ANIONE

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

Project ID	875024
PRD 2022 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 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, PV3 Technologies 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 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 (TRL 4). Advanced AEMs have been developed in conjunction with non-critical raw materials (CRMs) high-surface-area electrocatalysts and membrane electrode assemblies. These advanced AEMs have shown promising performance and stability.

NON-QUANTITATIVE OBJECTIVES

- **Enhanced oxygen evolution catalysts.** 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.** The project 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.** The project 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

- ANIONE has developed a highly conductive and chemically stable hydrocarbon ionomer/membrane for AEM water electrolysis.
- It has developed a high-performing and electrochemically stable NiFe oxide oxygen evolution anode electrocatalyst for AEM water electrolysis.
- The project has developed enhanced-catalyst-coated-electrodes-based membrane electrode assemblies for AEM water electrolysis.

FUTURE STEPS AND PLANS

- The project will further improve AEM membrane conductivity.
- Large-area stacks will be assembled and tested.
- Promising results have been achieved with functional materials. These need to be validated at 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	2020
	Membrane conductivity	mS/cm	50 mS/cm	105	✓	80	2021

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BioROBURplus

ADVANCED DIRECT BIOGAS FUEL PROCESSOR FOR ROBUST AND COST-EFFECTIVE DECENTRALISED HYDROGEN PRODUCTION

Project ID	736272
PRD 2022 Panel	1 – H2 production
Call topic	FCH-02-2-2016: Development of compact reformers for distributed bio-hydrogen production
Project total costs	EUR 3 813 536.24
Clean H_2 max. contribution	EUR 2 996 248.74
Project period	1/1/2017 – 30/6/2021
Coordinator	Politecnico di Torino, Italy
Beneficiaries	ACEA Pinerolese Industriale SpA, EngiCer SA, Dbi – Gastechnologisches Institut gGmbH Freiberg, Karlsruher Institut Für Technologie, Hysytech SRL, Parco Scientifico Tecnologico Per L'Ambiente – Environment Park Torino SpA, UAB Modernios E-Technologijos, Ethniko Kentro Erevnas kai Technologikis Anaptyxis, Scuola universitaria professionale della Svizzera italiana, Johnson Matthey plc, Centre national de la recherche scientifique

http://www.bioroburplus.org/

PROJECT AND OBJECTIVES

BioROBURplus builds upon the now-closed BioROBUR (direct biogas oxidative steam reformer) project to develop a pre-commercial fuel processor delivering 50 Nm³/h (i.e. 107 kg/day) of 99.9 % hydrogen from different biogas types (landfill gas, anaerobic digestion of organic wastes, anaerobic digestion of wastewater-treatment sludges) in a cost-effective manner. The energy efficiency of the conversion of biogas into H_2 will exceed 80 % on a higher heating value (HHV) basis due to increased internal heat recovery, tailored pressure–temperature swing adsorption (PTSA) and a recuperative burner.

NON-QUANTITATIVE OBJECTIVES

- The safety level of the H_2 production plant was assessed as high in this project.
- ACEA personnel were well-trained to operate the BioROBURplus plant.
- Through successful project management, the objectives were achieved, and the risks and deviations during the project were mitigated.

PROGRESS AND MAIN ACHIEVEMENTS

- A TRL6 demonstration unit for green H_2 production from biogas with a high degree of integration has been manufactured and installed, and is being commissioned.
- A robust catalyst for biogas reforming has been developed.
- Ceramic media with a continuous porosity gradient were developed for the catalyst support and burner.

FUTURE STEPS AND PLANS

The assessment of the process with the solutions that were suggested for the issues faced during the demonstration period is partially complete. During the final part of the demonstration period, some changes were made and better results were obtained, reaching the target efficiency level.

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	Nominal H_2 production capacity	Nm³/h	50	⚙	50 Nm³/h, with an overall efficiency of the conversion of biogas to green hydrogen of 65 %	2016
	Overall plant efficiency	%	≥ 80	✓	65	
	Production cost	€/kg	2	⚙	5	

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CHANNEL

DEVELOPMENT OF THE MOST COST-EFFICIENT HYDROGEN PRODUCTION UNIT BASED ON ANION EXCHANGE MEMBRANE ELECTROLYSIS

Project ID	**875088**
PRD 2022 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 max. contribution	**EUR 1 999 906.25**
Project period	**1/1/2020 – 31/12/2022**
Coordinator	**Sintef AS, Norway**
Beneficiaries	Enapter SRL, Evonik Creavis GmbH, Shell Global Solutions International BV, Evonik Operations GmbH, Norges teknisk-naturvitenskapelige universitet (NTNU), Forschungszentrum Jülich GmbH

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

PROJECT AND OBJECTIVES

The CHANNEL project 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 for 8 months to date.
- 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).

PROGRESS AND MAIN ACHIEVEMENTS

- The production of highly active and durable hydrogen and oxygen evolution reaction electrocatalysts was developed and 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.

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 the platform 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 assembling of the preliminary stack and validation. These are 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 SoA target
Project's own objectives	Oxygen evolution reaction (OER) catalyst performance	mV	< 300 mV (at 10 mA/cm^2 in 1 M of KOH)	237 mV in 1 M of KOH, 270 mV in 0.1 M of KOH	✓	Ir-based catalyst (250 mV at 10 mA/cm^2)	2019
	Hydrogen evolution reaction (HER) catalyst performance	mV	< 150 mV (at – 0.2 V versus Reversible hydrogen electrode (RHE)	60 mV in 1 M of KOH, 120 mV in 0.1 M of KOH	✓	Pt-based catalyst (30 mV at – 10 mA/cm^2) in 1 M of KOH	
	OER catalyst stability	mV	< 25 mV degradation over 1 000 hours in rotating disk electrode (RDE)	33 mV	⚙	N/A	N/A
	HER catalyst stability	mV	< 25 mV degradation over 1 000 hours in RDE	26 mV	⚙		
	Single-cell performance (at 1 A.cm^{-2})	V	1.85	1.85	✓	1.8	2021
AWP 2019	Membrane OH^- conductivity (T=RT)	mS/cm	50	< 45	⚙	Approximately 120 (50-micron membrane from Sustainion) 40–45 mS/cm FAA-3 (Fumatech)	2020
	Ionomer OH conductivity (temperature = 60 °C)	mS/cm	20	> 60	✓	N/A	N/A

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Demo4Grid

DEMONSTRATION OF 4 MW PRESSURIZED ALKALINE ELECTROLYSER FOR GRID BALANCING SERVICES

Project ID	736351
PRD 2022 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 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 (PAE) 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 was installed at the demonstration site and produced its first hydrogen on 22 March 2022.

QUANTITATIVE TARGETS AND STATUS

Target source	Parameter	Unit	Target	Target achieved?	SoA result achieved to date (by others)	Year of SoA target
	H_2 production electrolysis, hot start from minimum to maximum power	seconds	2		60	
	Start-up time KPIs from cold to minimum part-load for alkaline electrolysers	minutes	20		30	
Project's own objectives	Minimum part-load operation targets for alkaline electrolysers	% (full load)	20		30	2015
	Ramp up	% (full load)/s	7		7	
	Ramp down	% (full load)/s	10		10	

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Djewels

DELFZIJL JOINT DEVELOPMENT OF GREEN WATER ELECTROLYSIS AT LARGE SCALE

Project ID	826089
PRD 2022 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 max. contribution	EUR 10 999 999
Project period	1/1/2020 – 31/12/2025
Coordinator	Nobian Industrial Chemicals BV, the 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 TRL 7 to TRL 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 hazard and operability analysis for the completed design has been carried out.

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

- The stack testing and optimisation will be finished. This has been delayed and is anticipated to be completed in July 2022.
- An investment decision will be made in September 2022.
- Group breaking is expected at the end of 2022.
- Construction is expected to be completed in 2024.

QUANTITATIVE TARGETS AND STATUS

Target source	Parameter	Unit	Target	Target achieved?
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	
Project's own objectives	Nominal capacity	MW	25	

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GAMER

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

Project ID	779486
PRD 2022 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 max. contribution	EUR 2 998 951.25
Project period	1/1/2018 – 31/12/2021
Coordinator	Sintef AS, Norway
Beneficiaries	Mc2 Ingenieria y Sistemas SL, Carbon Recycling International EHF, Coorstek Membrane Sciences AS, Shell Global Solutions International BV, Universitetet i Oslo, Stiftelsen Sintef, Agencia Estatal Consejo Superior de Investigaciones Científicas

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

PROJECT AND OBJECTIVES

The GAMER project is developing a novel cost-effective tubular proton ceramic electrolyser (PCE) stack to produce pure, dry, pressurised hydrogen. The main objective of GAMER is to design, build and operate a low-cost 10 kW electrolyser system delivering at least a 30-bar output of dry H_2. The technology is based on tubular cells integrating a proton-conducting ceramic electrolyte produced using mass-manufacturing techniques.

NON-QUANTITATIVE OBJECTIVES

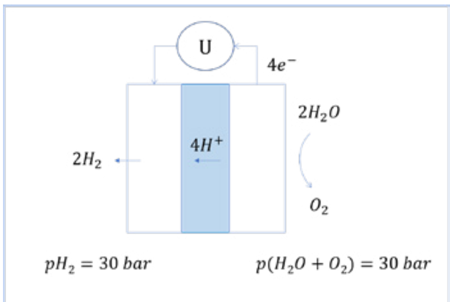
- An engineering model enabling the description of the performance of the 10 kW system was developed. The tool is available online and can be used for free. It is now used alongside other technologies in projects such as Winner.
- Several articles have been submitted and are under review. One *Nature* article has been published.
- The first stack of PCE was designed. This is thought to be the first PCE demonstration at stack level at an international scale.
- Several single engineering units (SEUs) have been tested at 600 °C at up to 10 bars, producing efficiently pressurised H_2.

PROGRESS AND MAIN ACHIEVEMENTS

- The testing of an SEU with a 60 cm^2 surface area at 10 bars at 600 °C was successful.
- A techno-economic analysis of GAMER technology was performed for several integration cases.
- The environmental impact of GAMER technology was assessed.

FUTURE STEPS AND PLANS

- The finalisation of racks 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.



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 bars in electrolysis mode	$ohm.cm^2$	2	2.5	⚙	< 2	2022
	Faradaic efficiency of the SEU at 3 bars at 0.1 mA/cm^2 at 600 °C	%	> 85	95	✓	> 85	2020
	Degradation rate: maximum decrease of the voltage after 500 hours at 600 °C at 100 mA/cm^2	%/h	1.2	< 5	✓	N/A	N/A
	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 2022 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 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 a 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 (AC) and an electrical efficiency of 84 % lower heating value (LHV). While assessing 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 by steel production in Salzgitter.

PROGRESS AND MAIN ACHIEVEMENTS

- The electrical efficiency target was reached (84 % LHV).
- The high-temperature electrolyser system's operating hours are progressing (8 000 out of 13 000 hours). By April 2022, a total of 67.6 t of hydrogen were produced in 8 000 operating hours.
- Stack degradation was below what was expected (15 mohm.cm^2.kh^{-1})

FUTURE STEPS AND PLANS

- The project will achieve production of at least 100 t of hydrogen by the end of 2022. The system is currently operating normally. So far, about 56 t of green hydrogen have been produced. Provided there is steady operation, the objective will be reached by December 2022.
- A project objective is to reach 13 000 operational hours and system availability of 95 % by the end of 2022. Provided there is steady operation, this objective will also be reached by December 2022.
- The project will achieve completion of 16 000 hours of continuous stack testing by the end of 2022. The stack has reached continuous operation of 7 000 hours. Thus, the initial objective of 20 000 hours will not be reached. Provided there is steady operation, the new stack will be able to complete 15 000 hours by the end of the project.

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	Hydrogen production rate	kg/h	18	18	✓	3.6	2017
	Total production of green hydrogen	t	100	56	⚙	N/A	
	Electrical efficiency based on LHV	%	84	84	✓	78	
	CAPEX	€/(kg/d)	4 500	4 500	✓	12 000	
	Demonstration of hot start from min to max. power	minutes	5	15	⚙	10	2018
	Hours of operation	hours	13 000	8 000	⚙	10 000	2019
	Availability	%	95	84	⚙	66	
	Cost of hydrogen	€/kg	7	N/A	⚙	N/A	N/A
Project's own objectives	Hours of continuous stack testing	hours	20 000	7 000	⚙	8 700	2019

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H2Future

HYDROGEN MEETING FUTURE NEEDS OF LOW CARBON MANUFACTURING VALUE CHAINS

H2FUTURE
Green Hydrogen

Project ID	735503
PRD 2022 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 17 852 540.38
Clean H_2 max. contribution	EUR 11 997 820.01
Project period	1/1/2017 – 31/12/2021
Coordinator	Verbund Energy4Business GmbH, Austria
Beneficiaries	Siemens Energy Austria GmbH, Siemens Energy Global GmbH & Co. KG, K1-MET GmbH, Verbund Solutions GmbH, voestalpine Stahl GmbH, Austrian Power Grid AG, Siemens Aktiengesellschaft Oesterreich, Siemens Aktiengesellschaft, Stichting Energieonderzoek Centrum Nederland, Nederlandse Organisatie voor Toegepast Natuurwetenschappelijk Onderzoek

http://www.h2future-project.eu/

PROJECT AND OBJECTIVES

The main goals of the project H2Future are to design and install a 6 MW PEM electrolyser system at the voestalpine steel plant in Linz, and to execute a 2-year demonstration operation of the electrolyser system with ambitious efficiency targets. The plant had started production by the end of 2019. While in commission, the plant has been pre-qualified to provide grid-balancing services such as primary, secondary or tertiary reserves. Since 15 October 2020, the H2Future unit is in quasi-commercial operation.

NON-QUANTITATIVE OBJECTIVES

- The project aimed to optimise production to allow the reduction of production costs by supplying ancillary services. By participating in the electricity-balancing market and by utilising additional energy market options, H_2 production costs have decreased between 25 % and 45 %.
- The project aimed to show that plant operation at overload capacity is feasible with PEM electrolysers: 50 % overload capacity was achieved during the project. However, auxiliary units have to be designed for that purpose.

PROGRESS AND MAIN ACHIEVEMENTS

- The quasi-commercial operation phase was completed.
- The electrolyser has achieved a stack efficiency of up to 83 %.

FUTURE STEPS AND PLANS

- The plant has remained in operation since the end of the funding period of the project on 31 December 2021.
- The plant will facilitate the external delivery of the produced hydrogen by adding an upgrading unit. Some members of the project team are planning a follow-up project to supply green hydrogen for further research projects (methanation, power to liquid, etc.).
- Green hydrogen will be produced for external consumers: apart from supplying green hydrogen for research purposes, the plant will also supply it to industrial and/or mobility consumers.

QUANTITATIVE TARGETS AND STATUS

Target source	Parameter	Unit	Target	Target achieved?
Project's own objectives	H_2 production	Nm³/h	1 200	
	H_2 purity	%	99.9	
	System efficiency at full load	%	≤ 83	✓
	Range and scalability	%	20–100	
	O_2 purity	%	99.0	

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Haeolus

HYDROGEN-AEOLIC ENERGY WITH OPTIMISED ELECTROLYSERS UPSTREAM OF SUBSTATION

Project ID	779469
PRD 2022 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 7 793 995
Clean H_2 max. contribution	EUR 4 997 738.63
Project period	1/1/2018 – 31/12/2023
Coordinator	Sintef AS, Norway
Beneficiaries	Varanger KraftHydrogen AS, Varanger Krauftutvikling AS, Varanger KraftMarked AS, Varanger KraftEnterprenør AS, Varanger Kraft AS, Varanger KraftNett AS, Varanger KraftVind AS, Communauté d'universités et d'établissements Université Bourgogne Franche-Comté, New NEL Hydrogen AS, KES Knowledge Environment Security SRL, Hydrogenics Europe NV, Università degli Studi del Sannio, École Nationale Supérieure de Mécanique et des Microtechniques, Université de technologie de Belfort-Montbéliard, Fundacion Tecnalia Research & Innovation, Université de Franche-Comté, Stiftelsen Sintef

http://www.haeolus.eu/

PROJECT AND OBJECTIVES

The project has deployed a 1 t/day electrolyser in the remote village of Berlevåg in Norway, together with a storage tank and fuel cells for re-electrification, in connection with a wind farm. 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 has received a 2-year extension and is now following the 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. It has received additional funding from Norway to support exploitation.

PROGRESS AND MAIN ACHIEVEMENTS

- The system was deployed and commissioned.
- All control algorithms were defined.
- The demonstration has started.

FUTURE STEPS AND PLANS

Demonstration of the energy storage strategy has started and is planned to be completed by summer 2022.

QUANTITATIVE TARGETS AND STATUS

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

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HYDROSOL-beyond

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

Project ID	826379
PRD 2022 Panel	1 – H2 production
Call topic	FCH-02-4-2018: Thermochemical hydrogen production from concentrated sunlight
Project total costs	EUR 2 999 940
Clean H_2 max. contribution	EUR 2 999 940
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 B.V., HyGear BV, Scuola universitaria professionale della svizzera Italiana, Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas (Ciemat), 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

The HYDROSOL-beyond project 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. HYDROSOL-beyond 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 increase the potential of the technology's future commercialisation.

NON-QUANTITATIVE OBJECTIVES

The objective is to develop a novel high-temperature heat exchanger. The design of a hybrid (metal/ceramic) heat exchanger capable of operating at temperatures of over 1 000 °C has been finalised and the manufacture of a small-scale prototype is in progress.

PROGRESS AND MAIN ACHIEVEMENTS

- Stable $NiFe_2O_4$ lattice structures have been produced.
- A small-scale hybrid ceramic/metallic heat exchanger has been constructed.

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 for 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.
- Data from the operation of the solar reactor at the solar simulator facility at Jülich will be available.

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	Demonstrate the process at realistic scale and working conditions, using an existing solar demonstration facility (> 200 kW range)	kW/reactor	250	N/A		250	2018
	Durability	cycles	1 000	150		602	
	Achieve heat recovery rates of high-temperature heat in excess of 60 %	%	60	46		N/A	

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MegaSyn

MEGAWATT SCALE CO-ELECTROLYSIS AS SYNGAS GENERATION FOR E-FUELS SYNTHESIS

Project ID	101007108
PRD 2022 Panel	1 – H2 production
Call topic	FCH-02-8-2020 – Demonstration of large-scale co-electrolysis for the industrial power-to-X market
Project total costs	EUR 785 793.75
Clean H_2 max. contribution	EUR 4 999 449.39
Project period	1/4/2021 – 31/3/2025
Coordinator	Danmarks Tekniske Universitet, Denmark
Beneficiaries	OMV Downstream GmbH, Paul Wurth SA, Sunfire GmbH, Technische Universität Graz

http://www.megasyn.eu/

PROJECT AND OBJECTIVES

The MegaSyn project aims to install and integrate the world's first solid oxide co-electrolyser system on a MW scale at an existing refinery site. It aims to run a 2-year demonstration (12 000 hours of continuous operation) of the co-electrolyser system with a production capacity of 900 t of syngas and an availability above 95 %, while keeping the degradation rate below 1.2 %/1 000 h.

NON-QUANTITATIVE OBJECTIVES

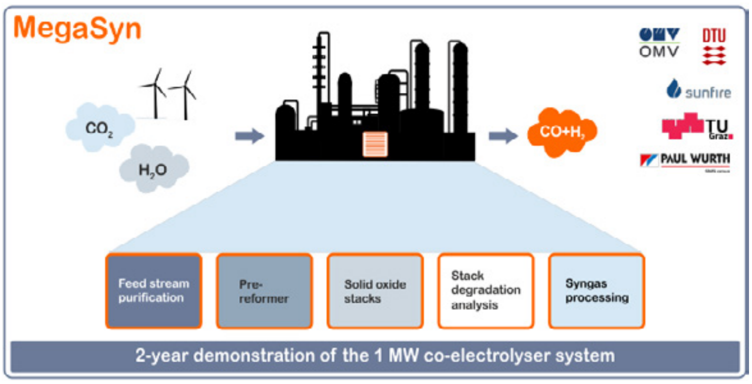
- **Feed stream contamination.** Report on relevant contaminants and purification technologies is close to being finalised (due on 31 March 2022).
- **Designing and manufacturing of the MW-scale system.** Report on the design basis of the MegaSyn system is close to being finalised (due on 31 March 2022).

PROGRESS AND MAIN ACHIEVEMENTS

- A Sunfire single cell has been successfully tested for 2 000 hours of co-electrolysis operation so far.
- A safety plan for handling flammable and toxic gases such as hydrogen and carbon monoxide is in place.

FUTURE STEPS AND PLANS

- Various tasks in different work plans will be carried out according to the project plan. Most of the project tasks are progressing in line with the plan.
- Detailed analysis of the 2 000-hour single-cell test will be conducted, and the identification of major degradation mechanisms and possible counteracting measures is ongoing.
- The project will design and manufacture an efficient MW-scale co-electrolyser system and demonstrate how to lower future CAPEX, and operation and maintenance costs. The design basis of the MegaSyn system needs to be revised because of the outcome of the hazard and operability analysis and safety-related issues.



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 objective	Degradation rate	mohm. cm²/1 000 h	17	80		30	2016

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MultiPLHY

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

Project ID	875123
PRD 2022 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 9 751 722.50
Clean H_2 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	Neste Engineering Solutions BV, Neste Netherlands BV, Engie Energie Services, Neste Engineering Solutions Oy, Paul Wurth SA, Sunfire GmbH, Neste Oyj, ENGIE

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 manufacturing 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 TRL 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 CAPEX.

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

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NEPTUNE

NEXT GENERATION PEM ELECTROLYSER UNDER NEW EXTREMES

Project ID	779540
PRD 2022 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 max. contribution	EUR 1 926 221.25
Project period	1/2/2018 – 31/4/2022
Coordinator	ITM Power (Trading) Limited, United Kingdom
Beneficiaries	Pretexo, IRD Fuel Cells A/S, Solvay Specialty Polymers Italy SpA, ENGIE, Consiglio Nazionale delle Ricerche

http://www.neptune-pem.eu/

PROJECT AND OBJECTIVES

The NEPTUNE project addresses challenges associated with reducing capital costs and increasing production rates and output pressures of water electrolysis that will be required to achieve large-scale application of polymer electrolyte membrane (PEM) electrolysers. NEPTUNE is developing a set of breakthrough solutions at material, stack and system levels to increase hydrogen pressure to 100 bars and current density to 4 A/cm² for the base load, while keeping the 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

- The project designed and built a new simplified balance of plant for PEM electrolysis, to extend operating conditions.
- The membrane electrode assembly (MEA) 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 will seek to demonstrate the advanced cost-effective PEM electrolysis stack operating at high temperatures and with high differential pressure.
- Techno-economic assessment and life cycle analysis of the advanced PEM electrolyser will be completed shortly.

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 a low-temperature electrolyser	%/1 000 h	0.29	0.23	✓	0.2	

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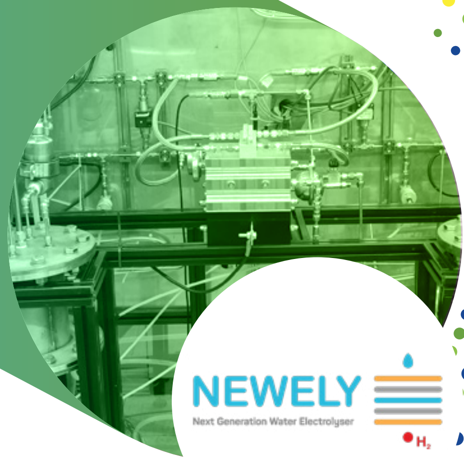
NEWELY

NEXT GENERATION ALKALINE MEMBRANE WATER ELECTROLYSERS WITH IMPROVED COMPONENTS AND MATERIALS



Project ID	875118
PRD 2022 Panel	1 – H2 production
Call topic	FCH-02-4-2019: New anion exchange membrane electrolysers
Project total costs	EUR 2 597 413.75
Clean H_2 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	Membrasenz SARL, ProPuls GmbH, Cutting-Edge Nanomaterials Cenmat UG haftungsbeschrankt, Air Liquide Forschung und Entwicklung GmbH, Korea Institute of Science and Technology, Westfälische Hochschule Gelsenkirchen, Bocholt, Recklinghausen, DLR Institut für Vernetzte Energiesysteme eV, Ústav makromolekulárni chemie AV ČR VVI, Fondazione Bruno Kessler, Vysoká škola chemicko-technologická v Praze, L'air Liquide SA, Commissariat à l'énergie atomique et aux énergies alternatives

http://www.newely.eu/

PROJECT AND OBJECTIVES

This project aims to redefine AEMWE (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, twice the performance of the state of the art (SoA) of AEMWE will be validated. This will have an impact on the cost of green hydrogen.

NON-QUANTITATIVE OBJECTIVES

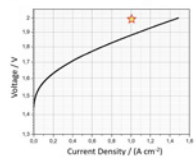
The techno-economic assessment and life cycle assessment demonstrate a reduction of CAPEX and OPEX for AEMWE relative to proton-exchange membrane WE and alkaline WE. Data collection is complete, and evaluation has started.

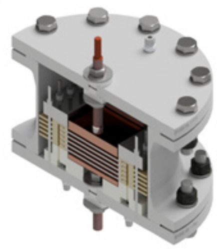
PROGRESS AND MAIN ACHIEVEMENTS

- The membrane electrode assembly (MEA) with NiFe anode, Mo_2C cathode and commercial anion-exchange membrane (AEM) / ionomer achieves 2 V at 2 A/cm² in 0.1 M KOH. No irreversible degradation was seen in a 400-hour test.
- AEM with conductivity of 60 mS/cm and area-specific resistance of 0.065 ohm/cm² was achieved.
- The project created a new method for AEM membrane reinforcement with covalent bonds between the matrix and ionomer, with conductivity of 62 mS/cm.

FUTURE STEPS AND PLANS

- MEAs will be prepared at 25 cm² and 200 cm² with project materials and targeted performance. The first MEAs have been prepared; the next step is testing of the 25 cm² MEA.
- Stack design will be finalised and constructed. The first draft has already been prepared, and is awaiting 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 small scale; 25 cm² single-cell and in-stack testing are still to be carried out.
- Data analysis has started for the life cycle assessment and cost analysis.





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	0.014	⚙	2.4	2021
	Cell area	cm²	200	4		N.A	
	Pressure	bars (relative)	≤ 40	0	✓	≤ 35	
MAWP Addendum (2018–2020)	Energy consumption @ power	kWh/kg @ W/cm²	53.6 @ 2	53.6 @ 3.6	✓	53.6 @ 2.4	
	Corresponding to cell voltage @ current	V @ A/cm²	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/cm²	1	1	✓	1	
MAWP Addendum (2018–2020) and AWP 2019	Stable operation for 2 000 hours, cell voltage gap after 2 000 hours of operation	mV	50	No test yet	⚙	< 2	2021
	Extrapolated to efficiency degradation @ rated power and assuming 8 000 hours of operation per year	Extrapolated to %/year	Extrapolated to 7.2			< 0.3	
	Chemically, thermally and mechanically stable AEM ionomer and membrane with conductivity	mS/cm	≥ 50	62	✓	80	2021
	Area-specific resistance	ohm/cm²	≤ 0.07	0.065	✓	0.045	

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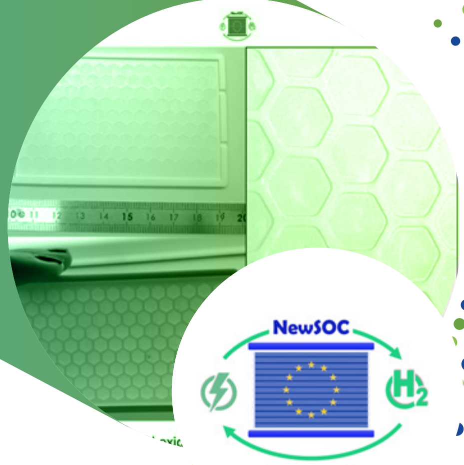

NewSOC

NEXT GENERATION SOLID OXIDE FUEL CELL AND ELECTROLYSIS TECHNOLOGY

Project ID	**874577**
PRD 2022 Panel	**1 – H2 production**
Call topic	**FCH-02-6-2019 – New materials, architectures and manufacturing processes for solid oxide cells**
Project total costs	**EUR 2 499 992.5**
Clean H_2 max. contribution	**EUR 2 499 992.5**
Project period	**1/1/2020 – 30/6/2023**
Coordinator	**Danmarks Tekniske Universitet, Denmark**
Beneficiaries	Teknologian tutkimuskeskus VTT Oy, Sunfire GmbH, Ceres Power Limited, SOLIDpower SpA, Aktsiaselts Elcogen, Fundació Institut de Recerca de l'Energia de Catalunya, Hexis AG, Ethniko Kentro Erevnas kai Technologikis Anaptyxis, Instytut Energetyki, Università degli Studi di Salerno, École Polytechnique Fédérale de Lausanne, Politecnico di Torino, Nederlandse Organisatie voor Toegepast Natuurwetenschappelijk Onderzoek, Commissariat à l'énergie atomique et aux énergies alternatives, Idryma Technologias kai Erevnas

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 state of the art, focusing on (i) structural optimisation and innovative architectures, (ii) alternative materials and (iii) innovative manufacturing. NewSOC 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

- The project aimed to identify the electrocatalytic mechanism under solid oxide co-electrolysis cells (co-SOEC). It sought to elucidate the effect of the pH_2O and pCO_2 on the co-SOEC mechanism for the Ni/GDC fuel electrode.
- A project objective was the definition of industrial targets. Detailed numbers are to be provided by the industrial partners to guide further developments.
- The project aimed to screen potential environmental impacts. The interconnector is the largest contributor in all impact categories for both electrolyte-supported cell (ESC) and anode-supported cell (ASC) technologies.

PROGRESS AND MAIN ACHIEVEMENTS

- The project reduced the use of critical raw materials via development of a Co-free air electrode.
- It improved the cell based on the LSCr-Fe perovskite fuel electrode: the performance is not compromised by the exposure to oxidising conditions (absence of H_2).
- An interface coating was developed to improve the stability and the strength of the interface between the integrated circuit and the glass sealing to cycling operation.

FUTURE STEPS AND PLANS

- Developed components (electrodes, etc.) will be integrated into commercial cells/stacks. The identification of improved components and pairing with industrial partners have been accomplished, and the integration has started.
- Ni migration modelling to better understand the mechanism involved in the cermet degradation is in progress.
- The development of improved components will continue, with a focus on dynamic operation (cycles, redox). The development and durability assessment of candidates is in progress.

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	0.7	
	Electrolysis current for operation with degradation rate below 1 %/1 000 h	A/cm²	0.75–1	1.2	
	Operating temperature	°C	650	650–700	

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OYSTER

OFFSHORE HYDROGEN FROM SHORESIDE WIND TURBINE INTEGRATED ELECTROLYSER

Project ID	101007168
PRD 2022 Panel	1 – H2 production
Call topic	FCH-02-6-2020: Electrolyser module for offshore production of renewable hydrogen
Project total costs	EUR 4 999 843.51
Clean H_2 max. contribution	EUR 4 999 843
Project period	1/1/2021 – 31/12/2024
Coordinator	Element Energy, France
Beneficiaries	Ørsted Wind Power A/S, ITM Power (Trading) Limited, Siemens Gamesa Renewable Energy SA, Element Energy Limited

https://oysterh2.eu/

PROJECT AND OBJECTIVES

The overall aim of the OYSTER project 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. The project has progressed with marinisation designs and has completed the system modelling for the electrolyser's transient electronic response. Procurement exercises for the power supply unit and water treatment unit are at an advanced stage.
- It aims to deploy and test a new MW-scale electrolyser designed for marine environments for 18 months, covering all seasons.
- A project objective is to complete a design exercise of an integrated offshore wind turbine electrolysis module, drawing on the lessons 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. Offshore wind farm sites that are expected to become available in the North Sea in the near future will be reviewed for potential dedicated offshore hydrogen production.
- 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

- The water treatment system design has been finalised.
- The system modelling to be used for simulation of direct connected power electronics has been finalised.
- The location for the trial has been selected. Following investigation, a trial site has been selected in Grimsby, United Kingdom.

FUTURE STEPS AND PLANS

- The project will plan and gain permits for the electrolyser trial.
- Components (offshore component, water treatment unit, power supply unit) will be procured. Due to the innovative aspects of the components, long lead times are expected – all materials are expected to be delivered by the end of 2022.
- A shoreside trial and data collection are expected to start in the second quarter of 2022.
- The trial and studies will be concluded. By combining technical developments and a shoreside test of a pilot plant with detailed studies and business case assessment for deployment at scale, this project will provide a solid foundation for implementation of the solution at scale in the 2020s.

QUANTITATIVE TARGETS AND STATUS

Target source	Parameter	Unit	Target	Target achieved?
Project's own objectives	Electrolyser footprint	m²/MW	20	
	Maintenance cost	€/(kg/year)	28	
	Efficiency degradation at rated power	%/1 000 h	0.09	
	Energy consumption at rated power (system AC efficiency including balance of plant)	kWh/kg	51.6	
	Electrolyser CAPEX (at rated power), including ancillary equipment and commissioning	€/(kg/day)	950	
	Electrolyser CAPEX (at rated power), including ancillary equipment and commissioning	€/kW	500	
	Time for hot start (min to max power)	seconds	< 1	
	Current density	A/cm²	3.0	
	Operational load-run hours within the project	hours	3 000	
	Design of an integrated electrolyser–wind-turbine solution	%	Demonstrate a 30 % capital-cost saving in electrolyser costs (avoided power electronics)	

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PRETZEL

NOVEL MODULAR STACK DESIGN FOR HIGH PRESSURE PEM WATER ELECTROLYSER TECHNOLOGY WITH WIDE OPERATION RANGE AND REDUCED COST

Project ID	779478
PRD 2022 Panel	1 – H2 production
Call topic	FCH-02-1-2017: Game changer water electrolysers
Project total costs	EUR 1 999 088.75
Clean H_2 max. contribution	EUR 1 999 088.75
Project period	1/1/2018 – 30/6/2021
Coordinator	Deutsches Zentrum für Luft- und Raumfahrt eV, Germany
Beneficiaries	iGas Energy GmbH, Adamant Aerodiastimikes Efarmoges Etaireia Periorismenis Efthynis, Soluciones Cataliticas Ibercat SL, Gkn Sinter Metals Filters GmbH Radevormwald, Westfälische Hochschule Gelsenkirchen, Bocholt, Recklinghausen, GKN Sinter Metals Engineering GmbH, École nationale supérieure des mines de Paris, Ethniko Kentro Erevnas kai Technologikis Anaptyxis, Universitatea Politehnica Timișoara, Association pour la Recherche et le Développement des Méthodes et Processus Industriels

https://pretzel-electrolyzer.eu/

PROJECT AND OBJECTIVES

The overall goal of PRETZEL was to develop an innovative polymer electrolyte membrane electrolyser (PEMEL) components. The central objective was the development of a 25 kW PEM electrolysis stack, employing these innovative components, generating 4.5 m³/h of hydrogen at rated power, at 100 bars and 90 °C. The PRETZEL innovations of cost-efficient VPS-coated polar plates, high-performance titanium and stainless-steel-based porous transport layers (PTLs), among other things, have been demonstrated, reported and published. The COVID-19 pandemic caused delays, preventing the full-stack operation within the project period. The stack characterisation is ongoing.

PROGRESS AND MAIN ACHIEVEMENTS

- Regarding current density, coatings for stainless steel BPPs and PTLs were developed and tested up to a current density of 6 A/cm², achieving an unprecedented cell efficiency of 77 %.
- Regarding temperature, Ti-based PTLs allow operation of up to 6 A/cm² at 90 °C, completely eliminating mass transport limitations and passing the durability accelerated stress test.
- The 25 kW PRETZEL stack was commissioned and put in operation, reaching the target initial performance of 90 bars and 90 °C stably.

FUTURE STEPS AND PLANS

A 2 000-hour test of the PEM water electrolysis system at 90 °C, 100 bars and up to 6 A/cm² is ongoing.

QUANTITATIVE TARGETS AND STATUS

Target source	Parameter	Achieved to date by the project
MAWP (2014–2020) and AWP 2017	Reduce PEM electrolyser CAPEX costs: new cost-effective current collectors for PEM electrolysers for hydrogen generation from renewable energies	Novel PTL structures allow for an unprecedented efficiency of 77 %
	Increase energy efficiency of hydrogen production: increased catalyst activity and optimisation of supporting material	Iridium-supported material (Ir/SnO_2) has been prepared and evaluated on its catalytic activity and economic feasibility for scaling up
	Development and validation of a game-changing PEM electrolyser meeting the 2023 targets: 210 cm² high-pressure stack with all components tested	The cell parts and computer-aided design of the high-pressure electrolyser stack have been finalised and manufactured. The design is based on partners' prototypes using the principle of hydraulic cell compression, which were developed in the publicly funded projects Vompels (EFRE-0800099) and MoDePEM (EFRE-0400094)
AWP 2017	Step-change improvements: 100 bars, rapid response (< 1 s hot start), nominal current density of 4 A/cm² and overload of 6 A/cm², temperature of > 80 °C	The initial cell test for a polarisation curve up to 6 A/cm² at 90 °C and 100 bars was successful
	Enable additional commercial roll-out of electrolyser: cost considerations and market analysis from project results extrapolated to MW scale	Market analysis started by investigating possible users of produced gases

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PROMETEO

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

Project ID	101007194
PRD 2022 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 max. contribution	EUR 2 499 531.25
Project period	1/1/2021 – 30/6/2024
Coordinator	Agenzia nazionale per le nuove tecnologie, l'energia e lo sviluppo economico sostenibile, Italy
Beneficiaries	Capital Energy SL, Snam SpA, Stamicarbon BV, NextChem SpA, SOLIDpower SA, Fundación Imdea Energia, Fondazione Bruno Kessler, École Polytechnique Federale de Lausanne

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 (TES). Partial-load operation, transients and hot standby periods will be studied.

PROGRESS AND MAIN ACHIEVEMENTS

- The project defined end users' cases.
- Preliminary process flow diagrams were created.

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) versus 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	
	The SOE with renewable heat integration will demonstrate electrical efficiency of ≥ 85 % based on the LHV and specific energy consumption of < 39 kWh/kg of H_2 in a market representative of the relevant environment: power-to-hydrogen energy conversion efficiency of the heat-integrated SOE system (LHV basis)	%	85	

FUTURE STEPS AND PLANS

- The development of reduced-scale prototypes for the SOE stack and the heat storage unit combined with the steam generator to be validated in the laboratory is in progress – it is expected to be complete by the end of 2022.
- The integrated pilot plant will be designed and built. The basic design is in progress. The pilot plant is expected to be ready to operate by 2023.

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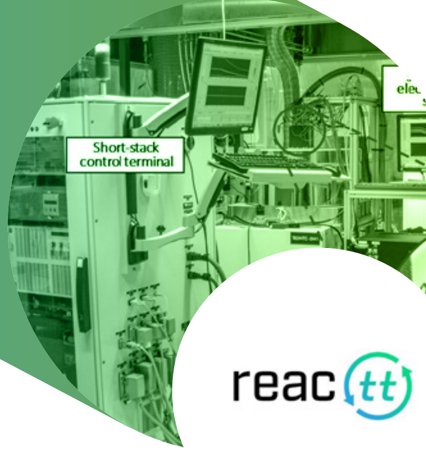
REACTT

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



reac(tt)

Project ID	101007175
PRD 2022 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 max. contribution	EUR 2 712 322.50
Project period	1/1/2021 – 31/12/2023
Coordinator	Institut 'Jožef Stefan', Slovenia
Beneficiaries	Teknologian tutkimuskeskus VTT Oy, Bitron SpA, SOLIDpower SA, Haute Ecole Spécialisée de Suisse Occidentale, Università degli Studi di Salerno, AVL List GmbH, École Polytechnique Fédérale de Lausanne, Agenzia nazionale per le nuove tecnologie, l'energia e lo sviluppo economico sostenibile, Commissariat à l'énergie atomique et aux énergies alternatives

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

PROJECT AND OBJECTIVES

REACTT will realise a monitoring, diagnostic, prognostic and control (MDPC) tool for and 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. The development of the hardware platform and embedded diagnostics and prognostics algorithms is under way.

NON-QUANTITATIVE OBJECTIVES

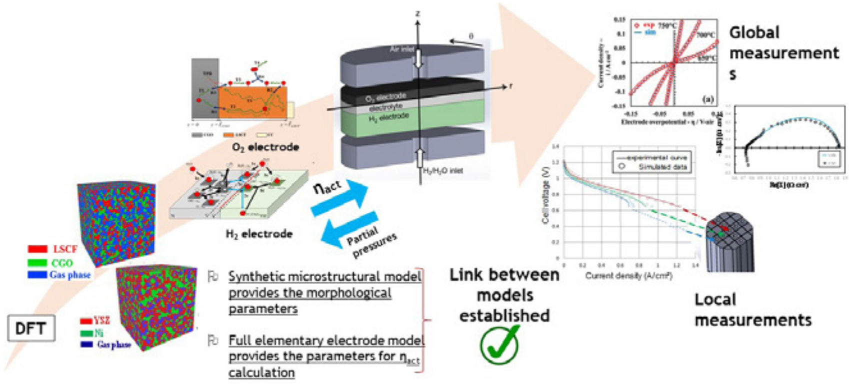
- **Education/training.** The possible inclusion of the topic of SOC technologies in MSc and PhD study programmes was to be considered.
- **Public awareness.** The project web page and dissemination material are the first step towards raising public awareness.
- **Safety.** Fault detection, isolation and mitigation in SOEC/ SOFC preclude process disruption and potential hazards.
- **Regulations and standards.** The formulation of a new work item proposal (NWIP) set out in M12–M36 is to be submitted to Technical Committee 105 of the International Electrotechnical Commission (IEC-TC105).

PROGRESS AND MAIN ACHIEVEMENTS

The project has developed the excitation module.

FUTURE STEPS AND PLANS

An application for a project extension has been made. Delays in stack delivery suggest 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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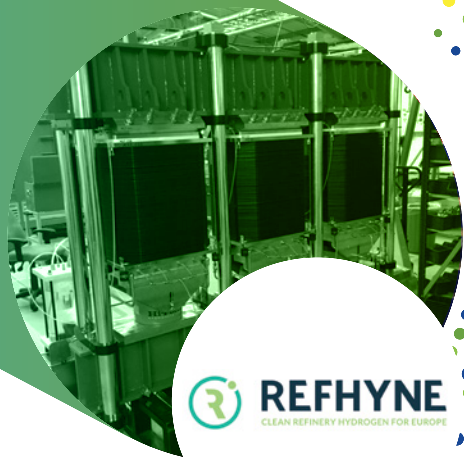
REFHYNE

CLEAN REFINERY HYDROGEN FOR EUROPE



Project ID	779579
PRD 2022 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 max. contribution	EUR 9 998 043.50
Project period	1/1/2018 – 31/12/2022
Coordinator	Sintef AS, Norway
Beneficiaries	Shell Energy Europe Limited, Shell Deutschland Oil GmbH, Sphera Solutions GmbH, ITM Power (Trading) Limited, Element Energy Limited, Stiftelsen Sintef

http://www.refhyne.eu/

PROJECT AND OBJECTIVES

The overall objective of the REFHYNE project 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 are installed, the plant has been tested and is ready for commissioning, and full operation will start in 2022.

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 focused on policymakers recommending changes to existing policies.
- It aims to assess the legislative and regulations, codes and standards implications of these systems. 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

- REFHYNE finalised the detailed design of the electrolyser system plant and it was adapted to the refinery.
- The permit application was approved by the local authorities.
- A 10 MW PEM electrolyser system was commissioned.

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 that needs 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 100 % ready. However, data will be stored and 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	SoA result achieved to date (by others)	Year of SoA target
Project's own objectives and MAWP Addendum (2018–2020)	Electricity consumption @ nominal capacity	kWh/kg	52	55	2020
	Capital cost	€/(kg/day)	2 000	2 100	
	Degradation rate	%/1 000 h	0.15	0.19	
	Hot idle ramp time for H_2 production	seconds	1	2	

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REFLEX

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

Project ID	779577
PRD 2022 Panel	1 – H2 production
Call topic	FCH-02-3-2017: Reversible solid oxide electrolyser (rSOC) for resilient energy systems
Project total costs	EUR 2 999 575.48
Clean H_2 max. contribution	EUR 2 999 575.25
Project period	1/1/2018 – 31/12/2022
Coordinator	Commissariat à l'énergie atomique et aux énergies alternatives, France
Beneficiaries	Sylfen, Teknologian tutkimuskeskus VTT Oy, Engie Servizi SpA, Aktsiaselts Elcogen, Green Power Technologies SL, Parco Scientifico Tecnologico Per L'ambiente – Environment Park Torino SpA, Universidad De Sevilla, ENGIE, Danmarks Tekniske Universitet

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

PROJECT AND OBJECTIVES

The REFLEX project aims to develop an innovative renewable energies storage solution, based on reversible solid oxide cell (rSOC) technology, that can operate either in electrolysis mode, to store excess electricity to produce H_2, or in 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 defined the system, its setpoints and advanced operation strategies. An in-field demonstration will be performed in 2021.

NON-QUANTITATIVE OBJECTIVES

- The project aims to complete a techno-economic assessment.
- It 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.

FUTURE STEPS AND PLANS

- The modules and system assembly are to be finalised (ongoing).
- The installation of the system for an in-field test is planned for 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	Current density in SOEC mode	A/cm²	1.2	N/A	✓	– 1.15 A/cm² at 750 °C, – 1 A/cm² 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 %/1 000 h 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

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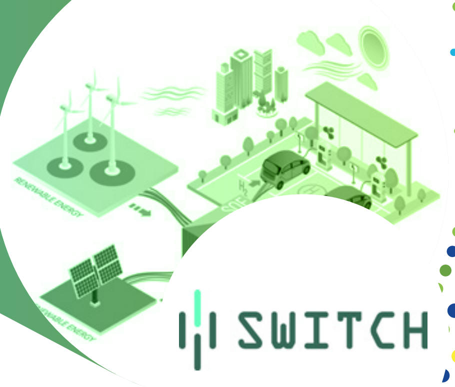
SWITCH

SMART WAYS FOR IN-SITU TOTALLY INTEGRATED AND CONTINUOUS MULTISOURCE GENERATION OF HYDROGEN



Project ID	875148
PRD 2022 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 max. contribution	EUR 2 992 521
Project period	1/1/2020 – 31/12/2022
Coordinator	Fondazione Bruno Kessler, Italy
Beneficiaries	Sweco Polska Spółka Z Ograniczona Odpowiedzialnoscia, SOLIDpower SA, HyGear BV, Shell Global Solutions International BV, École Polytechnique Fédérale de Lausanne, Deutsches Zentrum für Luft- und Raumfahrt eV

https://switch-fch.eu/about/

PROJECT AND OBJECTIVES

The SWITCH project aims to design, build and test a 25 kW (SOFC) / 75 kW (SOEC) 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 cogeneration 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 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 14687. Hydrogen will be purified to within the range of 99.7 % to 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, installing the final SWITCH system prototype 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 (LCA) and life cycle cost analysis (LCC) will help to evaluate the benefits of the SWITCH technology in comparison with SoA steam methane reforming (SMR) and other H_2 production technologies (electrolysis).

PROGRESS AND MAIN ACHIEVEMENTS

- The project completed the construction and testing of the solid oxide electrolysis cell (SOEC) stack in reversible operations under SWITCH modes.
- A multiperiod and multi-objective optimisation approach was adopted. This approach optimises operations over multiple periods with different characteristics in terms of pressure, temperature, flow rate and composition.
- The project determined the operating envelope of the (1 t/day) SWITCH system.

FUTURE STEPS AND PLANS

- The hazard and operability analysis (HAZOP) for the safety control of the system will be finalised. The HAZOP is in progress, and it will update the HAZOP of the CH2P prototype by revising issues such as the management of the exhaust fuel from the burner.
- The H_2 compressor in the cold balance of plant will be installed. HyGear and the supplier are discussing the interfaces to design the compressor.
- The project will finalise the piping and instrumentation diagram and update the pressure swing adsorption of the system. All vessels have been ordered and they are being delivered. The piping and instrumentation diagram for the SWITCH system is a work in progress.
- SWITCH will manufacture the hot balance of plant (BoP). All materials have been ordered. The manufacturing of the heat exchangers and the other key components is in progress. The work on the SPLC is in progress. The delta hot BoP has not started yet. The testing of the gamma hot BoP is in progress, and it will provide relevant information for building the delta hot BoP.
- In terms of the data collection for LCA and life cycle cost analysis, the LCA approach to data collection has been defined, as have the functional units that will be used for the analysis. The data collection will start in the second half of 2022.
- An exploitation workshop will be organised to start working 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	Target achieved?	SoA result achieved to date (by others)	Year of SoA target
Project's own objectives	Electrolyser conversion efficiency	%	85		80	2021
	Fuel cell conversion efficiency	%	75		80	
	Hydrogen cost	€/kg	5		11.2	2020
	Stack lifetime	hours	10 000		3 000	2021
	Low switching time	minutes	30		N/A	N/A

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