
	Diaphragm with reduced HTO (Hydrogen-to-Oxygen) demonstrated	% HTO @ 50 mA/cm²	HTO ≤ 0.4% (on > 5 cm² area)	
	Development and use of a proposed accelerated stress test protocol, mimicking reverse currents during flexible operation, combined with advanced cell characterisation	% per cycle	Cell: ≤ 0.0033%/cycle Electrode: ≤ 0.0016%/cycle	✓

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HERAQCLES

NEW MANUFACTURING APPROACHES FOR HYDROGEN ELECTROLYSERS TO PROVIDE RELIABLE AEM TECHNOLOGY BASED SOLUTIONS WHILE ACHIEVING QUALITY, CIRCULARITY, LOW LCOH, HIGH EFFICIENCY AND SCALABILITY

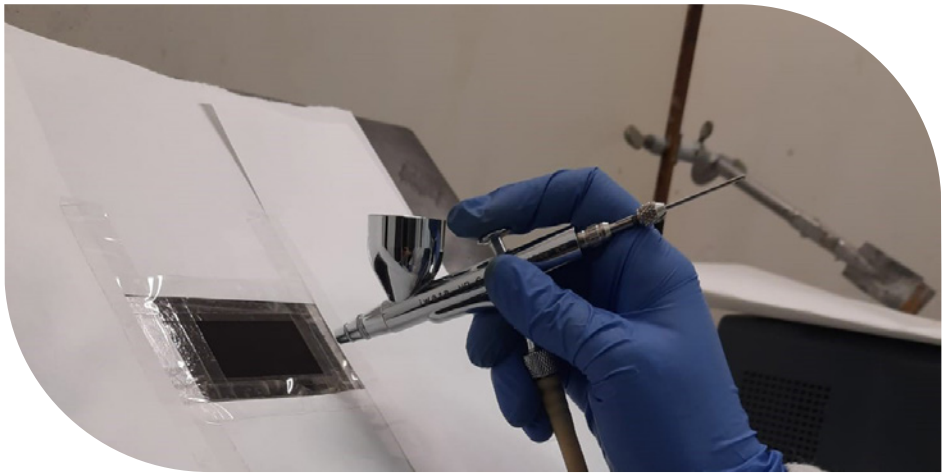
Project ID	101111784
PRR 2026	Pillar 1 - H_2 Production
Call Topic	HORIZON-JTI-CLEANH$_2$-2022-01-04
Project Total Costs	2 342 385.00
Clean H_2 JU Max. Contribution	1 999 622.50
Project Period	01-06-2023 - 31-05-2027
Coordinator Beneficiary	SCHAEFFLER TECHNOLOGIES AG and CO. KG, DE
Beneficiaries	HYGEAR TECHNOLOGY AND SERVICES BV, HYGEAR BV, MANUFACTURE FRANCAISE DES PNEUMATIQUES MICHELIN, HYGEAR OPERATIONS BV, CONSIGLIO NAZIONALE DELLE RICERCHE, VLAAMSE INSTELLING VOOR TECHNOLOGISCH ONDERZOEK N.V., HYGEAR FUEL CELL SYSTEMS BV, EXENTIS TECHNOLOGY GMBH, JOHN COCKERILL HYDROGEN BELGIUM, MONOLITHOS KATALITES KE ANAKIKLOSI ETAIREIA PERIORISMENIS EVTHINIS, HYGEAR HYDROGEN PLANT BV

https://www.schaeffler.com/en/technology-innovation/culture-of-innovation/funded-projects/

PROJECT AND GENERAL OBJECTIVES

HERAQCLES has the following project aims:

- Development of automated manufacturing processes for anion- exchange membrane (AEM) water electrolysers and validation of a proof- of concept 25 kW system operating at 30-50 bar with a hydrogen production rate of about 12. 5 kg H_2/d (manufacturing readiness level 5), with detailed design and cost calculation for a 100 MW electrolysis plant.
- Marked increase in operating current density (1 A/cm 2 nominal at 1. 8 V/cell and 2 A/cm 2 at 2.2 V) while keeping energy consumption < 48 kWh/kg at 1 A/cm 2, with a stack efficiency of 80% with respect to the higher heating value (~70% with respect to the lower heating value). This will bring an efficiency improvement of at least 2-4 % with respect to the lower heating value compared with the present state- of- the- art in the field of liquid alkaline electrolysers, while enabling operation at much higher current density.
- Reduction in capital cost for large- scale production (100 MW production volume) to less than 0. 0.6 € million/ (tonnes/day H 2). This corresponds to 300 €/kW for a production volume of 100 MW. The development of an automated manufacturing process for a novel stack architecture, the use of non- critical raw materials (cheap Ni- based electrocatalysts, hydrocarbon membranes, and cost- effective Ni- coated stainless- steel bipolar plates), minimisation of materials use, a simplified balance of plant for differential- pressure operation, and increased current density (according to Faraday's law) will bring a perspective.
- Validation of durability under steady and intermittent duty cycles in time studies of at least 2 000 hours cumulative (1, 000 hours of steady- state and 1 000 hours of cycled operation), with a targeted degradation rate lower than 5-7 µV/h at a fixed current density of 1 A/cm 2, corresponding to about 0. 2-0. 4%/1 000 h.
- System lifetime of 10 years of operation without stack replacement and of 20 years with a single stack replacement (cut- off voltage: 2. 4 V).
- Significant reduction in the levelised cost of hydrogen to less than 2- 3/kg H 2, with capital expenditure of 0. 6 € million/ (tonnes/



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- day H 2) and operation and maintenance costs of less than € 20/(kg/day)/year, assuming a € 40 /MWh renewable electricity cost and 4 000 h/year of uptime.
- Market competitiveness for green hydrogen, targeting a cost of 2-3 €/kg H 2 (theoretically corresponding to about 50-75 €/MWh).

NON-QUANTITATIVE OBJECTIVES

HERAQCLES aims to develop new manufacturing approaches for AEM electrolysers to provide reliable, AEM-technology-based solutions, directly fulfilling targets for the large-scale deployment of cheap green hydrogen. Thus, the project will contribute to EU policy by limiting the environmental impact of current hydrogen technology applications, minimising material use, avoiding critical raw materials, improving the cost-effectiveness of clean hydrogen solutions, and reinforcing the EU's scientific and industrial ecosystem.

FUTURE STEPS AND PLANS

- Testing of Loop 1.
- Stack defining parameters for loop 2 stack.

PROJECT TARGETS

Target source	Parameter	Unit	Target	Achieved to date by the project	Target achieved?
Project's own objectives	Voltage	V	1.8V/cell @ 1A/cm^2 current density	1.8V/cell at 1A/cm^2 achieved at single cell level by partner CNR-ITAE.	
	CAPEX	€/(kg/d)	600	-	
	CAPEX	€/kW	300	-	
	O&M cost	€/(kg/d)/y	20	-	
	Degradation	%/1 000h	0.4	Prototype tested for at least 2 000 hours cumulative (steady state/dynamic) with targeted degradation rate at 5-7 µV/h at a current density of 1 A/cm^2 (0.2 to 0.4 %/ 1 000 h).	
	Current density	A/cm^2	1	MEA performance of 1.82 V/cell at 1 A cm-2 and 50°C and 2.2 V at 3.6 A cm-2 was achieved at CNR-ITAE in the presence of a noble metal loading of 0 mg cm-2.	

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HY-SPIRE

HYDROGEN PRODUCTION BY AN INNOVATIVE SOLID OXIDE CELL FOR FLEXIBLE OPERATION AT INTERMEDIATE TEMPERATURE

Project ID	101137866
PRR 2026	Pillar 1 - H_2 Production
Call Topic	HORIZON-JTI-CLEANH$_2$-2023-01-02
Project Total Costs	2 999 523.00
Clean H_2 JU Max. Contribution	2 999 523.00
Project Period	01-02-2024 - 31-01-2027
Coordinator Beneficiary	INSTYTUT ENERGETYKI - PANSTWOWY INSTYTUT BADAWCZY, PL
Beneficiaries	DANMARKS TEKNISKE UNIVERSITET, ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE, DEUTSCHES ZENTRUM FÜR LUFT - UND RAUMFAHRT E.V., FONDAZIONE BRUNO KESSLER, FUNDACIO INSTITUT DE RECERCA EN ENERGIA DE CATALUNYA, SOLYDERA S.P.A.

https://hy-spire.eu/project/

PROJECT AND GENERAL OBJECTIVES

Hy-SPIRE aims to advance solid oxide electrolysis (SOEL) technology to enable the large-scale deployment of renewable hydrogen as a key energy vector for EU decarbonisation goals. The project focuses on lowering SOEL operating temperatures below 700 °C and increasing system flexibility to better match renewable energy generation profiles.

To achieve this, Hy-SPIRE develops novel oxygen-ion- and proton-conducting cells (O-SOE and P-SOE) on ceramic and metallic supports. The project targets ambitious key performance indicators, including low degradation rates (≤0.75% per 1 000 h), operation at high current densities (~1.2 A/cm²), and fast dynamic ramping capability.

These objectives are pursued through the development of advanced materials, innovative manufacturing techniques, and optimised cell and stack designs that go beyond the current state of the art in performance, operation, and scalability.

The consortium combines expertise across the European SOEC value chain, including stack manufacturing, materials development, fabrication processes, testing infrastructure, and technology assessment. Techno-economic analysis and life cycle assessment (LCA) are integrated to evaluate market potential and sustainability impacts.

Hy-SPIRE also contributes to long-term SRIA objectives by supporting reductions in hydrogen production costs, CAPEX, and OPEX, while ensuring that the developed technologies are suitable for large-scale manufacturing and integration with renewable energy systems and industrial applications.

NON-QUANTITATIVE OBJECTIVES

- Optimisation of the design and materials of cells to allow flexible operation with reduced startup time, rapid cycling and faster stop.
- Application of thin electrolytes, which substantially reduce the content of critical raw materials (CRM) in stack repeating units (SRU), paving the way for compact stack design.
- Establishing compact design of solid oxide electrolyser stacks with reduced volume, which will be able to operate dynamically and be easier to manage thermally.
- Establishing stacks with reduced operating temperature and reduced footprint, which will ease the integration of SOEL with renewables and industrial processes.
- Demonstration of the scalability of ultra-high-temperature sintering, which will shorten the fabrication time (by reducing thermal treatments from several hours to minutes) and the energy cost of the fabrication of the electrochemically active components of SOELs.
- Adaptation of existing and newly developed testing protocols for electrolysers which operate at elevated temperatures (i.e., SUSTAINCELL, NewSOC, FCTESQA, SOCTESQA, and the harmonised testing protocols for EU (EU harmonised testing protocols for high-temperature steam electrolysis, 2023)).

PROGRESS, MAIN ACHIEVEMENTS AND RESULTS

- Development and adaptation of testing protocols for oxygen-ion conducting solid oxide electrolysers (O-SOE) and proton-conducting solid oxide electrolysers (P-SOE). These protocols build upon and refine existing methodologies from key initiatives such as SUSTAINCELL, NewSOC, FCTESQA, and SOCTESQA, as well as the harmonised EU testing protocols for high-temperature steam electrolysis (2023).
- Establishment of standardised evaluation procedures, enabling reliable performance assessment, durability testing, and benchmarking of O-SOE and P-SOE technologies.

FUTURE STEPS AND PLANS

The developed testing protocols for single-cell Solid Oxide Electrolysers (SOEs) with oxygen-ion-conducting (O-SOEs) and proton-conducting (P-SOEs) electrolytes.

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PROJECT TARGETS

Target source	Parameter	Unit	Target	Target achieved?
Project's own objectives	Degradation rate	%/1 000 h	0.75	
	Current density	A/cm^2	1.2	
	Thickness of the electrolyte	um	1-2	
	Hot idle ramp time	sec	240	
	Cold start ramp time	hours	6	

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HYIELD

A NOVEL MULTI-STAGE STEAM GASIFICATION AND SYNGAS PURIFICATION DEMONSTRATION PLANT FOR WASTE TO HYDROGEN CONVERSION

Project ID	101137792
PRR 2026	Pillar 1 - H_2 Production
Call Topic	HORIZON-JTI-CLEANH$_2$-2023-01-05
Project Total Costs	15 472 352.50
Clean H_2 JU Max. Contribution	9 999 964.63
Project Period	01-01-2024 - 31-12-2027
Coordinator Beneficiary	MAGTEL OPERACIONES SL, ES
Beneficiaries	LA FARGA LACAMBRA SA, CEMEX ESPANA OPERACIONES SL, FUNDACIO EURECAT, AGENCIA ESTATAL CONSEJO SUPERIOR DE INVESTIGACIONES CIENTIFICAS, AQUAMBIENTE CIRCULAR ECONOMY SOLUTIONS SL, WASTE TO ENERGY ADVANCED SOLUTIONS SL, ENAGAS SA, CETAQUA, CENTRO TECNOLOGICO DEL AGUA, FUNDACION PRIVADA, SINTEF AS, LABAQUA SA, MINCATEC ENERGY SAS, HYDROGEN ONSITE, SL, ARISTENG SARL, SYNHELION SA, AQUAMBIENTE SERVICIOS PARA EL SECTOR DEL AGUA SA, CARTAGO VENTURES SL, ARCELORMITTAL BREMEN GMBH

https://hyield.eu/

PROJECT AND GENERAL OBJECTIVES

The overall objective of HYIELD is to open a new low-cost pathway for clean hydrogen production and waste management, accelerating Europe's progress towards zero-carbon and zero-landfill goals. HYIELD aims to build Europe's first large-scale waste-to-hydrogen demonstration plant, which will produce over 400 tonnes of green hydrogen over the project's duration. The ambition is to develop a robust and efficient solution that will pave the way for commercial scale-up and replication across Europe, enabling the closure of landfills and the production of sufficient volumes of low-cost green hydrogen to help decarbonise sectors such as shipping and heavy industry.

The demonstration plant will utilise WtEnergy Advanced Solutions' CleanTech gasification technology and H_2Site membrane separation reactor, and it will be implemented at a CEMEX cement factory in Spain, where the green hydrogen will be utilised in cement production.

NON-QUANTITATIVE OBJECTIVES

- Design a multi-stage gasification, gas cleaning and gas separation process for a beyond-state-of-the-art waste-to-hydrogen plant.
- Gain deeper insight into organic waste gasification reactions to identify opportunities to optimise H_2 yield.
- Develop new digital tools and models to optimise the performance of waste-to-hydrogen plants.
- Unlock the energy potential of new organic waste feedstocks for waste-to-hydrogen applications.
- Increase knowledge of planning and regulatory requirements for implementing waste-to-hydrogen plants.
- Develop and test a novel water-gas shift membrane reactor at an industrial scale.
- Develop and test a novel metal hydride hydrogen storage unit at an industrial scale.
- Validate the integrated waste-to-hydrogen plant at near-industrial scale and in a real-world setting.
- Validate clean hydrogen quality certification and clean hydrogen guarantees of origin for waste-to-hydrogen technologies.
- Benchmark the waste-to-hydrogen solution developed against other clean H_2 pathways.
- Develop a regional scale-up plan for after the project.

PROJECT TARGETS

Target source	Parameter	Unit	Target	Target achieved?	SoA result achieved to date (by others)	Year for reported SoA result
	System CAPEX	€/(kg/d)	2 736		1 806	2020
	System OPEX	€/kg	0.328		0.013	
	Conversion efficiency	%	>50		40-50	
	LCOH at target production	€/kg	< 3		1.8-3.4 (USD/kg)	
	Reactor size	MW	≥3		N/A	N/A

PRR 2026 PILLAR
H_2 Production

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HYP3D

HYDROGEN PRODUCTION IN PRESSURIZED 3D-PRINTED SOLID OXIDE ELECTROLYSIS STACKS

Project ID	101101274
PRR 2026	Pillar 1 - H_2 Production
Call Topic	HORIZON-JTI-CLEANH$_2$-2022-01-01
Project Total Costs	2 543 398.75
Clean H_2 JU Max. Contribution	2 543 398.75
Project Period	01-01-2023 - 31-12-2026
Coordinator Beneficiary	FUNDACIÓ INSTITUT DE RECERCA EN ENERGIA DE CATALUNYA, ES
Beneficiaries	VAC TRON SA, POLITECNICO DI TORINO, DANMARKS TEKNISKE UNIVERSITET, SAS 3DCERAM SINTO, SNAM S.P.A., BARCELONA SUPERCOMPUTING CENTER CENTRO NACIONAL DE SUPERCOMPUTACIÓN, H2B2 ELECTROLYSIS TECHNOLOGIES SL

https://hyp3d.eu/

PROJECT AND GENERAL OBJECTIVES

The main goal of the HyP3D project is to develop a new generation of ultra-compact, high-pressure, standalone SOEC stacks capable of converting electricity into compressed hydrogen for power-to-gas (P2G) and hydrogen refuelling station (HRS) applications.

HyP3D technology is based on disruptive 3D-printed SOEC cells with a large active area (70 cm²) and embedded functionalities, enabling hydrogen production at high current densities above 0.60 A/cm² (~1.3 V) under operating conditions of 850 °C and high pressure (5+ bar).

Ultimately, the project aims to deliver ultra-high-power-density SOEC stacks of 1 kW (30 cells in a total volume of 630 cm³), achieving a threefold increase in power density per unit volume (1.4 kW/L) and a fourfold increase per unit mass (0.6 kW/kg) compared to the state of the art.

The HyP3D manufacturing approach represents a breakthrough compared to conventional ceramic SOEC processing, significantly reducing time-to-market (from years to months), raw material usage (by 76%), and initial investment costs (by 42% compared to conventional cell manufacturing plants at the first MW scale), while offering improved flexibility and scalability of production lines.

NON-QUANTITATIVE OBJECTIVES

- Develop disruptive electrolyte-supported Solid Oxide Electrolysis Cells based on 3D-printed 3YSZ and 8YSZ with non-flat geometries.
- Design high-pressure sealing using 3D-printed self-tightening joints and optimised glass sealants with enhanced adhesion through surface modification.
- Fabricate ultra-compact, lightweight kW-range stacks based on 3D-printed HyP3D cells, cost-effective flat-coated interconnects, and surface-modified sealants.
- Build a neural network-based digital twin of the HyP3D stack capable of running in high-performance computing environments.
- Design simple SOEL systems based on standalone HyP3D stacks for the specific applications of H_2 injection into the gas grid and on-site generation for hydrogen refuelling stations.

PROGRESS, MAIN ACHIEVEMENTS AND RESULTS

- The cell design has been optimised, considering both printing and post-printing processes. The first generation of designed cells features large active-area corrugated membranes (45 cm² projected and 72 cm² real area) with embedded functionalities (gas channels) that enable the use of flat, thin (200 µm) interconnects at the stack level, with anticipated advantages in power density.
- Large-area cells 3D-printing processes (paste formulation, printing, and post-printing) were successfully optimised. 3YSZ 3D-printed cells were produced with good reproducibility and were free of cracks and deformation.
- 3YSZ 3D-printed cells were successfully tested at SRU and sub-stack (three cells) level at atmospheric pressure, with performance in line with the literature considering the thickness of the electrolyte and its ionic conductivity; OCV of 0.8 V/cells in SOEC mode, injected current of 25 A corresponding to 0.55 A/cm² and 35 W/cell.
- One stack (18 cells) was successfully built and tested in SOEC mode at atmospheric pressure, with the following recorded performance metrics: 330 W, corresponding to 508 W/L, 274 W/kg, 290 mA/cm², and 3.65 kg/kW.
- Commercial glass-ceramic sealants were successfully modified to increase their viscosity at operating temperatures, achieve refractory behaviour, and enhance their resistance to differential pressures and shear stresses generated during real-world operations for HyP3D stacks.
- Laser milling of metallic interconnects and 3D-printed YSZ was developed to increase the surface roughness of the metals in the sealing regions. By increasing the inter

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- locking effect and the resistance to shear stresses, roughness values of 5.7 um and 4.9 um were achieved for Crofer22APU and YSZ, respectively. The developed joints demonstrated excellent compatibility between the interfaced materials, sound, continuous interfaces, and good infiltration of the glass-ceramics into the tracks of the milled materials.
- The interlocking sealing concept was successfully tested at room temperature and under high differential pressures. The joint laser-milled Crofer22APU/modified glass-ceramic/laser-milled YSZ demonstrated leakage rates below the detection limit at room temperature under 4 bar of applied pressure.
- Compressive sealing concepts for high pressure were also developed by introducing 3D structures into YSZ, enabled by 3D printing. The developed non-flat sealing geometries are suitable for coupling with compressive mica-based sealants. The introduction of notches on YSZ improved gas tightness relative to flat geometries by up to 5 times at high pressures (5 bar).
  - HyP3D 3YSZ cells have been demonstrated to withstand up to 1.5 bar of unbalanced pressure across the membrane.
- Protective coatings deposition via EPD (Electrophoretic Deposition) was developed, and the sintering treatment was optimised. The resulting coatings exhibit suitable thicknesses (>10 µm) and satisfactory densification (>80%).
- Initial simplified thermo-mechanical and fluid-dynamic simulations were successfully performed on both cell and SRU models.

FUTURE STEPS AND PLANS

- Assembly and testing of high-pressure 5-cell sub-stacks.
- Development of a digital twin of the SOEC stack.

PROJECT TARGETS

Target source	Parameter	Unit	Target	Target achieved?
Project's own objectives	Power per stack	kW	1	⚙
	Use of critical raw materials	kg/kW	0.9	
	Electrical consumption nominal capacity	kWh/kg	38	✓
	Cold start ramp time	hours	8	

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HYPRAEL

ADVANCED ALKALINE ELECTROLYSIS TECHNOLOGY FOR PRESSURISED H_2 PRODUCTION WITH POTENTIAL FOR NEAR-ZERO ENERGY LOSS

Project ID	101101452
PRR 2026	Pillar 1 - H_2 Production
Call Topic	HORIZON-JTI-CLEANH$_2$-2022-01-03
Project Total Costs	2 653 916.00
Clean H_2 JU Max. Contribution	2 653 915.00
Project Period	01-03-2023 - 31-08-2027
Coordinator Beneficiary	FUNDACIÓN PARA EL DESARROLLO DE LAS NUEVAS TECNOLOGÍAS DEL HIDRÓGENO EN ARAGÓN, ES
Beneficiaries	AGFA GEVAERT NV, FRAUNHOFER GESELLSCHAFT ZUR FÖRDERUNG DER ANGEWANDTEN FÖRSCHUNG EV, GREEN HYDROGEN SYSTEMS A/S, VECO BV, SPECIALTY OPERATIONS FRANCE, SYENSQO LABORATOIRE DU FUTUR SAS, SYENSQO SPECIALTY POLYMERS ITALY S.P.A., ARIEMA ENERXIA SL, RHODIA OPERATIONS

http://hyprael.eu/

PROJECT AND GENERAL OBJECTIVES

HYPRAEL's goal is to develop and validate the next-generation alkaline electrolysis (AEL) for highly pressurised H_2 production (at least 80 bar). In addition, an immense increase in energy efficiency will be achieved by raising the temperature to at least 120 °C. HYPRAEL will achieve these goals and move beyond the state-of-the-art by performing research covering areas from design and advanced assessment of electrocatalysts and polymers to the engineering and process intensification of an innovative cell design in four phases: (i) materials development for pressurised electrolysis with an elevated temperature; (ii) material screening for applicability in pressurised electrolysers (both phases will be performed at lab scale and in a single cell with an area of 10 cm^2, 1-30 bar, 80-120 °C;(iii) scale up of the most promising materials from phase 1 and 2; and (iv) scale up of developed materials and their integration into an advanced stack.

The validation of the components scaled up in phase 3 will be performed in the existing test bench of FHa, designed in the frame of the Grid-integrated multi-megawatt high-pressure alkaline electrolysers for energy applications project (Elyntegration) at 60 bar, 120 °C, 6-15 kW (pilot scale). In contrast, the demonstration at a target pressure above 80 bar, at a minimum temperature of 120 °C, and in a cell stack with a capacity of at least 50 kW will be developed by Green Hydrogen Systems on a new test bench. In addition, the HYPRAEL concept will focus on developing an energy-efficient high-pressure electrolyser while addressing the circularity principle of the EU objectives for a carbon-neutral economy.

NON-QUANTITATIVE OBJECTIVES

- Contributing to climate neutrality by producing green hydrogen with zero CO_2 emissions and utilising renewable energy, thereby supporting climate change mitigation.
- Advancing industry, innovation, and infrastructure by fostering technological advances in electrolysis and promoting the development of a sustainable hydrogen infrastructure.
- Enhancing access to affordable and clean energy by providing a renewable energy source and reducing operating costs through high-pressure hydrogen production, eliminating the need for additional compression.
- Promoting responsible consumption and production by optimising resource use, improving efficiency, and minimising environmental impact.
- Strengthening international cooperation by encouraging global partnerships for the development and deployment of green hydrogen technology.

PROGRESS, MAIN ACHIEVEMENTS AND RESULTS

- Veco and Fraunhofer IFAM collaborated to develop highly active and stable electrodes for harsh conditions (120 °C, 40 wt.% KOH).
- Fraunhofer IFAM developed a dedicated single-cell test environment to evaluate new materials under relevant conditions.
- Testing demonstrated that higher operating temperatures significantly improve performance compared to state-of-the-art alkaline electrolysers.
- An optimised substrate was identified through combined testing and data analysis by Veco and Fraunhofer IFAM.
- Extensive testing of Raney Nickel (RaNi) electrodes led to further performance improvements, resulting in long-term stability and high activity, making them ready for high-pressure testing and scale-up.
- A new polymer developed by Syensqo showed improved stability under high-temperature and high-KOH-concentration conditions.
- Based on this, Agfa developed an improved Zirfon membrane with enhanced microstructure for high-pressure operation.
- Combined Syensqo–Agfa efforts resulted in a membrane with significantly improved stability for next-generation alkaline water electrolysis.
- The new Zirfon separator was successfully characterised, showing excellent perfor

PRR 2026 PILLAR
H_2 Production

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- mance and long-term stability at 120 °C and 40 wt.% KOH.
- Fraunhofer IWS successfully transferred atmospheric plasma spraying (APS) technology to coat the new Zirfon separator.
- The separator–electrode assembly (SEA) was further optimised and demonstrated excellent performance under extreme operating conditions, even with Ni-only catalyst layers.
- Ariema continued stack development for pressurised alkaline electrolysis, maintaining state-of-the-art performance while improving system capabilities.
- A new stack concept was developed to enable cell-by-cell health diagnostics, with plans for implementation in large-scale prototypes.

FUTURE STEPS AND PLANS

- Development of materials for pressurised electrolysis at elevated temperatures.
- Screening of materials for applicability in pressurised electrolysers.
- Scale-up of developed materials and integration into an advanced stack.
- Validation in the relevant environment and at scale.

PROJECT TARGETS

Target source	Parameter	Unit	Target	Target achieved?
Project's own objectives	Temperature	°C	120	
	Pressure	bar	80	
	Long-term stable and highly active materials improving stack durability for harsh environmental conditions	%/1 000h	Stack degradation meets the target of a maximum efficiency loss of 0.1%/1 000 h at 1 A/cm^2.	
	Current density	A/cm^2	1	✓

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HYSCALE

HYSCALE – ECONOMIC GREEN HYDROGEN PRODUCTION AT SCALE VIA A NOVEL, CRITICAL RAW MATERIAL FREE, HIGHLY EFFICIENT AND LOW-CAPEX ADVANCED ALKALINE MEMBRANE WATER ELECTROLYSIS TECHNOLOGY

Project ID	101112055
PRR 2026	Pillar 1 - H_2 Production
Call Topic	HORIZON-JTI-CLEANH$_2$-2022-01-05
Project Total Costs	5 295 799.25
Clean H_2 JU Max. Contribution	5 295 799.25
Project Period	01-06-2023 - 31-05-2027
Coordinator Beneficiary	CUTTING-EDGE NANOMATERIALS CENMAT UG HAFTUNGSBESCHRANKT, DE
Beneficiaries	BEKAERT NV, HYGEAR OPERATIONS BV, HYGEAR HYDROGEN PLANT BV, HYGEAR TECHNOLOGY AND SERVICES BV, DIMOSIA EPICHEIRISI ILEKTRISMOU ANONYMI ETAIREIA, CONSIGLIO NAZIONALE DELLE RICERCHE, META, HYGEAR FUEL CELL SYSTEMS BV, COMMISSARIAT A L ENERGIE ATOMIQUE ET AUX ENERGIES ALTERNATIVES, UNIVERZA V LJUBLJANI, DEUTSCHES ZENTRUM FUR LUFT - UND RAUMFAHRT EV, HYGEAR BV, META GROUP SRL

https://www.hyscale.eu/

PROJECT AND GENERAL OBJECTIVES

HYScale is a pioneering project focused on developing a scalable, cost-effective green water electrolysis system. The project leverages an advanced alkaline membrane water electrolyser using innovative components free of critical raw materials, enabling high current densities and reduced operating costs. By optimising key materials—including membranes, ionomers, electrodes, and porous transport layers (PTLs)—as well as stack design, HYScale aims to bridge the gap between research and industrial deployment, delivering a robust solution for a sustainable energy future.

The main objectives of HYScale are:

- Development of an innovative alkaline membrane water electrolyser free of critical raw materials, capable of achieving high current densities (2 A/cm² at 1.85–2 V/cell) with durable and efficient operation at 60 °C and hydrogen pressures up to 15 bar.
- Optimisation of materials synthesis and component manufacturing (membranes, ionomers, electrodes, and PTLs) to enable the development of a 400 cm², 100 kW stack targeting a CAPEX of 400 €/kW.
- Validation of stack performance under dynamic grid conditions and integration into a complete electrolyser demonstrator, targeting technology readiness level TRL 5.

NON-QUANTITATIVE OBJECTIVES

- Foster strong cross-sector collaboration among academia, SMEs, and industry to accelerate innovation and the uptake of technology.
- Bridge the gap between research and industrial deployment through scalable materials and stack design strategies.
- Support sustainability and circularity by developing a critical raw material–free, environmentally friendly electrolysis technology.
- Improve system safety, robustness, and long-term reliability through optimised component design and rigorous testing.
- Promote stakeholder engagement, knowledge transfer, dissemination, and regulatory alignment to support market readiness and societal impact.

PROGRESS, MAIN ACHIEVEMENTS AND RESULTS

- Upscaled materials production: enhancement of the synthesis and reproducibility of critical components—such as the AionFLX membrane and ionomer—with improved strategies to reduce hydrogen crossover and ensure safety.
- Large-area cell development: development of a 400 cm² single cell that matches the performance of small-scale cells at low current densities and excels at higher current densities, confirming its scalability.
- Durability and efficiency: extended continuous tests have shown faradaic efficiencies exceeding 98% and robust performance over prolonged operation, validating the design's long-term reliability.
- Component optimisation: development of advanced catalyst-coated substrates and improved porous transport layers, reducing catalyst loadings and production time while enhancing mass transport and adhesion.
- System integration and scalability: progress towards a fully integrated 100 kW stack is underway, with ongoing discussions on balance-of-plant design and system-level validation that will elevate the technology to TRL 5.

FUTURE STEPS AND PLANS

- Finalise the upscaling and assembly of the 100-kW electrolyser stack, ensuring all components operate harmoniously under realistic operating conditions.
- Conduct comprehensive long-term and dynamic grid-condition tests to validate durability, efficiency, and safety at high current densities.

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- Further optimise manufacturing processes and scale up membrane and catalyst production to achieve the target CAPEX of 400 €/kW and reduce operating expenses.
- Deepen the assessment of the levelised cost of hydrogen and develop robust strategies for market deployment.
- Strengthen collaboration with industrial partners and end-users to ensure smooth knowledge transfer and regulatory alignment for a successful market launch.

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	Active surface area	cm^2	400	⚙	65.5	2021
	System size	kW	100		2.4	2021
	Stack performance	A/cm @ 2V/cell	2		0.47	2020
	Degradation rate	µV/h	5	✓	N/A	N/A
	Single cell performance	A/cm^2 @2V	2		0.7	2024

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HYSEAS

HYDROGEN FROM SEAWATER ELECTROLYSIS

Project ID	101192418
PRR 2026	Pillar 1 - H_2 Production
Call Topic	HORIZON-JTI-CLEANH$_2$-2024-01-03
Project Total Costs	3 999 970.85
Clean H_2 JU Max. Contribution	3 999 970.85
Project Period	01-05-2025 - 30-04-2028
Coordinator Beneficiary	ETHNIKO KENTRO EREVNAS KAI TECHNOLOGIKIS ANAPTYXIS, EL
Beneficiaries	ETHNICON METSOVION POLYTECHNION, SINTEF AS, NORGES TEKNISK-NATURVITENSKAPELIGE UNIVERSITET NTNU, KEMIJSKI INSTITUT, THE MANCHESTER METROPOLITAN UNIVERSITY, ASSOCIACIO REVOLVE MEDITERRANEO, HYLAB - GREEN HYDROGEN COLABORATIVE LABORATORY

https://hyseas.eu/

PROJECT AND GENERAL OBJECTIVES

HySEas uses an advanced Bipolar Membrane (BPM) to precisely control ion transport during electrolysis, enabling a cleaner, safer, and more efficient process.

The main objectives of the project are:

- Develop an innovative seawater electrolysis technology through the design and optimisation of a Bipolar Membrane Water Electrolyser (BPMWE) capable of producing hydrogen directly from seawater while avoiding chlorine formation and corrosion.
- Improve the efficiency and durability of electrolysis systems by enhancing membrane materials, catalysts, and overall system design.
- Reduce reliance on critical raw materials through the development of low-cost, earth-abundant catalysts as alternatives to scarce metals such as platinum and iridium.
- Demonstrate sustainable hydrogen production in coastal environments using seawater and renewable electricity.
- Promote resource efficiency and circularity by exploring recovery of valuable elements from seawater and brine streams and integrating hydrogen production into broader circular economy approaches.

NON-QUANTITATIVE OBJECTIVES

HySEas aims to address the efficiency and material challenges of seawater electrolysis while contributing to EU climate neutrality and green transition goals.

The project seeks to:

- Advance scientific understanding of direct seawater electrolysis, including ion transport, membrane behaviour, catalyst activity, and side reactions such as chlorine evolution.
- Foster innovation in electrolysis materials and system design through the development of novel membranes, catalysts, and bipolar membrane electrolyser architectures adapted to saline environments.
- Strengthen European collaboration in hydrogen technologies by bringing together universities, research institutes, and technology developers across Europe.
- Support the transition toward sustainable and circular energy systems by enabling hydrogen production directly from seawater and exploring resource recovery opportunities from seawater and brine streams.
- Contribute to the future deployment of coastal hydrogen production solutions by generating technological knowledge, design guidelines, and scientific insights for future industrial implementation.

PROGRESS, MAIN ACHIEVEMENTS AND RESULTS

The project management framework and data management procedures were successfully established, providing a solid foundation for project implementation.

- A comprehensive HySEas master plan was developed, defining the experimental and design framework for bipolar membrane water electrolysis (BPMWE) under seawater operating conditions.
- A public webinar was successfully organised, attracting strong participation and stakeholder engagement across the hydrogen community.
- The baseline performance assessment of commercial PEM, AEM, and BPM membrane technologies was completed under pure water and simulated seawater conditions.
- Extensive electrochemical characterisation was performed on 5 cm² MEAs, including polarisation, steady-state, EIS, and LSV measurements, establishing reference benchmarks for future HySEas developments.
- Initial testing confirmed the feasibility of benchmarking membrane technologies for direct seawater electrolysis applications.
- Dissemination and communication activities were successfully launched, including the full project website, regular newsletters, and growing social media engagement.

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FUTURE STEPS AND PLANS

- Additional membrane candidates will be identified and selected based on DFT/MD simulations and information generated within WP6.
- The 3rd General Assembly meeting of the HYSEAS project will take place in Trondheim, Norway, bringing together project partners to review progress and coordinate upcoming activities.
- Publication of Newsletter Issue #4 to further disseminate project developments and results.
- Continuous updates of the project website with news, events, and project achievements.
- Development of a project video animation to support communication, dissemination, and stakeholder engagement activities.

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	Energy consumption @ nominal load for low temperature EL	kwhe/kg	53		55	2020
	Energy consumption @ nominal load for high temperature EL	kwhe/kg	< 40		40	
	Energy consumption @ nominal load for low temperature EL	kwhth/kg	< 10		25	
	Current density for nominal operation	A/cm^2	≥ 0,5		0.5	
	Degradation	% / h	5/500		> 1	
	Operational flexibility	% of nominal load	20-100		10-50	
	Minimal capacity of electrolyser	gH_2/h	20		34	
	Recover and reuse metal ions from seawater	%	30		N/A	N/A
	Effective stack break-in procedures	%	< 5			
	Cost of Green H_2 production	€/kg	2-3			
	Stack cost	€/kW	40-50		300	

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MULTIPLHY

MULTIMEGAWATT HIGH-TEMPERATURE ELECTROLYSER TO GENERATE GREEN HYDROGEN FOR PRODUCTION OF HIGH-QUALITY BIOFUELS

Project ID	875123
PRR 2026	Pillar 1 - H_2 Production
Call Topic	FCH-02-2-2019
Project Total Costs	9 751 722.51
Clean H_2 JU Max. Contribution	6 993 725.39
Project Period	01-01-2020 - 31-12-2025
Coordinator Beneficiary	COMMISSARIAT À L'ÉNERGIE ATOMIQUE ET AUX ÉNERGIES ALTERNATIVES, FR
Beneficiaries	NESTE ENGINEERING SOLUTIONS OY, PAUL WURTH SA, NESTE ENGINEERING SOLUTIONS BV, NESTE OYJ, ENGIE, ENGIE ENERGIE SERVICES, NESTE NETHERLANDS BV, SUNFIRE GMBH

http://www.multiplhy-project.eu

PROJECT AND GENERAL OBJECTIVES

MultiPLHY will demonstrate the EU's technological and industrial leadership in solid oxide electrolyser cell (SOEC) technology, with a rated electrical connection of ~3.5 MW, a nominal electrical power of ~2.6 MWel, and a hydrogen production rate exceeding 670 Nm^3/h. MULTIPLHY's electrical efficiency, at about 85% of the lower heating value, will be at least 20% higher than that of low-temperature electrolysers, enabling reductions in operational costs and the connected load at the refinery, and hence in the impact on the local power grid.

MultiPLHY aims to install and integrate the world's first high-temperature electrolyser (HTE) system on a multi-MW scale at a renewable product refinery in Rotterdam, the Netherlands. The project's central element is the manufacturing and demonstration of a multi-MW high-temperature electrolyser and its operation in a renewable product refinery. As a result, MultiPLHY promotes SOEC-based HTE from technological readiness level 7 to 8.

NON-QUANTITATIVE OBJECTIVES

- Successful scale-up of SOEC technology to multi-MW level, including manufacturing, commissioning, FAT, site preparation, installation, and successful coupling of the HTE and HPU systems.
- Demonstration of high system efficiencies, reaching up to 85% el, LHV at full load and above 80% at part load, confirming successful scale-up without efficiency losses compared with smaller systems.
- Integrated HTE + HPU efficiency of 78% achieved for hydrogen compression up to 30 bar.
- System availability reached 94%, supported by a modular system design, operator training, maintenance strategies, and spare-part management.
- More than 42,000 hours of stack operation accumulated, positioning MULTIPLHY among the leading projects in large-scale SOEC durability testing.
- Stack degradation rates below project targets were achieved, with ASR degradation values as low as 11 $m\Omega \cdot cm^2/kh$.
- Stable long-term stack operation was demonstrated through operational strategies that compensate for degradation via temperature control.
- Development of a Design-to-Cost strategy and refinement of cost assessment methodologies, considering operational data and market conditions.
- Development of Sunfire Gen3 SOEC technology featuring higher stack power density, improved thermal integration, higher efficiency, and a more cost-effective module design.
- Significant CAPEX reduction potential identified: up to 60% for phase-in products and 72% for full-scale deployment compared with MULTIPLHY Gen2 systems.
- Techno-economic evaluations completed for multiple industrial hydrogen production scenarios, highlighting the importance of electricity cost, efficiency, CAPEX integration, and full-load operation hours.
- Recommendations formulated for future scale-up projects, including reduction of EPC costs and deployment in locations with access to low-cost renewable electricity.
- Assessment of renewable electricity procurement strategies completed, identifying Guarantees of Origin (GO) purchase as the only feasible sourcing option under current conditions.
- Evaluation of hydrogen certification pathways performed, highlighting current regulatory and economic challenges associated with certifying the origin of renewable hydrogen.

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PROGRESS, MAIN ACHIEVEMENTS AND RESULTS

- The High-Temperature Electrolyser (HTE) system, designed and manufactured by Sunfire, comprises 12 modules capable of producing 60 kg/h of hydrogen at 850 °C. All modules passed factory acceptance testing before deployment at Neste's renewable products refinery in Rotterdam.
- A dedicated Hydrogen Processing Unit (HPU) was designed and validated to meet refinery hydrogen quality and pressure requirements.
- The Rotterdam refinery site was fully prepared for integration of the SOEC and HPU systems, including electrical connections and utility infrastructure.
- The complete system was successfully installed, commissioned, started up, and operated within the refinery environment.
- High system efficiencies were demonstrated, reaching 85% el, LHV at full load and above 80% at 30%-part load.
- FAT testing confirmed module efficiencies above 86% el, LHV at full load and up to 89% at part load, validating successful technology scale-up without efficiency losses compared with smaller-scale systems.
- An integrated HTE + HPU efficiency of 78% was achieved for hydrogen compression up to 30 bar.
- Extensive long-term laboratory testing was conducted on both electrode-supported (CEA) and electrolyte-supported (Sunfire) stack technologies, covering stack sizes from a few kW up to 10–20 kW.
- Multiple stack generations were developed and evaluated throughout the project using harmonised testing protocols, including performance mapping, thermal cycling, and long-duration operation.
- More than 43,000 hours of stack testing were accumulated.
- Smart operational strategies based on gradual temperature adjustment successfully compensated for degradation effects, allowing constant current density operation without hydrogen production losses throughout the full testing campaigns.

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	Demonstration duration	hours	as possible in the year 2025	⚙	longest operation reported at system level is also by Sunfire > 15 000 h (Grinhy sequence of projects)	2023
	Downtime	%	2		98	N/A
	H_2 production loss	% / 1 000 h	1.2	✓	1.9	2017

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$NOAH_2$

NOVEL SOE ARCHITECTURES FOR HYDROGEN PRODUCTION

Project ID	101137600
PRR 2026	Pillar 1 - H_2 Production
Call Topic	HORIZON-JTI-CLEANH$_2$-2023-01-02
Project Total Costs	2 656 024.00
Clean H_2 JU Max. Contribution	2 655 084.00
Project Period	01-01-2024 - 31-12-2026
Coordinator Beneficiary	DANMARKS TEKNISKE UNIVERSITET, DK
Beneficiaries	HAUTE ÉCOLE SPÉCIALISÉE DE SUISSE OCCIDENTALE, COMMISSARIAT À L'ÉNERGIE ATOMIQUE ET AUX ÉNERGIES ALTERNATIVES, IDRYMA TECHNOLOGIAS KAI EREVNAS, SINTEF AS, LIBERTY POWDER METALS, GENVIA

https://noah2.dtu.dk/

PROJECT AND GENERAL OBJECTIVES

$NOAH_2$ aims to accelerate the transition to a decarbonised economy by developing next-generation solid oxide electrolysis (SOEL) technology to enable efficient, sustainable green hydrogen production. By utilising renewable electricity sources such as wind and solar, SOEL enables highly efficient hydrogen generation while reducing both capital and operating costs.

The project addresses key barriers to large-scale SOEL deployment, including durability, degradation, operational flexibility, and manufacturing costs. To overcome these challenges, $NOAH_2$ is developing an innovative monolithic stack architecture based on metal-supported materials and advanced electrode designs, reducing reliance on critical raw materials and improving overall system performance.

The main objectives are:

- Reduce SOEL stack costs by 50% compared with current state-of-the-art technologies.
- Increase hydrogen production rates to 1.2 A/cm² at temperatures below 700°C.
- Achieve long-term durability with degradation rates below 0.75% per 1 000 operating hours.
- Enable rapid start-up and dynamic operation suitable for integration with variable renewable energy sources.

By delivering a robust, cost-competitive, and scalable hydrogen production technology, $NOAH_2$ will support the commercialisation of green hydrogen and contribute to Europe's transition towards a sustainable energy future.

NON-QUANTITATIVE OBJECTIVES

$NOAH_2$ will support the pathway towards commercialisation by:

- Defining a clear route to large-scale manufacturing (MW to GW scale), including cost projections aligned with 2030 targets for capital expenditure (CAPEX) of ~520 €/(kg/d) and operational expenditure (OPEX) of ~45 €/(kg/d)/year.
- Developing a sustainability classification framework based on life cycle assessment (LCA), with a strong focus on reducing and substituting critical raw materials (CRM).
- Assessing the commercial potential of the technology in comparison with state-of-the-art SOEL, PEM, and alkaline electrolysers.
- Identifying and actively engaging industrial stakeholders to support high-volume manufacturing and facilitate uptake and exploitation of project results.

PROGRESS, MAIN ACHIEVEMENTS AND RESULTS

- Developed a modelling framework to improve electrode performance by simulating the influence of microstructure on infiltrated electrodes, enabling optimisation of catalyst loading, particle size, and porosity.
- Improved electrode performance based on modelling insights, leading to oxygen-impregnated electrodes and two new hydrogen electrode catalysts with 2–3× higher performance compared to conventional LSCF-GDC and Ni/YSZ electrodes.
- Developed corrosion-resistant metal powders and coatings, including three new alloy powders with enhanced oxidation resistance compared to standard FeCr powders, further improved via CGO coating infiltration.
- Advanced monolithic stack development through physics-based modelling and successful fabrication and testing of monolithic SOEL stack architectures.
- Performed preliminary environmental and economic assessments showing 22–85% lower environmental impact for monolithic stacks (4 out of 5 indicators), a 72% reduction in critical raw material use, and cost reductions of 28% (materials) and 52% compared to FESC and ESC SOEL stacks.
- Established project communication and dissemination activities, including a visual

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- identity, public website, and LinkedIn presence.
- Conducted extensive outreach activities targeting scientific audiences (conferences and publications), the public (industrial fairs such as Hannover Messe), and students (educational events, courses, and schools).

FUTURE STEPS AND PLANS

- Finalise the development of electrodes and metallic components.
- Integrate performance improvements into both monolithic and conventional short-stack platforms.
- Evaluate short-stack performance and long-term durability under relevant operating conditions.
- Extend sustainability assessments to quantify further environmental, economic, and critical raw material impacts.
- Strengthen dissemination activities to the scientific community and the public to maximise project impact and visibility.

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	Cell Current Density	A/cm^2	1.2	1.2	✓	1	N/A
	Stack production costs	%	50	50		2 737 €/kWel - 1 210 €/kWel	2020

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OUTFOX

OPTIMISED UPSCALED TECHNOLOGY FOR NEXT-GENERATION SOLID OXIDE ELECTROLYSIS

Project ID	101101439
PRR 2026	Pillar 1 - H_2 Production
Call Topic	HORIZON-JTI-CLEANH$_2$-2022-01-09
Project Total Costs	2 925 824.25
Clean H_2 JU Max. Contribution	2 925 824.00
Project Period	01-02-2023 - 31-01-2027
Coordinator Beneficiary	NEDERLANDSE ORGANISATIE VOOR TOEGEPAST NATUURWETENSCHAPPELIJK ONDERZOEK TNO, NL
Beneficiaries	SHELL GLOBAL SOLUTIONS INTERNATIONAL BV, POLITECNICO DI MILANO, ELCOGEN OY, AKTSIASELTS ELCOGEN, TEKNOLOGIAN TUTKIMUSKESKUS VTT OY, FONDAZIONE POLITECNICO DI MILANO, CONVION OY, LINQ CONSULTING AND MANAGEMENT LTD

http://outfoxproject.com

PROJECT AND GENERAL OBJECTIVES

The main objective of OUTFOX is to remove scale as a limiting factor in deploying oxide-based electrolyser (SOEL) technologies while demonstrating their potential to become the preferred option for green hydrogen production. By combining experimental results up to the 80-kW scale with the identification of optimal cell, stack, and system designs, OUTFOX will prepare SOEL for industrial-scale systems of 100 MW, with a levelised cost of hydrogen as low as 2.7 €/kg H_2 and applicability to mass-manufacturing lines.

NON-QUANTITATIVE OBJECTIVES

OUTFOX will lead to the realisation of ground-breaking large-area geometric electrolysis cells, a novel stack and module architecture, and new approaches for reproducible, high-volume manufacturing. OUTFOX aims to overcome the current economic and technological SOEL roadblocks and push Europe into the forefront of the green hydrogen technological landscape.

PROGRESS, MAIN ACHIEVEMENTS AND RESULTS

Cell Development:

- Over 1 000 reference cells manufactured and delivered for the first 80 kW demonstration.
- Two types of scaled-up cells:
  - Industrial cells (≥300 cm², by Elcogen): Successfully produced up to 361 cm². Met current density KPIs; lifetime tests (2000h at 0.86 A/cm²) revealed higher degradation due to contamination.
  - Next-generation cells (up to 900 cm², by TNO): Successfully developed and tested. Met thickness and dimension targets; lifetime tests (2000h at 0.85–1.0 A/cm²) also showed higher degradation linked to contamination.

Stack Development:

- Three reference short stacks (15 cells each) built by Elcogen.
  - Two stacks with 400 µm cells, one with 300 µm.
- Stacks tested by VTT at 0.5 and 0.85 A/cm² for up to 2 000 hours.
- Internal stack design tools developed for large area cells.
- Reference stack (119 cells) tested for cycling lifetime—promising results.
- Eight stacks were manufactured for the 80-kW demonstrator and delivered to Convion.

System Development & Module Scale-up:

- CFD-based modelling tool created to support SOEC stack scaling and system design.
- 80 kW system module designed and updated; demonstration site moved from Shell to VTT.
- Steam generator built; first 80 kW demonstration module to be commissioned.

Techno-Economic Analysis, Circularity & Pilot Roadmap:

- Plant/system model by POLIMI captures modularity up to gigawatt-scale.
- Techno-economic analysis (TEA) using data from:
  - Liquid water inlet: Efficiency up to 70.2% (with heat integration).
  - Steam inlet: Efficiency 82.4%, energy use 40 kWhe/kg H_2.
  - CAPEX (10 MW): 950–1 500 EUR/kW.
  - LCOH: Electricity price is the main driver; steam use reduces LCOH by 12%.
- Life cycle assessment ongoing. Nickel oxide is the main CO_2 source in cell manufacture. Reducing energy use, using renewables, and lowering nickel oxide content are key to minimising impact.

FUTURE STEPS AND PLANS

- Manufacturing of up-scaled cells for the second-phase 80 kW demonstrator.

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- Manufacturing and delivery of stacks for the second-phase 80-kW testing campaign.
- Operation and validation of the first and second phases of the 80-kW system in a relevant industrial environment.
- Finalisation of the life cycle assessment (LCA) and business case studies.
- Completion of the webinar series to support effective dissemination and communication of project results.

PROJECT TARGETS

Target source	Parameter	Unit	Target	Target achieved?
Project's own objectives	Levelised Cost of Hydrogen	€/kg	2.7	⚙
	Module size	kW	400	
	Footprint	m^2/MW	< 150	✓
	Current density	A/cm^2	0.85	
	Cell area	cm^2	300 - 900	
	Degradation rate	% / 1 000 h	< 1	

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PEACE

PRESSURISED EFFICIENT ALKALINE ELECTROLYSER

Project ID	101101343
PRR 2026	Pillar 1 - H_2 Production
Call Topic	HORIZON-JTI-CLEANH$_2$-2022-01-03
Project Total Costs	2 504 965.00
Clean H_2 JU Max. Contribution	2 504 964.75
Project Period	01-06-2023 - 31-05-2026
Coordinator Beneficiary	DEUTSCHES ZENTRUM FÜR LUFT- UND RAUMFAHRT E. V., DE
Beneficiaries	BRANDENBURGISCHE TECHNISCHE UNIVERSITÄT COTTBUS-SENFTENBERG, DANMARKS TEKNISKE UNIVERSITET, MATERIALS MATES ITALIA SRL, GRANT GARANT SRO, HYCC B.V., TECHNISCHE UNIVERSITÄT EINDHOVEN

http://www.h2peace.eu/

PROJECT AND GENERAL OBJECTIVES

PEACE aims to develop a high-pressure alkaline electrolysis (AEL) technology to substantially reduce hydrogen production costs, enhancing the competitiveness of the hydrogen economy. A new concept for hydrogen production with two-stage pressurisation will be developed and demonstrated on an AEL system with more than 50 kW of power, capable of operating at pressures exceeding 50 bar. The integration of advanced components, innovative design, and optimised operation strategies will be explored through modelling and experimental testing, ultimately aiming to demonstrate a system with impressive efficiency characteristics.

The PEACE-produced hydrogen will already be compressed, representing a significant advantage for its subsequent use in downstream processes that operate with compressed hydrogen, reducing a significant share of the CAPEX and OPEX of an electrolysis system for the chemical sector. PEACE places a strong emphasis on sustainability and circularity aspects – a life cycle assessment of the PEACE technology will be conducted to quantify its environmental impacts.

NON-QUANTITATIVE OBJECTIVES

- High-efficiency stack development by incorporating advanced and qualified components that are free of precious metals.
- Implementation of an innovative two-stage pressurisation concept to decrease the compression costs for downstream integration.
- Balance of plants and auxiliary optimisation and qualification with a focus on the high-pressure operation.
- Technology demonstration by constructing and operating a newly developed pressurised and high-efficiency stack of > 50kW.
- Effective integration of the PEACE technology with downstream chemical plants to directly use the PEACE-produced hydrogen.
- Reduction of the capital cost of the system by increasing stack efficiency, reducing compression need and optimising the plant's balance.

PROGRESS, MAIN ACHIEVEMENTS AND RESULTS

- Cell component qualification under atmospheric conditions demonstrated performance of at least 1 A/cm² at cell voltages of 1.78 V (diaphragm) and 1.68 V (membrane), while maintaining high gas purity across a 10–100% operating range.
- Research activities focused on pressurised testing and evaluation of larger active-area cells, including a 0.5 m long pressurised cell approaching industrial-scale dimensions.
- A key achievement was the successful operation below 1.8 V at 1 A/cm² under pressurised conditions, confirming that pressurised operation does not significantly impact electrochemical performance.
- Electrochemical stability of the selected components was demonstrated during a 100-hour constant-load pressurised test with negligible degradation.
- HTO levels of approximately 0.15% were achieved at 3 bar pressure.
- Components for full-size stacks were produced and submitted to initial testing.
- An improved stack design addressing previously identified critical issues was successfully implemented in a new generation of components prepared for integration into the Proof-of-Concept (PoC) stack.
- Process simulation scenarios were developed for upstream and downstream integration, including ammonia production, methanol production, and hydrogen refuelling station applications.
- Operational optimisation strategies combining solar and wind power supply were established through dispatch modelling.
- Stable operation models of the PEACE stack within the BTU system were successfully developed, alongside draft process and hydrogen dispatch models.
- Detailed material inventories were compiled to support life cycle assessment (LCA) activities.
- A robust Data Management Plan aligned with FAIR data principles was implemented.

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- Strong communication and dissemination activities resulted in growing engagement across PEACE communication channels and successful presentation of project outcomes at scientific and industrial events.

FUTURE STEPS AND PLANS

- Assembly and testing of the PEACE AEL stack demonstrator using the best-performing components identified during previous development phases.
- Integration of a dual-stage pressurisation concept into the demonstrator system.
- Operation and evaluation of the demonstrator to validate functionality, performance, and simulation models.
- Further assessment of sustainability and circularity aspects through detailed modelling activities and integration of project data.
- Analysis of interactions between AEL technology and surrounding energy systems, including electricity, heat, and fuel production requirements.
- Development of a new cell design targeting improved gas purity under high-pressure operating conditions.
- Advancement of integration concepts linking high-pressure AEL with methanol production, ammonia synthesis, and hydrogen refuelling stations.
- Validation of transient electrolyser models using experimental measurement data to support the development of optimised operating strategies.

PROJECT TARGETS

Target source	Parameter	Unit	Target	Target achieved?
Project's own objectives	Max current density	A/cm^2	1.45	
	Overall system efficiency	%	68-72	
	Nominal current density	A/cm^2	1	
	Minimal load	% of nominal load	14	
	Voltage efficiency (LHV)	%	62-75	
	Minimum pressurisation level	bar	50	
	Cell voltage	V	1.65-2	
	Use of critical materials	mg/W		
	Specific energy use, sys	kWh/kg	49	
	Minimum stack size	kW	50	
	LCOH	€/kg	3	

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PEPPER

PERFORMANT AND EFFICIENT PLANAR PROTON-CONDUCTING ELECTROLYSIS REACTOR

Project ID	101192341
PRR 2026	Pillar 1 - H_2 Production
Call Topic	HORIZON-JTI-CLEANH$_2$-2024-01-01
Project Total Costs	2 999 764.87
Clean H_2 JU Max. Contribution	2 998 152.37
Project Period	01-01-2025 - 31-12-2027
Coordinator Beneficiary	DEUTSCHES ZENTRUM FÜR LUFT- UND RAUMFAHRT E. V., DE
Beneficiaries	CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE CNRS, AVL LIST GMBH, UNIVERSITÉ DE MONTPELLIER, UNIVERSITÉ DE TECHNOLOGIE DE BELFORT - MONTBELIARD, EIFER EUROPAISCHES INSTITUT FÜR ENERGIEFORSCHUNG EDF KIT EWIV, AKTSIASELTS ELCOGEN, COMMISSARIAT À L'ÉNERGIE ATOMIQUE ET AUX ÉNERGIES ALTERNATIVES, DANMARKS TEKNISKE UNIVERSITET, GRANT GARANT SRO

https://www.h2pepper.eu/

PROJECT AND GENERAL OBJECTIVES

PEPPER aims to develop a next-generation hydrogen electrolysis technology tailored to Europe's industrial and energy transition needs.

The project focuses on planar proton-conducting ceramic electrolysis cells (PCCELs) operating at intermediate temperatures (≤600 °C). This approach enables more efficient hydrogen production by combining electrical energy with steam generated from industrial waste heat. It also delivers high-purity hydrogen, reduces reliance on critical raw materials, and improves compatibility with existing industrial environments.

A key emphasis of PEPPER is the development of planar cell and stack designs at industrially relevant sizes, bridging the gap between laboratory-scale concepts and scalable, manufacturable technologies ready for deployment.

Looking ahead, PEPPER will:

- Scale up electrolysis cells and integrate them into compact stack systems.
- Evaluate performance, durability, cost, and environmental impact under relevant conditions.
- Develop a clear pathway towards commercialisation by 2035.

Through these activities, PEPPER aims to strengthen Europe's leadership in clean hydrogen technologies and transform industrial waste heat into a valuable resource for a climate-neutral future.

NON-QUANTITATIVE OBJECTIVES

- Develop two robust planar cell technologies up to ~100 cm² in size, using mechanically stable cermet and metal supports to enhance durability under transient operating conditions.
- Reduce start-up time, enable rapid cycling, and improve shutdown performance of planar short stacks through 3D transient modelling of PCCEL systems.
- Implement porous metal supports to significantly reduce reliance on ceramic materials, achieving a reduction of over 90% in critical and strategic raw material use.
- Develop multilayer electrolytes and optimise oxygen electrode interfaces to minimise current leakage and achieve a faradaic efficiency above 90%.
- Use thin electrolytes (~5 µm) and surface-engineered oxygen electrodes to reach current densities above 0.75 A/cm² at thermoneutral voltage and temperatures below 600 °C, while improving tolerance to



PRR 2026 PILLAR
H_2 Production

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- volatile poisons such as silicon and chromium species in the gas feed.
- Validate the scalability of magnetron sputtering (MS-PVD) for producing thin-film electrolytes and protective coatings on bipolar plates.
- Establish a clear roadmap towards commercialisation supported by life cycle assessment (LCA) and techno-economic analysis (TEA).

PROGRESS, MAIN ACHIEVEMENTS AND RESULTS

- Established the technical foundations for proton-conducting ceramic electrolysis technology through first-generation cell development and scalable fabrication validation.
- Fabricated ceramic-supported cells (5 × 5 cm²) using tape casting and spray coating, enabling thin (~3 µm), dense BCZYYb7111 electrolytes with near single-grain structure.
- Produced and optimised metal-supported cell components, including improved screen-printing inks for smoother functional layers.
- Investigated interface engineering strategies to improve faradaic efficiency, including LWO electron-blocking layers and ceria-based interlayers to reduce electronic leakage.
- Gained key insights into material behaviour, interface stability, and multilayer integration to support further optimisation and upscaling.
- Developed advanced 3D electrochemical and gas transport models to guide cell and stack design and optimise diffusion layers and metal supports.
- Designed two alternative 3D stack configurations with different flow concepts for future simulation and optimisation.
- Procured key materials (bipolar plates, seals, coatings) for compatibility and durability testing under relevant conditions.
- Initiated harmonised testing protocols and prepared a pressurised PCCEL test bench (1–10 bar), including sealing and steam supply solutions.

FUTURE STEPS AND PLANS

- Further improve cell performance for both ceramic- and metal-supported concepts through continued development and optimisation.
- Continue cell manufacturing and screening activities, supported by harmonised testing protocols aligned with performance milestones.
- Finalise stack architectures using advanced modelling and design tools, including optimisation of flow fields and component selection.
- Initiate and scale up short-stack assembly activities as a bridge towards system-level validation.
- Prepare and execute upcoming stack-level testing campaigns to evaluate performance and durability.
- Advance sustainability work by finalising the Life Cycle Assessment (LCA) framework.
- Begin systematic data collection to support future environmental and techno-economic assessments.

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	Cermet Supported Cell	cm²	100		100	2022
	Metal Supported Cell	cm²	100		25	2024
	Current density	A / cm²	-0.75		-2	2025
	Electrolyte thickness	µm	5		N/A	N/A
	Numbers of Short Stacks Assembled with 5 Repeat Units	pc	4		1 - 3 Repeat Units Short Stack and 1 - 10 Repeat Units Short Stack	2022

$PH_2OTOGEN$

ACCELERATION OF PHOTOCATALYTIC GREEN HYDROGEN PRODUCTION TO MARKET READINESS THROUGH VALUE-ADDED OXIDATION PRODUCTS

Project ID	101137889
PRR 2026	Pillar 1 - H_2 Production
Call Topic	HORIZON-JTI-CLEANH$_2$-2023-01-04
Project Total Costs	2 498 813.75
Clean H_2 JU Max. Contribution	2 498 813.25
Project Period	01-01-2024 - 30-06-2027
Coordinator Beneficiary	TOYOTA MOTOR EUROPE NV, BE
Beneficiaries	COMMISSARIAT À L'ÉNERGIE ATOMIQUE ET AUX ÉNERGIES ALTERNATIVES, SOLARONIX SA, LGI SUSTAINABLE INNOVATION, STICHTING NEDERLANDSE WETENSCHAPPELIJK ONDERZOEK INSTITUTEN, HELMHOLTZ-ZENTRUM BERLIN FÜR MATERIALIEN UND ENERGIE GMBH, FRIEDRICH-ALEXANDER-UNIVERSITÄT ERLANGEN-NÜRNBERG, ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

https://ph2otogen.eu/

PROJECT AND GENERAL OBJECTIVES

$PH_2OTOGEN$ aims to generate solar hydrogen through a photocatalytic reaction. While most research on photocatalytic hydrogen generation focuses on splitting water to form hydrogen and oxygen, $PH_2OTOGEN$ aims to couple hydrogen generation with the oxidation of an organic molecule, such as glycerol oxidation to 1,3-dihydroxyacetone (DHA), rather than oxygen formation. Some of the advantages are:

- Avoidance of the concomitant production of hydrogen and oxygen, which can result in the formation of an explosive mixture.
- Since hydrogen (gas) and DHA (oil) are in different states, they can be separated without the need for specially engineered membranes.
- The value of DHA is around 50 times higher than glycerol as a starting material, unlocking other possible revenue streams and accelerating the market introduction of green hydrogen.

$PH_2OTOGEN$ will develop two types of efficient light-absorbing semiconductor materials: (i) a hydrogen-evolving particle, and (ii) an oxidising particle.

Through efficiency and stability testing of candidate materials at the laboratory scale and advanced analysis, $PH_2OTOGEN$ will provide insights into degradation mechanisms and identify countermeasures to mitigate them. The particles will be deposited on a novel transparent, conductive, porous support to allow electronic (electrons and holes) transfer between the two particle types. The synthesis of the most promising materials will be scaled up and tested outdoors in a 500 cm^2 device, with a target of 5% solar-to-hydrogen efficiency. The technical studies, performance data, lifecycle, and techno-economic assessment will be used to select the most promising materials for scale-up and to build a business case. The technology readiness level (TRL) is expected to increase from 2-3 to 5.

NON-QUANTITATIVE OBJECTIVES

- Development of novel semiconductors and co-catalysts for hydrogen evolution and glycerol oxidation.
- Building and outdoor testing of a scalable demonstrator capable of concomitant hydrogen evolution and glycerol oxidation.
- Lifecycle, technoeconomic and market analysis of the materials and device to establish a business case.
- Advanced material analysis to elucidate degradation mechanisms and develop countermeasures.
- Engagement with research communities (through publications, conference presentations, social media and webinars) and the public (through social media and outreach events).

PROGRESS, MAIN ACHIEVEMENTS AND RESULTS

- Finalised benchmarking of key semiconductor and co-catalyst materials for oxidising and hydrogen-evolving particles. Testing was done separately in half-cell setups.
- Tandem testing of the best combinations began in mid-2025 in small-scale reactors, with semiconductors transferred to the transparent porous conductive support (TPCS).
- Demonstrator photoreactor prototypes were built, guided by experimental and modelling studies.
- For hydrogen-evolving particles, the project focused on organic semiconductors, optimising charge transport, passivation layers, and MoSx nanoflake co-catalysts. Achieved photocurrent densities up to 3.7 mA cm-2 at 0.6 V.
- For oxidising particles, BiVO4 showed good selectivity (>55%) to DHA. Organic semiconductors yielded higher photocurrents under sacrificial conditions but did not exceed 1 mA cm-2 for glycerol oxidation, so BiVO4 was prioritised.

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- Tandem devices (organic HEP + BiVO4 OP) achieved bias-free photocurrents of 0.3 mA cm-2 for 3 hours. Efforts are now on improving OP transparency to boost overall photocurrent.
- TPCS synthesis has scaled up, supplying partners with large, robust samples (>6 cm diameter).
- Prototype cells have been developed and optimised for the TPCS architecture.
- Techno-economic, lifecycle, and market analyses confirmed that most semiconductor candidates can be produced at scale with low environmental impact. DHA is the highest-value product, but the market size is limited; formic acid is a promising alternative.
- LinkedIn has been more successful than X for dissemination, with 488 followers (target: 350). Biannual newsletters share results and updates.

FUTURE STEPS AND PLANS

- Improve photocurrent densities at the operating potential to maximise solar-to-hydrogen efficiency in the final demonstrator.
- Scale up the synthesis towards the 100 cm² modules that will be used in the final demonstrator.
- Define the conditions that will be used in the testing protocol.
- Carry out a full TEA and LCA study based on the obtained data.

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	Develop a stable and efficient tandem system	%, mmol m-2 h-1, hours	Average of >5% solar-to-hydrogen (750 mmol m-2 h-1) over 500 hours with oxidation reaction forming a value-added product (> 70% purity). Size: 5 - 10 cm^2	56 mmol m-2 h-1 over 3 hours		115 mmol m-2 h-1	2021
	Lifecycle assessment (LCA) and technoeconomic analysis (TEA) studies to establish a competitive advantage.	USD, kg CO_2 / kg H_2	Demonstrate economic feasibility (< 50 USD / m^2) and environmental impact feasibility (GWP) (< 1 kg CO_2 / kg H_2)	TEA and LCA of semiconductor candidates completed, now being extended to full device/ infrastructure		TEA done for photoelectrochemical system - demonstrated to be highly competitive, LCA study done of H_2 production coupled with hydrogenation reaction	2024
	Develop a stable and efficient oxidising particle (OP)	%	Activity for oxidation (tentative target: "greater than" 4 mA cm-2 at approx. 0.6 V) that matches 5% solar-to-hydrogen under sacrificial conditions over 500 hours	Photocurrent of 2.5 mA cm-2 at 0.6 V for oxidation of glycerol		Photocurrent of 2 mA cm-2 at 0.6 V	2019
	Demonstration device with power density 25 kWh / m^2	kWh / m^2, cm^2, %	Cumulative H_2 production: 25 kWh / m^2 (750 mmol m-2 h-1) (over 500 hours) Performance: Average of > 5% solar-to-hydrogen over 500 hours with oxidation reaction forming a value-added product (> 70% purity) Size: 500 cm^2	56 mmol m-2 h-1 over 3 hours, 3 cm^2		0.76% STH (115 mmol m-2 h-1), 1 m^2 (for overall water splitting)	2021
	Develop a stable and efficient hydrogen evolving particle (HEP)	%	Activity equivalent to > 5% solar to hydrogen efficiency (tentative target > 4 mA cm-2 at 0.6 V) under sacrificial conditions over 500 hours	3.7 mA cm-2		3 mA cm-2 at 0.6 V	2022

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PILOTSOEL

ADVANCED PROCESSES ENABLING LOW-COST AND HIGH-PERFORMING LARGE-SCALE SOLID OXIDE ELECTROLYSER PRODUCTION

Project ID	101112026
PRR 2026	Pillar 1 - H_2 Production
Call Topic	HORIZON-JTI-CLEANH$_2$-2022-01-04
Project Total Costs	2 000 000.00
Clean H_2 JU Max. Contribution	2 000 000.00
Project Period	01-06-2023 - 31-05-2026
Coordinator Beneficiary	DANMARKS TEKNISKE UNIVERSITET, DK
Beneficiaries	AKTSIASELTS ELCOGEN, BENEQ OY, UNIVERZA V LJUBLJANI, SIA NACO TECHNOLOGIES, ELCOGEN OY

https://pilotsoel.dtu.dk/

PROJECT AND GENERAL OBJECTIVES

PilotSOEL aims to develop innovative, scalable, and cost-effective manufacturing processes for solid oxide electrolysis (SOEL) components while reducing the use of Critical Raw Materials (CRM), minimising waste generation, and increasing automation in stack assembly to lower manufacturing costs.

The project focuses on developing an environmentally friendly, water-based tape-casting process with fewer processing steps for half-cell production. Advanced thin protective barrier layers produced through ALD and PVD technologies, combined with microstructural optimisation of the cells, are expected to reduce cell resistance and improve both performance and durability during high-current operation.

In parallel, dense protective coatings produced by PVD will enhance the oxidation resistance of interconnectors, enabling the use of lower-cost alloys while maintaining long stack lifetimes.

PilotSOEL also integrates life-cycle assessment (LCA) and techno-economic analysis (TEA) to benchmark the developed manufacturing approaches against current state-of-the-art SOEL production technologies.

Overall, the project targets an increase in manufacturing readiness level (MRL) from MRL 4 to at least MRL 5 by the end of the project.

PROGRESS, MAIN ACHIEVEMENTS AND RESULTS

- A water-based tape co-casting process was successfully developed, enabling the production and testing of large SOEL cells with dimensions of 13 × 13 cm².
- A comprehensive review and selection of coating candidates for both air-side and fuel-side interconnector plates was completed.
- The design of the Optical Inspection System (OIS) for automated stack assembly and quality assurance was finalised.
- PVD and ALD coating processes were successfully developed, enabling deposition of doped ceria inter-diffusion barrier layers with total thickness variation limited to 15%.
- Long-term testing of project-developed cells demonstrated the targeted degradation rate of 1%/1 000 h at −0.85 A/cm² on several cell designs.
- SOEL stacks integrating the developed project components were successfully manufactured and characterised.
- Cell production activities incorporating up to 100% recycling of unsintered waste materials are ongoing, supporting improved circularity and resource efficiency.

FUTURE STEPS AND PLANS

- Preparation and assembly of the final 20 kW demonstration stack are ongoing.
- Activities targeting 100% recycling of waste materials in cell production are continuing to support circular manufacturing and resource efficiency objectives.

PROJECT TARGETS

Target source	Parameter	Unit	Target	Target achieved?
Project's own objectives	Stack assembly	kW	20	⚙
	Waste material recycle	%	Up to 100% recycle of waste tapes and comparable mechanical and electrochemical performance of the cell	
	Cells produced by a water-based tape casting process	Number of cells	30	
	Stack assembly defect recognition	%	> 95% accuracy in defect recognition by the optical inspection system	
	Developing a recycling process for unsintered waste materials	%	up to 100% recycling	✓
	Interconnector coating degradation	mOhm. cm²	5 (after 3 000 hours)	

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PRESSHYOUS

PRESSURIZED HYDROGEN PRODUCED BY HIGH TEMPERATURE STEAM ELECTROLYSIS

Project ID	101101337
PRR 2026	Pillar 1 - H_2 Production
Call Topic	HORIZON-JTI-CLEANH$_2$-2022-01-01
Project Total Costs	2 499 426.00
Clean H_2 JU Max. Contribution	2 499 426.00
Project Period	01-09-2023 - 31-08-2026
Coordinator Beneficiary	COMMISSARIAT À L'ÉNERGIE ATOMIQUE ET AUX ÉNERGIES ALTERNATIVES, FR
Beneficiaries	NEDERLANDSE ORGANISATIE VOOR TOEGEPAST NATUURWETENSCHAPPELIJK ONDERZOEK TNO, GENVIA, HYGEAR TECHNOLOGY AND SERVICES BV, TEKNOLOGIAN TUTKIMUSKESKUS VTT OY, ECOLE POLYTECHNIQUE FEDERALE DE LAUSANNE, HYGEAR HYDROGEN PLANT BV, HYGEAR FUEL CELL SYSTEMS BV, HAUTE ECOLE SPECIALISEE DE SUISSE OCCIDENTALE, AKTSIASELTS ELCOGEN, HYGEAR OPERATIONS BV, HYGEAR BV

https://presshyous-project.eu/

PROJECT AND GENERAL OBJECTIVES

PressHyous aims to advance the understanding of pressurised solid oxide electrolysis (SOEL) for hydrogen production, addressing key technical and system-level challenges to assess whether operating under pressure delivers overall efficiency and cost benefits for relevant industrial use cases.

The project focuses on delivering scientific and technological insights into SOEL operation under pressure, supporting faster industrial uptake. Two main outcomes are targeted: a validated lab-scale SOEL stack operating at up to 30 bar within a pressurised vessel (20 kWe scale, ~13.5 kg H_2/day), and a 10-bar pressurised stack concept operating without a pressure vessel, thereby reducing balance-of-plant complexity and cost.

These goals are achieved through improvements in key stack and system components, including cells, interconnects, sealings, protective coatings, and balance-of-plant elements such as vessels, heat exchangers, and compression systems, all optimised for operation up to 30 bar at current densities of at least 1 A/cm².

The project also investigates and validates long-term operation concepts for both pressurised configurations and short-stack operation without pressure vessels, enabling comparison of performance, cost, and scalability.

In parallel, model-based analyses support up to five industrial use cases, combining techno-economic analysis (TEA) and life cycle assessment (LCA) to evaluate performance against competing technologies such as AEL and PEMEL under pressurised conditions.

NON-QUANTITATIVE OBJECTIVES

- Develop and validate modelling tools across multiple scales to optimise SOEL components and system-level performance in high-pressure operation.
- Design and demonstrate a pressurised SOEL system operating up to 30 bar using a dedicated pressure vessel at 20 kWe scale.
- Develop an alternative pressurised stack concept capable of operation up to 10 bar without a pressure vessel, reducing balance-of-plant complexity and cost.
- Improve key system components (cells, interconnects, sealings, coatings, and balance-of-plant) for reliable operation under pressurised conditions up to 30 bar and ≥1 A/cm².
- Reduce hydrogen production costs by minimising downstream compression requirements through direct pressurised electrolysis.
- Decrease energy consumption by reducing the number of hydrogen compression stages required in large-scale systems.
- Provide techno-economic analysis (TEA) for multiple use cases to evaluate performance and competitiveness against existing technologies.
- Conduct life cycle assessment (LCA) to ensure comparability and assess environmental impacts of pressurised hydrogen production pathways.

PROGRESS, MAIN ACHIEVEMENTS AND RESULTS

- Definition of use cases with the Advisory Board, including selection of relevant industrial scenarios.
- System modelling and hazard identification to assess the feasibility of configurations and support stack and system development.
- Design and manufacturing of two next-generation cell designs for operation in electrolysis mode up to 30 bar.
- Successful operation of a pressurised stack up to 7 bar, achieving 1.5 A/cm² at thermoneutral voltage and 750 °C.
- Design of an integrated lab-scale SOEL system including stack and pressure vessel for operation up to 30 bar at 20 kWe scale (≈13.5 kg H_2/day).
- Selection and definition of Balance of Plant components (vessels, compression system, heat exchangers, etc.) for the pressurised setup.
- Implementation of techno-economic (TEA) and life cycle (LCA) analyses, with first results on selected use cases.

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FUTURE STEPS AND PLANS

- Continued improvement of cells and stack components for pressurised hydrogen production, including interconnects, sealings, protective coatings, and stack clamping systems.
- Finalisation of the design, assembly, installation, and validation of a 20 kWe lab-scale SOEL system with integrated pressure vessel for operation up to 30 bar (≈13.5 kg H_2/day).
- Investigation of an alternative pressurised stack concept operating without a pressure vessel to reduce balance-of-plant cost and complexity.
- Estimation of cell and stack lifetime performance for operation up to 30 bar in non-vessel configurations.
- Development of model-based insights for up to five use cases, comparing both pressurised concepts and supporting large-scale deployment scenarios.
- Techno-economic (TEA) and life-cycle (LCA) assessments of selected use cases, benchmarking against AEL and PEMEL under pressurised operation.
- Demonstration of the industrial viability of high-pressure SOEL technology and strengthening its role in decarbonising hard-to-abate sectors.

PROJECT SRIA TARGETS

Target source	Parameter	Unit	Target	Target achieved?
Project's own objectives	Current density	A/cm²	-1	✓
	Pressure	bar	5 - 30	
	Lifetime	%/kh	1	
	H_2 production cost	€/kg	3	

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PROMETEO

HYDROGEN PRODUCTION BY MEANS OF SOLAR HEAT AND POWER IN HIGH TEMPERATURE SOLID OXIDE ELECTROLYSERS

Project ID	101007194
PRR 2026	Pillar 1 - H_2 Production
Call Topic	FCH-02-2-2020
Project Total Costs	2 662 654.82
Clean H_2 JU Max. Contribution	2 499 531.25
Project Period	01-01-2021 - 31-08-2026
Coordinator Beneficiary	AGENZIA NAZIONALE PER LE NUOVE TECNOLOGIE, L'ENERGIA E LO SVILUPPO ECONOMICO SOSTENIBILE, IT
Beneficiaries	SNAM SPA, STAMICARBON B.V., ATENA SCARL - DISTRETTO ALTA TECNOLOGIA ENERGIA AMBIENTE, GREEN CAPITAL POWER SL, CAPITAL ENERGY SERVICES SLU, ALKEYMIA GROUP SL, ANGUITA FOTOVOLTAICO SL, NEXTCHEM TECH SPA, FONDAZIONE BRUNO KESSLER, ECOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE, SOLYDERA SA, UNIVERSITÀ DEGLI STUDI DI NAPOLI PARTHENOPE, Fundación IMDEA Energía

https://prometeo-project.eu

PROJECT AND GENERAL OBJECTIVES

PROMETEO aims to produce hydrogen from renewable heat and power sources using solid oxide electrolysis (SOE) in areas with low electricity prices associated with photovoltaic or wind power. A 25 kWe SOE prototype (approximately 15 kg/day of H_2 production) will be developed and validated in a real production environment, combined with intermittent sources; non-programmable renewable electricity and high-temperature solar heat with thermal energy storage (TES). Partial-load operation, transients and hot stand-by periods will be studied.

NON-QUANTITATIVE OBJECTIVES

Demonstrate the capability to transfer technology from component developers to system integrators and end users.

PROGRESS, MAIN ACHIEVEMENTS AND RESULTS

- Definition of end-user cases.
- Setting up preliminary process flow diagrams.
- Identification and laboratory validation of the TES system.
- Development of process modelling tools.

FUTURE STEPS AND PLANS

- Experimental determination of the performance map for the SOE stack and the plant balance on a laboratory scale.
- Finalisation of process flow diagrams for the 25 kWe pilot plant under different operation modes.
- Design and construction of integrated pilot plant (25 kWe).
- Shipping of pilot plant to project site.
- Analysis of case studies on multi-MW scale based on finalised process flow diagrams for the pilot plant (25 kWe).

PROJECT TARGETS

Target source	Parameter	Unit	Target	Target achieved?
Project's own objectives	Demonstrate the production of hydrogen by operation of >1 000 hours: Hours of experimental validation runs of the prototype	hours	1 000	
	Obtain Solar-to-Hydrogen energy conversion efficiency from global solar radiation to H_2 energy (LHV basis)	%	10	

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PROTOSTACK

TUBULAR PROTON-CONDUCTING CERAMIC STACKS FOR PRESSURIZED HYDROGEN PRODUCTION

Project ID	101101504
PRR 2026	Pillar 1 - H_2 Production
Call Topic	HORIZON-JTI-CLEANH$_2$-2022-01-02
Project Total Costs	2 497 013.75
Clean H_2 JU Max. Contribution	2 497 013.75
Project Period	01-01-2023 - 31-12-2026
Coordinator Beneficiary	SINTEF AS, NO
Beneficiaries	DEMCON LIFE SCIENCES and HEALTHEINDHOVEN B.V., UNIVERSITÀ DEGLI STUDI DI NAPOLI PARTHENOPE, COORSTEK MEMBRANE SCIENCES AS, SHELL GLOBAL SOLUTIONS INTERNATIONAL BV, ATENA SCARL - DISTRETTO ALTA TECNOLOGIA ENERGIA AMBIENTE, AGENZIA NAZIONALE PER LE NUOVE TECNOLOGIE, L'ENERGIA E LO SVILUPPO ECONOMICO SOSTENIBILE, AGENCIA ESTATAL CONSEJO SUPERIOR DE INVESTIGACIONES CIENTÍFICAS, DEMCON HIGH-TECH SYSTEMS EINDHOVEN B.V., DEMCON HIGH-TECH SYSTEMS ENSCHEDE BV

https://protostack.eu/

PROJECT AND GENERAL OBJECTIVES

PROTOSTACK will create a radically new, compact and modular PCCEL stack design with an integrated hot-box for hydrogen production and delivery at pressures up to 30 bar. The stack will be demonstrated at 5 kW and will provide a clear pathway for scale-up to systems in the hundreds-of-kW range. These achievements will serve as strong proof of technological feasibility, demonstrating the advancement of PCCEL technology from TRL 2 to TRL 4.

To achieve these objectives, the consortium brings together leading academic and industrial partners with world-class expertise in proton ceramic technologies, electrolysers, membrane reactors, materials development, electrochemistry, and process engineering.

NON-QUANTITATIVE OBJECTIVES

The overall consortium will engage in extensive communication and dissemination activities to ensure maximum impact of the project's outcomes, and the industry partners have high ambitions for the business exploitation and commercialisation of PROTOSTACK technology.

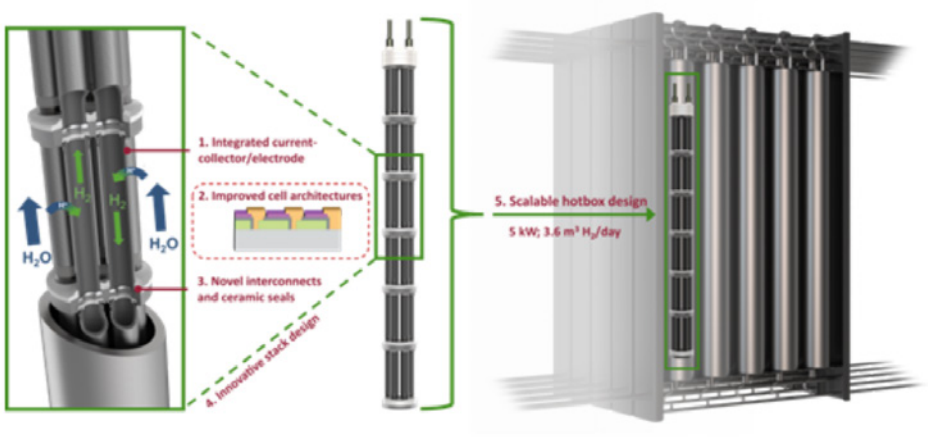
PROGRESS, MAIN ACHIEVEMENTS AND RESULTS

The final designs of the hot-box and stack concept have been completed within the first year, and the production of stack components is well underway. The first year has primarily focused on validating key cell and stack components for functionality, scalable manufacturing, and stability, as well as producing the first short stack using the new design to validate the overall stack concept.

In parallel, the project co-organised an Autumn School in Valencia with more than 100 participants, mainly graduate students.

FUTURE STEPS AND PLANS

- Continue the validation and optimisation of cell and stack components, with focus on durability and performance benchmarking under varying operating conditions and delivery pressures.
- Construction and integration of the new hot-box, including updated balance of plant (BoP) and safety assessment.
- Detailed techno-economic (TEA) and life cycle (LCA) analyses for selected integration scenarios and use cases of the technology.



Stack concept and overview of key innovations in PROTOSTACK

PRR 2026 PILLAR
H_2 Production

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REACTT

RELIABLE ADVANCED DIAGNOSTICS AND CONTROL TOOLS FOR INCREASED LIFETIME OF SOLID OXIDE CELL TECHNOLOGY

Project ID	101007175
PRR 2026	Pillar 1 - H_2 Production
Call Topic	FCH-02-3-2020
Project Total Costs	2 712 322.50
Clean H_2 JU Max. Contribution	2 712 322.50
Project Period	01-01-2021 - 31-05-2025
Coordinator Beneficiary	INSTITUT JOZEF STEFAN, SI
Beneficiaries	AGENZIA NAZIONALE PER LE NUOVE TECNOLOGIE, L'ENERGIA E LO SVILUPPO ECONOMICO SOSTENIBILE, ÉCOLE POLYTECHNIQUE FÉDÉRALES DE LAUSANNE, SOLYDERA S.A., UNIVERSITÀ DEGLI STUDI DI SALERNO, COMMISSARIAT À L'ÉNERGIE ATOMIQUE ET AUX ÉNERGIES ALTERNATIVES, TEKNOLOGIAN TUTKIMUSKESKUS VTT OY, BITRON S.P.A., HAUTE ÉCOLE SPÉCIALISÉE DE SUISSE OCCIDENTALE, AVL LIST GMBH

http://www.reactt-project.eu

PROJECT AND GENERAL OBJECTIVES

REACTT will realise a monitoring, diagnostic, prognostic, and control (MDPC) tool for reversible solid oxide cell (rSOC) stacks and systems to increase stack lifetime by 5 %; reach a production loss rate of 1.2 %/1 000 h; increase availability by 3 %, targeting overall availability of 98 %, and reduce operation and maintenance costs by 10 %. The additional cost of the MDPC tool will not exceed 3 % of the overall system manufacturing costs.

NON-QUANTITATIVE OBJECTIVES

- Education/training. Inclusion of the topic of solid oxide cell technologies in MSc and PhD study programmes.
- Public awareness. The web page and the dissemination material are the first step towards raising public awareness.
- Safety. Fault detection, isolation, and mitigation in solid oxide electrolyser cells (SOECs) / solid oxide fuel cells (SOFCs) help prevent process disruption and potential hazards.
- Regulations and standards. A new work item proposal is to be submitted to Technical Committee 105 of the International Electrotechnical Commission.

PROGRESS, MAIN ACHIEVEMENTS AND RESULTS

- Test protocols were developed, including fingerprint tests under normal operation, as well as fault-emulation tests to better understand stack response and recovery after faults.
- Four short stacks (6 cells each) and three full stacks with 70 repeating elements were delivered by the manufacturer SolydEra.
- An extensive experimental campaign was conducted by EPFL on a segmented cell stack and by CEA and EPFL on SolydEra SOEC short stacks, accumulating over 11 000 hours and 2 100 hours of operation, respectively. Fault scenarios included high steam conversion, H_2 inlet starvation, and humidity in the O_2 electrode, supported by more than 1 000 EIS measurements (sinusoidal and DRBS excitation).
- A second upgraded release of the MDPC hardware platform was developed, enabling execution of monitoring, diagnostic, prognostic, and control algorithms with low cost and high computational performance.
- Firmware for the MDPC platform was implemented, including embedded algorithms, data management structures, and communication with external control units.
- An innovative excitation module (EM) was developed to enable stack perturbation using both conventional sinusoidal and discrete random binary signal (DRBS) methods.
- A real-time optimisation (RTO) algorithm was developed and extensively validated on a 5 kW SOEC simulator to ensure optimal system efficiency during operation.
- A comprehensive diagnostic framework was established, combining passive (data- and model-based) and active (EIS-based perturbation) approaches, with fault identification expressed in probabilistic terms using equivalent circuit models.
- A multiscale model was developed linking global SOEC performance to electrode-level reaction mechanisms.
- A supervisor module was created to coordinate and manage MDPC functional tasks.
- The MDPC tool was experimentally validated on three SolydEra full stacks at EPFL, CEA, and VTT.
- Diagnostic algorithms were successfully validated for pump faults, steam flow instability, and noise-related disturbances.
- The RTO algorithm was validated on a 70-cell SolydEra stack at EPFL, demonstrating autonomous operation within safe and optimal conditions without manual tuning.
- A data-driven prognostic algorithm was implemented to predict health indicator trends online.

FUTURE STEPS AND PLANS

- The project is formally completed.
- Activities related to the publication and dissemination of project results are still ongoing.
- Consortium members are developing follow-up collaborations, including two new FCH JU project proposals.
- Two bilateral project proposals are being prepared between IJS and EPFL.

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REDHY

REDOX-MEDIATED ECONOMIC, CRITICAL RAW MATERIAL FREE, LOW CAPEX AND HIGHLY EFFICIENT GREEN HYDROGEN PRODUCTION TECHNOLOGY

Project ID	101137893
PRR 2026	Pillar 1 - H_2 Production
Call Topic	HORIZON-JTI-CLEANH$_2$-2023-01-01
Project Total Costs	2 998 988.75
Clean H_2 JU Max. Contribution	2 990 238.75
Project Period	01-01-2024 - 31-12-2027
Coordinator Beneficiary	DEUTSCHES ZENTRUM FÜR LUFT- UND RAUMFAHRT E. V., DE
Beneficiaries	CUTTING-EDGE NANOMATERIALS CENMAT UG HAFTUNGSBESCHRÄNKT, UNIRESEARCH BV, INDUSTRIE DE NORA SPA-IDN, CONSIGLIO NAZIONALE DELLE RICERCHE, UNIVERSITÀ POLITECNICA DE VALENCIA, CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE CNRS

https://redhy.eu/

PROJECT AND GENERAL OBJECTIVES

The REDHy project addresses key limitations of current electrolyser technologies by fundamentally rethinking water electrolysis, enabling performance beyond state-of-the-art systems, and positioning water electrolysis as a central technology in the emerging hydrogen economy. The REDHy concept is designed to be adaptable, durable, environmentally sustainable, intrinsically safe, and cost-efficient, enabling economically viable green hydrogen production at significantly higher current densities than conventional electrolysers.

It builds on results from multiple EU-funded initiatives and is protected by a DLR patent (TRL 2), bringing together academic and industrial partners with complementary expertise. Unlike state-of-the-art systems, REDHy is fully free of critical raw materials and does not rely on fluorinated membranes or ionomers, while still targeting key 2024 performance benchmarks.

In line with Europe's circular economy action plan, the project aims to develop a 5-cell stack with an active area exceeding 100 cm² per cell and a nominal power of 1.5 kW, capable of operating over a wide dynamic range using stable, cost-effective materials. The system is designed to achieve efficient hydrogen production at high current densities (1.5 A/cm² at 1.8 V per cell), low operating temperature (60 °C), and relevant hydrogen output pressure (15 bar).

The final objective is to deliver and validate a laboratory prototype that operates for 1 200 hours with a degradation rate below 0.1% per 1 000 hours, thereby reaching TRL 4. This phase will demonstrate the potential of the REDHy approach, support future investment decisions, and highlight the importance of innovative electrolysis concepts in achieving climate neutrality targets.

NON-QUANTITATIVE OBJECTIVES

- Development of highly efficient, durable, and fluorine-free materials for REDHy technology, including membranes, ionomers, electrodes, redox mediators, and heterogeneous catalysts.



- Scale-up of materials into a large-area short stack (5 cells, >100 cm² per cell) targeting >1.5 kW nominal power, aligned with circular economy principles.
- Validation of stack efficiency and robustness under dynamic operating conditions typical of high renewable energy penetration.
- Elimination of critical raw materials and fluorinated components at the stack and system level.
- Optimisation of porous electrode structures to improve mass transport and overall energy efficiency.
- Integration of highly reversible redox mediators to reduce energy consumption to ≤48 kWh/kg H_2.
- Reduction of interface resistances across all cell components to achieve system efficiencies >82%.
- Demonstration of decoupled oxygen and hydrogen production enabling stable operation at ≥5% partial load while maintaining <0.4% H_2 in O_2.
- Exploration and validation of direct seawater electrolysis capability within the REDHy system.
- Integration of the short stack into a prototype full system for operational validation.

- Long-term demonstration of REDHy operation at 1.5 A/cm² with ≤48 kWh/kg H_2 consumption over ≥1 200 hours and degradation ≤0.1% per 1 000 hours.

PROGRESS, MAIN ACHIEVEMENTS AND RESULTS

- Completion of theoretical modelling and synthesis optimisation of redox mediators to identify optimal candidates for system operation.
- Further development and optimisation of membranes and ionomers for bipolar membrane configurations to improve stability and performance.
- Advancement of electrode modelling, including electron transfer kinetics analysis and refinement of 3D printing-based electrode fabrication.
- Selection and scale-up of electrode materials based on improved performance criteria and durability testing.
- Continued development of heterogeneous catalysts and expansion of single-cell testing under relevant operating conditions.
- Finalisation of the 5-cell stack design and progression towards assembly and integrated testing.
- Ongoing collection and analysis of LCA data to assess environmental performance and sustainability impacts.
- Continued dissemination activities including newsletters, website updates, social media engagement, and workshop organisation.
- Consolidation of project results to support system integration, validation, and future scale-up activities.

FUTURE STEPS AND PLANS

- Development of a cost-effective, efficient, robust, scalable, and environmentally friendly electrolysis technology for green hydrogen production in line with the Renewable Energy Directive (RED) 2018/2001 delegated act.
- Support for renewable energy storage through conversion of surplus electricity into hydrogen.
- Expansion of green hydrogen supply for multiple industrial applications, including high-grade heat for steel production.
- Provision of ultra-pure hydrogen for chemical industry applications.
- Enablement of hydrogen supply for transport and mobility sectors.
- Contribution to long-term societal and environmental goals through decarbonisation and improved energy system flexibility.

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	Critical raw material-free catalyst	mg/W	0		PEMWE: 2.5 / AWE: 0.6	2020
	Energy consumption	kWh/kg(H_2)	48		PEMWE: 55 / AWE: 50	
	Current density	A/cm²	1.5		PEMWE: 2.2 / AWE: 0.6	
	Degradation	% / 1 000 h	0.1		PEMWE: 0.19 / AWE: 0.12	
	Partial load	%	5		N/A	N/A
	H_2 conc. in O_2	%	0.4			
	Short stack	Number of cells	5			
	Active area	cm²	100			
	Hours of operation (system)	hours	1 200			
	Energy efficiencies	%	82			
	Nominal power	kW	1.5			

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SEA4VOLT

SEA WATER ELECTROLYSIS BY AEM TECHNOLOGY FOR VARIOUS LIQUID FEEDS WITHOUT PRE-TREATMENT

Project ID	101192235
PRR 2026	Pillar 1 - H_2 Production
Call Topic	HORIZON-JTI-CLEANH$_2$-2024-01-03
Project Total Costs	3 996 557.00
Clean H_2 JU Max. Contribution	3 996 557.00
Project Period	01-09-2025 - 31-08-2028
Coordinator Beneficiary	TEKNOLOGIAN TUTKIMUSKESKUS VTT OY, FI
Beneficiaries	POLITECHNIKA GDANSKA, AALTO KORKEAKOULUSAATIO SR, F6S EU TECH INNOVATION NETWORK DESIGNATED ACTIVITY COMPANY, FUNDACIÓN CIDAUT, OU STARGATE HYDROGEN SOLUTIONS, HYDROLITE LTD, FRAUNHOFER GESELLSCHAFT ZUR FÖRDERUNG DER ANGEWANDTEN FÖRSCHUNG EV

https://sea4volt.eu/

PROJECT AND GENERAL OBJECTIVES

Sea4Volt aims to develop a novel low-temperature anion-exchange membrane (AEM) electrolyser designed to operate efficiently, selectively, and durably on direct seawater feed. Running from September 2025 to August 2028, the project focuses on advancing seawater electrolysis for practical, scalable applications.

By integrating PFAS-free membranes, corrosion-resistant components, and cost-effective materials, Sea4Volt aims to reduce the cost of green hydrogen production while enabling the direct use of seawater, thereby avoiding competition with scarce freshwater resources. The project also contributes to brine valorisation and supports more sustainable water management strategies within the hydrogen value chain.

NON-QUANTITATIVE OBJECTIVES

- Understand seawater–material interactions using experimental methods and machine-learning tools.
- Develop PFAS-free membranes and corrosion-resistant components for seawater electrolysis systems.
- Create low-PGM electrodes that reduce precious metal use and resist seawater-induced degradation and poisoning.
- Design and build a new anion exchange membrane (AEM) single-cell and multi-cell stack prototype for direct seawater electrolysis.
- Develop performance and durability testing protocols for both artificial and real seawater conditions.
- Design an integrated process flowsheet for a Net Zero Liquid Discharge approach, linking seawater electrolysis with brine valorisation.

PROGRESS, MAIN ACHIEVEMENTS AND RESULTS

- Early project milestones successfully achieved, establishing a solid operational and coordination framework.
- Quality management and data management systems approved and implemented across the consortium.
- Project website launched and fully operational, supporting visibility and dissemination activities.
- Communication materials were developed and made publicly available to support outreach and engagement.
- Collaboration links initiated with external projects to strengthen knowledge exchange and networking.
- Key seawater electrolysis materials and components (catalysts, membranes, coatings, electrodes, and hardware) identified and development initiated.
- Initial modelling framework for single-cell design established, including defined operating parameters.
- Experimental data collection from partners is underway to support model validation and refinement.
- Preparatory work for alkaline baseline stack and seawater-operated prototype assembly progressing.
- System-level sustainability assessment framework established to guide environmentally responsible design and scalability.

FUTURE STEPS AND PLANS

- Testing and validation of key seawater electrolysis materials and components (catalysts, membranes, coatings, plates, and supporting hardware) under relevant performance and durability conditions.
- Continued refinement and validation of the single-cell model using experimental data provided by project partners.
- Preparation and execution of initial full testing campaigns for the developing cell architecture.

- Use of validated design parameters to support the assembly of baseline and seawater-operated stack prototypes.
- Planned shipment and on-site testing of first prototype systems in the coming months.
- Upscaling of key materials and stack components from laboratory scale to stack-compatible dimensions, supported by mechanical design and quality control tools.
- Integration of new technical results into life-cycle assessment (LCA) and techno-economic (TEA) models to benchmark performance against state-of-the-art technologies.
- Expansion of dissemination and stakeholder engagement activities through scientific events, communication initiatives, and strengthened external collaborations.
- Support for long-term impact, visibility, and exploitation of project results through increased outreach and cooperation activities.

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	Energy consumption @ nominal load	kWh/kg	48		55	2020
	CAPEX	€ (kg/d) €/kW	600 300		2 259 1 000	
	O&M cost	€/(kg/day)/y	21		34	
	Hot idle ramp time	sec	5		30	
	Cold start ramp time	sec	150		1 800	
	Degradation	%/1 000h	0.5		> 1.0	
	Current density	A/cm^3	1,5		0.5	

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SEAL-HYDROGEN

STABLE AND EFFICIENT ALKALINE WATER ELECTROLYSERS WITH ZERO CRITICAL RAW MATERIALS FOR PURE HYDROGEN PRODUCTION

Project ID	101137915
PRR 2026	Pillar 1 - H_2 Production
Call Topic	HORIZON-JTI-CLEANH$_2$-2023-01-01
Project Total Costs	3 000 048.75
Clean H_2 JU Max. Contribution	3 000 000.00
Project Period	01-01-2024 - 31-12-2026
Coordinator Beneficiary	UNIVERSITAT DE VALENCIA, ES
Beneficiaries	FORSCHUNGSZENTRUM JULICH GMBH, SIEMENS ENERGY GLOBAL GMBH and CO. KG, MATTECO TEAM SL, HORIBA FRANCE SAS

https://seal-hydrogen.eu/

PROJECT AND GENERAL OBJECTIVES

SEAL-HYDROGEN aims to develop a new class of alkaline water electrolysers (AWE) that combine the robustness of conventional systems with advances in materials science, catalyst design, and process engineering.

The main objectives are:

- Optimisation and upscaling of LDH catalyst manufacturing for oxygen evolution reaction (OER) and hydrogen evolution reaction (HER) in alkaline water electrolysis (AWE).
- Validation of catalyst activity and stability using electrochemical methods combined with in-operando Raman spectroscopy.
- Design and testing of innovative alkaline water electrolysis (AWE) cell architectures.
- Validation of a 6-cell AWE stack under relevant operating conditions.

NON-QUANTITATIVE OBJECTIVES

SEAL-HYDROGEN adopts a multidisciplinary approach to develop a highly efficient and durable 6-cell alkaline water electrolysis (AWE) stack, with performance targets that are competitive with state-of-the-art AEM and PEM electrolysers.

Other objectives include:

- Increasing the technology readiness level (TRL) of the stack to enable integration into large-scale systems.
- Exploiting project results following a circular economy approach.
- Communicating and disseminating all project activities through peer-reviewed publications, workshops, and broader outreach activities.

PROGRESS, MAIN ACHIEVEMENTS AND RESULTS

- Up to 75 different NiFe-LDH catalyst compositions were synthesised, characterised, and evaluated for the oxygen evolution reaction (OER) in alkaline water electrolysis.
- Comprehensive physicochemical characterisation was performed by UVEG, supporting detailed material screening.
- Electrochemical testing conducted by UVEG and HiERN, combined with Raman spectroscopy analysis by HORIBA, enabled robust performance assessment.
- Five top-performing catalyst compositions were selected for in-depth evaluation, including formulations free of critical raw materials (CRMs).
- MATTECO successfully up-scaled selected catalyst compositions to a kilogram scale through an adapted synthesis route for LDH production.
- Dedicated testing setups were developed by HiERN and HORIBA to simultaneously assess electrochemical performance and chemical stability on catalyst-coated metallic substrates.
- Promising catalyst formulations are currently being tested in single-cell configurations at SIEMENS ENERGY for validation under relevant operating conditions.

FUTURE STEPS AND PLANS

- Development of multiple advanced approaches by HiERN, UVEG, and SIEMENS ENERGY to enhance catalyst and electrolyser performance.
- Integration of ionomers into catalysts to improve electrode adhesion, stability, and electrochemical performance.
- Investigation of direct catalyst coating on separators as an alternative to traditional catalyst-coated substrates.
- Operation under dry cathode conditions with controlled gas crossover to improve efficiency and safety.
- Evaluation of bipolar membrane concepts as potential replacements for conventional separators.
- Optimisation of flow field and flow structure design to improve fluid distribution and catalyst utilisation.
- Use of MATTECO-produced electrodes by SIEMENS ENERGY for integration into the 6-cell stack for testing and validation.

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PROJECT SRIA TARGETS

Target source	Parameter	Unit	Target	Target achieved?
Project's own objectives	Electricity consumption in stacks	kWh/Kg	48	⚙
	Partial load operation	%	5	
	Stability	Current: A/cm^2	1	
	CRM	mg/W Pt	< 0.3	✓

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SWEETHY

DIRECT SEAWATER ELECTROLYSIS TECHNOLOGY FOR DISTRIBUTED HYDROGEN PRODUCTION

Project ID	101192342
PRR 2026	Pillar 1 - H_2 Production
Call Topic	HORIZON-JTI-CLEANH$_2$-2024-01-03
Project Total Costs	3 999 768.04
Clean H_2 JU Max. Contribution	3 999 768.04
Project Period	01-03-2025 - 28-02-2029
Coordinator Beneficiary	RISE RESEARCH INSTITUTES OF SWEDEN AB
Beneficiaries	INSTITUT DE LA CORROSION SASU, CONSIGLIO NAZIONALE DELLE RICERCHE, PROPULS GMBH, CUTTING-EDGE NANOMATERIALS CENMAT UG HAFTUNGSBESCHRANKT, UNIRESEARCH BV, DEUTSCHES ZENTRUM FÜR LUFT- UND RAUMFAHRT EV, SINTEF AS, FUNDACIÓN CIDETEC

https://sweethy.eu/

PROJECT AND GENERAL OBJECTIVES

The SWEETHY project aims to develop an innovative European direct seawater electrolysis platform to improve energy efficiency, cost-effectiveness, material durability, by-product utilisation, renewable power integration, and overall environmental performance.

The specific objectives are:

- Develop high-performance, cost-effective, and durable materials for direct seawater anion-exchange membrane water electrolyser (AEMWE) components.
- Design, develop, and test an energy-efficient and stable 0.5 kW AEMWE short stack operating with direct seawater feed.
- Identify opportunities for industrial symbiosis through by-product utilisation and provision of system services to the grid.
- Minimise the environmental impact of the electrolyser stack and overall system.

NON-QUANTITATIVE OBJECTIVES

- The materials for each component used in the SWEETHY AEMWE short-stack prototype will be carefully selected to ensure high performance and durability in saline conditions.
- A scalable electrolyser design concept based on hydraulic cell compression will enable transition from single-cell testing to prototype scale while preserving operating conditions and maintaining performance during upscaling.
- Techno-economic analysis (TEA) and optimisation will identify opportunities for efficient system integration, including valorisation of waste heat, oxygen, and brine, as well as provision of grid support services, while reducing the levelised cost of hydrogen/energy.
- Life cycle assessment (LCA) will support material selection and system design to minimise environmental impact. At the same time, TEA-driven optimisation will enable industrial symbiosis, improved resource efficiency, reduced waste generation, and lower reliance on external resource supply.

PROGRESS, MAIN ACHIEVEMENTS AND RESULTS

- PGM-free HER catalysts were synthesised (up to 5 g) and characterised; materials include Ni- and Mo-based powders, Ni-based electrodeposited alloys, and Ni nanowire-based PTLs. Initial three-electrode tests have been performed, with single-cell seawater testing planned for early 2026.
- PGM-free OER catalysts were synthesised (0.8–1.5 g) and characterised, including NiFe and NiMn LDHs and Ni–Mo/Ni–Mo–S alloys. Three-electrode testing has been completed, with single-cell seawater testing planned.
- The PFAS-free AionFLX™ membrane was scaled to 900 cm² and tested for over 2 000 h, achieving 1.9 V at 2 A/cm² with excellent durability in non-seawater conditions; further optimisation of ion selectivity is ongoing.
- AionFLX™-based ionomer binders showed good stability, with further development in progress.
- Corrosion testing of Ti and stainless-steel components in seawater revealed significant degradation, leading to the development of protective coatings (VPS/APS) and electrodeposition approaches.
- Work on the corrosion resistance of pipe materials has started.
- Testing protocols and benchmark materials have been harmonised across partners.
- Stakeholder engagement has informed system design, including environmental, circularity, safety, and socio-economic considerations, supporting upcoming LCA activities.

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FUTURE STEPS AND PLANS

- Continue project management activities and deliver a preliminary exploitation plan, with updates to the data management and ethics plans.
- Organise the European Symposium on Durability Issues in Low-Temperature Electrolysers, bringing together ANEMEL, PROTIS, SWEETHY, and related seawater electrolysis projects (HySeas, Sea4Volt, ASTERISK) for scientific exchange and networking.
- Conclude electrocatalyst development for seawater electrolysis by delivering >2 g of catalysts for MEA testing, alongside reports on stability and post-operation analysis.
- Finalise membrane and ionomer development, delivering targeted materials and associated reports.
- Complete corrosion studies of uncoated bipolar plates, PTLs, and pipe materials, and finalise anticorrosion coating development.
- Begin integration of newly developed materials into membrane-electrode assemblies (MEAs).
- Complete benchmark testing in single cells and start performance optimisation of new seawater electrolysis materials.
- Finalise a 5-cell short stack and initiate seawater operation testing, while starting design of a 10-cell prototype stack.
- Complete screening life cycle assessment and begin full LCA and techno-economic studies, including system integration and symbiosis analysis.
- Start social LCA activities and complete the first reporting period.

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	Anode and cathode electrode overpotentials vs thermoneutral potential at 0.5 A/cm^2 under direct seawater operation	mV	< 150		N/A	N/A
	Anode and cathode catalysts' degradation rate	%/h	0.01-0.05		> 0.01, for pure water AEMEL	2020
	Membrane conductivity at 80°C in alkaline seawater	mS/cm	> 50		40	2023
	Durable anti-corrosion coatings for BPP and PTL: interfacial contact resistance	mΩ cm^2	≤ 10		N/A	N/A
	Electricity consumption of AEMWE stack at nominal load (> 0.5 A/cm^2)	kWh/kg	53		55, for pure water AEMEL	2020
	AEMWE stack test	hours	> 2 000		N/A	N/A
	AEMWE stack degradation per 1000h of operation	%	< 10		> 1.0	2020
	Salinity in the electrolyte during the AEMWE stack testing	g/L	> 35		33-35	2019
	Current density	A/cm^2	0.5		0.5	2020
	Use of critical raw material as a catalyst	mg / W	< 0.4		1.7	2020

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X-SEED

EXPERIMENTAL SUPERCRITICAL ELECTROLYSER DEVELOPMENT

Project ID	101137701
PRR 2026	Pillar 1 - H_2 Production
Call Topic	HORIZON-JTI-CLEANH$_2$-2023-01-01
Project Total Costs	2 989 495.00
Clean H_2 JU Max. Contribution	2 989 495.00
Project Period	01-01-2024 - 30-06-2027
Coordinator Beneficiary	ACONDICIONAMIENTO TARRASENSE ASOCIACIÓN, ES
Beneficiaries	INDUSTRIE DE NORA SPA-IDN, DANMARKS TEKNISKE UNIVERSITET, PARTICULAR MATERIALS SRL, SNAM SPA

https://www.xseedproject.eu/

PROJECT AND GENERAL OBJECTIVES

X-SEED aims to develop an innovative alkaline membrane-less electrolyser operating under supercritical water conditions (>374 °C; >220 bar), enabling the production of high-quality hydrogen at pressures above 200 bar. The concept relies on novel catalysts and electrode materials that are designed, synthesised, and characterised to achieve high efficiency and durability.

Through multiscale modelling and advanced cell design, the system ensures laminar fluid flow, enabling effective separation of hydrogen and oxygen without a membrane.

The technology will be validated at laboratory scale (TRL 4), including both a single cell and a 5-cell stack, targeting high-performance metrics such as:

- Energy efficiency of ~42 kWh/kg H_2
- Current density above 3 A/cm²
- Degradation rate of ~1% per 1 000 hours

The project also integrates circularity and sustainability principles into its design choices, limiting the use of critical raw materials (to below 0.3 mg/W) and exploring the use of wastewater for both catalyst synthesis and as a potential electrolyte source.

Beyond its technological advances, X-SEED aims to accelerate the development of the hydrogen ecosystem and support Europe's climate objectives, reinforcing its position as a leader in green energy innovation, production, and export.

NON-QUANTITATIVE OBJECTIVES

- Maximise the efficiency, sustainability and stability of the innovative nanostructured catalysts and electrodes for anode and cathode based on earth-abundant materials.
- Improve the efficiency, cost, and durability of the electrolyser by developing an innovative electrolysis cell and short stack that does not use an electrolysis membrane, based on use in supercritical water conditions (SPWC).
- Gather evidence of the sustainability and circularity benefits of SPWC electrolyser over current solutions (proton-exchange membrane electrolysis (PEMEL), alkaline water electrolysis (AWEL)) by assessing the economic (life cycle costing), environmental (life cycle assessment) and social (social life-cycle assessment) impacts.
- Demonstrate the improvement of the sustainability and cost competitiveness of the SPWC electrolyser in comparison with PEMEL and AWEL technology.
- Contribution to scientific advances and creation of social awareness and acceptance of the green H_2 economy.
- Ensuring exploitation of materials, components, and technologies developed in the X-SEED project.

PROGRESS, MAIN ACHIEVEMENTS AND RESULTS

- Membrane-less single cell and 5-cell stack were designed using 2D and 3D multiphysics simulations, optimised for high-purity hydrogen and oxygen outlet streams.
- A dedicated reactor was developed and validated to measure electrolyte conductivity under high-temperature, high-pressure, and supercritical conditions.
- The new measurement capability expands the limited existing datasets and enables improved electrolyte characterisation.
- Results support the development of improved equations of state (EOS), advanced simulation tools, and industrial process design.
- Multiple catalysts were synthesised using electrospinning and continuous hydrothermal flow synthesis methods.
- Electrodes were fabricated using the developed catalyst materials.
- First catalysts derived from industrial wastewater were successfully synthesised, supporting circularity objectives.
- Extensive electrochemical characterisation of catalysts and electrodes was performed, enabling identification of the best-performing electrode materials.

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FUTURE STEPS AND PLANS

- Completion of catalyst and electrode production, including full material characterisation and stability assessment.
- Fabrication and integration of the supercritical electrolysis cell into a dedicated test rig for evaluation of renewable hydrogen production using a membrane-less configuration fed with supercritical water.
- Conduct of sustainability assessments (LCA, LCC, and LCA-s) to evaluate the techno-economic viability and environmental impacts of the X-SEED electrolysis technology.

PROJECT TARGETS

Target source	Parameter	Unit	Target	Target achieved?
Project's own objectives	Metals (Ni, Co, Cu, etc.) for the catalyst used come from wastewater (e.g. mining, galvanic, etc.) using the Continuous Hydrothermal Flow Synthesis process	% of metals from wastewater	50	
	Catalysts with high surface area	m^2/g	> 10	
	Feedback received through one workshop or participatory activity, as part of the social assessment	Number of feedback	> 15	
	External interactions through social media, workshops, and disclosure articles	Number	5 000	✓
	Synthesis and study of different classes of catalysts (perovskites, metal oxides and transition metal decorated nanoparticles)	Types of catalyst	3	
	Expand the use of renewable H_2 technology among existing and potential end users.	Number	5	
	Production capacity (Synthesis of catalysts using up-scalable processes -supercritical hydrothermal and electrospinning)	kg/h	1	
	Catalyst and electrodes with high electrolytic efficiency	mVη10 @ NTP	< 100 for HER < 150 for OER	
	High stability catalyst and electrodes (in the electrochemical, thermal, and chemical ageing tests).	%/1000h	< 0.8	
	Cell and stack electrolyser work at current density	A/cm^2 @ 1.8 V at SPWC	3	
	Validate electricity consumption at nominal capacity	kWh/kg of H_2	42	
	Separation of products (O_2 and H_2), ensuring that outflows are outside the flammability limits of mixtures at operating temperatures and pressures	% of H_2 @ O_2 gas stream	< 4	
	Degradation rate, demonstrated by ageing stress tests at the SPWC cell and stack level	%/1000h	< 1	⚙
	High operational flexibility: load range, fast start-up and cold down	% sec	5-100 in 600	
	Cost production	€/kg	3	
	Reduction of electricity consumption in comparison to AWEL and PEMEL, resulting in a decrease 20% of kg CO_2 eq considering electrolysers powered by the electrical grid	% of kgCO_2 eq reduction with respect to AWEL and PEMEL	20	
	Non-use Pt, Ru, decrease use of CRM	mg/W	< 0.3	
	Recovery of internal heat and demonstrate the feasibility of meeting over 30% of the system's heat demand by utilising industrial waste heat	% of heat recovered	50	
	Contributions in peer-reviewed open-access articles and conference papers	Number	22	
	Patents	Number	2	

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