ANIONE

ANION EXCHANGE MEMBRANE ELECTROLYSIS FOR RENEWABLE HYDROGEN PRODUCTION ON A WIDE-SCALE

Project ID:	875024
PRD 2023:	Panel 1 – H2 production
Call topic:	FCH-02-4-2019: New anion exchange membrane electrolysers
Project total costs:	EUR 1 999 995
Clean H_2 JU max. contribution:	EUR 1 999 995
Project period:	1.1.2020–31.12.2022
Coordinator:	Consiglio Nazionale delle Ricerche, Italy
Beneficiaries:	Hydrolite Ltd, Université de Montpellier, TFP Hydrogen Products Ltd, Hydrogenics Europe NV, IRD Fuel Cells A/S, Uniresearch BV, Centre national de la recherche scientifique

https://anione.eu/

PROJECT AND OBJECTIVES

ANIONE aims to develop a high-performance, cost-effective and durable anion-exchange membrane (AEM) water electrolysis technology. The approach taken involves using an AEM and ionomer dispersion in the catalytic layers for hydroxide ion conduction. The project aims to validate a 2 kW AEM electrolyser with a hydrogen production rate of about 0.4 Nm^3/h (technology readiness level (TRL) 4). Advanced AEMs have been developed in conjunction with non-critical raw material non-CRM high-surface-area electrocatalysts and membrane electrode assemblies. These advanced AEMs have shown promising performance and stability.

NON-QUANTITATIVE OBJECTIVES

- **Enhanced oxygen evolution catalyst.** ANIONE aims to develop an advanced non-CRM Ni- and Fe-based catalyst for the oxygen evolution reaction, providing reduced overpotential and enhanced stability.
- **Enhanced hydrogen evolution catalyst.** ANIONE aims to develop an advanced non-CRM Ni-based catalyst for the hydrogen evolution reaction, providing reduced overpotential and enhanced stability.
- **Advanced cost-effective membrane.** ANIONE aims to develop cost-effective advanced AEMs with proper hydroxide ion conductivity and stability.
- **Process implementation.** ANIONE aims to develop an AEM electrolysis operating mode providing enhanced stability.
- **AEM electrolysis hardware components.** ANIONE aims to implement advanced AEM electrolysis components in terms of diffusion layers and current collectors.

PROGRESS AND MAIN ACHIEVEMENTS

- A highly conductive and chemically stable hydrocarbon ionomer/membrane for AEM water electrolysis.
- ANIONE has produced reinforced and composite AEM hydrocarbon membranes for water electrolysis showing the capability to operate at higher temperatures.
- It has also produced a high-performing and electrochemically stable NiFe oxide, oxygen evolution, anode electrocatalyst for AEM water electrolysis.
- Enhanced catalyst-coated electrode-based membrane electrode assemblies for AEM water electrolysis.
- It has also produced large-area membrane–electrode assemblies based on non-CRMs performing similarly to small-area membrane electrode assemblies.

FUTURE STEPS AND PLANS

- Large area stack assembling and testing will be carried out.
- There will be full validation of functional materials at the stack level.

QUANTITATIVE TARGETS AND STATUS

Target source	Parameter	Unit	Target	Achieved to date by the project	Target achieved?	SoA result achieved to date (by others)	Year of SoA target
Project's own objectives and AWP 2019	Cell voltage at 1 A/cm^2 (cell performance at 45 °C)	V	2	1.75		1.67	2020
	Degradation rate: voltage increase at 1 A/cm^2	mV/h	< 0.005	< 0.005	✓	2	
	Membrane conductivity	mS/cm	50	105	✓	80	2022
	Maximum operating temperature	°C	90	90	✓	60	
	Series resistance	$ohm.cm^2$	< 0.07	0.06	✓	0.1	

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CHANNEL

DEVELOPMENT OF THE MOST COST-EFFICIENT HYDROGENPRODUCTIONUNITBASEDONANION EXCHANGE MEMBRANE ELECTROLYSIS

Project ID:	875088
PRD 2023:	Panel 1 – H2 production
Call topic:	FCH-02-4-2019: New anion exchange membrane electrolysers
Project total costs:	EUR 1 999 906.25
Clean H_2 JU max. contribution:	EUR 1 999 906.25
Project period:	1.1.2020–30.6.2023
Coordinator:	SINTEF AS, Norway
Beneficiaries:	Enapter SRL, Evonik Creavis GmbH, Shell Global Solutions International BV, Evonik Operations GmbH, Norwegian University of Science and Technology

https://www.sintef.no/projectweb/channel-fch/

PROJECT AND OBJECTIVES

CHANNEL aims to build a cost-efficient 2 kW anion-exchange membrane (AEM) water electrolyser able to operate at differential pressure and under dynamic operation, optimal for producing high-quality, low-cost green hydrogen from renewable energy sources. CHANNEL will conduct a techno-economic analysis and determine detailed future size and cost targets for AEM electrolysers. It will identify markets and their requirements, establishing the production quantities essential to meet market needs, accounting for the expected cost decrease.

NON-QUANTITATIVE OBJECTIVES

- The project aims to contribute to science and technology through the submission of journal articles for publication and through conference contributions.
- The CHANNEL promotional video was released in early 2021.
- Two students from the University of St Andrews were trained and have been working on the project.
- CHANNEL aims to contribute to the AEM test protocol harmonisation workshop alongside NEWELY and ANIONE.
- The transient AEM model code is to be released on a public platform (GitHub).
- Education: two PhD students (Forschungszentrum Jülich) and one postdoctoral researcher (Norwegian University of Science and Technology) were hired as part of the project.

PROGRESS AND MAIN ACHIEVEMENTS

- Highly active and durable hydrogen and oxygen evolution reaction electrocatalysts were developed and production was scaled up.
- The single-cell electrolyser performance target of 1.85 V at 1 A/cm^2 using a non-PGM electrocatalyst was achieved.
- High-performance AEMs were developed.
- Stack design has been finalised and the deliverable was due to be submitted by the end of March 2023.

FUTURE STEPS AND PLANS

- A journal article based on the modelling of the transient pseudo-two-dimensional (P2D) AEM model and simulation of electrode catalyst loading and composition as a function of KOH concentration, temperature and cell current density is in the process of being published, offering additional insight into the drivers of AEM cell performance and assisting optimisation activities.
- The model will be shared through an open-source modelling system to allow others in the research community to utilise it to make informed decisions on how best to optimise AEM electrolyser technologies.
- A demonstration of the preliminary AEM stack prototype will take place, as will the assembly of the preliminary stack and validation. This is in addition to finalising the stack design.

QUANTITATIVE TARGETS AND STATUS

Target source	Parameter	Unit	Target	Achieved to date by the project	Target achieved?	SoA result achieved to date (by others)	Year of reported SoA result
Project's own objectives	OER catalyst performance	mV	< 300 (at 10 mA/cm^2 1 M KOH)	237 (1 M KOH) 270 (0.1 M KOH)	✓	250 at 10 mA/cm^2 (Ir-based catalyst)	2023
	HER catalyst performance	mV	< 150 (at – 0.2 V versus RHE)	60 in 1 M KOH 120 in 0.1 M KOH	✓	30 at – 10 mA/cm^2 (Pt-based catalyst) in 1 M KOH	2023
	OER catalyst stability	mV	< 25 degradation over 1 000 hours in RDE	33	⚙	N/A	N/A
	HER catalyst stability	mV	< 25 degradation over 1 000 hours in RDE	26	⚙		
	Single-cell performance (at 1 A/cm^2)	V	1.85	1.85	✓	1.85	2023
AWP 2019	Membrane OH^- conductivity (T = RT)	mS/cm	50	< 50	⚙	Approximately 120 (50-micron membrane from Sustainion) 40–45 FAA-3 (Fumatech)	2023
	Ionomer OH conductivity (60 °C)	mS/cm	Not specified	> 60	✓	N/A	N/A

Demo4Grid

DEMONSTRATION OF 4 MW PRESSURIZED ALKALINEELECTROLYSERFORGRIDBALANCING SERVICES

Project ID:	736351
PRD 2023:	Panel 1 – H2 production
Call topic:	FCH-02-7-2016: Demonstration of large-scale rapid response electrolysis to provide grid balancing services and to supply hydrogen markets
Project total costs:	EUR 7 736 682.5
Clean H_2 JU max. contribution:	EUR 2 932 554.38
Project period:	1.3.2017–31.8.2023
Coordinator:	Diadikasia Business Consulting Symvouloi Epicheiriseon AE, Greece
Beneficiaries:	FEN Sustain Systems GmbH, MPREIS Warenvertriebs GmbH, Instrumentación y Componentes SA, Fundación para el Desarrollo de las Nuevas Tecnologías del Hidrógeno en Aragón, IHT Industrie Haute Technologie SA

http://www.demo4grid.eu/

PROJECT AND OBJECTIVES

The main aim of this project is the commercial set-up and demonstration of a technical solution utilising above-state-of-the-art pressurised alkaline electrolyser technology to provide grid-balancing services in real operational and market conditions. The ultimate goal is to provide grid-balancing services to the transmission system operator (primary and secondary balancing services). The electrolysis plant will be installed in Völs near Innsbruck.

PROGRESS AND MAIN ACHIEVEMENTS

The pressurised alkaline electrolyser has been installed. It has been producing hydrogen since 22 March 2022.

QUANTITATIVE TARGETS AND STATUS

Target source	Parameter	Unit	Target	Achieved to date by the project	Target achieved?	SoA result achieved to date (by others)	Year of SoA target
Project's own objectives	H_2 production electrolysis, hot start from min. to max. power	seconds	2			60	2015
	Start-up time KPIs from cold to minimum part-load for alkaline electrolysers	minutes	20	4–6 hours depending on thermal conditions		30	
	Minimum part-load operation targets for alkaline electrolysers	% (full load)	20			30	
	Ramp up	% (full load)/s	7	3		7	N/A
	Ramp down	% (full load)/s	10	2		10	

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Djewels

DELFZIJLJOINTDEVELOPMENTOFGREENWATER ELECTROLYSIS AT LARGE SCALE

Project ID:	826089
PRD 2023:	Panel 1 – H2 production
Call topic:	FCH-02-1-2018: Demonstration of a large-scale (min. 20 MW) electrolyser for converting renewable energy to hydrogen
Project total costs:	EUR 41 967 250
Clean H_2 JU max. contribution:	EUR 10 999 999
Project period:	1.1.2020–31.12.2025
Coordinator:	Nobian Industrial Chemicals BV, Netherlands
Beneficiaries:	McPhy Energy Italia SRL, BioMethanol Chemie Nederland BV, McPhy Energy Deutschland GmbH, Industrie De Nora SpA-IDN, Hinicio SA, McPhy Energy, NV Nederlandse Gasunie

https://djewels.eu

PROJECT AND OBJECTIVES

Djewels demonstrates the operational readiness of the 20 MW electrolyser for the production of green fuels (green methanol) in real-life industrial and commercial conditions. It will bring the technology from technology readiness level 7 to 8 and lay the foundation for the next scale-up step: a 100 MW electrolyser at the same site. Djewels will enable the development of the next generation of pressurised alkaline electrolysers by developing more cost-efficient, better-performing high-current-density electrodes, and is preparing for the mass production of the stack and scale-up of the balance-of-plant components.

NON-QUANTITATIVE OBJECTIVES

Safety performance. The design has been finalised and the hazard and operability analysis has been completed.

PROGRESS AND MAIN ACHIEVEMENTS

- The Djewels 1 design was finalised.
- An irrevocable permit was issued.
- Testing of the 1 MW stack has started.

FUTURE STEPS AND PLANS

- Stack testing and optimisation will be completed.
- The investment decision is expected to be made in Q2 2023.
- Ground breaking is expected to take place in Q3 2023.
- Construction is expected to be completed in 2025.

QUANTITATIVE TARGETS AND STATUS

Target source	Parameter	Unit	Target	Target achieved?
Project's own objectives	System nominal capacity	MW	25	
MAWP addendum (2018–2020)	Energy consumption	kWh/kg	< 52.8	
	Degradation	%/year	0.72	
	Flexibility with degradation below 2 %/year	% of nominal power	3–110	

GAMER

GAMECHANGER IN HIGH TEMPERATURE STEAM ELECTROLYSERS WITH NOVEL TUBULAR CELLS AND STACKS GEOMETRY FOR PRESSURIZED HYDROGEN PRODUCTION

Project ID:	779486
PRD 2023:	Panel 1 – H2 production
Call topic:	FCH-02-2-2017: Game changer high temperature steam electrolysers
Project total costs:	EUR 2 998 951.25
Clean H_2 JU max. contribution:	EUR 2 998 951.25
Project period:	1.1.2018–30.9.2022
Coordinator:	SINTEF AS, Norway
Beneficiaries:	MC2 Ingenieria y Sistemas SL, CRI EHF, CoorsTek Membrane Sciences AS, Shell Global Solutions International BV, Universitetet i Oslo, Stiftelsen SINTEF, Agencia Estatal Consejo Superior de Investigaciones Cientificas

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

PROJECT AND OBJECTIVES

GAMER is developing a novel cost-effective tubular proton ceramic electrolyser (PCE). The project focuses on a novel 'tube-in-shell' single engineering unit (SEU) design in which each tubular cell is placed in a steel shell, which has all necessary gas inlet/outlet connections. The steel shell also acts as a pressure containment vessel. The SEU stack technology is operational at 600 °C in pressurised operation. The main objectives of the project are to:

- design an innovative electrolysis system integrated in a renewable methanol plant with efficient thermal coupling of heat source (waste heat or heat from a renewable geothermal source);
- develop a high-volume cost-effective tubular SEU technology;
- assemble the novel SEUs and necessary balance-of-plant (BoP) equipment in a 10 kW prototype for pressurised operation;
- carry out techno-economic evaluation and life cycle analysis (LCA) of the integrated technology.

NON-QUANTITATIVE OBJECTIVES

The project has developed a novel design for a PCE stack in the form of tube-in-shell SEU operational at 600 °C and operated at up to 10 bar total pressure for more than 1 000 hours. It has also designed a 10 kW system, including assemblies of SEUs integrated in racks in a hot box, with BoP and power electronics developed for pressurised operation, delivering hydrogen with an output pressure of at least 30 bar. The containerised plant has been built and commissioned by Agencia Estatal Consejo Superior de Investigaciones Científicas. It has also been used to test two racks (each containing 16 SEUs) at a pressure of up to 7 bar. Due to some technical limitations and the project coming to an end, no more testing could be carried out. The plant will be exploited after project completion as part of the follow-up PROTOSTACK project, a new Clean Hydrogen JU project. The targeted production volume of the SEUs by CTMS was successfully achieved in the project, with reproducible results achieved when comparing the performance of the individual functional layers on both short segments (4–5 cm^2) and upscaled tubular cells (60 cm^2). The project demonstrates that PCE performance is improved by increasing the operational pressure from ambient pressure to at least 10 bar (in terms of both increasing the faradaic efficiency and reducing the cells' area-specific resistance).

PROGRESS AND MAIN ACHIEVEMENTS

Sixteen SEUs were tested in pressurised operation up to 10 bar at 600 °C. Good reproducibility was achieved after optimisation of the manufacturing process and steam electrode architectures. The stability of an SEU operating at 600 °C for more than 500 hours at 10 bar was successfully demonstrated in the project, while operated at a constant current density of 0.3 A/cm^2 (steam utilisation of 60 %).

The second rack of 16 SEUs was tested at atmospheric pressure at three different temperatures (600 °C, 575 °C, 550 °C). At 600 °C and atmospheric pressure, H_2 production of 0.47 Nl/min and a faradaic efficiency of 61 % were reached by applying a current of 100 A.

Techno-economic analysis and LCA have been conducted on this technology, integrated in various user cases (ammonia plant, refineries, geothermal plant). The results of this work show that a projected upscaled technology can reach a system cost below 8.8 M€/(t/d). Furthermore, a roadmap for further cost reduction below 2.7 M€/(t/d) post 2020, which relies on both the reduction of system cost and improved cell performance, has been set out.

FUTURE STEPS AND PLANS

- The finalisation of rack assembly and quality assurance is in progress.
- Integration of racks in the 10 kW testing unit and commissioning will take place. Testing will start with one rack, with the progressive integration of the other.
- The testing plant will be used in a new project named PROTOSTACK, funded by the Clean Hydrogen Joint Undertaking.

QUANTITATIVE TARGETS AND STATUS

Target source	Parameter	Unit	Target	Achieved to date by the project	Target achieved?	SoA result achieved to date (by others)	Year of SoA target
Project's own objectives	ASR of cell at 600 °C at 3 bar in electrolysis mode	ohm.cm^2	2	2.5	⚙	< 2	2022
	Faradaic efficiency of the SEU at 3 bar at 0.1 mA/cm^2 at 600 °C	%	> 85	95	✓	> 85	2020
	Degradation rate max. decrease of the voltage after 500 hours at 600 °C at 100 mA/cm^2	%/kh	1.2	< 5	⚙	N/A	2021
	System cost	M€	8.8	4.2–8.9	✓	N/A	N/A
	Hydrogen cost	€/kg	2.7	4.2–7.4	⚙	N/A	N/A

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GrInHy2.0

GREEN INDUSTRIAL HYDROGEN VIA STEAM ELECTROLYSIS

Project ID:	826350
PRD 2023:	Panel 1 – H2 production
Call topic:	FCH-02-2-2018: Demonstration of large-scale steam electrolyser system in industrial market
Project total costs:	EUR 5 882 492.50
Clean H_2 JU max. contribution:	EUR 3 999 993.25
Project period:	1.1.2019–31.12.2022
Coordinator:	Salzgitter Mannesmann Forschung GmbH, Germany
Beneficiaries:	Paul Wurth SA, Sunfire GmbH, Salzgitter Flachstahl GmbH, Tenova SpA, Commissariat à l'énergie atomique et aux énergies alternatives

https://salcos.salzgitter-ag.com/de/grinhy-20.html

PROJECT AND OBJECTIVES

GrInHy2.0 is about implementing the world's biggest high-temperature electrolyser, with a capacity of 720 kW alternating current and electrical efficiency of 84 % lower heating value. During the assessment of the technology's carbon direct avoidance potential for the future European steel industry, the electrolyser will produce more than 100 t of green hydrogen based on steam from industrial waste heat produced over > 13 000 operational hours from steel production in Salzgitter.

PROGRESS AND MAIN ACHIEVEMENTS

- Electrolyser scale-up to 720 kWel and 200 Nm^3H_2/h was successful.
- The electrical efficiency target of 84 % lower heating value was reached.
- By the end of 2022, the system had been operating for more than 14 000 hours.
- Stack degradation at 15 mΩcm².kh-1 is below what was expected.
- Production of more than 100 t of climate-neutral hydrogen was achieved.
- Electrolyser investment costs were reduced to below 4 500 €/(kgH_2/d).

FUTURE STEPS AND PLANS

The project was successfully concluded, and no further steps are planned.

QUANTITATIVE TARGETS AND STATUS

Target source	Parameter	Unit	Target	Achieved to date by the project	Target achieved?	SoA result achieved to date (by others)	Year of SoA target
AWP 2018	Total production of green hydrogen	t	100	102	✓	N/A	2017
	Demonstration of hot start from min. to max. power	minutes	5	15	⚙	10	2018
	Hours of operation	hours	13 000	14 000	✓	10 000	2019
	Availability	%	95	85	⚙	66	
Project's own objectives	Hours of continuous stack testing	hours	20 000	10 000	⚙	8 700	2019

Haeolus

HYDROGEN-AEOLIC ENERGY WITH OPTIMISED ELECTROLYSERS UPSTREAM OF SUBSTATION

Project ID:	779469
PRD 2023:	Panel 1 – H2 production
Call topic:	FCH-02-4-2017: Highly flexible electrolysers balancing the energy output inside the fence of a wind park
Project total costs:	EUR 8 740 110.00
Clean H_2 JU max. contribution:	EUR 4 997 738.63
Project period:	1.1.2018–31.12.2023
Coordinator:	SINTEF AS, Norway
Beneficiaries:	Communauté d'universités et d'établissements université Bourgogne–Franche–Comté, École Nationale Superieure de Mécanique et des Microtechniques, Fundacion Tecnalia Research and Innovation, Hydrogenics Europe NV, Knowledge Environment Security SRL, Universita Degli Studi del Sannio, Université de Franche-Comté, Université de technologie de Belfort-Montbéliard, Varanger Kraft AS, Varanger KraftEnterprenor AS, Varanger KraftHydrogen AS, Varanger KraftMarked AS, Varanger KraftNett AS, Varanger KraftVind AS, Varanger KraftUtvikling AS

http://www.haeolus.eu/

PROJECT AND OBJECTIVES

The project has deployed a 1 t/day electrolyser, together with a storage tank and fuel cells for re-electrification, in connection with a wind farm in the remote village of Berlevåg in Norway. The objective is to test the operation of the electrolyser in different scenarios to demonstrate algorithms for energy storage, isolated grid operation and fuel production. After significant delays due to the COVID-19 pandemic, the project received a 2-year extension and is now following a new schedule.

NON-QUANTITATIVE OBJECTIVES

The objective is to promote the 'hydrogen valley' in Finnmark. Local authorities and business stakeholders are very interested in the project. Varanger Kraft has decided to proceed with building a distribution station, and local actors are involved in multiple multimillion-euro research and innovation proposals for further development.

PROGRESS AND MAIN ACHIEVEMENTS

- Varanger Kraft made its investment decision (EUR 4 million investment).
- Fuel cells were refurbished and redeployed.
- A cloud control system was deployed and open-sourced.
- Demonstration is ongoing.

FUTURE STEPS AND PLANS

Demonstration is to be completed and results are to be analysed.

QUANTITATIVE TARGETS AND STATUS

Target source	Parameter	Unit	Target	Achieved to date by the project	Target achieved?
Project's own objectives	CAPEX	M€/(t/d)	3	2.3	✓
MAWP addendum (2018–2020) and AWP 2017	Efficiency	kWh/kg	52	53.8	✓
	Degradation	%/year	1.5	2	⚙
	Cold start	minutes	0.5	20	⚙
	Hot start	seconds	2	30	⚙

HYDROSOL-beyond

THERMOCHEMICAL HYDROGEN PRODUCTION IN A SOLAR STRUCTURED REACTOR: FACING THE CHALLENGES AND BEYOND

Project ID:	826379
PRD 2023:	Panel 1 – H2 production
Call topic:	FCH-02-4-2018: Thermochemical hydrogen production from concentrated sunlight
Project total costs:	EUR 3 182 911.25
Clean H_2 JU max. contribution:	EUR 2 999 940.00
Project period:	1.1.2019–31.12.2023
Coordinator:	Ethniko Kentro Erevnas kai Technologikis Anaptyxis, Greece
Beneficiaries:	HyGear Operations BV, HyGear Hydrogen Plant BV, HyGear Technology and Services BV, EngiCer SA, Abengoa Innovacion Sociedad Anonima, HyGear Fuel Cell Systems BV, HyGear BV, Scuola universitaria professionale della Svizzera Italiana, Medioambientales y Tecnológicas (Ciemat) (Centro de Investigaciones Energéticas), Deutsches Zentrum für Luft- und Raumfahrt eV, Commissariat à l'énergie atomique et aux énergies alternatives

http://www.hydrosol-beyond.certh.gr/

PROJECT AND OBJECTIVES

HYDROSOL-beyond is a continuation of the Hydrosol-technology series of projects that focus on using concentrated solar power to produce hydrogen from the dissociation of water through redox-pair-based thermochemical cycles. The project is an ambitious scientific endeavour aiming to address the major challenges and bottlenecks identified during previous projects and to further boost the performance of solar hydrogen production technology through innovative solutions that will also increase the potential of the technology's future commercialisation.

NON-QUANTITATIVE OBJECTIVES

- Heat recovery.
- Minimisation of the parasitic losses mostly related to the high consumption of inert gas.
- Improvement of reactor design.

PROGRESS AND MAIN ACHIEVEMENTS

- Stable $NiFe_2O_4$ lattice structures have been produced.
- A small-scale hybrid ceramic/metallic heat exchanger has been constructed and tested. The results were taken into account in the development of the full-scale heat exchanger.
- The production of $NiFe_2O_4$ lattice structures for application on the tubular solar reactor at the solar platform has been scaled up.
- The scaled-up hybrid ceramic/metallic heat exchanger has been constructed and is ready for integration on the solar platform.

FUTURE STEPS AND PLANS

- The novel heat exchanger will be integrated in the existing solar platform. A small-scale apparatus has been manufactured and is being evaluated at the laboratory. The results will be taken into account in the development of the full-scale heat exchanger and its integration in the solar plant.
- The solar platform will be operated in H_2 production mode at the Plataforma Solar de Almería in Spain to run thermal tests on solar reactors.
- Operation of the solar reactor at the solar simulator facility at Forschungszentrum Jülich was achieved, with production of 8.8 gH_2/cycle. The desired temperatures for the operation were achieved using less power than expected (150 kW from solar simulator lamps).

QUANTITATIVE TARGETS AND STATUS

Target source	Parameter	Unit	Target	Achieved to date by the project	Target achieved?	SoA result achieved to date (by others)	Year of SoA target
AWP 2018	Demonstration of the process at realistic scale and in realistic working conditions, using an existing solar demonstration facility (> 200 kW range)	kW/reactor	250	150		250	2018
	Durability	cycles	1 000	150		602	
	Heat recovery rates of high-temperature heat in excess of 60 %	%	60	46		N/A	

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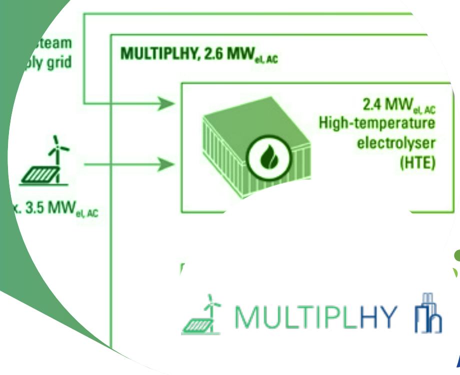
MultiPLHY

MULTIMEGAWATT HIGH-TEMPERATURE ELECTROLYSERTOGENERATEGREENHYDROGEN FORPRODUCTIONOFHIGH-QUALITYCHEMICAL PRODUCTS



Project ID:	875123
PRD 2023:	Panel 1 – H2 production
Call topic:	FCH-02-2-2019: Multi megawatt high-temperature electrolyser for valorisation as energy vector in energy intensive industry
Project total costs:	EUR 10 907 722.50
Clean H_2 JU max. contribution:	EUR 6 993 725.39
Project period:	1.1.2020–31.12.2024
Coordinator:	Commissariat à l'énergie atomique et aux énergies alternatives, France
Beneficiaries:	Engie, Engie Energie Services, Neste Engineering Solutions BV, Neste Engineering Solutions Oy, Neste Netherlands BV, Neste Oyj, Paul Wurth SA, Sunfire GmbH

https://multiplhy-project.eu

PROJECT AND OBJECTIVES

MultiPLHY aims to install and integrate the world's first high-temperature electrolyser (HTE) system on a multi-MW scale at a biorefinery located in Rotterdam, the Netherlands, demonstrating both technological and industrial leadership of the EU in the application of solid oxide electrolyser cell (SOEC) technology. The central element of the project is the manufacture and demonstration of a multi-MW high-temperature electrolyser and its operation in a biorefinery. As a result, MultiPLHY promotes the SOEC-based HTE from technology readiness level 7 to 8.

PROGRESS AND MAIN ACHIEVEMENTS

- The project demonstrated stack durability for more than 7 000 hours without H_2 production loss.
- A new-generation HTE module was developed to decrease capital expenditure.
- FAT of all 12 modules has been completed, and the installation in Rotterdam is in progress.

FUTURE STEPS AND PLANS

Project tasks will be executed in accordance with a revised plan owing to a delay in completing some tasks. Tasks are continuously monitored regarding achievements and the timeline.

QUANTITATIVE TARGETS AND STATUS

Target source	Parameter	Unit	Target	Target achieved?	SoA result achieved to date (by others)	Year of SoA target
AWP 2019	Electrical consumption	kWh/kg	85	✓	39.7	2017
	H_2 production loss	%/1 000 h	< 1.2		1.9	
	Downtime	%	5	⚙	N/A	N/A

Clean Hydrogen Partnership
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NEPTUNE

NEXT GENERATION PEM ELECTROLYSER UNDER NEW EXTREMES

Project ID:	779540
PRD 2023:	Panel 1 – H2 production
Call topic:	FCH-02-1-2017: Game changer water electrolysers
Project total costs:	EUR 1 927 335.43
Clean H_2 JU max. contribution:	EUR 1 926 221.25
Project period:	2.1.2018–30.4.2022
Coordinator:	ITM Power (Trading) Limited, United Kingdom
Beneficiaries:	Consiglio Nazionale delle Ricerche, Engie, IRD Fuel Cells A/S, Pretexo, Solvay Specialty Polymers Italy SpA

https://cordis.europa.eu/project/id/779540

PROJECT AND OBJECTIVES

NEPTUNE addresses challenges associated with reducing capital costs and increasing production rates and output pressures of water electrolysis, which will be required to achieve large-scale application of polymer electrolyte membrane electrolysers. The project is developing a set of breakthrough solutions at the material, stack and system levels to increase hydrogen pressure to 100 bar and current density to 4 A/cm² for the base load, while keeping nominal energy consumption at < 50 kWh/kg of H_2. The novel solutions will be validated by demonstrating a robust and rapid-response electrolyser.

NON-QUANTITATIVE OBJECTIVES

The objective was to extend the protocols for testing electrolysis systems under the new operating conditions (high temperature and pressure).

PROGRESS AND MAIN ACHIEVEMENTS

- Under the project, a new simplified balance of plant for polymer electrolyte membrane electrolysis was designed and built to extend operating conditions.
- The membrane electrode assembly degradation rate achieved at 80 °C was 4.4 μV/h/cell at 4 A/cm² in a test lasting more than 2 000 hours (single-cell level).
- At 90 °C, cell voltages of 1.74 V at 4 A/cm² and 1.98 V at 8 A/cm² were achieved, with noble metal loading of 0.34 mg/cm² (anode) and 0.1 mg/cm² (cathode).

FUTURE STEPS AND PLANS

The project has been completed.

QUANTITATIVE TARGETS AND STATUS

Target source	Parameter	Unit	Target	Achieved to date by the project	Target achieved?	SoA result achieved to date (by others)	Year of SoA target
Project's own objectives	Anode catalyst loading per W	mg/W	0.05	0.0459	✓	0.23	2018
	Cathode catalyst loading per W	mg/W	0.0071	0.0135	⚙	0.035	
	Efficiency degradation per 1 000 hours for LT electrolyser	%/1 000 h	0.29	0.23	✓	0.2	

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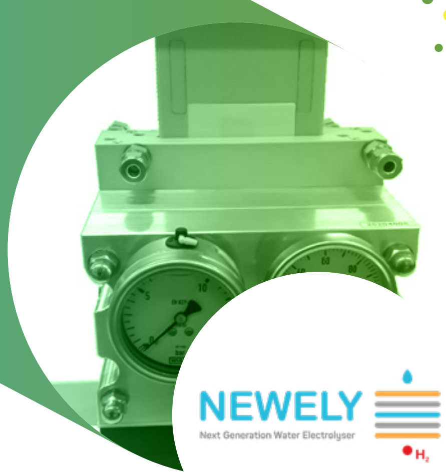
NEWELY

NEXTGENERATIONALKALINEMEMBRANEWATER ELECTROLYSERSWITHIMPROVEDCOMPONENTS AND MATERIALS



Project ID:	875118
PRD 2023:	Panel 1 – H2 production
Call topic:	FCH-02-4-2019: New anion exchange membrane electrolysers
Project total costs:	EUR 2 892 889.25
Clean H_2 JU max. contribution:	EUR 2 204 846.25
Project period:	1.1.2020–31.12.2022
Coordinator:	Deutsches Zentrum für Luft- und Raumfahrt eV, Germany
Beneficiaries:	Air Liquide Forschung und Entwicklung GmbH, Commissariat á l'énergie atomique et aux énergies alternatives, Cutting-Edge Nanomaterials (CENmat) UG Haftungsbeschrankt, DLR-Institut Für Vernetzte Energiesysteme EV, Fondazione Bruno Kessler, Korea Institute of Science and Technology, Air Liquide SA, Membrasenz SARL, Propuls GmbH, Ústav Makromolekulární chemie AV ČR v. v. i., Vysoká škola chemicko-technologická v Praze, Westfälische Hochschule Gelsenkirchen

https://newely.eu/

PROJECT AND OBJECTIVES

This project aims to redefine anion-exchange membrane water electrolysis (AEMWE), surpassing the current state of alkaline water electrolysis (WE) and bringing it one step closer to proton-exchange membrane WE in terms of efficiency, but at a lower cost. The three main challenges of AEMWE – membrane, catalyst and stack – are addressed by three small and medium-sized enterprises and a large hydrogen company supported by seven renowned research and development centres. With a prototypic five-cell stack at elevated pressure in a 2 000-hour endurance test, the performance of the state of the art (SoA) of AEMWE will be validated twice. This will have an impact on the cost of green hydrogen.

NON-QUANTITATIVE OBJECTIVES

The techno-economic assessment and life cycle assessment are expected to demonstrate a reduction of capital expenditure and operating expenses for AEMWE relative to proton-exchange membrane WE and alkaline WE. Data collection and evaluation are complete and under review.

PROGRESS AND MAIN ACHIEVEMENTS

- The membrane electrode assembly (MEA) with OXYGN-N anode, H2GEN-M cathode (both catalysts from project partner CENmat) and commercial anion-exchange membrane (AEM)/ionomer achieves 2 V at 2 A/cm^2 in 0.1 M KOH. No irreversible degradation was seen in a 400-hour test.
- AEM conductivity of 62 mS/cm and area-specific resistance of 0.065 ohm.cm^2 were achieved.
- The project created a new method for AEM membrane reinforcement with covalent bonds between the matrix and the ionomer, with conductivity of 62 mS/cm.

FUTURE STEPS AND PLANS

- MEAs for the stack will be prepared at 200 cm^2. Project materials will also be prepared, and targeted performance set. The long-term testing of the 25 cm^2 MEA is proceeding.
- Stack design will be finalised and constructed. The first draft has already been prepared and is awaiting finalisation of the configuration of components.
- The stack has not yet been put into operation at increased pressure.
- Long-term testing of the stack will seek to demonstrate the required stability. To date, testing has been up to 25 cm^2 (single cell). In-stack testing is still to be carried out.
- Data analysis for the life cycle assessment and cost analysis is at an advanced stage.

QUANTITATIVE TARGETS AND STATUS

Target source	Parameter	Unit	Target	Achieved to date by the project	Target achieved?	SoA result achieved to date (by others)	Year of SoA target
	Maximum AEMWE stack size realised in the project						
Project's own objectives and MAWP addendum (2018–2020)	Stack power	kW	2	0.075		2.4	2021
	Cell area	cm^2	200	25		N/A	
	Pressure	bar (relative)	≤ 40	0		≤ 35	
MAWP addendum (2018–2020)	Energy consumption @ power	kWh/kg @ W/cm^2	53.6 @ 2	53.6 @ 3.6		53.6 @ 2.4	
	Corresponding to cell voltage @ current	V @ A/cm^2	2 @ 1	2 @ 1.8		2 @ 1.2	
	Non-PGM catalysts						
Project's own objectives and MAWP addendum (2018–2020)	Added overpotentials (anode and cathode)	mV	415	232	✓	250	2020
	Current density	mA/cm^2	1	1		1	
MAWP addendum (2018–2020)	Stable operation for 2 000 hours, cell voltage gap after 2 000 hours of operation	mV	50	No 2 000-hour test yet		< 2	2021
	Extrapolation to efficiency degradation at rated power and assuming 8 000 hours of operation per year	Extrapolated to %/year	Extrapolated to 7.2	No test yet		< 0.3	
	Chemically, thermally and mechanically stable AEM ionomer and membrane with conductivity	mS/cm	≥ 50	62	✓	80	
	Area-specific resistance	ohm.cm^2	≤ 0.07	0.065		0.045	

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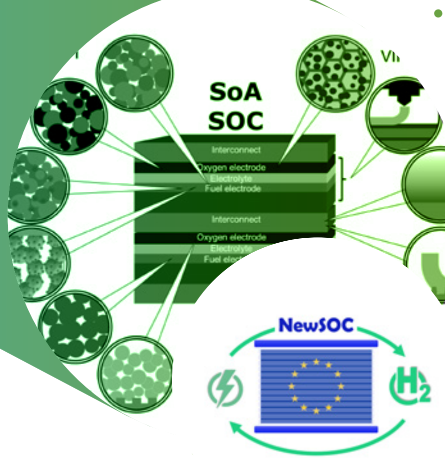
NewSOC

NEXT GENERATION SOLID OXIDE FUEL CELL AND ELECTROLYSIS TECHNOLOGY



Project ID:	874577
PRD 2023:	Panel 1 – H2 production
Call topic:	FCH-02-6-2019: New materials, architectures and manufacturing processes for solid oxide cells
Project total costs:	EUR 4 999 726.25
Clean H_2 JU max. contribution:	EUR 4 999 726.25
Project period:	1.1.2020–30.6.2023
Coordinator:	Danmarks Tekniske Universitet, Denmark
Beneficiaries:	Aktsiaselts Elcogen, Ceres Power Limited, Commissariat a l'énergie atomique et aux énergies alternatives, École polytechnique fédérale de Lausanne, Ethniko Kentro Erevnas Kai Technologikis Anaptyxis, Fundacio Institut de Recerca de L'energia de Catalunya, Hexis AG, Idryma Technologias Kai Erevnas, Instytut Energetyki, Nederlandse Organisatie voor Toegepast Natuurwetenschappelijk Onderzoek TNO, Politecnico di Torino, SolydEra SpA, Sunfire GmbH, Teknologian tutkimuskeskus VTT Oy, Università degli Studi di Salerno

http://www.newsoc.eu/

PROJECT AND OBJECTIVES

NewSOC aims to significantly improve the performance, durability and cost competitiveness of solid oxide cells and stacks compared with the state of the art, focusing on (i) structural optimisation and innovative architectures, (ii) alternative materials and (iii) innovative manufacturing. The project succeeded in improving the cells, yielding a 25 % increase in applicable current density and a 25 % lower area-specific resistance (ASR), which marked the first milestone. Progress was achieved for all proposed concepts, and specific plans were agreed with the industry partners for integration into their commercial platforms.

NON-QUANTITATIVE OBJECTIVES

- Achieve redox stability in the cells.
- Produce a cell/stack with improved cycling stability.
- Reduce toxic organics/materials during manufacture.

PROGRESS AND MAIN ACHIEVEMENTS

- The integration of NewSOC development concepts into industrial platforms (cells and stacks) was achieved and tests were carried out.
- Quantities of toxic organics/materials were reduced through the development of a Co-free oxygen electrode. Cobalt was reduced in the protective coating for interconnects, and toxic solvents were removed for the deposition of sealants.
- A redox-stable cell with doped lanthanum chromite fuel electrodes was developed.

FUTURE STEPS AND PLANS

- The development of NewSOC concepts will be completed.
- Validation tests integrating the NewSOC developments into industrial cells and stacks will be completed.
- The 5 000-hour test is to be completed.

QUANTITATIVE TARGETS AND STATUS

Target source	Parameter	Unit	Target	Achieved to date by the project	Target achieved?
Project's own objectives	ASR (80 × 120 mm² solid power anode electrolyte half-cell)	ohm.cm² at 650 °C	0.4	0.5	
	ASR (Co-free cell, LSF oxygen electrode with improved microstructure)	ohm.cm² at 650 °C	0.4	0.4	✓
	Electrolysis current for operation with a degradation rate below 1 %/1 000 h	A/cm²	0.75–1	0.5 … 0 %/1 000 h	
	Electrolysis current for operation with a degradation rate below 1 %/1 000 h	A/cm²	0.75–1	0.3 … 0.5 %/1 000 h	
	Operating temperature	°C	650	650–700	

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OYSTER

OFFSHORE HYDROGEN FROM SHORESIDE WIND TURBINE INTEGRATED ELECTROLYSER

Project ID:	101007168
PRD 2023:	Panel 1 – H2 production
Call topic:	FCH-02-6-2020: Electrolyser module for offshore production of renewable hydrogen
Project total costs:	EUR 5 025 093.51
Clean H_2 JU max. contribution:	EUR 4 999 843.00
Project period:	1.1.2021–31.12.2024
Coordinator:	ERM, France
Beneficiaries:	Element Energy, Orsted Wind Power A/S, ITM Power (Trading) Limited, Siemens Gamesa Renewable Energy AS, Element Energy Limited

https://oysterh2.eu/

PROJECT AND OBJECTIVES

The overall aim of OYSTER is to justify, develop and demonstrate an electrolyser suitable for deployment in offshore environments. The end goal is to produce a marinised electrolyser that is integrated with offshore wind turbines to produce 100 % renewable, low-cost bulk hydrogen, while facilitating increased roll-out of offshore wind.

NON-QUANTITATIVE OBJECTIVES

- The project aims to develop an electrolyser system capable of operating reliably in an offshore environment.
- It aims to deploy and test a new MW-scale electrolyser designed for marine environments for 18 months, covering all seasons.
- It aims to complete a design exercise for an integrated offshore wind turbine electrolysis module, drawing on the lessons learned from the pilot trial and insights from expert partners in the offshore oil and gas sector. These lessons and insights will contribute to the basis of a detailed design of a complete offshore hydrogen production system.
- The project plans to undertake a preliminary front-end engineering and design study for a specific offshore wind farm site, linked to an existing industrial hydrogen customer.
- It aims to formulate business cases for further deployment of large-scale electrolysis systems in offshore environments. A business case will be developed for the use of hydrogen across different applications, including hydrogen for industrial users, transport applications and heating, by exploiting the onshore gas networks for use in hydrogen distribution.

PROGRESS AND MAIN ACHIEVEMENTS

- Early versions of the water treatment system design and system modelling to be used for simulation of direct connected power electronics have been finalised. These will form the basis for the design used by Stiesdal.
- The location of the trial has been selected. Following investigation, a site in Zeeland, the Netherlands, was selected.

FUTURE STEPS AND PLANS

- Stiesdal will start design and marinisation work for the electrolyser, focusing on compartmentalisation and component specification for marinisation.
- A shoreside trial and data collection are expected to start in 2024.

QUANTITATIVE TARGETS AND STATUS

Target source	Parameter	Unit	Target	Target achieved?
Project's own objectives	Electrolyser footprint	m^2/MW	50	
	Maintenance cost	€/(kg/year)	20	
	Efficiency degradation at rated power	%/1 000 h	0.11	
	Electrolyser CAPEX (at rated power), including ancillary equipment and commissioning	€/(kg/day)	800	
	Time for hot start (min. to max. power)	seconds		
	Current density	A/cm^2	0.2–0.4	

PROMETEO

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

Project ID:	101007194
PRD 2023:	Panel 1 – H2 production
Call topic:	FCH-02-2-2020: Highly efficient hydrogen production using solid oxide electrolysis integrated with renewable heat and power
Project total costs:	EUR 2 765 206.25
Clean H_2 JU max. contribution:	EUR 2 499 531.25
Project period:	1.1.2021–30.6.2021
Coordinator:	Agenzia nazionale per le nuove tecnologie, l'energia e lo sviluppo economico sostenibile, Italy
Beneficiaries:	Capital Energy Services SLU, École Polytechnique Fédérale de Lausanne, Fondazione Bruno Kessler, Fundación Imdea Energia, NextChem SpA, SNAM SpA, SolydEra SA, Stamicarbon BV

https://prometeo-project.eu

PROJECT AND 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 photovoltaics or wind. A 25 kWe SOE prototype (approximately 15 kg/day of H_2 production) will be developed and validated in the relevant environment, combined with intermittent sources: non-programmable renewable electricity and high-temperature solar heat with thermal energy storage. Partial-load operation, transients and hot standby periods will be studied.

NON-QUANTITATIVE OBJECTIVES

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

PROGRESS AND MAIN ACHIEVEMENTS

- The project defined end users' cases.
- Preliminary process flow diagrams were created.
- A thermal energy storage system was identified and was experimentally validated in the laboratory.
- Process modelling tools were developed.

FUTURE STEPS AND PLANS

- Experimental determination of the performance map for the SOE stack and the balance of plant in the laboratory is in progress – it was expected to be complete by January 2023.
- Process flow diagrams for the 25 kWe pilot plant under different operation modes are being finalised. They were expected to be complete by March 2023.
- The integrated pilot plant (25 kWe) will be designed and built. The basic design is in progress. The pilot plant is expected to be shipped to the project site in the first half of 2024.
- Based on finalised process flow diagrams for the pilot plant (25 kWe), analysis of case studies at multi-MW scale will be performed. This was expected to start by April 2023.

QUANTITATIVE TARGETS AND STATUS

Target source	Parameter	Unit	Target	Target achieved?
Project's own objectives	Demonstrate ≥ 98 % availability of the electrolyser: hours in which the SOE has been kept at ≥ 650 °C (i.e. ready to start) v total hours	%	98	
	Demonstrate the production of hydrogen by operation of > 1 000 hours: hours of experimental validation runs of the prototype	hours	1 000	
	Demonstrate, using SOE with renewable heat integration, electrical efficiency of ≥ 85 % based on lower heating value (LHV) and specific energy consumption of < 39 kWh/kg H_2 in a relevant market-representative environment: power-to-hydrogen energy conversion efficiency of the heat-integrated SOE system (LHV basis)	%	85	
	Obtain solar-to-hydrogen energy conversion efficiency from global solar radiation to H_2 energy (LHV basis): ≥ 10 %	%	10	

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REACTT

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

Project ID:	101007175
PRD 2023:	Panel 1 – H2 production
Call topic:	FCH-02-3-2020: Diagnostics and control of SOE
Project total costs:	EUR 2 712 322.50
Clean H_2 JU max. contribution:	EUR 2 712 322.50
Project period:	1.1.2021–31.12.2023
Coordinator:	Jožef Stefan Institute, Slovenia
Beneficiaries:	Agenzia nazionale per le nuove tecnologie (l'energia e lo sviluppo economico sostenibile), AVL LIST GmbH, Bitron SpA, Commissariat à l'énergie atomique et aux énergies alternatives, École Polytechnique Fédérale de Lausanne, Haute Ecole Spécialisée de Suisse occidentale, SolydEra SA, Teknologian tutkimuskeskus VTT Oy, Università degli Studi di Salerno

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

PROJECT AND OBJECTIVES

REACTT aims to realise a monitoring, diagnostic, prognostic and control (MDPC) tool and reversible solid oxide cell 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. The development of the hardware platform and embedded diagnostics and prognostics algorithms is under way.

NON-QUANTITATIVE OBJECTIVES

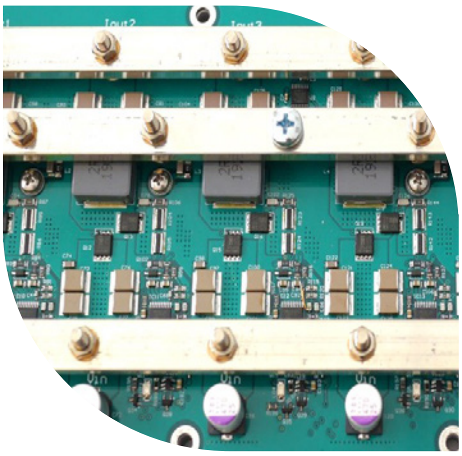
- **Education/training.** The possible inclusion of the topic of solid oxide cell technologies in MSc and PhD study programmes was to be considered.
- **Public awareness.** The project web page and dissemination material are the first step towards raising public awareness.
- **Safety.** Fault detection, isolation and mitigation in SOEC/SOFC preclude process disruption and potential hazards.
- **Regulations and standards.** The formulation of a new work item proposal set out in M12–M36 is to be submitted to Technical Committee 105 of the International Electrotechnical Commission.

PROGRESS AND MAIN ACHIEVEMENTS

The first prototype of the MDPC board was developed.

FUTURE STEPS AND PLANS

An application for a project extension has been made. Delays in stack delivery are likely to result in delayed data acquisition from the long-term experiments under various degradation modes. The data are an important prerequisite for the design and validation of the diagnostic and prognostic algorithms.



QUANTITATIVE TARGETS AND STATUS

Target source	Parameter	Unit	Target	Target achieved?	SoA result achieved to date (by others)
MAWP (2014–2020)	Availability	%	98		95
	Q & M cost	€/(kg/d)/year	120		N/A
	Electrical consumption at rated capacity	kWh/kg of H_2	39		40–45

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REFHYNE

CLEAN REFINERY HYDROGEN FOR EUROPE

Project ID:	779579
PRD 2023:	Panel 1 – H2 production
Call topic:	FCH-02-5-2017: Demonstration of large electrolysers for bulk renewable hydrogen production
Project total costs:	EUR 19 759 516.50
Clean H_2 JU max. contribution:	EUR 9 998 043.50
Project period:	1.1.2018–30.6.2024
Coordinator:	SINTEF AS, Norway
Beneficiaries:	Element Energy Limited, ITM Power (Trading) Limited, Shell Deutschland GmbH, Shell Energy Europe Limited, Sphera Solutions GmbH, SINTEF AS

https://refhyne.eu/

PROJECT AND OBJECTIVES

The overall objective of REFHYNE is to deploy and operate a 10 MW electrolyser in a power-to-refinery setting. REFHYNE will validate the business model for using large-scale electrolytic hydrogen as an input to refineries, show the revenues available from primary and secondary grid balancing in today's markets and create an evidence base for the policy/regulatory changes needed to underpin the required development of this market. The electrolysers have been installed, and the plant has been tested and is ready for commissioning.

NON-QUANTITATIVE OBJECTIVES

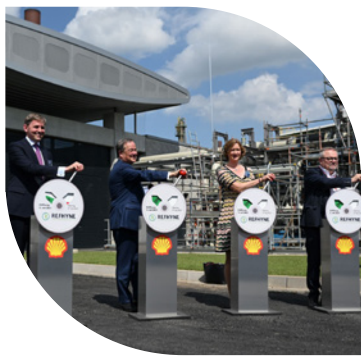
- The project aims to make recommendations for policymakers and regulators on measures required to stimulate the market for these systems. One of the key outputs of the project is a suite of reports providing the evidence base for changes to existing policies. This will include specific analysis aimed at policymakers, recommending changes to existing policies.
- It aims to assess the legislative implications of these systems and their implications for regulations, codes and standards. REFHYNE will produce a detailed assessment of the consenting process for the system and any safety or codes and standards issues encountered.

PROGRESS AND MAIN ACHIEVEMENTS

The electrolyser has been tested and operated at different modes of operation, up to 10 MW (not analysed or uploaded). Lessons learned from the design, construction and initial operation have been summarised and published (not yet analysed or uploaded).

FUTURE STEPS AND PLANS

- The full operation of the electrolyser, including dynamic response testing in grid connection mode, will begin. The system is ready for full operation. The main issue to be resolved is that of timing in relation to other site activities.
- REFHYNE will undertake economic and technical analysis of electrolyser performance. Data gathering, storage and transfer to relevant partners is not fully ready. However, data will be stored and made available for later analysis.
- The project will perform an environmental analysis of the electrolyser system and concept. The framework and models are in place, and analysis will begin once system data are available.



QUANTITATIVE TARGETS AND STATUS

Target source	Parameter	Unit	Target	Target achieved?	SoA result achieved to date (by others)	Year of SoA target
Project's own objectives and MAWP addendum (2018–2020)	Electricity consumption at nominal capacity	kWh/kg	52		55	2020
	Capital cost	€/(kg/day)	2 000		2 100	2020
	Degradation rate	%/1 000 h	0.15		0.19	2020
	Hot idle ramp time for H_2 production	seconds	1		2	2020

REFLEX

REVERSIBLE SOLID OXIDE ELECTROLYZER AND FUEL CELL FOR OPTIMIZED LOCAL ENERGY MIX

Project ID:	779577
PRD 2023:	Panel 1 – H2 production
Call topic:	FCH-02-3-2017: Reversible solid oxide electrolyser (rSOC) for resilient energy systems
Project total costs:	EUR 3 033 654.71
Clean H_2 JU max. contribution:	EUR 2 999 575.25
Project period:	1.1.2018–30.6.2023
Coordinator:	Commissariat à l'énergie atomique et aux énergies alternatives, France
Beneficiaries:	Aktsiaselts Elcogen, Danmarks Tekniske Universitet, Engie, Engie Servizi SpA, Green Power Technologies SL, Parco Scientifico Tecnologico per l'Ambiente SpA, Sylfen, Teknologian tutkimuskeskus VTT Oy, Universidad de Sevilla

http://www.reflex-energy.eu/

PROJECT AND OBJECTIVES

REFLEX aims to develop an innovative renewable energy storage solution, based on reversible solid oxide cell (rSOC) technology, that can operate in either electrolysis mode, to store excess electricity to produce H_2, or fuel cell mode, when energy needs exceed local production levels, to produce electricity and heat from H_2 or any other fuel that is locally available. It has developed improved rSOC components (cells, stacks, power electronics, heat exchangers) and has defined the system, its set points and advanced operation strategies. An in-field demonstration will be performed in 2023.

NON-QUANTITATIVE OBJECTIVES

- The project aims to complete a techno-economic assessment.
- It also aims to create an inventory of regulations, codes and standards applicable to rSOC systems in France and Italy.

PROGRESS AND MAIN ACHIEVEMENTS

- Enlarged cells were produced.
- The project has improved the stack for rSOC operation.
- The rSOC module design was completed.
- The rSOC module assembly has started.
- The site integration is almost complete.

FUTURE STEPS AND PLANS

- The modules and system assembly are being finalised.
- The installation of the system for an in-field test was planned for 2023.

QUANTITATIVE TARGETS AND STATUS

Target source	Parameter	Unit	Target	Achieved to date by the project	Target achieved?	SoA result achieved to date (by others)	Year of SoA target
Project's own objectives	Current density in SOEC mode	A/cm²	1.2	N/A	⚙	– 1.15 at 750 °C, – 1 at 800 °C	2015–2016
	Durability in SOEC step during rSOC operation at 0.58 A/cm² and SC = 68 %	%/1 000 h	2	1.2	⚙	2.3 for current densities of 0.6–0.7 A/cm² and SC = 50 %	2015
	Cell active area	cm²	200	200	✓	128	2021
	Power electronic efficiency	%	95	96	✓	88	2019
	Power modulation SC = 80 %	%	50–100 (SOFC), 70–100 (SOEC)	58–100 in SOEC, 13–100 in natural-gas SOFC and 23–100 in H_2 SOFC	⚙	57–100 in SOEC	2019

SWITCH

SMARTWAYSFORIN-SITUTOTALLYINTEGRATED ANDCONTINUOUSMULTISOURCEGENERATIONOF HYDROGEN

Project ID:	875148
PRD 2023:	Panel 1 – H2 production
Call topic:	FCH-02-3-2019: Continuous supply of green or low carbon H2 and CHP via solid oxide cell based polygeneration
Project total costs:	EUR 3 746 753.75
Clean H_2 JU max. contribution:	EUR 2 992 521.00
Project period:	1.1.2020–31.3.2024
Coordinator:	Fondazione Bruno Kessler, Italy
Beneficiaries:	Deutsches Zentrum für Luft- und Raumfahrt EV, École Polytechnique Fédérale de Lausanne (EPFL), HyGear BV, Shell Global Solutions International BV, SolydEra SA, Sweco Polska sp. z.o.o.

https://switch-fch.eu/

PROJECT AND OBJECTIVES

SWITCH aims to design, build and test a 25 kW (solid oxide fuel cell) / 75 kW (solid oxide electrolyser cell) system prototype for hydrogen production, operating in an industrial environment for 5 000 hours. The SWITCH system will be a stationary, modular and continuous multisource H_2-production technology designed for H_2 refuelling stations. The core of the system will be a reversible solid oxide cell operating in electrolysis mode (SOE) and fuel cell mode (SOFC).

NON-QUANTITATIVE OBJECTIVES

- SWITCH aims to ensure the reliability and stability of power and hydrogen supply. A system with co-generation potential with substantial dynamic behaviour can deliver reliable and stable production of hydrogen and power to match demand-side management, securing the form of energy needed and connecting the generation profile to the end user.
- The project aims to ensure modularity through the development and validation of a 50 kg of H_2/day technology, realised by integrating modules composed of high-reliability stack modules provided by SOLIDpower.
- SWITCH aims to ensure that the hydrogen purity level complies with ISO standard 14687. Hydrogen will be purified to within the range of 99.7–99.99 % and will have a water content of less than 5 parts per million.
- In-field testing in a relevant environment will be assured, with the final SWITCH system prototype being installed in a bench infrastructure and in a real operational environment. The system operation time will be 5 000 hours in the relevant environment.
- Life cycle analysis and life cycle cost analysis will help to evaluate the benefits of the SWITCH technology in comparison with state-of-the-art (SoA) steam methane reforming and other H_2-production technologies (e.g. electrolysis).

PROGRESS AND MAIN ACHIEVEMENTS

- EPFL conducted the analysis on the SWITCH SOEC mode three damage impacts in OPENLCA and carried out a comparison of H_2-production technologies including SOE, AEL, CH2P OM3 and steam methane reforming (SMR).
- HyGEAR and SolydEra performed a hazard and operability analysis of the latest piping and instrumentation diagram.
- The cold balance of plant (BoP) and purification section have been designed and constructed.
- The hot BoP gamma has been finalised and successfully tested, and integrated in the SOE operating mode.
- The control system has been developed, and power electronics have been selected and acquired.
- The analysis of the experiments with the 25 kW LSM was finalised in work package 5. This included steady-state performance in electrolysis, polygeneration and fuel cell mode, and the analysis of the transient behaviour while switching between the modes. In addition, a transient model was developed and validated.
- A 1 000-hour durability test with daily switches between SOFC and SOE mode was performed by EPFL in work programme 5.
- Four articles have been published, with input from partners. The results have been presented in several conferences and workshops.

FUTURE STEPS AND PLANS

- The assembly of the full SWITCH system is in progress. Arrangements are being made to accommodate the testing of the full system at HyGear's premises. Initial work on operating condition optimisation has been carried out during the qualification test of the hot BoP and the LSM at SolydEra facilities.
- An exploitation workshop will be organised to enable work to start on the business model and business plan. The project consortium will apply for module B of the Horizon Results Booster to continue the activity related to the future exploitation of the SWITCH prototype. The focus will be on the business model and potential go-to-market strategy.

QUANTITATIVE TARGETS AND STATUS

Target source	Parameter	Unit	Target	Achieved to date by the project	Target achieved?	SoA result achieved to date (by others)	Year of SoA target
Project's own objectives	Electrolyser conversion efficiency	%	85	80		80	
	Fuel cell conversion efficiency	%	75			80	2021
	Hydrogen cost	€/kg	5	N/A		11.2	
	Stack lifetime	hours	10 000			3 000	
	Low switching time	minutes	30	15	✓	N/A	N/A

Clean Hydrogen Partnership
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