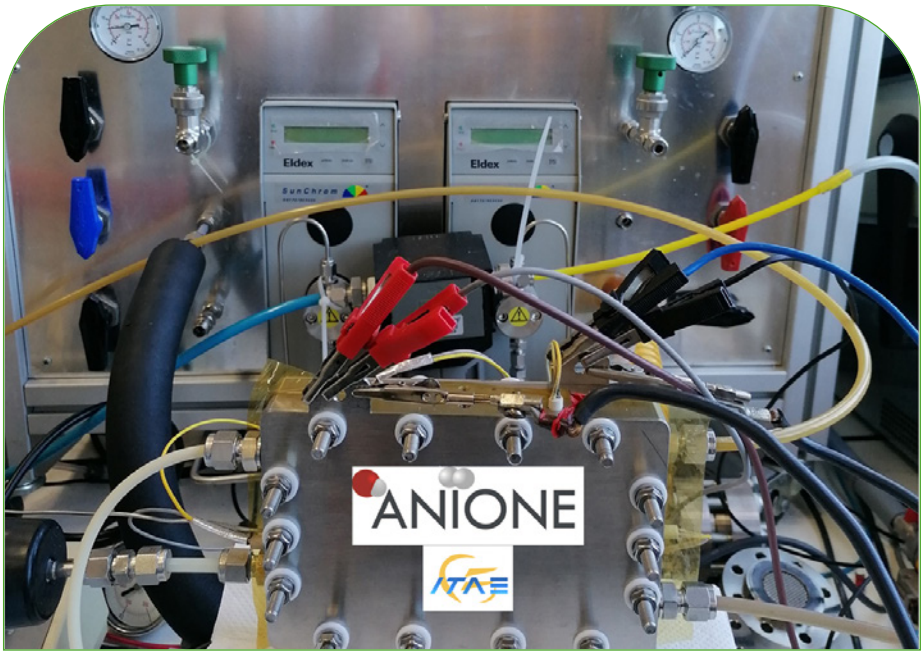
ANIONE

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



Project ID:	**875024**
Call topic:	**FCH-02-4-2019:** New Anion Exchange Membrane Electrolysers
Project total costs:	**€1 999 995**
FCH JU max. Contribution:	**€1 999 995**
Project start - end:	01/01/2020 - 31/12/2022
Coordinator:	**CONSIGLIO NAZIONALE DELLE RICERCHE, IT**
Website:	**anione.eu/**

BENEFICIARIES: POCELL TECH LTD, UNIVERSITE DE MONTPELLIER, PV3 TECHNOLOGIES LTD, HYDROGENICS EUROPE NV, IRD FUEL CELLS A/S, UNIRESEARCH BV, CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE CNRS

PROJECT AND OBJECTIVES

ANIONE aims to develop a high-performance, cost-effective and durable anion exchange membrane (AEM) water electrolysis technology. The approach uses 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 Nm3/h (TRL 4). Advanced AEMs have been developed in conjunction with non-critical raw materials (CRMs) high surface area electro-catalysts and membrane-electrode assemblies showing promising performance and stability.

NON-QUANTITATIVE OBJECTIVES

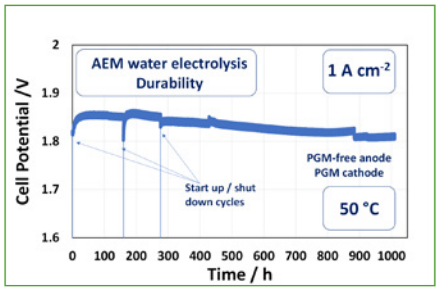
- Enhanced oxygen evolution catalyst. Development of an advanced non-CRM, Ni-Fe-based catalyst for the oxygen evolution reaction, showing a reduced overpotential and enhanced stability
- Enhanced hydrogen evolution catalyst. Development of an advanced non-CRM, Ni-based catalyst for the hydrogen evolution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

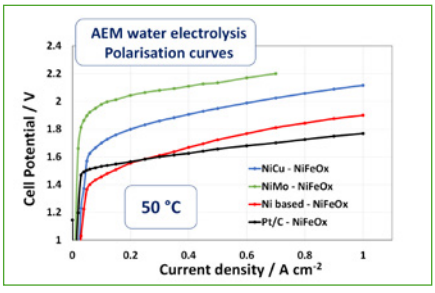
PROGRESS AND MAIN ACHIEVEMENTS

- Development of an advanced non-CRM, Ni-Fe-based catalyst for the oxygen evolution reaction, showing a reduced overpotential of 170 mV at 1 A cm^{-2}
- Development of an advanced non-CRM, Ni-based catalyst for the hydrogen evolution reaction, showing a reduced overpotential of 120 mV at 1 A cm^{-2}
- Development of cost-effective advanced AEMs with hydroxide ion conductivity better than 50 mS cm^{-1}.

FUTURE STEPS AND PLANS

- Further improvement of AEM membrane conductivity
- Large-area MEA testing with improved membranes
- Stack assembling and testing. Promising results have been achieved with new AEM membranes. These need to be consolidated in terms of low hydrogen crossover and MEA performance and stability.





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 FOR SOA TARGET
Project's own objectives and AWP 2019	Cell voltage at 1 A cm^{-2} (cell performance at 45 °C)	V	2	1.85	✗	1.67	2020
	Degradation rate: voltage increase at 1 A cm^{-2}	mV/h	<0.025	<0.005	✓	2	2020
	Voltage efficiency	% vs. HHV	74 %	80 %	✓	88 %	2020
	Membrane conductivity	mS cm^{-1}	50 mS cm^{-1}	20	✗	80	2021

BIG HIT

BUILDING INNOVATIVE GREEN HYDROGEN SYSTEMS IN AN ISOLATED TERRITORY: A PILOT FOR EUROPE

Project ID:	**700092**
Call topic:	**FCH-03.2-2015** - Hydrogen territories
Project total costs:	**€7 748 848**
FCH JU max. Contribution:	**€5 000 000**
Project start - end:	01/05/2016 - 30/04/2022
Coordinator:	**FUNDACION PARA EL DESARROLLO DE LAS NUEVAS TECNOLOGIAS DEL HIDROGENO EN ARAGON, ES**
Website:	**www.bighit.eu**

BENEFICIARIES: CALVERA MAQUINARIA E INSTALACIONES SL, THE SCOTTISH HYDROGEN AND FUEL CELL ASSOCIATION LTD, SHAPINSAY DEVELOPMENT TRUST, COMMUNITY ENERGY SCOTLAND LIMITED, MINISTRY FOR TRANSPORT, INFRASTRUCTURE AND CAPITAL PROJECTS, ORKNEY ISLANDS COUNCIL, GIACOMINI SPA, SYMBIO, ITM POWER (TRADING) LIMITED, THE EUROPEAN MARINE ENERGY CENTRE LIMITED, DANMARKS TEKNISKE UNIVERSITET

PROJECT AND OBJECTIVES

This BIG HIT project is a major first step towards creating a genuine hydrogen territory in the Orkney Islands. Orkney has over 50 MW of installed wind, wave and tidal capacity, generating over 46 GWh per year of renewable power and has been a net exporter of electricity since 2013. Hydrogen is proposed as a solution to minimise the curtailment problems in Orkney, caused by the weak connection with the UK mainland. The hydrogen produced is used in thermal, power (cogeneration) and transport applications locally.

NON-QUANTITATIVE OBJECTIVES

- LCA study has been completed. First report has been submitted, final report at the end of the project will include operational data
- Business model study for integrated energy systems based on hydrogen technologies across the islands. First report has been submitted, final report at the end of the project will include operational data
- Social LCA. First report has been submitted, final report at the end of the project will include operational data
- Hydrogen Territories Platform (HTP) has been launched. Two webinars have already been presented and 3 more are planned in 2021
- First analysis of project lessons learnt about the connection of electrolysers in power grids with high penetration of RES (optimal model) and marinisation of electrolysers, among other things.

PROGRESS AND MAIN ACHIEVEMENTS

- Main project equipment already built: 5 H2 trailers (250 kg H2 storage), H2 catalytic boiler (30 kW), 1 MW electrolyser; 5 H2 FC vans, 75 kW FC (cog)
- Operation of the hydrogen production site, logistics (MEGC moving H2 across the islands), H2 boiler and H2 FC vans
- Lessons learnt about: (i) connection of electrolyser in power grids with high penetration of RES (optimal model); and (ii) marinisation of electrolysers.

FUTURE STEPS AND PLANS

- Project and data analysis will run until April 2022. Problem with green hydrogen production using curtailed power to be solved (due to low curtailment)
- Consolidation of the Hydrogen Territories Platform, a tool to replicate the BIG HIT model in other locations and share lessons learnt and experiences (learning by doing approach). Four webinars are planned for 2021
- Final report on business models, LCA and S-LCA, including operational data, will be presented by the end of the project
- Main project results, conclusions and lessons learnt. To be presented at the final event in April 2022 in Orkney.

QUANTITATIVE TARGETS AND STATUS

TARGET SOURCE	PARAMETER	UNIT	TARGET	ACHIEVED TO DATE BY THE PROJECT	TARGET ACHIEVED?
MAWP Addendum (2018-2020)	DEMONSTRATION OF A HYDROGEN CATALYTIC BOILER (THERMAL STATIC APPLICATION)				
	Power	kW	40	30 kW commissioned; 10 kW FAT completed	✗
	FUEL CELL LIGHT DUTY VEHICLES (INCLUDING CARS) AVAILABILITY – FC VANS IN BIG HIT				
	Availability	%	98	98	✓
	HRS DURABILITY				
	Time	Years	10	3rd year of operation	✗

BIOROBURplus

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

Project ID:	**736272**
Call topic:	**FCH-02-2-2016** - Development of compact reformers for distributed bio-hydrogen production
Project total costs:	**€3 813 536.24**
FCH JU max. Contribution:	**€2 996 248.74**
Project start - end:	01/01/2017 - 30/06/2021
Coordinator:	**POLITECNICO DI MILANO, IT**
Website:	**www.bioroburplus.org**

BENEFICIARIES: ACEA PINEROLESE INDUSTRIALE SPA, ENGICER SA, DBI - GASTECHNOLOGISCHES INSTITUT GGMBH FREIBERG, KARLSRUHER INSTITUT FUER TECHNOLOGIE, HYSYTECH SRL, PARCO SCIENTIFICO TECNOLOGICO PER LAMBIENTE 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 CNRS

PROJECT AND OBJECTIVES

The BioRoburplus project is developing a pre-commercial oxidative steam reformer for the production of green hydrogen from biogas with no preliminary removal of CO2. The plant will produce 50 Nm3/h (107 kg/day) of hydrogen with a purity of 99.9 % and an energy efficiency of 81 % on an HHV basis. The plant has been constructed, installed and the commissioning is currently ongoing at the ACEA site. A dedicated TRL6 demo campaign, using real biogas from a municipal organic-waste anaerobic digester, will run until the end of the project.

NON-QUANTITATIVE OBJECTIVES

- Dissemination and training activities. News about the installed plant is continuously posted on social media to attract interested parties/potential clients
- Improve the efficiency of hydrogen production through better heat integration of the components. Different schemes have been evaluated
- Assess component and system sustainability (LCA, HAZOP, REACH). 'Exploitation plant and Market penetration study. An LCA analysis of the general system is being carried out. REACH and HAZOP analysis of the BioRoburplus process has been completed. Exploitation plan and decision support schemes for BioRoburplus system implementation are ongoing
- Manufacturing of supports and catalyst coating process. Final catalyst formulation has been coated on the support structure
- Development of a compact and cost-effective fuel processor for distributed H2 production that offers easy scalability. The BioRoburplus subunits were carefully developed to achieve the project's objectives. The plant can be scaled up, which is important for exploiting most of the decentralised application opportunities and reducing the final H2 costs. The techno-economic analysis showed that to reduce the cost of H2 and make it competitive, it is necessary to increase the production volume; mass production and a demand for green hydrogen is needed.

PROGRESS AND MAIN ACHIEVEMENTS

- A TRL6 demo unit for green H2 production from biogas with a high degree of integration has been manufactured, installed and 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 commissioning of the TRL6 demo plant is expected to be completed by April 2021
- Start the testing campaign using real biogas at the ACEA site in the coming weeks. It will run until June 2021
- Test the performance and stability of the structured catalyst developed. The performances and stability of the catalyst selected for the biogas reforming will be demonstrated in the final testing campaign in the coming weeks
- Collect and analyse the experimental data to complete the LCA and the techno-economic analysis and to drive future scale-up of the technology. Each component is being tested and the data analysed. The data from the test campaign will be used to assess the performance of the plant and identify potential improvements.

QUANTITATIVE TARGETS AND STATUS

TARGET SOURCE	PARAMETER	UNIT	TARGET	TARGET ACHIEVED?	SOA RESULT ACHIEVED TO DATE (BY OTHERS)	YEAR FOR SOA TARGET
Project's own objectives	Nominal H_2 production capacity	Nm^3/h	50	(still ongoing)	50 Nm^3/h with an overall efficiency of the conversion of biogas to green hydrogen of 65 %	2016
	Overall plant efficiency based on HHV	%	≥80	(still ongoing)	Overall plant efficiency of 65 % for a processor with a nominal production rate of 50 Nm^3/h of hydrogen	
	Reformer outlet CO concentration a dry-basis	%	<8	✓ Experimental test at lab scale. To be demonstrated at TRL6 level	10	
AWP 2016	H_2 purity	%	99.99	(still ongoing)	BioRobur delivered 50 Nm^3/h of 99.9 % hydrogen from biogas	

CHANNEL

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

Project ID:	**875088**
Call topic:	**FCH-02-4-2019** - New Anion Exchange Membrane Electrolysers
Project total costs:	**€1 999 906.25**
FCH JU max. Contribution:	**€1 999 906.25**
Project start - end:	01/01/2020 - 31/12/2022
Coordinator:	**SINTEF AS, NO**
Website:	**www.channel-fch.eu**

BENEFICIARIES: ENAPTER SRL, EVONIK CREAVIS GMBH, SHELL GLOBAL SOLUTIONS INTERNATIONAL BV, EVONIK OPERATIONS GMBH, NORGES TEKNISK-NATURVITENSKAPELIGE UNIVERSITET NTNU, FORSCHUNGSZENTRUM JULICH GMBH

PROJECT AND OBJECTIVES

The main objective of CHANNEL is to develop a low-cost and efficient electrolyser stack and balance of plant (BoP) that will become a game-changer for the electrolyser industry. The concept is to construct an AEM electrolyser unit using low-cost materials, advanced anion exchange membranes and ionomers, non-PGM electrocatalysts, as well as low-cost porous transport layers, current collectors and bipolar plates. To date, we have developed non-PGM catalysts and optimised AEM membranes and ionomers, in addition to a preliminary stack design and selection of stack components.

NON-QUANTITATIVE OBJECTIVES

- Design a preliminary 2 kW stack. A report has been submitted
- Characterisation of porous transport layers based on nickel and stainless steel. This has been completed
- Training students: two students from the University of St Andrews have been working on the project to date
- Journal publication: we have one publication on catalyst development
- Contribute to the AEM test protocol harmonisation workshop, attended with the NEWELY and ANIONE consortiums.

PROGRESS AND MAIN ACHIEVEMENTS

- We have developed highly active hydrogen evolution reaction (HER) and oxygen evolution reaction (OER) electrocatalysts
- Optimised properties for both AEM ionomers and membranes
- Submitted a preliminary stack design for the 2-kW demonstrator/prototype.

FUTURE STEPS AND PLANS

- Further optimisation of the membranes and ionomers to enhance mechanical and chemical properties, which is ongoing
- We are publishing a journal article (in progress) based on modelling of the transient P2D AEM model and simulation of electrode catalyst loading and composition as a function of KOH concentration, temperature and cell current density. This offers additional insights into the drivers of AEM cell performance and assists optimisation activities
- A plan to implement the model in the open-source system modelling to allow others in the research community to utilise the platform to make informed decisions about how best to optimise AEM electrolyser technologies
- Demonstration of the preliminary AEM stack prototype before end of 2021. The design of the preliminary stack has been finalised. Partners are in the process of providing materials, such as electrodes, porous transport layers, membranes, etc.

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 FOR SOA TARGET
Project's own objectives	OER catalyst performance	mV	<300 mV (at 10 mA/cm² 1 M KOH)	237 mV (1 M KOH) 270 mV (0.1 M KOH)	✓	Ir-based catalyst (250 mV at 10 mA/cm²)	2019
	HER catalyst performance	mV	<150 mV (at -0.2 V vs RHE)	60 mV in 1 M KOH, 120 mV in 0.1 M KOH	✓	Pt-based catalyst (30 mV at -10 mA/cm²) in 1 M KOH	
	OER catalyst stability	mV	<25 mV degradation over 1 000 h in RDE	33 mV	✗	N/A	N/A
	HER catalyst stability	mV	<25 mV degradation over 1 000 h in RDE	26 mV	✗		
AWP 2019	Membrane OH- conductivity (T=RT)	mS/cm	50	<45	✗	ca. 120 (50-micron membrane from Sustainion) 40-45 mS/cm FAA-3 (Fumatech)	2020
	Ionomer OH conductivity, T = 60 °C	mS/cm	20	>60	✓	N/A	N/A

Demo4Grid

DEMONSTRATION OF 4MW PRESSURIZED ALKALINE ELECTROLYSER FOR GRID BALANCING SERVICES

Project ID:	**736351**
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:	**€7 736 682.5**
FCH JU max. Contribution:	**€2 932 554.38**
Project start - end:	01/03/2017 - 31/08/2023
Coordinator:	**DIADIKASIA BUSINESS CONSULTING SYMVOULOI EPICHEIRISEON AE, EL**
Website:	**www.demo4grid.eu/**

BENEFICIARIES: FEN SUSTAIN SYSTEMS GMBH, MPREIS WARENVERTRIEBS GMBH, INSTRUMENTACION Y COMPONENTES SA, FUNDACION PARA EL DESARROLLO DE LAS NUEVAS TECNOLOGIAS DEL HIDROGENO EN ARAGON, IHT INDUSTRIE HAUTE TECHNOLOGIE SA

PROJECT AND OBJECTIVES

The main aim of Demo4Grid is the commercial setup and demonstration of a technical solution utilising 'above state-of-the-art' pressurized alkaline electrolyser (PAE) technology for providing grid balancing services in real operational and market conditions. The final 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

- Engineering documents, analysis of RCS and safety requirements are in place
- A project-specific business model has been updated
- Civil engineering works for the electrolysis building are being finalised, the KOH storage tank has been installed the first electrolysis BoP skids have been received.

FUTURE STEPS AND PLANS

- The PAE will be delivered at the demo site by October 2021. The hall of the electrolysis building is ready for installation and pipework. The first electrolysis BoP skids (pre-hearting unit) have been received and lifted into place. The installation of the HVAC on the first floor of building is progressing
- The PAE will be commissioned by mid-November 2021.
- The PAE will be fully operational by mid-December 2021.

QUANTITATIVE TARGETS AND STATUS

TARGET SOURCE	PARAMETER	UNIT	TARGET	TARGET ACHIEVED?	SOA RESULT ACHIEVED TO DATE (BY OTHERS)	YEAR FOR SOA TARGET
Project's own objectives	H_2 production electrolysis, hot start from min. to max. power	s	2		60	2015
	Start-up time KPIs from cold to minimum part load for alkaline electrolysers	min	20		20	
	Minimum part load operation targets for alkaline electrolysers	% (full load)	20		30	
	Ramp up	% (full load)/s	7		7	
	Ramp down	% (full load)/s	10		10	

DJEWELS

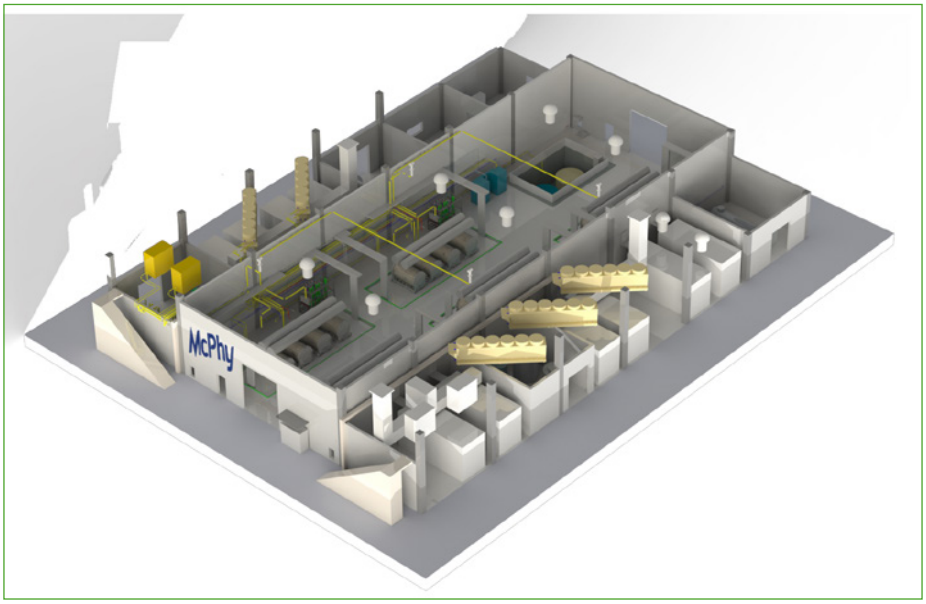
DELFZIJL JOINT DEVELOPMENT OF GREEN WATER ELECTROLYSIS AT LARGE SCALE

Project ID:	**826089**
Call topic:	**FCH-02-1-2018** - Demonstration of a large scale (min. 20MW) electrolyser for converting renewable energy to hydrogen
Project total costs:	**€43 929 750**
FCH JU max. Contribution:	**€10 999 999**
Project start - end:	01/01/2020 - 31/12/2025
Coordinator:	**NOURYON INDUSTRIAL CHEMICALS BV, NL**
Website:	**djewels.eu**

BENEFICIARIES: BIOMETHANOL CHEMIE NEDERLAND BV, INDUSTRIE DE NORA SPA-IDN, HINICIO SA, MCPHY ENERGY, NV NEDERLANDSE GASUNIE

PROJECT AND OBJECTIVES

The Djewels project aims to demonstrate the operational readiness of a 20 MW electrolyser for the production of renewable fuels (renewable methanol) in real-life industrial and commercial conditions. It will take the technology from TRL 7 to TRL 8 and lay the foundations for the next scale-up step, towards a 100 MW electrolyser at the same site. The project is currently in the engineering phase (20 MW) and piloting phase (1 MW stack) in Les Renardières (FR).



NON-QUANTITATIVE OBJECTIVES

- Safety performance
- Completion of HAZOP.

PROGRESS AND MAIN ACHIEVEMENTS

- Constructions of the 1 MW stack testing facility is complete
- Finalisation of HAZOP.

FUTURE STEPS AND PLANS

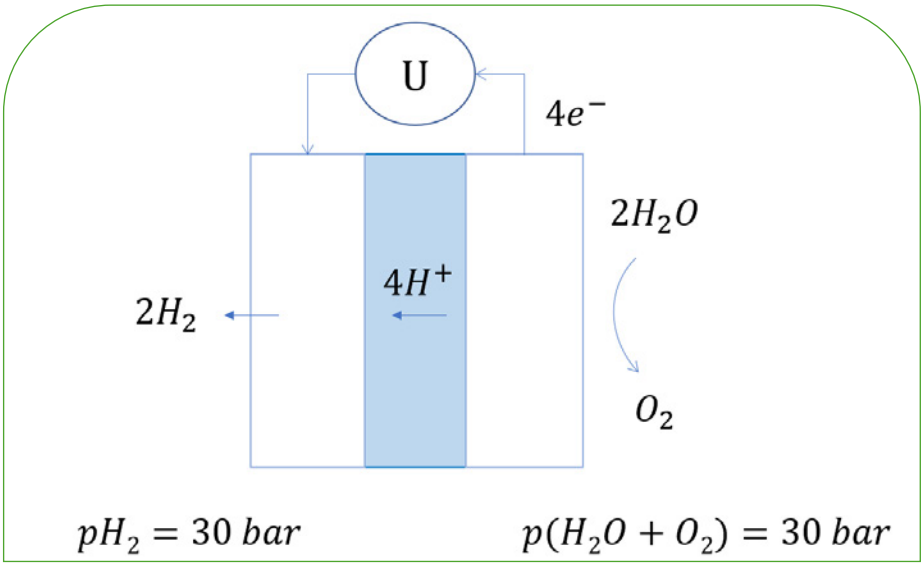
- Finish stack testing and optimisation. This is delayed and anticipated to be completed in summer 2021
- Investment decision in summer 2021
- Construction to be completed in 2024.

QUANTITATIVE TARGETS AND STATUS

TARGET SOURCE	PARAMETER	UNIT	TARGET	TARGET ACHIEVED?
MAWP Addendum (2018-2020)	Energy consumption	kWh/kg	<52.8	
	Efficiency degradation	%/year	0.72	
	Flexibility with degradation below 2 %/year	% of nominal power	3-110	
Project's own objectives	Nominal capacity	MW	20	

GAMER

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



Project ID:	**779486**
Call topic:	**FCH-02-2-2017** - Game changer High Temperature Steam Electrolysers
Project total costs:	**€2 998 951.25**
FCH JU max. Contribution:	**€2 998 951.25**
Project start - end:	01/01/2018 - 31/12/2021
Coordinator:	**SINTEF AS, NO**
Website:	**www.sintef.no/projectweb/gamer/**

BENEFICIARIES: AGENCIA ESTATAL CONSEJO SUPERIOR DEINVESTIGACIONES CIENTIFICAS, STIFTELSEN SINTEF, UNIVERSITETET I OSLO, SHELL GLOBAL SOLUTIONS INTERNATIONAL BV, COORSTEK MEMBRANE SCIENCES AS, CRI EHF, MC2 INGENIERIA Y SISTEMAS SL

PROJECT AND OBJECTIVES

The GAMER project will develop a novel cost-effective tubular proton ceramic electrolyser (PCE) stack that will produce pure dry pressurised hydrogen. The electrolyser system will be thermally coupled to renewable or waste heat sources in industrial plants to achieve higher AC electrical efficiency. The project will establish the science and technology for the high-volume production of novel tubular cells and will develop designs of system and balance of plant components supported by advanced modelling and simulation work, flowsheets of integrated processes.

NON-QUANTITATIVE OBJECTIVES

- Dissemination activities. Four papers are under preparation, and we participated in a seminar
- Process integration studies, producing a report that addresses the benefits and challenges of electrolysis integration in industrial plants
- Exploitation activities. Two spin-off projects have been established
- Technical activities. Factory acceptance test of the testing rig with BoP
- Assembly of single engineering units (SEUs) for qualification: 13 have been delivered to the project.

PROGRESS AND MAIN ACHIEVEMENTS

- Production of several SEUs was successfully tested in pressurised electrolysis mode at 600 °C
- Building of the testing equipment with the necessary BoP and power electronics
- Operation of SEU in pressurised electrolysis mode at 600 °C at up to 10 bar.

FUTURE STEPS AND PLANS

- Scale up production of SEUs: in progress
- Building of furnace and SEU assembly in the prototype demonstrator: in progress
- Publication of results. Several drafts are available
- Finalisation of LCA studies. Draft deliverable under review by partners
- Installation and commissioning of prototype. Planned for mid-2021
- Testing of prototype. Planned for/to perform after task 5.

QUANTITATIVE TARGETS AND STATUS

TARGET SOURCE	PARAMETER	UNIT	TARGET	ACHIEVED TO DATE BY THE PROJECT	TARGET ACHIEVED?	SOA RESULT ACHIEVED TO DATE (BY OTHERS)
Project's own objectives	Tubular electrochemical SEU resistance at 3 bar	ohm.cm^2	2-4	2-4	✓	2.8
	Faradaic efficiency of the SEU at 3 bar at 0.1 mA/cm^2 at 600 °C	%	80+	80	✓	No other project makes SEU
	Maximum decrease of the voltage after 500 h at 600 ° Cat 100 mA/cm^2	%	<5	1.4	✓	No other project makes SEU

GrInHy2.0

GREEN INDUSTRIAL HYDROGEN VIA STEAM ELECTROLYSIS

Project ID:	**826350**
Call topic:	**FCH-02-2-2018** - Demonstration of large scale steam electrolyser system in industrial market
Project total costs:	**€5 882 492.50**
FCH JU max. Contribution:	**€3 999 993.25**
Project start - end:	01/01/2019 - 31/12/2022
Coordinator:	**SALZGITTER MANNESMANN FORSCHUNG GMBH**
Website:	**www.green-industrial-hydrogen.com/**

BENEFICIARIES: PAUL WURTH SA, SUNFIRE GMBH, SALZGITTER FLACHSTAHL GMBH, TENOVA SPA, COMMISSARIAT A L'ENERGIE ATOMIQUE ET AUX ENERGIES ALTERNATIVES

PROJECT AND OBJECTIVES

GrInHy2.0 is about the manufacturing and operation of the world's biggest high-temperature electrolyser with a capacity of 720 kW AC and an electrical efficiency of 84 % LHV. While the technology's Carbon Direct Avoidance potential for the future European steel industry is being assessed, the electrolyser will produce more than 100 tons of 'green' hydrogen based on steam from industrial waste heat in >13 000 operational hours for today's steel production in Salzgitter. In December 2020, the system injected hydrogen for the first time and is currently being validated for operational procedures.

NON-QUANTITATIVE OBJECTIVES

- Assessing the CO_2 avoidance potential of hydrogen for the European steel industry
- First calculations show the CDA potential of hydrogen in DRP replacing carbon-reducing agents. The results will be used for a future roll-out study.

PROGRESS AND MAIN ACHIEVEMENTS

- The system's 'electrolyser' and 'hydrogen processing unit' have been manufactured and the installation site is being completed
- First-time injection was about 100 Nm^3/h during commissioning
- The long-term stack test at the CEA labs has started.

FUTURE STEPS AND PLANS

- Start of system operation in September 2020
- Production of at least 100 tonnes of hydrogen by the end of 2021
- Reaching the objectives of 13 000 operational hours and a system availability of 95 % in early 2022
- Completion of 20 000 hours of continuous stack testing in October 2022.

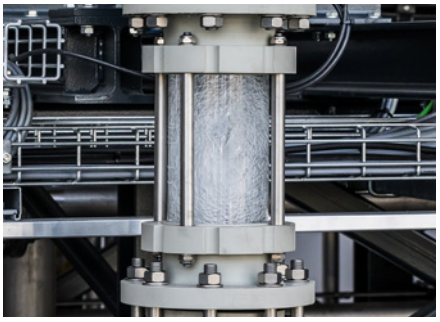
QUANTITATIVE TARGETS AND STATUS

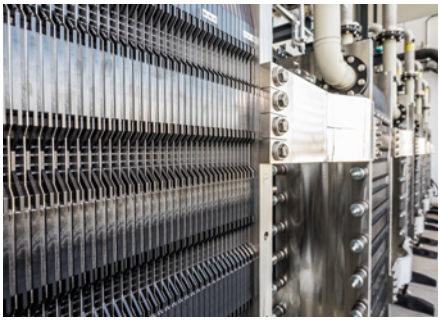
TARGET SOURCE	PARAMETER	UNIT	TARGET	ACHIEVED TO DATE BY THE PROJECT	TARGET ACHIEVED?	SOA RESULT ACHIEVED TO DATE (BY OTHERS)	YEAR FOR SOA TARGET
AWP 2018	Hydrogen production rate	kg/h	18	9		3.6	2017
	Total production of 'green' hydrogen	t	100	1	✂	N/A	
	Electrical efficiency based on LHV	%	84	-		78	
	CAPEX	€/(kg/d)	4 500	4 500	✓	12 000	
	Demonstration of hot start from min. to max. power	min	5	-		10	2018
	Hours of operation	Hours	13 000			10 000	2019
	Availability	%	95		✂	66	
	Cost of hydrogen	€/kg	7			N/A	N/A
Project's own objectives	Hours of continuous stack testing	Hours	20 000	4 500		8 700	2019

H2Future

HYDROGEN MEETING FUTURE NEEDS OF LOW CARBON MANUFACTURING VALUE CHAINS

H2FUTURE
Green Hydrogen





Project ID:	**735503**
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:	**€17 852 540.38**
FCH JU max. Contribution:	**€11 997 820.01**
Project start - end:	01/01/2017 - 30/06/2021
Coordinator:	**VERBUND Solutions GmbH, AT**
Website:	**www.h2future-project.eu**

BENEFICIARIES: SIEMENS ENERGY AUSTRIA GMBH, SIEMENS ENERGY GLOBAL GMBH & CO. KG, K1-MET GMBH, VOESTALPINE STAHL GMBH, AUSTRIAN POWER GRID AG, SIEMENS AKTIENGESELLSCHAFT OESTERREICH, SIEMENS AKTIENGESELLSCHAFT, STICHTING ENERGIEONDERZOEK CENTRUM NEDERLAND, NEDERLANDSE ORGANISATIE VOOR TOEGEPAST NATUURWETENSCHAPPELIJK ONDERZOEK TNO, VERBUND ENERGY4BUSINESS GMBH

PROJECT AND OBJECTIVES

The main goals of the H2FUTURE project are to design and install a 6 MW PEM electrolyser system at the voestalpine steel plant in Linz and to execute a two-year demonstration operation of the electrolyser system with ambitious efficiency targets. The plant started production at the end of 2019. During commissioning the plant was pre-qualified for grid-balancing services such as primary, secondary or tertiary reserves. The pilot test phase was executed from March to September 2020.

NON-QUANTITATIVE OBJECTIVES

- Project communication. In order to keep everyone well informed, there were more meetings between project participants than planned
- Range and scalability. The load range of the plant exceeded the targeted values.

PROGRESS AND MAIN ACHIEVEMENTS

- Finalisation of the pilot test phase in the scheduled time
- Plant has provided primary and secondary reserve to the electricity grid
- Plant has been in quasi-commercial operation since 15 October 2020.

FUTURE STEPS AND PLANS

- Application for project extension until the end of 2021 due to some project delays. The remaining project duration time was too short for the planned 3 000 operational hours
- Catch up with open deliverables. Some deliverables have been delayed.

QUANTITATIVE TARGETS AND STATUS

TARGET SOURCE	PARAMETER	UNIT	TARGET	TARGET ACHIEVED?
Project's own objectives	H_2 production	Nm^3/h	1 200	✓
	H_2 purity	%	99.9	
	System efficiency at full load	%	77-82	
	Range and scalability	%	20-100	

HAEOLUS

HYDROGEN-AEOLIC ENERGY WITH OPTIMISED ELECTROLYSERS UPSTREAM OF SUBSTATION

Project ID:	**779469**
Call topic:	**FCH-02-4-2017** - Highly flexible electrolysers balancing the energy output inside the fence of a wind park
Project total costs:	**€7 613 404.45**
FCH JU max. Contribution:	**€4 997 738.63**
Project start - end:	01/01/2018 - 31/12/2021
Coordinator:	**SINTEF AS, NO**
Website:	**www.haeolus.eu**

BENEFICIARIES: VARANGER KRAFTHYDROGEN AS, VARANGER KRAFTMARKED AS, VARANGER KRAUFTUTVIKLING AS, VARANGER KRAFTENTERPRENOR AS, VARANGER KRAFT AS, VARANGER KRAFTNETT AS, VARANGER KRAFTVIND AS, COMMUNAUTE D'UNIVERSITES ET ETABLISSEMENTS UNIVERSITE BOURGOGNE - FRANCHE - COMTE, NEW NEL HYDROGEN AS, KES KNOWLEDGE ENVIRONMENT SECURITY SRL, HYDROGENICS EUROPE NV, UNIVERSITA DEGLI STUDI DEL SANNIO, ECOLE NATIONALE SUPERIEURE DE MECANIQUE ET DES MICROTECHNIQUES, UNIVERSITE DE TECHNOLOGIE DE BELFORT - MONTBELIARD, FUNDACION TECNALIA RESEARCH & INNOVATION, UNIVERSITE DE FRANCHE-COMTE, STIFTELSEN SINTEF

PROJECT AND OBJECTIVES

The project will demonstrate the operation of a 2.5 MW electrolyser in conjunction with a wind park. The objectives are to deploy and demonstrate several operational concepts (re-electrification, mini-grid, fuel production) and remote operation, enabling higher wind power uptake in power grids. The project has been delayed by a number of issues, including the COVID-19 pandemic. The installation of the system was expected in May 2021 and operation within the project will then continue until the end of 2023 (pending amendment of the grant agreement).

NON-QUANTITATIVE OBJECTIVES

- Model-predictive controllers for multiple use cases, developed with corresponding test protocols
- Public studies on wind-hydrogen plants for techno-economic analysis, business case and impact on energy systems. LCA study awaits operational data
- Stimulate the 'Hydrogen valley' in Finnmark (NO). Several initiatives have started (biogas upgrade, maritime hydrogen and ammonia), with good contact with local authorities.

PROGRESS AND MAIN ACHIEVEMENTS

- Synthesised control algorithms and testing protocols for multiple use cases of hydrogen-wind systems
- Analysed several techno-economic aspects of the specific project plant and similar plants in multiple EU countries, including impact on energy systems
- Identified multiple opportunities for hydrogen and by-product valorisation in the region (biogas upgrade, ammonia production, maritime propulsion, etc.).

FUTURE STEPS AND PLANS

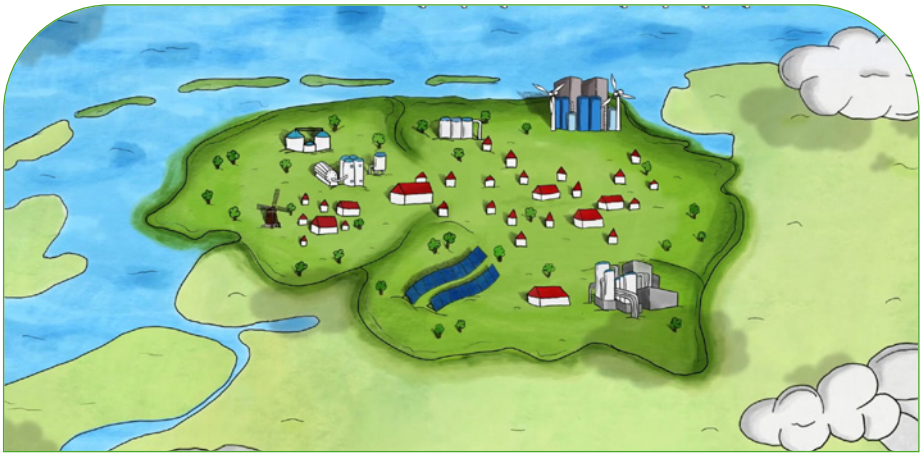
- System deployment, installation and start-up is expected in May 2021, depending on pandemic developments
- Demonstration of all three use cases
- Dissemination actions (site visit, industrial fair presence, etc.) compatible with pandemic developments.

QUANTITATIVE TARGETS AND STATUS

TARGET SOURCE	PARAMETER	UNIT	TARGET	ACHIEVED TO DATE BY THE PROJECT	TARGET ACHIEVED?
MAWP Addendum (2018-2020) and AWP 2017	CAPEX	M€/tpd	3	1.33	✓
	Efficiency	kWh/kg	52	51.88	✓
Project's own objectives	Degradation	%/year	1.5	N/A	✗

HEAVENN

HYDROGEN ENERGY APPLICATIONS FOR VALLEY ENVIRONMENTS IN NORTHERN NETHERLANDS



Project ID:	**875090**
Call topic:	**FCH-03-1-2019** - H2 Valley
Project total costs:	**€98 998 216.18**
FCH JU max. Contribution:	**€20 000 000**
Project start - end:	01/01/2020 - 31/12/2025
Coordinator:	**STICHTING ENERGY VALLEY, NL**

BENEFICIARIES: STICHTING NEW ENERGY COALITION, TOTAL NEDERLAND NV, GEMEENTE HOOGEVEEN, HYDROGEN IRELAND NATURAL RESOURCES ASSOCIATION COMPANY LBG, NEDERLANDSE PARTICULIERE RIJNVAART-CENTRALE COOPERATIE UA, UVO VERVOER BV, LENTEN SCHEEPVAART BV, BYTESNET GRONINGEN BV, EWE GASSPEICHER GMBH, ENERCY BV, GREEN PLANET REAL ESTATE BV, EMMTEC SERVICES BV, GEMEENTE EMMEN, HYENERGY TRANSSTORE BV, H2TEC BV, GEMEENTE GRONINGEN, GRONINGEN SEAPORTS NV, ENGIE ENERGIE NEDERLAND NV, EBN BV ENERGIE BEHEER NEDERLAND BV, HYENERGY CONSULTANCY LIMITED, EUROPEAN RESEARCH INSTITUTE FOR GAS AND ENERGY INNOVATION, PITPOINT. CREW BV, PITPOINT.PRO BV, QBUZZ BV, NEDERLANDSE AARDOLIE MAATSCHAPPIJ BV, PITPOINT.CNG BV, CEMTEC FONDEN, GEMEENSCHAPPELIJKE REGELING SAMENWERKINGSVERBAND NOORD-NEDERLAND, LOGAN ENERGY LIMITED, HINICIO SA, NOURYON INDUSTRIAL CHEMICALS BV, FUNDACION PARA EL DESARROLLO DE LAS NUEVAS TECNOLOGIAS DEL HIDROGENO EN ARAGON, NV NEDERLANDSE GASUNIE, THE EUROPEAN MARINE ENERGY CENTRE LIMITED, RIJKSUNIVERSITEIT GRONINGEN

PROJECT AND OBJECTIVES

HEAVENN is a large-scale demo project that brings together core elements – production, distribution, storage and local end-use of H2 – in a fully integrated and functioning 'H2 Valley' (H2V) that can serve as a blueprint for replication across Europe and beyond. The main goal is to make use of green hydrogen across the entire value chain, while developing replicable business models for wide-scale commercial deployment of H2 across the entire regional energy system. HEAVENN aims to become a Hydrogen Valley blueprint for other regions to replicate.

NON-QUANTITATIVE OBJECTIVES

- RCS certification. Relevant green H2 value chains will be tested against the CertiHy protocol
- The safety issues will be covered by the permitting procedures
- Education and training on technologies and acceptance via the GWB project, specifically for SMEs.

PROGRESS AND MAIN ACHIEVEMENTS

- First (15 of 105) passenger vehicles acquired for cluster 4 to participant in Green Planet. Now awaiting the opening of the Green Planet fuelling station
- Decision made on the minimum design capacity of the Shell electrolyser in Emmen (2 with a minimum 4 MW size)
- Underground storage activities initiated with first test setups in the Zuidwending salt dome.

FUTURE STEPS AND PLANS

Catch-up actions: make an inventory of delays due to COVID-19 and define mitigating measures to address time, scope and budget.

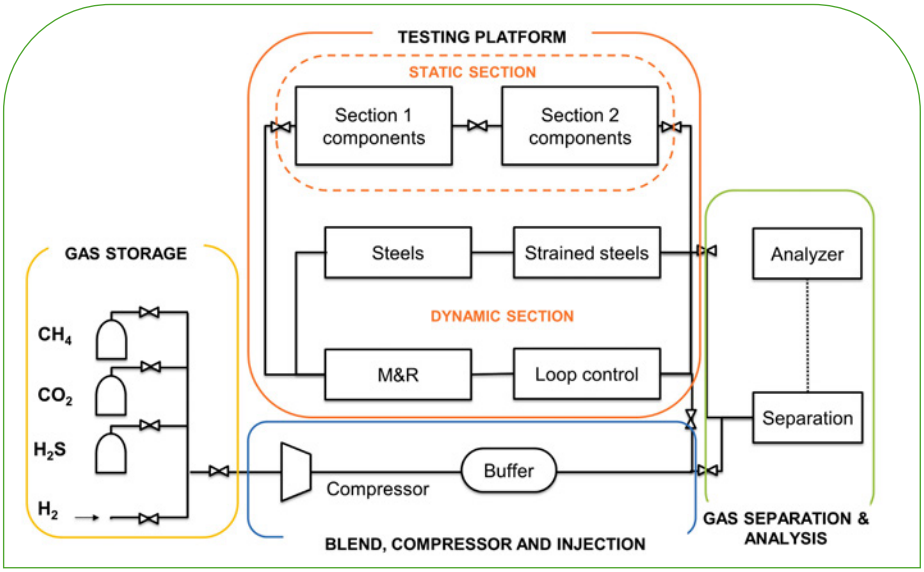
QUANTITATIVE TARGETS AND STATUS

TARGET SOURCE	PARAMETER	UNIT	TARGET	TARGET ACHIEVED?	SOA RESULT ACHIEVED TO DATE (BY OTHERS)	YEAR FOR SOA TARGET
MAWP Addendum (2018-2020)	**FCH PASSENGER CARS**					
	FC system cost	€/kWh	60		100	2019
	Maintenance	€/km	0.03		0.04	
	Availability	%	98		98	2017
	Durability	Hours	5 000		4 000	
	H_2 PRODUCTION (ELECTROLYSIS) – PEM					
	Energy commission consumption	kWh/kg	50		55	2020
	CAPEX	€/kWh	<900		900	
	O&M	€/kg d/y	41		41	
	STORAGE, DISTRIBUTION AND H_2 SUPPLY					
	Large storage system cost	€/kg	0.8		N/A	2024
	Release energy use	kWh/kg	10		10	
	HRS					
	CAPEX	k€/day	4-2		7	2017

HIGGS

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

Project ID:	**875091**
Call topic:	**FCH-02-5-2019** - Systematic validation of the ability to inject hydrogen at various admixture levels into high-pressure gas networks in operational conditions
Project total costs:	**€2 107 672.50**
FCH JU max. Contribution:	**€2 107 672.50**
Project start - end:	01/01/2020 - 31/12/2022
Coordinator:	**FUNDACION PARA EL DESARROLLO DE LAS NUEVAS TECNOLOGIAS DEL HIDROGENO EN ARAGON, ES**
Website:	**www.higgsproject.eu/**



BENEFICIARIES: REDEXIS GAS SA, EUROPEAN RESEARCH INSTITUTE FOR GAS AND ENERGY INNOVATION, HSR HOCHSCHULE FUR TECHNIK RAPPERSWIL, DVGW DEUTSCHER VEREIN DES GAS- UND WASSERFACHES - TECHNISCH-WISSENSCHAFTLICHER VEREIN EV, FUNDACION TECNALIA RESEARCH & INNOVATION

PROJECT AND OBJECTIVES

HIGGS aims to fill the gaps in our knowledge of the impact of high levels of hydrogen on high-pressure natural gas infrastructure, its components and its management. Several activities will be developed to reach this goal, including mapping technical, legal and regulatory barriers and enablers, testing materials/components, techno-economic modelling and preparing a set of conclusions as a pathway towards enabling the injection of hydrogen in high-pressure gas grids. The inventory of materials, equipment and RCS is partly finished and the testing platform has been designed.

NON-QUANTITATIVE OBJECTIVES

- Draw up RCS recommendations
- Determine a pathway for the stepwise integration of hydrogen in the EU gas network
- Develop a techno-economic model and study the role of technologies for integrating H2/CH4 and sector coupling at EU level.

PROGRESS AND MAIN ACHIEVEMENTS

- Admixture system and testing platform designed to enable dynamic and static testing
- List of materials, equipment and components from natural gas transmission grid selected for testing
- Mapping of RCS at EU level is partly finished.

FUTURE STEPS AND PLANS

- Commission and assemble the admixture system and testing platform. Civil works have started
- Test campaigns on materials, components and equipment carried out with different hydrogen concentrations blended with methane, including separation processes for admixtures up to 15 % H2 injected. The test campaigns are expected to start in summer 2021
- Characterise materials before and after hydrogen exposure in order to evaluate the effect of injecting this gas. Not yet started
- RSC review at European and national level to be assembled, reviewed and compiled in a comprehensive report comprising diagrams and graphs, for distribution on the website and for presentations and papers. The first overview report will be ready by June 2021 and results will be reviewed and updated throughout the project
- Baseline definition and studies of cases of blending hydrogen into natural gas. Simulation of these cases and analysis of techno-economic aspects. Literature review of international hydrogen strategies. Data acquisition for the techno-economic model (grid structure and parameters) and its boundary conditions in a European context
- Develop and describe a pathway towards integrating hydrogen into the EU gas networks, including proposals at national level (EU 26+). This is ongoing work and will deliver four reports, which are all public. The main and final report, published by the end of 2022, will be the pathway description. The results will be used beyond the project period.

QUANTITATIVE TARGETS AND STATUS

TARGET SOURCE	PARAMETER	UNIT	TARGET	ACHIEVED TO DATE BY THE PROJECT	TARGET ACHIEVED?
Project's own objectives	Blending percentage compatible with existing gas transmission networks	%	Not defined	Not started	
	H_2 compatibility of materials and equipment in transmission networks	%	Not defined	Not started	
	H_2 incorporated in standards through CEN technical committees	-	Recommendations	N/A	
	Scalable separation technology	TRL	4-6	3	

HyBalance
HYBALANCE

Project ID:	**671384**
Call topic:	**FCH-02.10-2014** - Demonstrating the feasibility of central large scale electrolysers in providing grid services and hydrogen distribution and supply to multiple high value markets
Project total costs:	**€15 803 441.25**
FCH JU max. Contribution:	**€7 999 370.8**
Project start - end:	01/10/2015 - 30/09/2020
Coordinator:	**AIR LIQUIDE ADVANCED BUSINESS, FR**
Website:	**www.hybalance.eu**

BENEFICIARIES: LUDWIG-BOELKOW-SYSTEMTECHNIK GMBH, HYDROGENICS EUROPE NV, COPENHAGEN HYDROGEN NETWORK AS, FORDONSGAS SVERIGE AB, NEAS ENERGY AS, CEMTEC FONDEN, AIR LIQUIDE GLOBAL E&C SOLUTIONS FRANCE

PROJECT AND OBJECTIVES

HyBalance demonstrates the link between energy storage in the form of hydrogen and the deployment of hydrogen mobility solutions. The production of green hydrogen based on wind power using electrolysis is a well-known and proven technology, but the HyBalance project implements advanced key technologies. It not only validates highly dynamic PEM electrolysis technology and the innovative hydrogen delivery processes involved, but also demonstrates these in a real-life industrial environment.

PROGRESS AND MAIN ACHIEVEMENTS

- Commissioning of the plant and supply of hydrogen to industrial and clean mobility customers
- PEM electrolysis technology achieved a high level of availability, efficiency, reactivity and flexibility during the plant operation
- The Danish Transmission System Operator Energinet.dk homologated the plant to provide grid services on all energy markets.

FUTURE STEPS AND PLANS

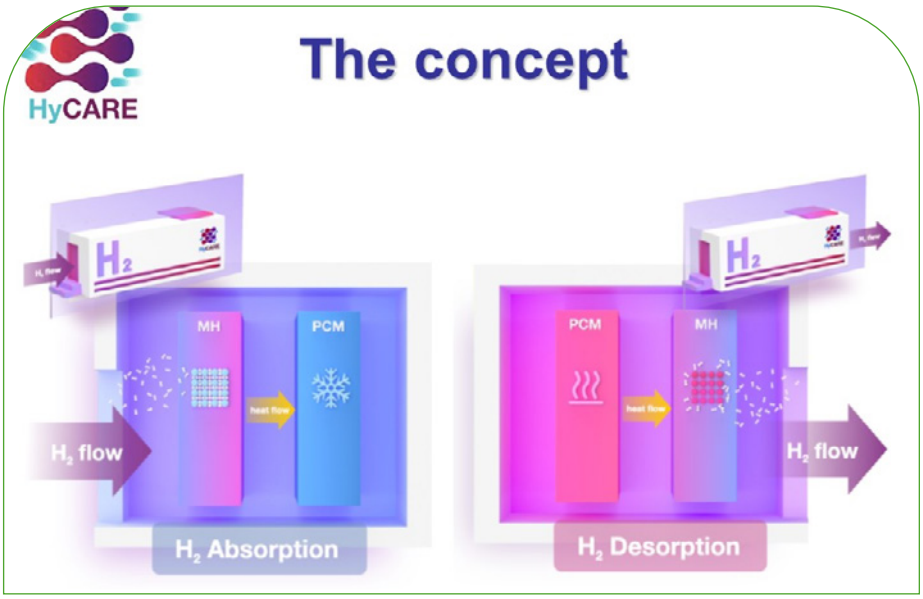
The project has finished.

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 FOR SOA TARGET
MAWP (2014-2020)	Cost goal	€/kW	1 570	1 810	✗	1 200	2020
AIP 2014	Efficiency	kWhel/kg H_2	57.5	56.5	✗	55.3 - 52.2	2018 - 2019
	System lifetime	Hours	20 000	>16 000	✗	>10 200	N/A

HyCARE

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



Project ID:	**826352**
Call topic:	**FCH-02-5-2018** - Hydrogen carriers for stationary storage of excess renewable energy
Project total costs:	**€1 999 230**
FCH JU max. Contribution:	**€1 999 230**
Project start - end:	01/01/2019 - 31/12/2021
Coordinator:	**PARCO SCIENTIFICO TECNOLOGICO PER LAMBIENTE ENVIRONMENT PARK TORINO SPA**
Website:	**hycare-project.eu/**

BENEFICIARIES: STUEHFF GMBH, TECNODELTA SRL, GKN SINTER METALS ENGINEERING GMBH, PARCO SCIENTIFICO TECNOLOGICO PER LAMBIENTE ENVIRONMENT PARK TORINO SPA, INSTITUTT FOR ENERGITEKNIKK, HELMHOLTZ-ZENTRUM GEESTHACHT ZENTRUM FUR MATERIAL- UND KUSTENFORSCHUNGGMBH, FONDAZIONE BRUNO KESSLER, ENGIE, CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE CNRS

PROJECT AND OBJECTIVES

The main objective of the HyCARE project is to develop a demonstration of a hydrogen storage tank using a solid-state hydrogen carrier at large scale. The tank will be based on an innovative concept, combining hydrogen and heat storage, in order to improve the energy efficiency of the whole system. The tank developed will be installed at the site of ENGIE Lab CRIGEN. The main steps of the project are up and running properly, but other activities have been delayed due to the pandemic. The project will now end in 2022 rather than 2021.

NON-QUANTITATIVE OBJECTIVES

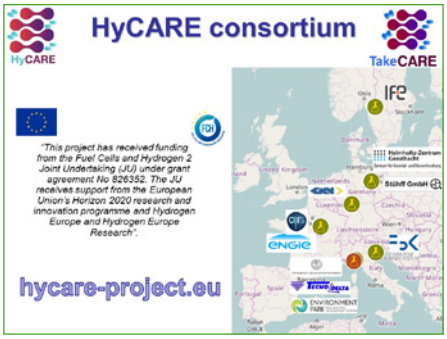
- Safety: low T and P for storing hydrogen using carriers
- Improving the energy efficiency of the hydrogen storage using heat storage via PCM.

PROGRESS AND MAIN ACHIEVEMENTS

- The composition of the MH has been defined and characterised. The PCM has been selected. Materials are available for the demonstrator
- MH and PCM tank design have been finalised. A draft of P&ID of the demonstrator is available. A prototype system has been built and tested
- The site for the demonstrator has been decided. EL and FC have been commissioned. TEA and LCA have been set up. Dissemination and exploitation are active.

FUTURE STEPS AND PLANS

- Set up and test the final demonstrator. This is under way, with the conclusions now delayed by 6 months and expected for June 2022
- The results obtained will be analysed by TEA and LCA and their potential for exploitation will be explored.

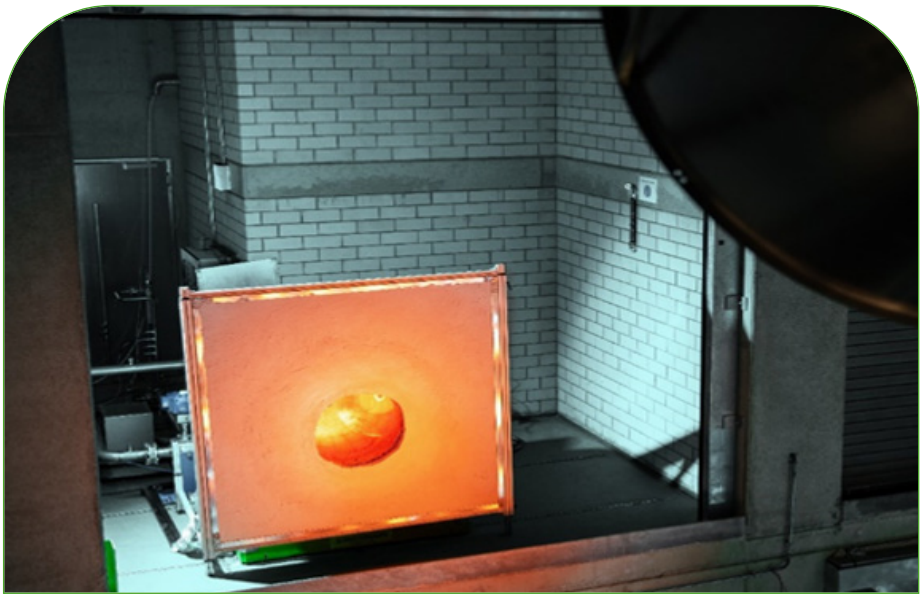


QUANTITATIVE TARGETS AND STATUS

TARGET SOURCE	PARAMETER	UNIT	TARGET	ACHIEVED TO DATE BY THE PROJECT	TARGET ACHIEVED?
Project's own objectives	Volumetric capacity of H_2 carrier	kg H_2 per unit of volume of carrier	N/A	Reversible capacity at 55 °C between 1-25 bar equal to 69.3	✗
	Gravimetric capacity of H_2 carrier	Gravimetric capacity of the H_2 carrier in weight %		Reversible capacity at 55 °C between 2-20 bar is equal to 1.4	✗
	Hydrogen storage capacity	Maximum amount of H_2 in kg that can be stored in the system		44 reversibly (55 °C, 1-25 bar)	✗
	Max. tank pressure	Pressure rating of the H_2 carrier tank in bar	<50	40	✓
	Cyclability	Number of full cycles until reaching 2 % reduction in the gravimetric capacity of the H_2 carrier	250	250	✓

HYDROSOL-beyond

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



Project ID:	**826379**
Call topic:	**FCH-02-4-2018** - Thermochemical Hydrogen Production from Concentrated Sunlight
Project total costs:	**€2 999 940**
FCH JU max. Contribution:	**€2 999 940**
Project start - end:	01/01/2019 - 31/12/2022
Coordinator:	**ETHNIKO KENTRO EREVNAS KAI TECHNOLOGIKIS ANAPTYXIS, EL**
Website:	**www.hydrosol-beyond.certh.gr/**

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, CENTRO DE INVESTIGACIONES ENERGETICAS, MEDIOAMBIENTALES Y TECNOLOGICAS-CIEMAT, DEUTSCHES ZENTRUM FUR LUFT- UND RAUMFAHRT EV, COMMISSARIAT A L'ENERGIE ATOMIQUE ET AUX ENERGIES ALTERNATIVES

PROJECT AND OBJECTIVES

Hydrosol-beyond is a 4-year project that focuses on two sets of activities running in parallel. The first is the investigation, design and development of novel concepts that will be integrated in the existing plant (super heat exchanger, N_2 minimisation and purification). Secondly, tasks and activities at the Solar Platform of Almeria (ES) to perform solar experiments.

NON-QUANTITATIVE OBJECTIVES

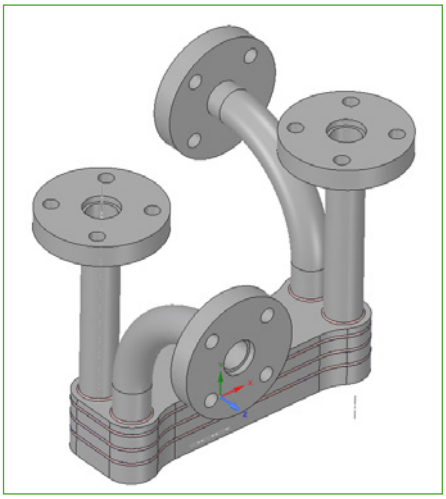
Development of a novel high-temperature heat exchanger. The design of a hybrid (metal/ceramic) capable of operating at temperatures over 1 000 °C, has been determined and the manufacture of a small-scale prototype is in progress.

PROGRESS AND MAIN ACHIEVEMENTS

- An overview of the improved plant concept was provided, containing new concepts for improving the plant performance
- A redesign of the reactor provides more stable embedding of the quartz window in the front flange
- Definition of specifications and completion of detailed refined process flowsheet layout and piping and instrumentation diagram of the solar plant.

FUTURE STEPS AND PLANS

- The integration of the novel heat exchanger in the existing solar platform. The manufacture and validation of a small-scale apparatus is in progress. The results will be used to develop the full-scale heat exchanger and integrate it in the solar plant
- The development of the nitrogen purification unit and a scaled-up PSA system capable of removing oxygen from the effluent N_2/O_2 stream
- On field Experiments

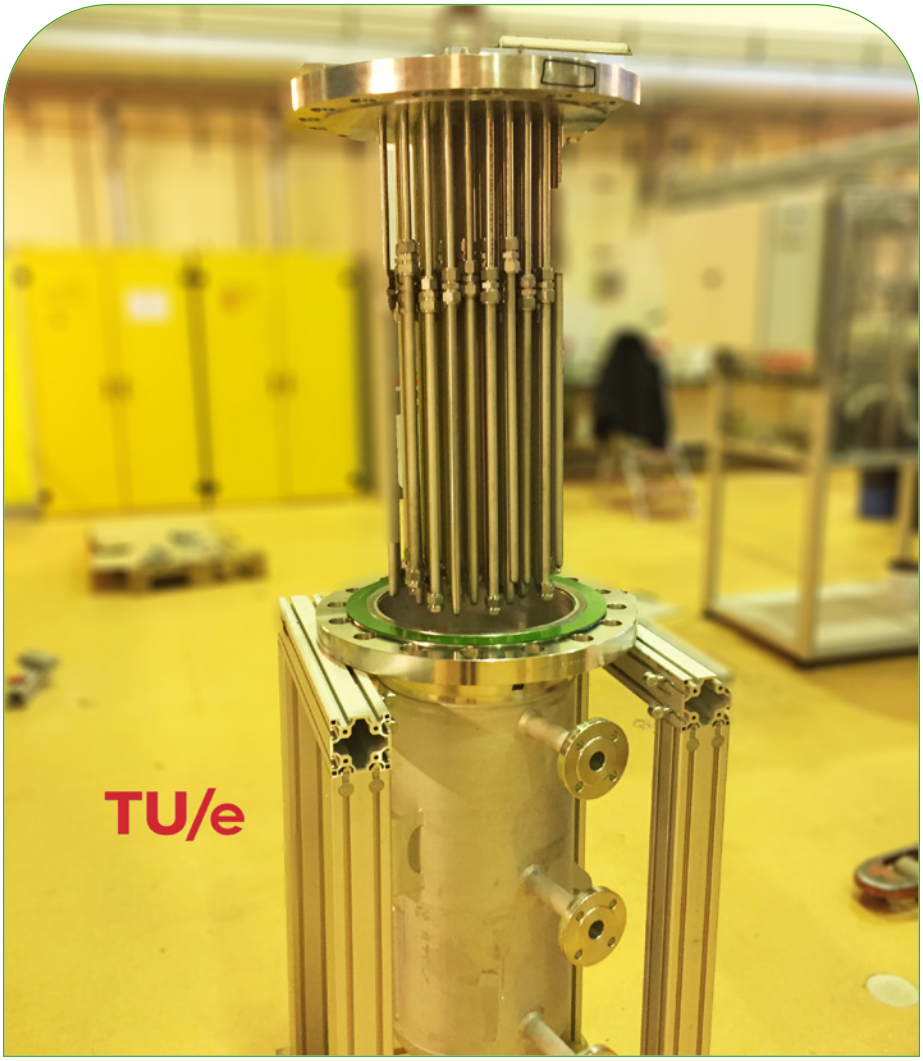


QUANTITATIVE TARGETS AND STATUS

TARGET SOURCE	PARAMETER	UNIT	TARGET	ACHIEVED TO DATE BY THE PROJECT	TARGET ACHIEVED?	SOA RESULT ACHIEVED TO DATE (BY OTHERS)	YEAR FOR SOA TARGET
Project's own objectives	Hydrogen production: H_2 yield	kg/week	9.6	0.025		3.2	2019
	Redox material lifetime	cycles	1 000	245		600	
	Heat recovery: parasitic losses	%	60	N/A		N/A	

HyGrid

FLEXIBLE HYBRID SEPARATION SYSTEM FOR H_2 RECOVERY FROM NG GRIDS



Project ID:	**700355**
Call topic:	**FCH-02.5-2015** - Development of technology to separate hydrogen from low-concentration hydrogen streams
Project total costs:	**€ 3,167,710**
FCH JU max. Contribution:	**€ 2,527,710**
Project start - end:	01/05/2016 - 30/04/2020
Coordinator:	**TECHNISCHE UNIVERSITEIT EINDHOVEN, NL**
Website:	**www.hygrid-h2.eu**

BENEFICIARIES: FUNDACION TECNALIA RESEARCH & INNOVATION, SAES GETTERS S.P.A., HYGEAR BV, HyGear Fuel Cell Systems B.V., QUANTIS, HYET HYDROGEN BV, HYGEAR TECHNOLOGY AND SERVICES BV, NORTEGAS ENERGIA DISTRIBUCION SOCIEDAD ANONIMA

PROJECT AND OBJECTIVES

The key objective of the HyGrid project is the design, scale-up and demonstration at industrially relevant conditions of a novel membrane-based hybrid technology for the direct separation of hydrogen from natural gas grids. The focus of the project is on hydrogen separation through a combination of membranes, electrochemical separation and temperature swing adsorption to decrease the total cost of hydrogen recovery. The project targets a pure hydrogen separation system with power and cost of <5 kWh/kg H_2 and <1.5 €/kg H_2. A pilot has been designed for >25 kg/day of hydrogen.

NON-QUANTITATIVE OBJECTIVES

Training for PhD students. One student has already finalised their PhD and found a job in a research centre to work on topics similar to HyGrid.

PROGRESS AND MAIN ACHIEVEMENTS

- All prototype components are finished and being installed/debugged
- Two patent applications on membranes and systems for hydrogen separation have been granted
- Several scientific papers on all components of the prototype have been published.

FUTURE STEPS AND PLANS

Finalise debugging and test the complete system. The components are available and being integrated. The software is being finalised.

QUANTITATIVE TARGETS AND STATUS

TARGET SOURCE	PARAMETER	UNIT	TARGET	ACHIEVED TO DATE BY THE PROJECT	TARGET ACHIEVED?
AWP 2015	Pure hydrogen separation system with low power	kWh/kg H_2	5	5	✓
	Pure hydrogen separation system with low cost	€/kg H_2	1.5	1.5	
	Prototype unit	TRL	5	5	
	Pure hydrogen production	kg/day	25	12	🛠

HySTOC

HYDROGEN SUPPLY AND TRANSPORTATION USING LIQUID ORGANIC HYDROGEN CARRIERS

Project ID:	**779694**
Call topic:	**FCH-02-6-2017** - Liquid organic hydrogen carrier
Project total costs:	**€2 499 921.25**
FCH JU max. Contribution:	**€2 499 921.25**
Project start - end:	01/01/2018 - 31/03/2022
Coordinator:	**HYDROGENIOUS LOHC TECHNOLOGIES GMBH, DE**
Website:	**hystoc.eu/**

BENEFICIARIES: HYGEAR OPERATIONS BV, TEKNOLOGIAN TUTKIMUSKESKUS VTT OY, HYGEAR TECHNOLOGY AND SERVICES BV, OY WOIKOSKI AB, HYGEAR FUEL CELL SYSTEMS BV, HYGEAR BV, FRIEDRICH-ALEXANDER-UNIVERSITAET ERLANGEN-NUERNBERG

PROJECT AND OBJECTIVES

The HySTOC project aims to demonstrate the feasibility of LOHC-based distribution of high purity hydrogen (ISO 14687:2-2012) to an HRS in Finland, in an unprecedented field test. The H_2 is produced and supplied by the project partner Woikoski in Kokkola, Finland. Here the H_2 is placed in the StorageBox of the project partner Hydrogeniou, from where it is transferred to the LOHC. The hydrated material is then transported to the project partner VTT in Espoo, where it placed in the ReleaseBox from Hydrogenious. In the dehydrogenation process, the H_2 is released from the LOHC in the ReleaseBox.

NON-QUANTITATIVE OBJECTIVES

- Gain further experience in the development, assembly, commissioning, operation, costs, etc. of the LOHC hydrogenation unit
- Gain further experience in the development, assembly, commissioning, operation, costs, etc. of the LOHC dehydrogenation unit
- Gain further experience in LOHC logistics
- Analyse H_2 gas from the LOHC.

PROGRESS AND MAIN ACHIEVEMENTS

- StorageBox was developed, built, assembled, commissioned. Currently, it is located in Kokkola and operated by project partners Woikoski and Hydrogenious
- ReleaseBox was developed, built, assembled and is almost commissioned. Currently, it is located in Espoo and final commissioning will be by VTT, HyGear and Hydrogenious
- LOHC is transported between Kokkola (Woikoski) and Espoo (VTT) in IBC containers on a truck.

FUTURE STEPS AND PLANS

- The LOHC hydrogenation unit to be operated by Woikoski and Hydrogenious
- Completion of commissioning and operation of the LOHC dehydrogenation unit to be performed by VTT and Hydrogenious
- LOHC logistics will be further improved by Woikoski
- The re-released hydrogen will be analysed by VTT
- Hydrogen refuelling station: interface clarification by Woikoski, VTT and Hydrogenious. Implementation of the HRS at the VTT site. Testing of the LOHC dehydrogenation unit at an HRS operated by Woikoski. The hydrogen refuelling with the HRS has been changed to be implemented by a simpler system with lower pressure (200 bar). This system is currently under development. The hydrogen produced will, however, be tested with a real FC vehicle.

QUANTITATIVE TARGETS AND STATUS

TARGET SOURCE	PARAMETER	UNIT	TARGET	ACHIEVED TO DATE BY THE PROJECT	TARGET ACHIEVED?
Project's own objectives	REDUCTION OF HYDROGEN STORAGE COSTS				
	Absolute material costs SB	€/(kg/d)	336 000	350 000	✗
	Absolute material costs RB	€/(kg/d)	400 000	380 000	
	ACCESSIBLE TO MOBILE APPLICATIONS				
	Hydrogen quality	-	ISO14687-2	ISO14687-2	✓

MultiPLHY

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

Project ID:	**875123**
Call topic:	**FCH-02-2-2019** - Multi-megawatt high-temperature electrolyser for valorisation as energy vector in energy intensive industry
Project total costs:	**€9 751 722.50**
FCH JU max. Contribution:	**€6 993 725.39**
Project start - end:	01/01/2020 - 31/12/2024
Coordinator:	**COMMISSARIAT A L'ENERGIE ATOMIQUE ET AUX ENERGIES ALTERNATIVES, FR**
Website:	**multiplhy-project.eu**

BENEFICIARIES: NESTE ENGINEERING SOLUTIONS BV, NESTE NETHERLANDS BV, ENGIE ENERGIE SERVICES, NESTE ENGINEERING SOLUTIONS OY, PAUL WURTH SA, SUNFIRE GMBH, NESTE OYJ, ENGIE

PROJECT AND OBJECTIVES

MULTIPLHY aims to install and integrate the world's first high-temperature electrolyser (HTE) system at multi-megawatt scale at a biorefinery in Rotterdam (NL), demonstrating the EU's technological and industrial leadership in the application of solid oxide electrolyser cell (SOEC) technology. A key element of the project is the manufacturing and demonstration of a multi-MW high-temperature electrolyser and its operation in a biorefinery. The results enable MULTIPLHY to promote the SOEC-based high-temperature electrolyser from TRL7 to 8.

PROGRESS AND MAIN ACHIEVEMENTS

- A first HyLink Gen 2.0 'Proof of Concept' module has been developed, manufactured and commissioned. The first electrolysis operation mode ran successfully
- System integration and operating concept have been defined. The approved layout of the HTE and HPU systems fits into the mandatory plot at the refinery
- A testing protocol enabling the benchmarking of stacks comprising cells of different technologies has been defined.

FUTURE STEPS AND PLANS

Execute project tasks as planned. Tasks are on track.

QUANTITATIVE TARGETS AND STATUS

TARGET SOURCE	PARAMETER	UNIT	TARGET	TARGET ACHIEVED?	SOA RESULT ACHIEVED TO DATE (BY OTHERS)	YEAR FOR SOA TARGET
AWP 2019	Electrical consumption	kWh/kg	39		39.7	2017
	Production loss	h=%/1 000 h	<1.2	✗	1.9	
	Downtime	%	5		Not available	N/A

NEPTUNE

NEXT GENERATION PEM ELECTROLYSER UNDER NEW EXTREMES

Project ID:	**779540**
Call topic:	**FCH-02-1-2017** - Game changer Water Electrolysers
Project total costs:	**€1 927 335.43**
FCH JU max. Contribution:	**€1 926 221.25**
Project start - end:	01/02/2018 - 31/10/2021
Coordinator:	**ITM POWER (TRADING) LIMITED, UK**
Website:	**www.neptune-pem.eu**

BENEFICIARIES: CONSIGLIO NAZIONALE DELLE RICERCHE, ENGIE, SOLVAY SPECIALTY POLYMERS ITALY SPA, IRD FUEL CELLS A/S, PRETEXO

PROJECT AND OBJECTIVES

The NEPTUNE project addresses challenges associated with reducing capital costs and increasing production rates and output pressures of water electrolysis to the levels required to achieve large-scale application of PEM electrolysers. NEPTUNE is developing a set of breakthrough solutions at material, stack and system levels to increase hydrogen pressure to 100 bar and current density to 4 A cm^{-2} for the base load, while keeping the nominal energy consumption <50 kWh/kg H_2. The novel solutions will be validated by demonstrating a robust and rapid-response electrolyser.

NON-QUANTITATIVE OBJECTIVES

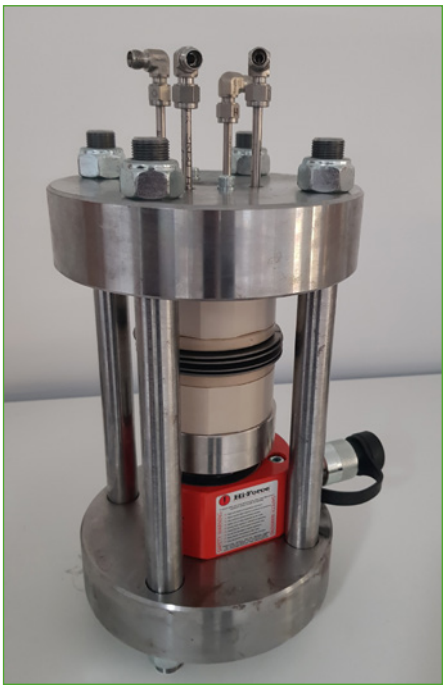
Extension of protocols for testing electrolysis systems under the new operating conditions (high temperature and pressure). Public deliverable report published.

PROGRESS AND MAIN ACHIEVEMENTS

- Design and build a new simplified balance of plant for PEM electrolysis to extend operating conditions
- MEA degradation rate achieved at 80 °C, 4.4 µV/h/cell at 4 A cm^{-2} in a test >2 000 h (single cell level)
- At 90 °C, cell voltages of 1.74 V and 1.98 V at 4 and 8 A cm^{-2}, respectively, with noble metal loading 0.34 mg cm^{-2} anode and 0.1 mg cm^{-2} cathode.

FUTURE STEPS AND PLANS

- Demonstration of advanced cost-effective PEM electrolysis stack operating at high temperature and with high differential pressure.
- Validation of PEM electrolysis stack durability in endurance tests and dynamic operating conditions.
- Techno-economic assessment and life cycle analysis on the advanced PEM electrolyser. Goal and scope defined.

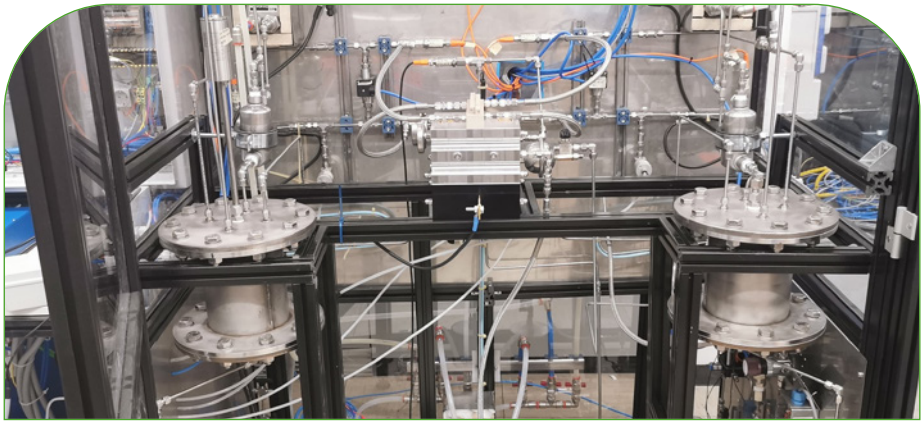


QUANTITATIVE TARGETS AND STATUS

TARGET SOURCE	PARAMETER	UNIT	TARGET	ACHIEVED TO DATE BY THE PROJECT	TARGET ACHIEVED?	SOA RESULT ACHIEVED TO DATE (BY OTHERS)	YEAR FOR 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 h for LT electrolyser	%/1 000 h	0.29	0.23	✓	0.2	

NEWELY

NEXT GENERATION ALKALINE MEMBRANE WATER ELECTROLYSERS WITH IMPROVED COMPONENTS AND MATERIALS



Project ID:	**875118**
Call topic:	**FCH-02-4-2019** - New Anion Exchange Membrane Electrolysers
Project total costs:	**€2 597 413.75**
FCH JU max. Contribution:	**€2 204 846.25**
Project start - end:	01/01/2020 - 31/12/2022
Coordinator:	**DEUTSCHES ZENTRUM FUR LUFT- UND RAUMFAHRT EV, DE**
Website:	**www.newely.eu**

BENEFICIARIES: MEMBRASENZ SARL, PROPULS GMBH, CUTTING-EDGE NANOMATERIALS CENMAT UG HAFTUNGSBESCHRANKT, AIR LIQUIDE FORSCHUNG UND ENTWICKLUNG GMBH, KOREA INSTITUTE OF SCIENCE AND TECHNOLOGY, WESTFALISCHE HOCHSCHULE GELSENKIRCHEN, BOCHOLT, RECKLINGHAUSEN, DLR-INSTITUT FUR VERNETZTE ENERGIESYSTEME EV, USTAV MAKROMOLEKULARNI CHEMIE AV CRVVI, FONDAZIONE BRUNO KESSLER, VYSOKA SKOLA CHEMICKO-TECHNOLOGICKA V PRAZE, AIR LIQUIDE SA, COMMISSARIAT A L'ENERGIE ATOMIQUE ET AUX ENERGIES ALTERNATIVES

PROJECT AND OBJECTIVES

The NEWELY project aims to redefine anion exchange membrane water electrolysis (AEMWE), surpassing the current state of alkaline WE and bringing it one step closer to proton exchange membrane WE in terms of efficiency but at lower cost. The three main challenges of AEMWE – membrane, catalyst and stack – are addressed by 3 SMEs and a large hydrogen company supported by 7 renowned R&D centres. With a prototypic 5-cell stack at elevated pressure in a 2 000-hour endurance test, twice the performance of the state of the art of AEMWE will be validated. This will impact the cost of green hydrogen.

NON-QUANTITATIVE OBJECTIVES

TEA (Techno- Economic Assessment) + LCA (life cycle assessment) demonstrate reduction of CAPEX and OPEX for AEMWE rel. PEMWE and AWE.

PROGRESS AND MAIN ACHIEVEMENTS

- MEA with NiFe anode and Mo2C cathode and commercial AEM/ionomer achieves 2 V at 2 A cm^{-2} in 0.1 M KOH. Degradation rate of 500 µV/h at constant 1 A cm^{-2}
- First publication of the project is a review paper on commercial AEMs
- Construction of the AEMWE test station for stacks.

FUTURE STEPS AND PLANS

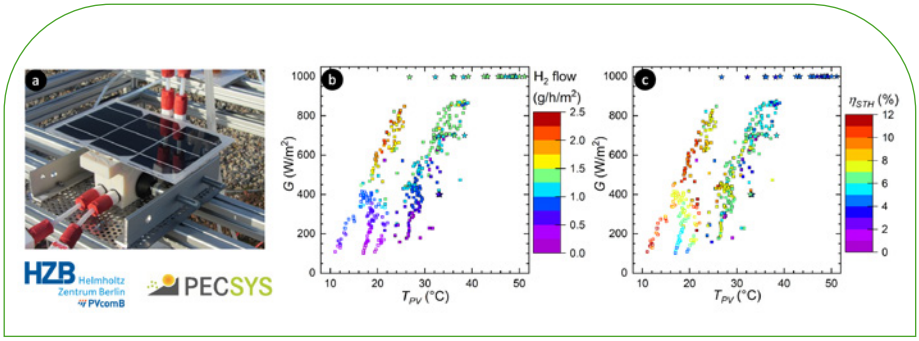
- MEA preparation at 25 cm^2 and 200 cm^2 with project materials and targeted performance. First MEAs prepared, with testing of the 25 cm^2 MEA next step
- First sketch completed of the stack design and construction
- Stack has not yet been in operation at increased pressure
- Long-term testing of the stack to demonstrate the required stability
- Data collection has started for LCA 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 FOR SOA TARGET
Project's own objectives and MAWP Addendum (2018-2020)	MAXIMUM AEMWE STACK SIZE REALISED IN THE PROJECT						
	Stack power	kW	2	0.014	✗	2.4	2021
	Cell area	cm^2	200	4	✗	N.A	
	Pressure	bar (rel.)	≤40	0	✓	≤35	
	Energy consumption @ power Corresponding to cell voltage @ current	kWh/kg @ W cm^{-2} Corresponding to V @ A cm^{-2}	53.6 @ 2 Corresponding to 2 @ 1	53.6 @ 3.6 Corresponding to 2 @ 1.8	✓	53.6 @ 0.7 Corresponding to 2 @ 0.35	2020
	NON-PGM CATALYSTS						
	Added overpotentials anode + cathode	mV	415	232	✗	250	2020
	Current density	mA cm^{-2}	1	1	✓	1	
MAWP Addendum (2018-2020) and AWP 2019	Stable operation for 2000 h, cell voltage gap after 2000 h operation Extrapolated to efficiency degradation @ rated power and considering 8000 h operations/year	mV Extrapolated to %/year	50 Extrapolated to 7.2	No test yet	✗	<2	2021
	Chemically, thermally and mechanically stable AEM ionomer and membrane with conductivity	mS cm^{-1}	≥50	>60	✓	80	2021
	Area-specific resistance (ASR)	Ω cm^2	≤0.07	0.08	✗	0.045	

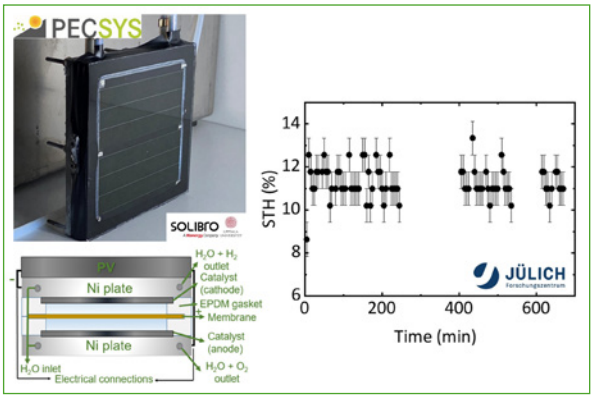
PECSYS

TECHNOLOGY DEMONSTRATION OF LARGE-SCALE PHOTO-ELECTROCHEMICAL SYSTEM FOR SOLAR HYDROGEN PRODUCTION



Project ID:	**735218**
Call topic:	**FCH-02-3-2016** - Development of processes for direct production of hydrogen from sunlight
Project total costs:	**€2 499 992.5**
FCH JU max. Contribution:	**€2 499 992.5**
Project start - end:	01/01/2017 - 31/12/2020
Coordinator:	**HELMHOLTZ-ZENTRUM BERLIN FUR MATERIALIEN UND ENERGIE GMBH, DE**
Website:	**https://www.helmholtz-berlin.de/projects/pecsys/**

BENEFICIARIES: UPPSALA UNIVERSITET, FORSCHUNGSZENTRUM JULICH GMBH, CONSIGLIO NAZIONALE DELLE RICERCHE, SOLIBRO RESEARCH AB, ENEL GREEN POWER SPA, 3SUN SRL



PROJECT AND OBJECTIVES

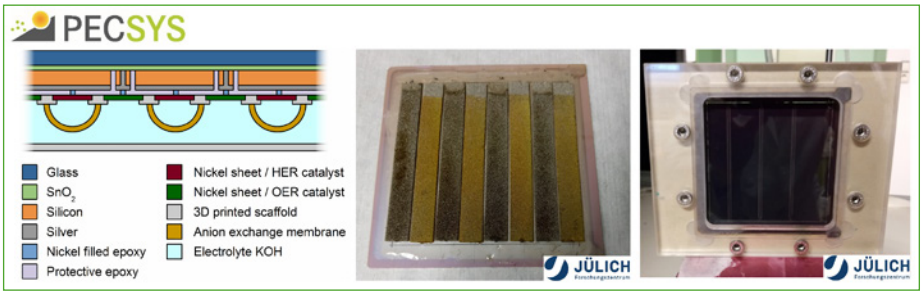
The PECSYS project demonstrated a solar-driven electrochemical hydrogen generator using a solar collection area >10 m². The best thermally integrated devices achieved solar-to-hydrogen (StH) conversion efficiencies of 13 % (100 cm²) and 5.1 % (2 600 cm²). The final 10 m² demonstrator installed at Jülich (DE) consisted of an array of CuInGaSe and silicon heterojunction photovoltaic modules directly electrically coupled to an electrolyser stack. The demonstrator was continuously operated for 9 months, during which 22 kg of hydrogen were generated with an average StH efficiency of 10 %.

PROGRESS AND MAIN ACHIEVEMENTS

- A CIGS PV integrated electrolyser with 100 cm² area achieved a StH conversion efficiency of 13 % at a rate of 2.2 g H2/h/m²
- A 10 m² array of PV modules directly connected to detached PEM electrolysers achieved a StH conversion efficiency of 10 % at a rate of 2.3 g/h/m²
- NiMo and NiFe catalysts grown on up to 125 cm² areas, for H2 and O2 evolution, respectively, achieved overpotentials of 94 mV and 200 mV at 10 mA/cm².

FUTURE STEPS AND PLANS

The project has finished.

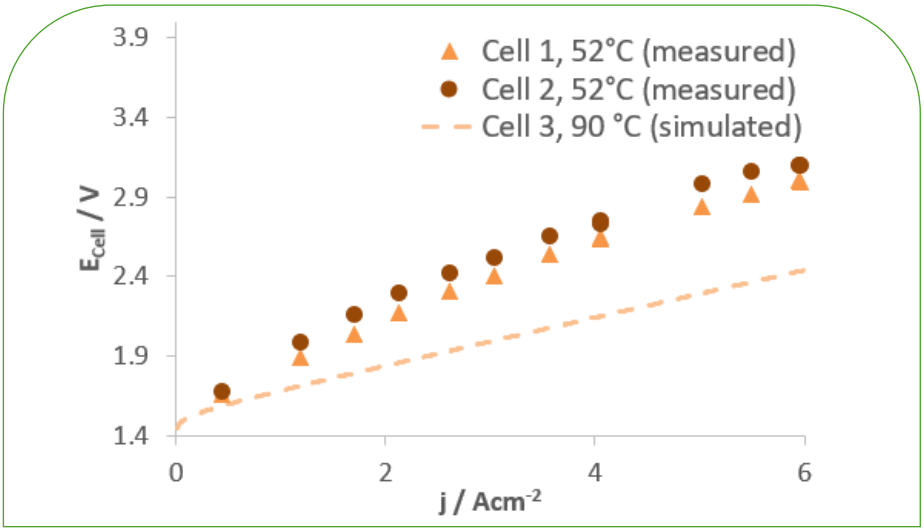


QUANTITATIVE TARGETS AND STATUS

TARGET SOURCE	PARAMETER	UNIT	TARGET	ACHIEVED TO DATE BY THE PROJECT	TARGET ACHIEVED?	SOA RESULT ACHIEVED TO DATE (BY OTHERS)
Project's own objectives	Hydrogen production rate	g/h/m²	1.6	2.3	✓	1.2
	Solar collection area	m²	10	10	✓	1.5
	Operation with less than 10 % drop in efficiency	Hours	1 825	2 680	✓	10

PRETZEL

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



Project ID:	**779478**
Call topic:	**FCH-02-1-2017:** Game changer Water Electrolysers
Project total costs:	**€1 999 088.75**
FCH JU max. Contribution:	**€1 999 088.75**
Project start - end:	01/01/2018 - 30/06/2021
Coordinator:	**DEUTSCHES ZENTRUM FUER LUFT- UND RAUMFAHRT EV, DE**
Website:	**pretzel-electrolyzer.eu/**

BENEFICIARIES: IGAS ENERGY GMBH, ADAMANT AERODIASTIMIKES EFARMOGES ETAIREIA PERIORISMENIS EFTHYNIS, SOLUCIONES CATALITICAS IBERCAT SL, GKN SINTER METALS FILTERS GMBH RADEVORMWALD, WESTFALISCHE HOCHSCHULE GELSENKIRCHEN, BOCHOLT, RECKLINGHAUSEN, GKN SINTER METALS ENGINEERING GMBH, ECOLE NATIONALE SUPERIEURE DES MINES DE PARIS, ETHNIKO KENTRO EREVNAS KAI TECHNOLOGIKIS ANAPTYXIS, UNIVERSITATEA POLITEHNICA TIMISOARA, ASSOCIATION POUR LA RECHERCHE ET LE DEVELOPPEMENT DES METHODES ET PROCESSUS INDUSTRIELS

PROJECT AND OBJECTIVES

The overall goal of PRETZEL is to develop an innovative polymer electrolyte membrane electrolyser (PEMEL) that provides significant increases in efficiency and operability to satisfy emerging market demands and becomes a game-changing electrolyser. A central objective is the development of a novel PEMEL system with a maximum of 25 kW electrical power consumption that generates 4.5 m3 h-1 H2 at rated power, at an output pressure of 100 bar and feed water temperature of maximum 90 °C. The components have been tested, are currently being manufactured and the system will be tested over 2 000 h.

NON-QUANTITATIVE OBJECTIVES

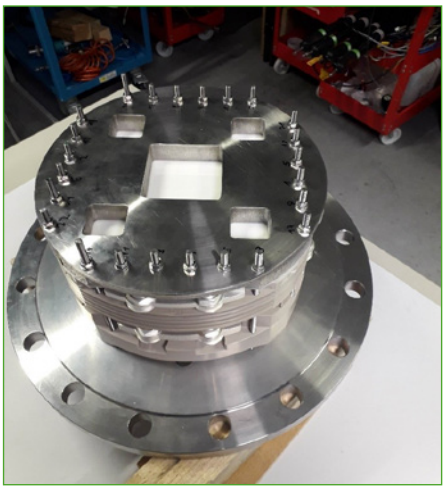
- An assessment of additional commercial opportunities that are available with the game-changing electrolyser compared to current electrolysers. Will be implemented.
- Enabling additional commercial roll-out of electrolysers post-2025.

PROGRESS AND MAIN ACHIEVEMENTS

- Coatings for stainless steel BPP and PTLs were developed and tested up to a current density of 6 A cm-2, achieving an unprecedented cell efficiency of 77 %
- Ti-based PTL allows operation up to 6 A cm-2 at 90 °C, eliminating mass transport limitations completely and passing the durability AST
- The first 100 bar H2 pressure test in a 5 Nm3 h-1 PEMWE system from iGas was carried out successfully with a stack containing the developed PTLs.

FUTURE STEPS AND PLANS

Completion of 2 000-hour test of PEMWE system at 90 °C, 100 bar up to 6 A cm-2. Not started yet.



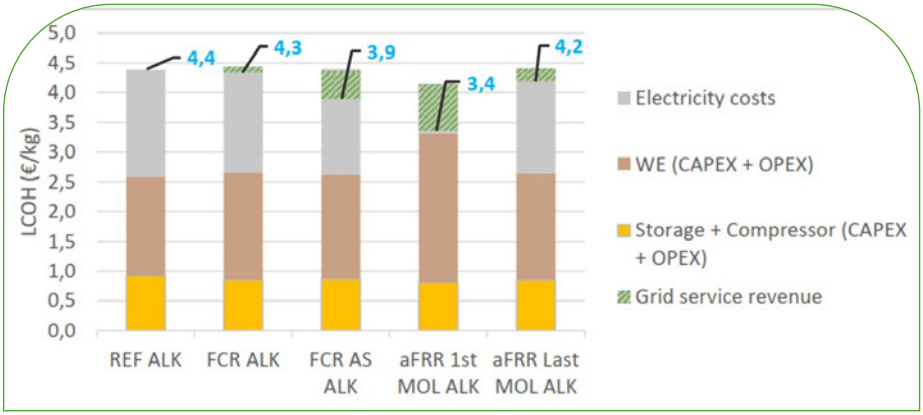
QUANTITATIVE TARGETS AND STATUS

TARGET SOURCE	PARAMETER	ACHIEVED TO DATE BY THE PROJECT
MAWP (2014–2020) and AWP 2017	Reducing PEM electrolyser CAPEX costs: new cost-effective current collectors for PEM electrolysers for hydrogen generation from renewable energies	500 cm2 manufactured PCD are ready for implementation and testing in high pressure stack
	Increase energy efficiency of hydrogen production: increase of catalyst activity and optimisation of supporting material	Iridium-supported material (Ir/SnO2) has been prepared and evaluated on its catalytic activity and economic feasibility for scaling up. Catalyst with adequate metal content and aerogel support for 500 cm2 MEA production produced
	Development and validation of game-changing PEM electrolyser meeting the targets of 2023: 210 cm2 high-pressure stack with all components tested	Cell parts and CAD design of high-pressure electrolyser stack are finalised and manufactured. The design is based on prototypes of our partners using the principle of hydraulic cell compression, which was developed in publicly funded projects VOMPELS (EFRE-0800099) and MoDePEM (EFRE-0400094)
AWP 2017	Step change improvements: 100 bar, rapid response (<1 s hot start), 4 A cm-2 nominal current density and overload of 6 A cm-2, temperature T>80 °C	Initial cell test performing polarisation curve up to 6 A cm-2 at 90 °C and 100 bar 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 potential users of the gases produced

QualyGridS

STANDARDIZED QUALIFYING TESTS OF ELECTROLYSERS FOR GRID SERVICES

Project ID:	**735485**
Call topic:	**FCH-02-1-2016:** Establish testing protocols for electrolysers performing electricity grid services
Project total costs:	**€2 811 262.5**
FCH JU max. Contribution:	**€1 996 795**
Project start - end:	01/01/2017 - 30/06/2020
Coordinator:	**DEUTSCHES ZENTRUM FUER LUFT- UND RAUMFAHRT EV, DE**
Website:	**www.qualygrids.eu**



BENEFICIARIES: COMMISSARIAT A L ENERGIE ATOMIQUE ET AUX ENERGIES ALTERNATIVES, DANMARKS TEKNISKE UNIVERSITET, IHT INDUSTRIE HAUTE TECHNOLOGIE SA, STICHTING KONINKLIJK NEDERLANDS NORMALISATIE INSTITUUT, FACHHOCHSCHULE ZENTRALSCHWEIZ - HOCHSCHULE LUZERN, FUNDACION PARA EL DESARROLLO DE LAS NUEVAS TECNOLOGIAS DEL HIDROGENO EN ARAGON, EUROPEAN FUEL CELL FORUM AG, ITM POWER (TRADING) LIMITED, NEW NEL HYDROGEN AS

PROJECT AND OBJECTIVES

The overall objective of the QualyGridS project was to establish standardised testing protocols for electrolysers to perform electricity grid services. Alkaline and PEM electrolysers are both considered in this project. A variety of different grid services are addressed as well as multiple hydrogen end users. The protocols developed were applied to alkaline and PEM electrolyser systems, using electrolyser sizes from 10 kW to 300 kW. In addition, a techno-economic analysis of business cases was performed, covering the grid and market situations in the most relevant regions of Europe.

NON-QUANTITATIVE OBJECTIVES

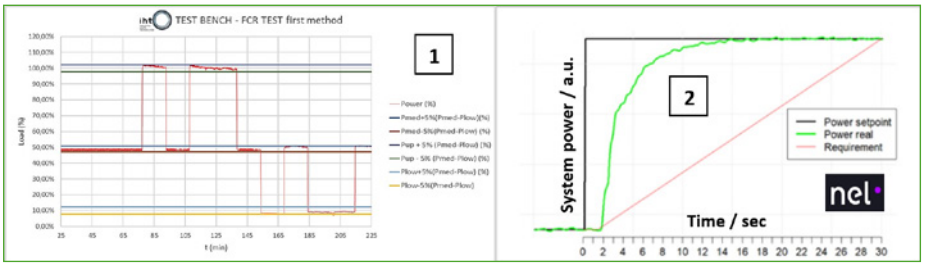
- AWP 2016: development of standardised protocols for electrolysers to provide grid services. Achieved 100 %. QualyGridS protocols are the basis of the ISO Technical Report
- AWP 2016: definition of specific KPIs for dynamic operation to provide grid services. Achieved 100 %
- Evaluation of business cases, sensitivities and a roadmap. Achieved 100 %. The evaluations led to the publication of final recommendations.

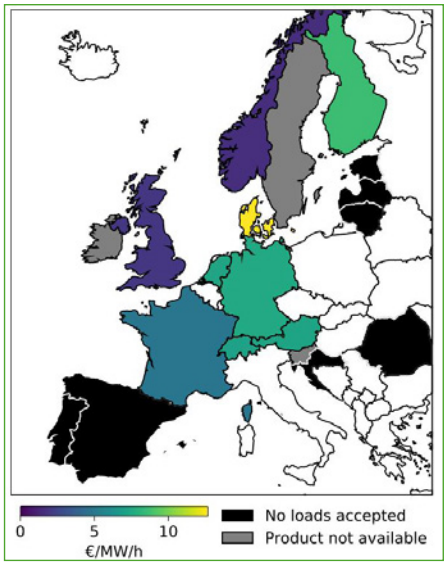
PROGRESS AND MAIN ACHIEVEMENTS

- Testing protocols for electrolysers performing grid services presented to ISO TC 197 Hydrogen technologies, approved as new working group to submit an ISO Technical Report
- Business case definition and detailed business case evaluation done, including recommendations
- 2 PEM and 3 alkaline electrolyser systems have been tested for their ability to perform grid services by running the project's testing protocols.

FUTURE STEPS AND PLANS

The project has finished.

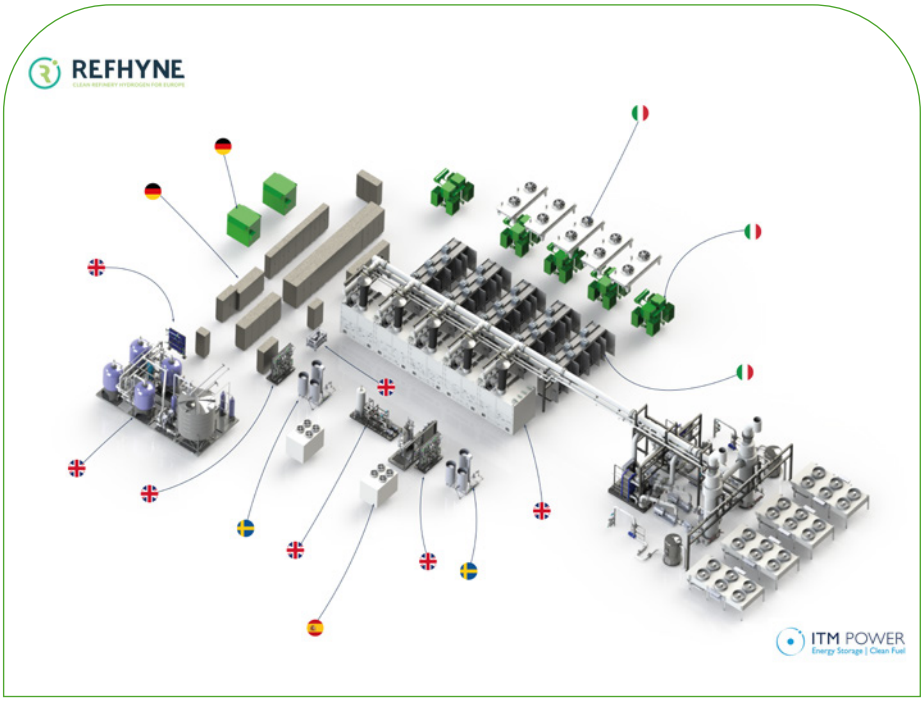




QUANTITATIVE TARGETS AND STATUS

TARGET SOURCE	PARAMETER	UNIT	TARGET	ACHIEVED TO DATE BY THE PROJECT	TARGET ACHIEVED?	SOA RESULT ACHIEVED TO DATE (BY OTHERS)	YEAR FOR SOA TARGET
Project's own objectives	Number of electrolysers that have performed test run	-	5	5 systems up to 300 kW performed the test run	✓	N/A	N/A
MAWP (2014-2020)	Cost of hydrogen	(€/kg)	4.5-7.0	Cost reduction by performing a FRR for the evaluated scenario can be as high as 24 %	✓	12	2017
AWP 2016	Development of standardised protocols for electrolysers to provide grid services across EU countries	Number of drafts and reviews of these drafts	3	3	✓	Draft harmonised testing protocols by JRC, including input from QualyGridS project, no standard	2020

REFHYNE
CLEAN REFINERY HYDROGEN FOR EUROPE



Project ID:	**779579**
Call topic:	**FCH-02-5-2017:** Demonstration of large electrolysers for bulk renewable hydrogen production
Project total costs:	**€19 759 516.50**
FCH JU max. Contribution:	**€9 998 043.50**
Project start - end:	01/01/2018 - 31/12/2022
Coordinator:	**SINTEF AS, NO**
Website:	**www.refhyne.eu**

BENEFICIARIES: SHELL ENERGY EUROPE LIMITED, SHELL DEUTSCHLAND OIL GMBH, SPHERA SOLUTIONS GMBH, ITM POWER (TRADING) LIMITED, ELEMENT ENERGY LIMITED, STIFTELSEN SINTEF

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, demonstrate 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 being installed and the plant is expected start operation around mid-2021.

NON-QUANTITATIVE OBJECTIVES

- 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 an evidence base for changes to existing policies. This will include a specific analysis focused towards policymakers recommending changes to existing policies. The first results are just in and will soon be released
- Assessment of the legislative and RCS implications of these systems. REFHYNE will produce a detailed assessment of the consenting process for the system and of any issues related to safety or codes and standards.

PROGRESS AND MAIN ACHIEVEMENTS

- Finalised detailed design of the electrolyser system plant and its adaptation to the refinery
- Permit application approved by the local authorities
- Refinery building and infrastructure ready for integration of electrolysers.

FUTURE STEPS AND PLANS

- Demonstration of the 10 MW PEM electrolyser in a refinery setting. Expected to be inaugurated in mid-2021
- Techno-economic assessment of the electrolyser system and concept. Framework and models are in place, thus assessments will begin once system operating data are available
- Environmental analysis of the electrolyser system and concept. Framework and models are in place, thus 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 FOR SOA TARGET
MAWP Addendum (2018-2020)	H_2 production	kWh/kg	52		57-60	2017
	H_2 production	M€/(t/d)	2		8	
	H_2 production	%	1.5	✗	2-4	
	H_2 production	%	0-100		5-100	
	H_2 production	s	2		60	

REFLEX

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

Project ID:	**779577**
Call topic:	**FCH-02-3-2017:** Reversible Solid Oxide Electrolyser (rSOC) for resilient energy systems
Project total costs:	**€2 999 575.48**
FCH JU max. Contribution:	**€2 999 575.25**
Project start - end:	01/01/2018 - 31/12/2020
Coordinator:	**COMMISSARIAT A L'ENERGIE ATOMIQUE ET AUX ENERGIES ALTERNATIVES, FR**
Website:	**www.reflex-energy.eu/**

BENEFICIARIES: SYLFEN, TEKNOLOGIAN TUTKIMUSKESKUS VTT OY, ENGIE SERVIZI SPA, AKTSIASELTS ELCOGEN, GREEN POWER TECHNOLOGIES SL, PARCO SCIENTIFICO TECNOLOGICO PER LAMBIENTE ENVIRONMENT PARK TORINO SPA, UNIVERSIDAD DE SEVILLA, ENGIE, DANMARKS TEKNISKE UNIVERSITET

PROJECT AND OBJECTIVES

The REFLEX project aims to develop an innovative renewable energy storage solution, based on reversible solid oxide cell (rSOC) technology, able to operate either in electrolysis mode to store excess electricity to produce H2, or in fuel cell mode when energy needs exceed local production, to produce electricity and heat again from H2 or any other fuel locally available. It has developed improved rSOC components (cells, stacks, power electronics, heat exchangers) and defined the system, its set points and advanced operation strategies. An in-field demonstration will be performed in 2021.

NON-QUANTITATIVE OBJECTIVES

- Techno-economic assessment is ongoing
- Inventory of RCS applicable to rSOC systems drawn up for France and Italy.

PROGRESS AND MAIN ACHIEVEMENTS

- Project performance target and durability target achieved in rSOC operation at cell scale
- Enlarged cells (200 cm^2) integrated successfully in the small and large stack with same performance as regular size cells
- Power electronics manufactured and fulfils efficiency requirement of >95 %.

FUTURE STEPS AND PLANS

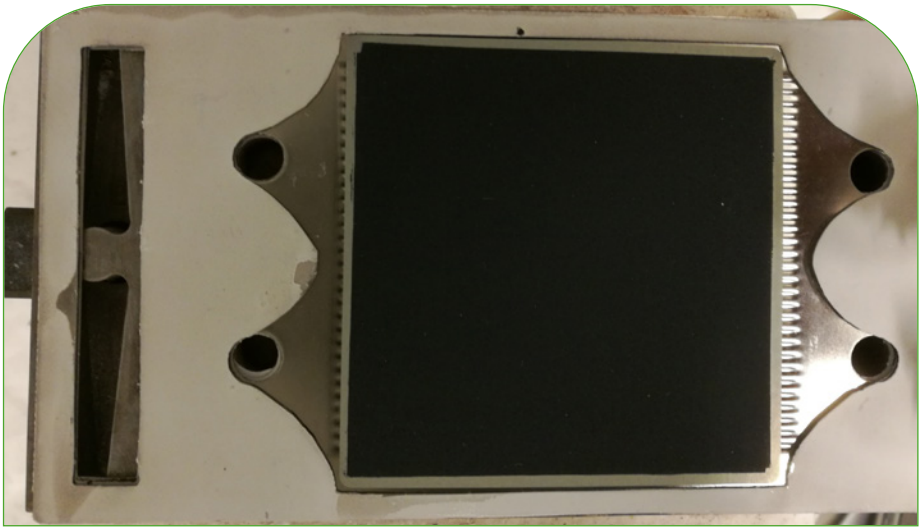
- Finalise modules and system assembly: ongoing and planned for M40
- Install and operate the system in-field: planned for M42.

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 FOR SOA TARGET
Project's own objective	Current density in SOEC mode	A/cm^2	-1.2	-1.25	✓	-1.15 A/cm^2 at 750 °C - 1 A/cm^2 at 800 °C	2015-2016
	Durability in SOEC step during rSOC operation at 0.58 A/cm^2 and SC=68 %	%/kh	2	1.2	✓	2.3 %/1 000 h for current densities of 0.6-0.7 A/cm^2 and SC=50 %	2015
	Cell active area	cm^2	200	200	✓	128	2020
	Power electronic efficiency	%	95	96	✓	88	2019
AWP	SC=80 %	%	80	85	✓	70	2015

SElySOs

DEVELOPMENT OF NEW ELECTRODE MATERIALS AND UNDERSTANDING OF DEGRADATION MECHANISMS ON SOLID OXIDE HIGH TEMPERATURE ELECTROLYSIS CELLS



Project ID:	**671481**
Call topic:	**FCH-02.1-2014:** Research in electrolysis for cost-effective hydrogen production
Project total costs:	**€2 939 655**
FCH JU max. Contribution:	**€2 939 655**
Project start - end:	02/11/2015 - 01/05/2020
Coordinator:	**IDRYMA TECHNOLOGIAS KAI EREVNAS, EL**
Website:	**selysos.iceht.forth.gr**

BENEFICIARIES: PROTOTECH AS, PYROGENESIS SA, ETHNIKO KENTRO EREVNAS KAI TECHNOLOGIKIS ANAPTYXIS, VYSOKA SKOLA CHEMICKO-TECHNOLOGICKA V PRAZE, FORSCHUNGSZENTRUM JULICH GMBH, CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE CNRS

PROJECT AND OBJECTIVES

SElySOs focused on the understanding of degradation and lifetime fundamentals of both SOEC electrodes in order to minimise their degradation and improve their performance and stability, mainly under H2O electrolysis and to a certain extent under H2O/CO2 co-electrolysis conditions. The project investigated: (i) modified SoA Ni-based cathode cement; (ii) alternative perovskite-type cathode materials; (iii) the O2 electrode in detail; and (iv) the development of a theoretical model to describe the performance and degradation of the SOEC H2 electrode.

NON-QUANTITATIVE OBJECTIVES

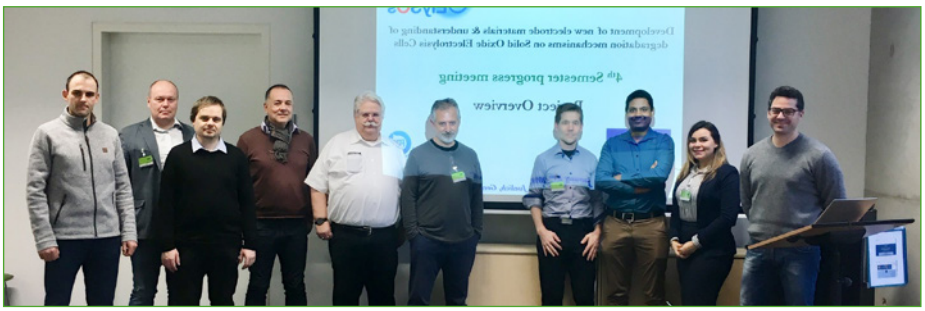
- New materials and component design less prone to degradation. During the project's last year, a series of modified Ni-based and Ni-free electrodes and a series of new air electrodes were investigated under various SOEC H2O electrolysis and H2O/CO2 co-electrolysis conditions. The results obtained were quite promising and specific electrodes were further examined, as larger size cells, for their long-term stability and in short stack tests, under SOEC operation
- Understanding of degradation mechanisms under dynamic operation. Mathematical modelling was developed for both of the SOEC H2O electrolysis and H2O/CO2 co-electrolysis processes. One key objective achieved was the correlation of the model/s with experimental data from the measurements performed as part of the project
- Development of improved and robust SOEC systems (cells /stack(s)). The newly developed electrodes were further investigated for their performance and tolerance in the form of complete cells. The latter were also investigated, in parallel, through long-term stability measurements of single large-area cells and the manufacture and testing of short stacks.

PROGRESS AND MAIN ACHIEVEMENTS

- Development of promising modified Ni-based and Ni-free cathodes and of new air electrodes with improved and tailored performance under SOEC operation
- Advanced operando analysis of Ni-based and Ni-free electrodes, which provided useful insights into their surface state during SOEC operation
- Thermodynamic and electrochemical modelling of the H2O and H2 and CO2 system by combining theoretical and experimental data, under SOEC operation.

FUTURE STEPS AND PLANS

The project has finished.



QUANTITATIVE TARGETS AND STATUS

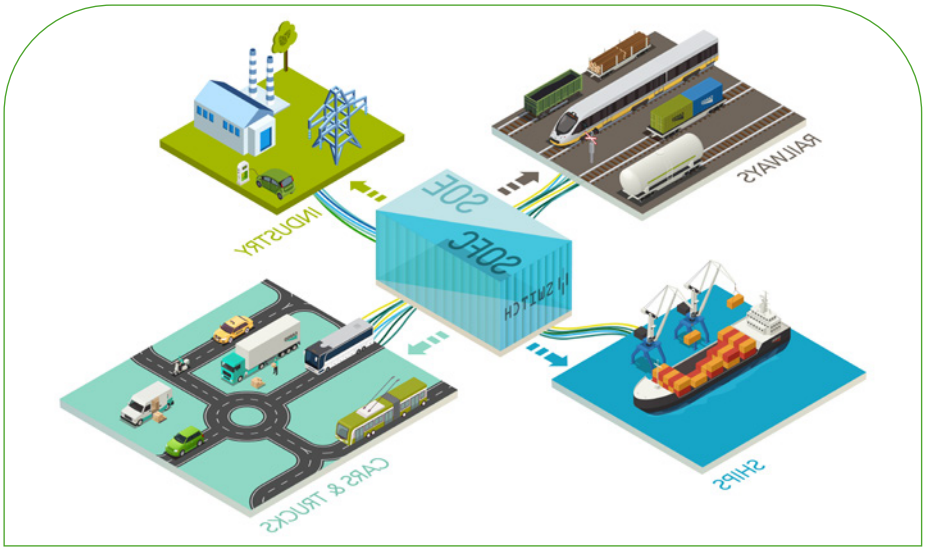
TARGET SOURCE	PARAMETER	UNIT	TARGET	ACHIEVED TO DATE BY THE PROJECT	TARGET ACHIEVED?	SOA RESULT ACHIEVED TO DATE (BY OTHERS)	YEAR FOR SOA TARGET
Project's own objective	Decrease the area-specific resistance on the fuel electrode compared to the SoA	Ohm * cm^2	N/A	0.4 for an Au-Mo-Ni/GDC modified fuel electrode and LSCoF as air electrode	✗	1.6 for Ni/GDC as fuel electrode and LSCoF as air electrode	2019
	Increase in the current density	A/cm^2	1	0.59 for an Au-Mo-Ni/GDC modified fuel electrode and LSCoF as air electrode		0.22 for Ni/GDC as fuel electrode and LSCoF as air electrode	
	Decrease of the catalyst (fuel electrode) loading per H2 capacity	g/(kg H_2/day)	N/A	18.5 for an Au-Mo-Ni /GDC modified fuel electrode and LSCoF as air electrode		50.3 for Ni/GDC as fuel electrode and LSCoF as air electrode	

Switch

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

Project ID:	**875148**
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:	**€3 746 753.75**
FCH JU max. Contribution:	**€2 992 521**
Project start - end:	01/01/2020 - 31/12/2022
Coordinator:	**FONDAZIONE BRUNO KESSLER, IT**
Website:	**switch-fch.eu/about/**

BENEFICIARIES: SWECO CONSULTING SPOLKA Z OGRANICZONA ODPOWIEDZIALNOSCIA, SOLIDPOWER SA, HYGEAR BV, SHELL GLOBAL SOLUTIONS INTERNATIONAL BV, ECOLE POLYTECHNIQUE FEDERALE DE LAUSANNE, DEUTSCHES ZENTRUM FUR LUFT- UND RAUMFAHRT EV



PROJECT AND OBJECTIVES

The 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 H2 production technology designed for H2 refuelling stations. The core of the system will be a reversible solid oxide cell operating in electrolysis mode (SOE) and fuel cell mode (SOFC). The goals of the project are to increase green H2 production from renewable sources to secure hydrogen supply and to reduce the overall technology costs for H2 production.

NON-QUANTITATIVE OBJECTIVES

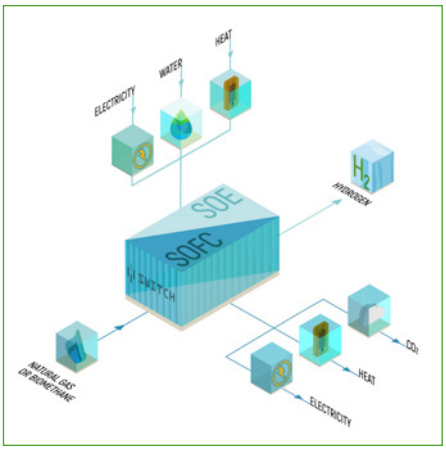
- Reliability and stability of power and hydrogen supply. The cogeneration potential with high dynamic behaviour offers a system able to deliver a reliable and stable production of hydrogen and power to facilitate demand-side management, securing the form of energy needed and connecting the generation profile to the proper end user
- Modularity. Development and validation of a 50 kg H2/day technology, realised by integrating modules composed of high-reliability stack modules provided by SP
- Hydrogen purity level. Hydrogen will be purified between the range 99.7% to 99.99 % and with a water content of less than 5 ppm, in compliance with ISO 14687
- In-field testing. The final SWITCH system prototype will be installed in a test-bench infrastructure and in a real-life operational environment, with an operation time of 5 000 hours in a relevant environment for in-field testing
- Life-cycle analysis (LCA) and life-cycle cost analysis (LCC) will help to evaluate the benefits of the SWITCH technology in comparison with SoA SMR and other H2 production technologies (electrolysis).

PROGRESS AND MAIN ACHIEVEMENTS

- Definition of the demand profiles for hydrogen and power related to four potential use cases at hydrogen refuelling stations
- Technical specifications of the SWITCH system: general description, proposed layout and utilities specification, operating modes for each module
- Results of multi-period and multi-objective optimisation analysis used to design SWITCH to operate efficiently in multiple modes that satisfy variable demand.

FUTURE STEPS AND PLANS

- 250 hours of LSM experimental analysis in electrolysis and polygeneration mode to test start-up and shutdown cycles. In February 2021, the LSM was delivered to DLR for testing and the test rig and test procedures were defined
- Definition of the PFD and finalisation of the design basis. HyGear and SOLIDpower are working on the final definitions of the requirement for each component.
- Definition of the P&ID of the complete system. Once the PFD has been completed by HyGear and SOLIDpower, it will be converted to a P&ID. The deadline is the end October 2021
- Realisation of the system: the Factory Acceptance Test is expected to start in May 2022.



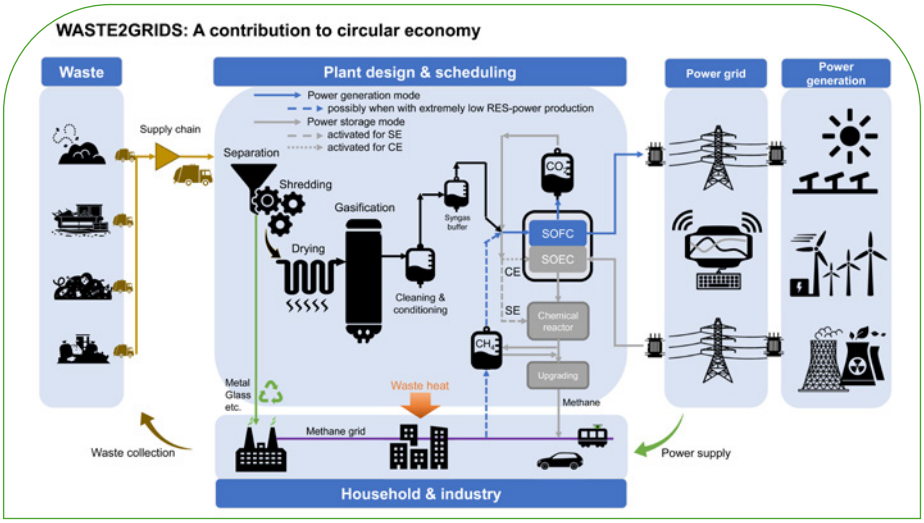
QUANTITATIVE TARGETS AND STATUS

TARGET SOURCE	PARAMETER	UNIT	TARGET	TARGET ACHIEVED?	SOA RESULT ACHIEVED TO DATE (BY OTHERS)	YEAR FOR SOA TARGET
Project's own objective	Electrolyser conversion efficiency	%	85		80	2021
	Fuel cell conversion efficiency	%	75		80	
	Hydrogen price	€/kg	5	✗	11.2	2020
	Stack lifetime	Hours	10 000		3 000	2021
	Low switching time	min	30		-	-

WASTE2GRIDS

CONVERTING WASTE TO OFFER FLEXIBLE GRID BALANCING SERVICES WITH HIGHLY-INTEGRATED, EFFICIENT SOLID-OXIDE PLANTS

Project ID:	**826161**
Call topic:	**FCH-02-8-2018:** Waste-stream based power balancing plants with high efficiency, high flexibility and power-to-X capability
Project total costs:	**€528 750**
FCH JU max. Contribution:	**€528 750**
Project start - end:	01/01/2019 - 31/12/2020
Coordinator:	**ECOLE POLYTECHNIQUE FEDERALE DE LAUSANNE, CH**
Website:	**www.waste2grids-project.net/**



BENEFICIARIES: SOLIDPOWER SA, AGENZIA NAZIONALE PER LE NUOVE TECNOLOGIE, L'ENERGIA E LO SVILUPPO ECONOMICO SOSTENIBILE, DANMARKS TEKNISKE UNIVERSITET

PROJECT AND OBJECTIVES

The overall objective is to identify the most promising industrial pathways of waste gasification and solid-oxide technology integrated plants, which provide grid-balancing services by switching among: (i) power generation (PowGen) mode, converting waste to electricity for the grid, (ii) power storage (PowSto) mode, using the grid electricity to convert waste into methane, and (iii) power neutral (PowNeu) mode, converting waste into methane with no grid interaction. The goals are to perform a preliminary investigation into the long-term techno-economic feasibility of the plants and to identify promising business cases with the necessary preconditions.

NON-QUANTITATIVE OBJECTIVES

- Grid flexibility needs. Theoretical flexibility needs for 2030 were identified with the multi-timescale data-driven method developed. Four of the six zones identified are interested, i.e. DK1, DK2 and Bornholm in Denmark and SUD in Italy
- Waste availability prediction. For the four RES-dominated zones, the following were quantified for 2030: the sustainable potentials of organic waste and residual biomass, including agriculture residues (straw and pruning), forest (net increment and residues), MSW (organic, wood and paper fraction) and bio-waste
- Multiple design evaluation. The optimal conceptual plant design has been drawn up with various combinations of technologies, resulting in an efficiency up to 50-60 % for PowGen mode, 72-76 % for PowSto mode and 47-55 % for PowNeu mode
- Promising business cases. At least two business cases have been identified with specific locations, plant design, sizes and scheduling.

PROGRESS AND MAIN ACHIEVEMENTS

- Proposed a novel concept of a triple-mode grid balancing plant enabled by biomass gasification and reversible solid-oxide cell technology
- Proposed a sequential optimisation method for thermo-economic feasibility that takes into account grid flexibility needs, waste availability and plant design
- Identification of business cases of the triple-mode concept and the necessary prerequisites.