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
PRD 2020 Panel:	5 - Hydrogen for Sectoral Integration
Project total costs:	**€7 748 848**
FCH JU max. contribution:	**€5 000 000**
Project start - end:	01/05/2016 - 30/04/2021
Coordinator:	**FUNDACION PARA EL DESARROLLO DE LAS NUEVAS TECNOLOGIAS DEL HIDROGENO EN ARAGON, ES**
Website:	**www.bighit.eu**

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

PROJECT AND OBJECTIVES

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

NON-QUANTITATIVE OBJECTIVES

- Life cycle assessment (LCA) completed
- First report submitted, to be followed by a final report, including operational data, at the end of the project
- Business model study for integrated energy systems based on hydrogen technologies
- Social LCA.

PROGRESS AND MAIN ACHIEVEMENTS

- Main project equipment has been built: 5 H_2 trailers (250 kg H_2 storage), H_2 catalytic boiler (30 kW), 1 MW electrolyser; 5 H_2 fuel cell vans, 75 kW fuel cell (cog)
- System design and detailed planning of sites have been finished. The HRS and H_2 production site has been commissioned and is operational
- First movements of H_2 in the multi-element gas containers (MEGC) in ferries throughout the islands have been completed successfully.

FUTURE STEPS AND PLANS

- First year of operation
- Commissioning of the second boiler unit
- Final report on LCA
- Final report on business models
- Final report on social-LCA.

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 addendum (2018-2020)	DEMONSTRATION OF A HYDROGEN CATALYTIC BOILER (THERMAL STATIC APPLICATION)						
	Power	kW	30	Partially (FAT completed, awaiting commissioning)	✗	N/A	N/A
	FUEL CELL LIGHT DUTY VEHICLES (INCLUDING CARS) AVAILABILITY - FC VANS IN BIG HIT						
	Availability	%	98	100	✓	98	2017
	HRS DURABILITY						
	Time	Years	10	Second year in operation	✗	N/A	N/A

BIONICO
BIOGAS MEMBRANE REFORMER FOR DECENTRALISED HYDROGEN PRODUCTION

Project ID:	**671459**
Call topic:	**FCH-02.2-2014** - Decentralised hydrogen production from clean CO_2-containing biogas
PRD 2020 Panel:	5 - Hydrogen for Sectoral Integration
Project total costs:	**€3 396 640**
FCH JU max. contribution:	**€3 147 640**
Project start - end:	01/09/2015 - 31/12/2019
Coordinator:	**POLITECNICO DI MILANO, IT**
Website:	**www.bionicoproject.eu**

BENEFICIARIES: TECHNISCHE UNIVERSITEIT EINDHOVEN, JOHNSON MATTHEY PLC, FUNDACION TECNALIA RESEARCH AND INNOVATION, ICI CALDAIE SPA, ABENGOA HIDROGENO SA, QUANTIS, RAUSCHERT KLOSTER VEILSDORF GMBH, ABENGOA RESEARCH SL, ENC POWER LDA, ENC ENERGY SGPS SA

PROJECT AND OBJECTIVES

The BIONICO project aimed to develop, build and demonstrate at a real biogas plant (TRL6) the use of a novel catalytic membrane reactor (CMR) for producing high-purity hydrogen from Biogas in a single step. The project achieved the targets set for component development (membrane and catalyst), energy-economic-environmental performance, laboratory experiments and reactor construction. Unfortunately, the reactor demonstration failed because of a severe auxiliary components failure that damaged the reactor, stopping the activity.

PROGRESS AND MAIN ACHIEVEMENTS

- A novel CMR for H_2 production was designed and constructed with 125 membranes and a catalyst
- A new type of membrane, thin Pd-Ag membranes (>40 cm long), was successfully prepared onto finger-like asymmetric alumina 14/7 mm
- A novel reforming catalyst was developed for the biogas composition identified in the project.

FUTURE STEPS AND PLANS

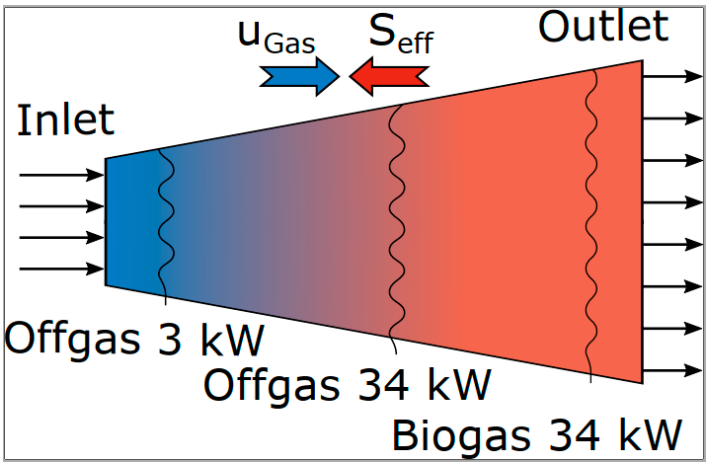
- The project has finished
- Demonstrate the catalytic membrane reactor performance in long-term tests
- Demonstrate membrane stability over long periods.

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	Overall efficiency	%	72	71.9	✓	65	2014
AWP 2014	Perform hydrogen production in a single step	Step	1	1	✓	4	2016
	Demonstrate BIONICO concept at a landfill plant delivering 100 kg/day	kg/day	100	N/A	✗	No system exists	N/A

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
PRD 2020 Panel:	5 - Hydrogen for Sectoral Integration
Project total costs:	**€3 813 536.24**
FCH JU max. contribution:	**€2 996 248.74**
Project start - end:	01/01/2017- 30/06/2020
Coordinator:	**POLITECNICO DI MILANO, IT**
Website:	**www.bioroburplus.org/**

BENEFICIARIES: CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE CNRS, JOHNSON MATTHEY PLC, SCUOLA UNIVERSITARIA PROFESSIONALE DELLA SVIZZERA ITALIANA, ETHNIKO KENTRO EREVNAS KAI TECHNOLOGIKIS ANAPTYXIS, UAB MODERNIOS E-TECHNOLOGIJOS, PARCO SCIENTIFICO TECNOLOGICO PER L'AMBIENTE ENVIRONMENT PARK TORINO SPA, HYSYTECH SRL, KARLSRUHER INSTITUT FUER TECHNOLOGIE, DBI - GASTECHNOLOGISCHES INSTITUT GGMBH FREIBERG, ENGICER SA, ACEA PINEROLESE INDUSTRIALE SPA

PROJECT AND OBJECTIVES

The BioROBURplus project aimed to develop a pre-commercial oxidative steam reformer (OSR) for sustainable and decentralised hydrogen production from biogas, with no preliminary removal of CO_2. The goal for the TRL6 demo plant was to deliver at least 50 Nm^3/h (107 kg/day) of H_2 at 99.9 % purity and 1.5 bar with an energy-efficiency conversion of 81 % on an HHV basis. The ways to reach this objective were.

- high thermal integration
- pressure swing adsorption (PSA) off-gas exploitation for reformer feed preheating
- power consumption minimisation through CO_2 removal prior to the PSA.

NON-QUANTITATIVE OBJECTIVES

- Conduct dissemination and training activities
- These activities have been implemented correctly, with participation in several conferences and publicised using posters and oral presentations
- Improve hydrogen production efficiency with better heat integration of the components
- Different schemes were studied to determine the best method to achieve the target
- An LCA analysis of the general system has been carried out. REACH and HAZOP analyses of the BioROBURplus process have been completed. The exploitation plan and decision support schemes for system implementation are ongoing
- Manufacturing of supports and catalyst coating process
- Coating and manufacturing process have been optimised
- Development of a compact and cost-effective fuel processor for distributed H_2 production
- Easy scalability
- The BioROBURplus sub-units were carefully developed to achieve the project's objectives
- The system can be scaled up, which is important for matching most of the decentralised application opportunities and reducing the final H_2 cost.

PROGRESS AND MAIN ACHIEVEMENTS

- A TRL6 demo-unit for green hydrogen production from biogas has been designed with a high heating integration
- Ceramic support structures as catalyst carriers with enhanced heat and mass transport properties have been developed
- Develop an off-gas burner for waste gas enthalpy valorisation.

FUTURE STEPS AND PLANS

- Complete the manufacturing and assembly of the final TRL6 demo plant
- Perform the installation and commissioning at an ACEA site
- Conduct the testing campaign in a real environment at the ACEA site
- Test the performances and stability of the developed structured catalyst
- Collect and analyse the experimental data to scale up the technology.

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		50 Nm^3/h with an overall biogas to green hydrogen conversion efficiency of 65 %	2016
	Overall plant efficiency based on HHV	%	≥ 80		Overall plant efficiency of 65 % for a processor with a nominal hydrogen production rate of 50 Nm^3/h	
	Reformer outlet CO concentration on a dry basis	%	<8		Experimental test at lab scale has validated the design and confirmed this target. It needs still to be demonstrated at TRL6 level	
AWP 2016	H_2 purity	%	99.99		BioROBUR delivered 50 Nm^3/h of 99.9 % hydrogen from biogas	
	Cold-start-up time not exceeding	Hours	2		BioROBUR value 6 h owing to the significantly oversized mass of the reformer and related BOP units	

DEMO4GRID

DEMONSTRATION OF 4MW PRESSURISED 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
PRD 2020 Panel:	5 - Hydrogen for Sectoral Integration
Project total costs:	**€7 736 682.50**
FCH JU max. contribution:	**€2 932 554.38**
Project start - end:	01/03/2017- 28/02/2022
Coordinator:	**DIADIKASIA BUSINESS CONSULTING SYMVOULOI EPICHEIRISEON AE, EL**
Website:	**www.demo4grid.eu/**

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

PROJECT AND OBJECTIVES

The main aim of the Demo4Grid project is the commercial set-up and demonstration of a technical solution utilising 'above state-of-the-art' pressurised 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 and analysis of RCS and safety requirements are in place
- The project-specific business model has been updated
- Building permits are in place.

FUTURE STEPS AND PLANS

- All permits to be in place by September 2020
- Building construction finished by December 2020
- PAE commissioning by February 2021
- SAT and test phase operation finished by March 2021
- PAE procurement and certification concluded by December 2020.

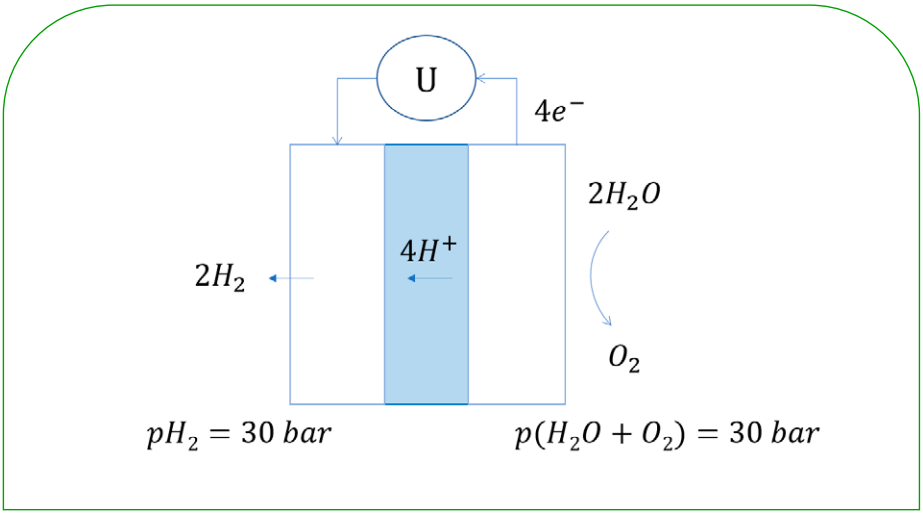
QUANTITATIVE TARGETS AND STATUS

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	sec	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)/sec	7		7	
	Ramp-down	% (full load)/sec	10		10	

GAMER

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

Project ID:	**779486**
Call topic:	**FCH-02-2-2017** - Game changer high temperature steam electrolysers
PRD 2020 Panel:	5 - Hydrogen for Sectoral Integration
Project total costs:	**€2 998 951**
FCH JU max. contribution:	**€2 998 951**
Project start - end:	01/01/2018 - 31/12/2020
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 to 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 electric efficiency. The project will establish the science and technology for high-volume production of the novel tubular cells and develop system designs and balance-of-plant components supported by advanced modelling and simulation work, and flowsheets of integrated processes.

NON-QUANTITATIVE OBJECTIVES

- Exploitation workshop carried out
- Workshop conducted in 2019
- Collaboration with advisory board
- Regular meetings are conducted with AB members to present the project's progress and define potential applications for electrolyser integration
- Stakeholder mapping
- In collaboration with industrial partners, the project has mapped relevant stakeholders and prepared an action plan for interaction with them
- Nine presentations about the project were made during open conferences in 2019. One project flyer is available
- One article about the project was published in Nature.

PROGRESS AND MAIN ACHIEVEMENTS

- Stable operation of the tubular cell at a total pressure of 3 bar, with 1.5 bar steam on anode side measured over 700 hours at 600 °C
- Design of 10 kW electrolyser with balance-of-plant defined. The subcontractor has started to build the system
- First assemblies of single engineering units undertaken: learning from practice.

FUTURE STEPS AND PLANS

- Reproducible experimental validation of SEU performance to initiate scaling up production
- Complete building the 10 kW electrolyser demonstration unit
- Install and commission the electrolyser prototype at CSIC ITQ
- Optimise the electrode/current collection to achieve both long-term stability and low ASR
- Publish articles on SEU, electrodes and current collection and make presentations.

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 cell resistance	ohm.cm²	2	3	✗	3
	Stability of cell = degradation of cell potential	%/500 hr	2	2	✓	2
	Efficiency of electrolyser system including BoP, steam available, HHV	%	75	73-77	✓	N/A

GRINHY2.0
GREEN INDUSTRIAL HYDROGEN VIA STEAM ELECTROLYSIS

GrInHy2.0
Green Industrial Hydrogen

Project ID:	**826350**
Call topic:	**FCH-02-2-2018** - Demonstration of large scale steam electrolyser system in industrial market
PRD 2020 Panel:	5 - Hydrogen for Sectoral Integration
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

The GrInHy2.0 project aims to manufacture and operate the world's biggest high-temperature electrolyser with a capacity of 720 kW AC and an electrical efficiency of 84 % LHV. While assessing the technology's carbon direct avoidance potential for the future European steel industry, the electrolyser will produce more than 100 tonnes of 'green' hydrogen based on steam from industrial waste heat in at least 13 000 operational hours for current steel production in Salzgitter. The installation site is under construction and the final commissioning is expected in September 2020.

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 rollout study.

PROGRESS AND MAIN ACHIEVEMENTS

- System design and electrolyser module manufacturing has been completed.
- Completion of installation site. The electrolyser unit and hydrogen processing unit are on schedule
- Long-term stack test bench has been constructed and is ready for the 20 000 hour stack test.

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 13 000 operational hours and 95 % system availability in early 2022
- Completing 20 000 hours continuous stack test by October 2022.

QUANTITATIVE TARGETS AND STATUS

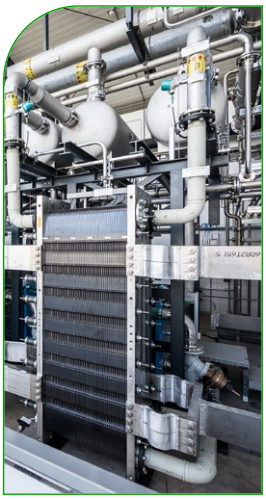
TARGET SOURCE	PARAMETER	UNIT	TARGET	TARGET ACHIEVED?	SOA RESULT ACHIEVED TO DATE (BY OTHERS)	YEAR FOR SOA TARGET
AWP 2018	Hydrogen production rate	kg/h	18		3.6	2017
	Electrical efficiency based on LHV	%	84		78	
	CAPEX	€/(kg/d)	4 500		12 000	
	Demonstration of hot start from min. to max. power	min	5		10	2018
	Hours of operation	Hours	13 000		10 000	2019
	Availability	%	95		66	
	Total production of 'green' hydrogen	Tonnes	100		N/A	N/A
	Cost of hydrogen	€/kg	7		N/A	N/A
Project's own objectives	Hours of continuous stack testing	Hours	20 000		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
PRD 2020 Panel:	5 - Hydrogen for Sectoral Integration
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: NEDERLANDSE ORGANISATIE VOOR TOEGEPAST, NATUURWETENSCHAPPELIJK ONDERZOEK TNO, STICHTING ENERGIEONDERZOEK CENTRUM NEDERLAND, SIEMENS AKTIENGESELLSCHAFT, SIEMENS AKTIENGESELLSCHAFT OESTERREICH, AUSTRIAN POWER GRID AG, VOESTALPINE STAHL GMBH, K1-MET GMBH, VERBUND TRADING GMBH

PROJECT AND OBJECTIVES

With a capacity of 6 MW and a production of 1 200 m³ of green hydrogen per hour, the EU flagship project H2FUTURE is currently the world's largest and most advanced hydrogen pilot facility using PEM electrolysis technology for producing green hydrogen from renewable electricity. The fundamental goal of H2FUTURE is to demonstrate that an industrially-integrated PEM electrolyser can simultaneously produce green hydrogen and supply grid services. The plant is currently in a pilot demonstration phase, with various use cases referring to future operation modes.

NON-QUANTITATIVE OBJECTIVES

- Permitting of the plant
- Due to an early contact, and in close coordination with the authorities, permits were issued earlier than expected
- Project communication
- To ensure all project participants are well informed, the number of meetings between the project partners has been higher than planned
- Dissemination activities
- All project partners have been very active and have ensured high project visibility.

PROGRESS AND MAIN ACHIEVEMENTS

- Demonstration-operation phase started in the first quarter of 2020
- Plant has been prequalified to provide primary, secondary and tertiary reserve to the grid
- Project has received a great deal of media attention.

FUTURE STEPS AND PLANS

- Scheduled number of operating hours acc. DoW will be fulfilled in a shorter time period, also depending on electricity pricests.

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	

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
PRD 2020 Panel:	5 - Hydrogen for Sectoral Integration
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: STIFTELSEN SINTEF, UNIVERSITE DE FRANCHE-COMTE, FUNDACION TECNALIA RESEARCH AND INNOVATION, UNIVERSITE DE TECHNOLOGIE DE BELFORT - MONTBELIARD, ECOLE NATIONALE SUPERIEURE DE MECANIQUE ET DES MICROTECHNIQUES, UNIVERSITA DEGLI STUDI DEL SANNIO, HYDROGENICS EUROPE NV, KES KNOWLEDGE ENVIRONMENT SECURITY SRL, NEW NEL HYDROGEN AS, COMMUNAUTE D'UNIVERSITES ET ETABLISSEMENTS UNIVERSITE BOURGOGNE - FRANCHE - COMTE, VARANGER KRAFTVIND AS, VARANGER KRAFTNETT AS, VARANGER KRAFT AS, VARANGER KRAFTENTERPRENOR AS, VARANGER KRAFTMARKED AS, VARANGER KRAUFTUTVIKLING AS

PROJECT AND OBJECTIVES

The main objective of Haeolus is the deployment and operation of a hydrogen production facility, with a capacity of 1 tonne per day, in extreme Arctic environments. The project has experienced some delays, mainly due to missing the first construction window in the summer of 2018. The experimental hall in Berlevåg, Norway is now ready and the electrolyser is being tested in Belgium before shipment. Production is expected to start in September 2020. Other aspects of the project are mostly on time, including the drafting of reports on energy system modelling and control.

PROGRESS AND MAIN ACHIEVEMENTS

- Detailed techno-economic and energetic analyses of hydrogen wind plants for multiple locations
- Dynamic plant model and control algorithms for energy storage and island use
- Site ready, additional power line finalised and electrolyser assembled, to be shipped soon.

FUTURE STEPS AND PLANS

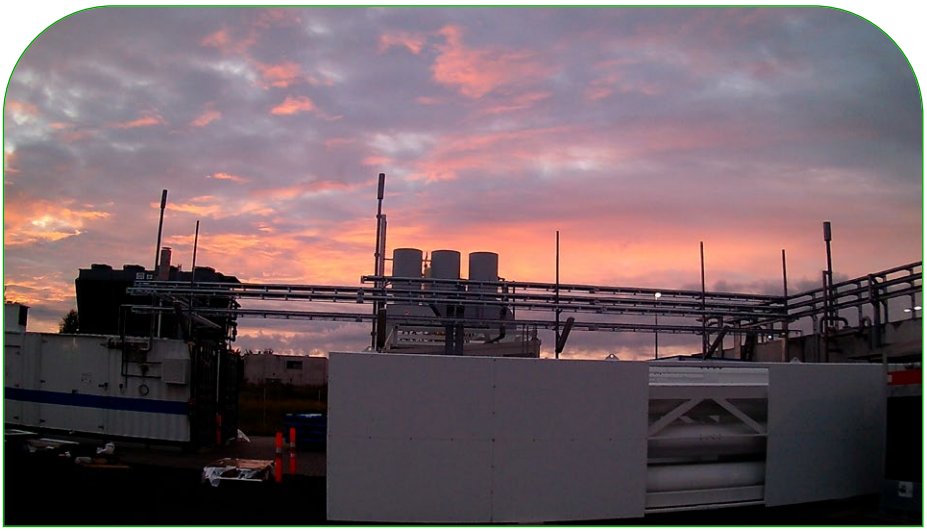
- Plant installation and operation
- Demonstration of control strategies
- Life cycle analysis
- Dissemination activities (site visit, trade fair presence, etc).

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
MAWP addendum (2018-2020)	Energy consumption	kWh/kg	50	52		45	2020
	CAPEX	M€/(t/d)	1.5	2.5		0.665	2020
	Degradation	%	1	2		N/A	
Project's own objective	Stack size	MW	2.5	1.25			

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
PRD 2020 Panel:	5 - Hydrogen for Sectoral Integration
Project total costs:	**€15 803 441.25**
FCH JU max. contribution:	**€7 999 370.80**
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 will demonstrate the link between energy storage in the form of hydrogen and the deployment of hydrogen mobility solutions. It will not only validate highly dynamic PEM electrolysis technology and the innovative hydrogen delivery processes involved, but also demonstrate these in a real industrial environment. Another project goal is to improve grid-balancing efficiency to take advantage of excess wind turbine electricity production by manufacturing H_2.

PROGRESS AND MAIN ACHIEVEMENTS

- Successful delivery of hydrogen in challenging environments for industrial, market and mobility applications
- Successful experimentation of grid-balancing in production conditions
- Fixed monthly hydrogen delivery through the pipeline since November 2018.

FUTURE STEPS AND PLANS

- Disseminate final project results in a workshop
- Submit all deliverables.

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/kgH_2	57.5	57	✓	55.3-52.2	2018-2019
AIP 2014	System lifetime	Hours	20 000	13 300 (approx.)	✗	N/A	

HYCARE

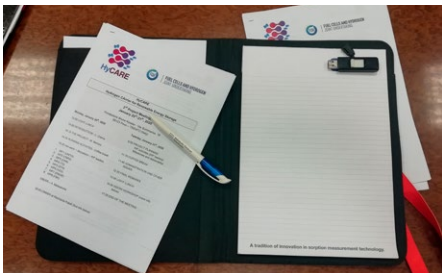
AN INNOVATIVE APPROACH FOR RENEWABLE ENERGY STORAGE BY A COMBINATION OF HYDROGEN CARRIERS AND HEAT STORAGE

Project ID:	**826352**
Call topic:	**FCH-02-5-2018** - Hydrogen carriers for stationary storage of excess renewable energy
PRD 2020 Panel:	5 - Hydrogen for Sectoral Integration
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, INSTITUTT FOR ENERGITEKNIKK, HELMHOLTZ-ZENTRUM GEESTHACHT ZENTRUM FUR MATERIAL- UND KUSTENFORSCHUNG GMBH, FONDAZIONE BRUNO KESSLER, UNIVERSITA DEGLI STUDI DI TORINO, ENGIE, CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE CNRS

PROJECT AND OBJECTIVES

The main objective of the HyCARE project is the development of a large-scale prototype hydrogen storage tank with use of a solid-state hydrogen carrier. The tank will be based on an innovative concept, joining hydrogen and heat storage, to improve the energy efficiency of the whole system. The developed tank will be installed at Engie Lab Crigen, in the Paris region (F). The tank will be joined with a PEM electrolyser as hydrogen provider and a PEM fuel cell as hydrogen user.

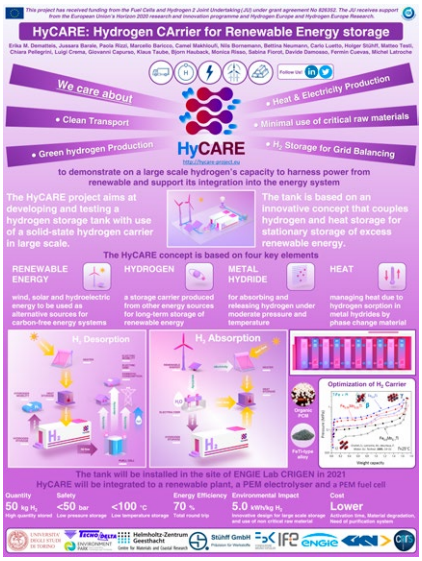


PROGRESS AND MAIN ACHIEVEMENTS

- The alloy with the composition TiFe0.85Mn0.05 has been selected for the HyCARE project and has been characterised at lab scale
- Crodatherm 53 is the PCM selected for the project. Some preliminary tests have been performed
- A preliminary piping and instrumentation diagram (PID) of the HyCARE system has been fixed. The final module design will be determined following simulation and validation.

FUTURE STEPS AND PLANS

- Validation of modelling
- Definition of PID of the HyCARE system
- Construction of the HyCARE system
- Testing and demonstration of the HyCARE system.



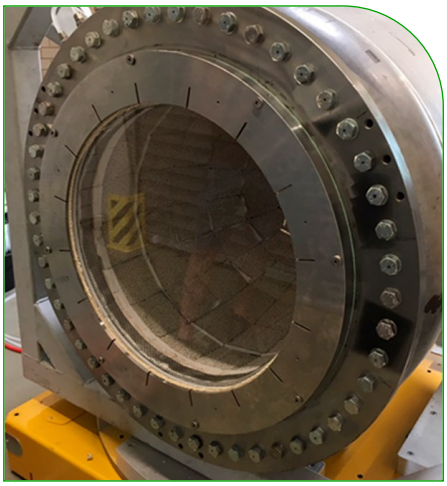
QUANTITATIVE TARGETS AND STATUS

TARGET SOURCE	PARAMETER	UNIT	TARGET	TARGET ACHIEVED?	SOA RESULT ACHIEVED TO DATE (BY OTHERS)	YEAR FOR SOA TARGET
Project's own objectives	Maximum amount of H_2 that can be stored in the system	kg H_2	50	✗	24	2015
	Total round trip efficiency	%	70	✗	<70	N/A
EU CRM targets	Critical raw materials	%	0	✓	>0	

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
PRD 2020 Panel:	5 - Hydrogen for Sectoral Integration
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 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 FUER LUFT - UND RAUMFAHRT EV, COMMISSARIAT A L'ENERGIE ATOMIQUE ET AUX ENERGIES ALTERNATIVES

PROJECT AND OBJECTIVES

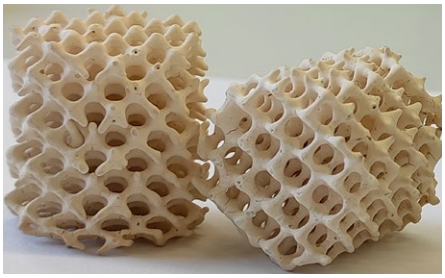
The HYDROSOL-beyond project is a continuation of the HYDROSOL-technology series of projects that focus on utilisation of concentrated solar power for hydrogen production from the dissociation of water, via redox pair-based thermochemical cycles. HYDROSOL-beyond is an ambitious scientific endeavour aiming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

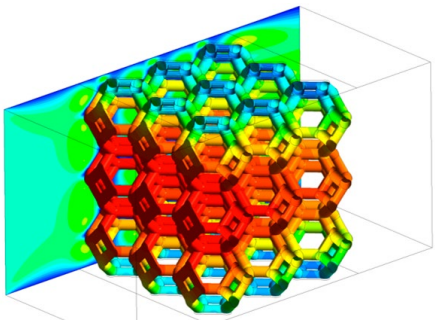
PROGRESS AND MAIN ACHIEVEMENTS

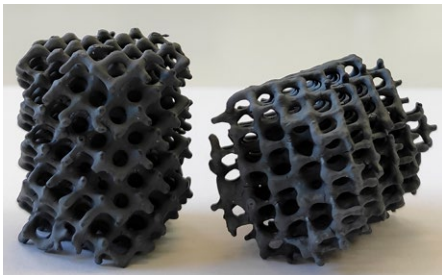
- Ageing tests of structured redox materials. At the time of this report >100 cycles have been achieved on Ni-ferrite coated ZrO2 foam
- Production of lattice structures consisting entirely of the redox material
- Preparation of solar platform for experimental solar campaigns.

FUTURE STEPS AND PLANS

- Operation of the solar platform in H_2 production mode at the Plataforma Solar de Almeria in Spain
- Gather data from operation of the solar reactor at the solar simulator facility at Julich
- Design, construct and evaluate the ceramic heat exchanger for efficient heat recovery.





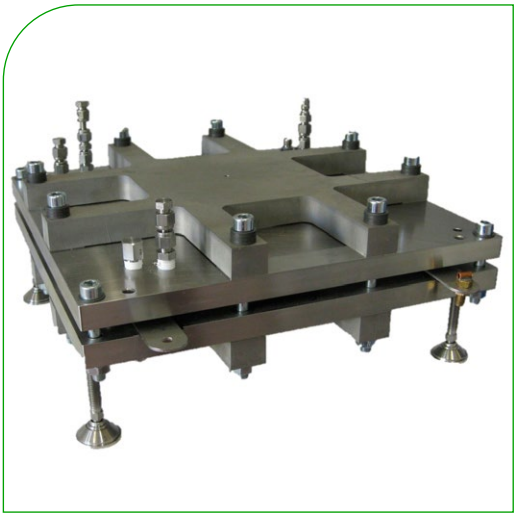


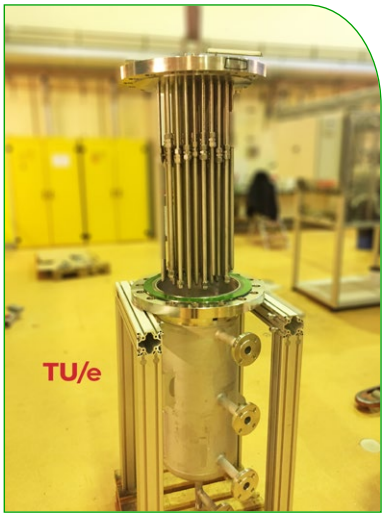
QUANTITATIVE TARGETS AND STATUS

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	Material durability	Cycles	1 000	150		602	2018
	Demonstrate the process at realistic scale and working conditions, using existing solar demonstration facility (>200 kW range)	kW/reactor	250	Pending		250	2018
	Achieve heat recovery rates in excess of 60 %	%	60			N/A	N/A
	Annual solar-to-fuel efficiencies in the 10 % range efficiency (in laboratory)	%	10			5.25	2017

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
PRD 2020 Panel:	5 - Hydrogen for Sectoral Integration
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 AND INNOVATION, SAES GETTERS SPA, HYGEAR BV, HYGEAR FUEL CELL SYSTEMS BV, 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, in industrially relevant conditions, of a novel membrane-based hybrid technology for the direct separation of hydrogen from natural gas grids. The project's focus will be 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 of <5 kWh/kgH_2 and at a cost of <1.5 $€/kgH_2$. A pilot facility designed for >25 kg/day of hydrogen will be built and tested.

NON-QUANTITATIVE OBJECTIVES

- Training of PhD students
- One student has completed their PhD and found a job in a research centre to work on HyGrid-related topics.

PROGRESS AND MAIN ACHIEVEMENTS

- Membrane separation prototype built and ready to be integrated
- Temperature swing adsorption prototype built and ready to be integrated
- EHC setup designed and being constructed.

FUTURE STEPS AND PLANS

- Integration and prototype testing will be finalised, to recover from the delay caused by COVID-19
- Complete the business plan with the final data.

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/kgH_2	5	5	✓
		$€/kgH_2$	1.5	1.5	✓
	Pure hydrogen production	kg/day	25	0	✗
	Prototype unit	TRL	5	5	✓

HYSTOC
HYDROGEN SUPPLY AND TRANSPORTATION USING LIQUID ORGANIC HYDROGEN CARRIERS

Project ID:	**779694**
Call topic:	**FCH-02-6-2017** - Liquid organic hydrogen carrier
PRD 2020 Panel:	5 - Hydrogen for Sectoral Integration
Project total costs:	**€2 499 921.25**
FCH JU max. contribution:	**€2 499 921.25**
Project start - end:	01/01/2018 - 31/12/2020
Coordinator:	**HYDROGENIOUS TECHNOLOGIES GMBH, DE**
Website:	**hystoc.eu/**

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

PROJECT AND OBJECTIVES

The HySTOC project has the primary objective to demonstrate the feasibility of liquid organic hydrogen carrier (LOHC) technology for the distribution and storage of hydrogen, to supply hydrogen refuelling stations (HRS) with hydrogen that meets all quality criteria defined in ISO 14687:2-2012.
Definition of requirements, preliminary LCA, specification of the logistics concept and engineering of hydrogen storage-, release- and purification-systems has been completed. The current focus is on assembly of the systems, the layout plan for the system setup and LOHC logistics to prepare for field testing.

NON-QUANTITATIVE OBJECTIVES

- Development of a cost-efficient, fully automated LOHC hydrogen storage system (Storage BOX) and a release system (Release BOX)
- Detail engineering of the systems has been completed. Programming is in progress to allow fully automated operation of the systems
- Demonstration of LOHC suitability for commercial roll-out
- Demonstration of full systems operation for HRS supply in Finland is in progress.

PROGRESS AND MAIN ACHIEVEMENTS

- Detail engineering of hydrogen storage-, release- and purification system has been completed, meeting all project-specific requirements
- Successful completion of preliminary LCA, indicating the environmental impacts of LOHC-based hydrogen supply
- Development of LOHC-based logistics concept for hydrogen transportation between two locations in Finland.

FUTURE STEPS AND PLANS

- Delivery of LOHC-based hydrogen storage- and release systems to Finland
- Demonstration of the feasibility of long-distance LOHC-based hydrogen transport in Finland
- Proof that hydrogen released from LOHC meets ISO 14687:2-2012.

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 addendum (2018-2020)	H_2 capacity of hydrogen trailer	kg	1 000	1 300	✓	850	2017
	Capital cost compressed gas tube trailer	€/kg	350	85	✓	400	2017
Project's own objectives	H_2 purity**	%	ISO 14687:2	To be measured in the coming months	🛠	99.95 % purity of H_2 released from LOHC (before purification)	2019
	H_2 input pressure	Bar	25	Design for 25-30 bar	✓	50	2017

* 1 300 kg capacity refers to a standard 30 m³ gasoline truck.
** Purity for hydrogen released from LOHC.

MEMPHYS
MEMBRANE BASED PURIFICATION OF HYDROGEN SYSTEM

Project ID:	**735533**
Call topic:	**FCH-03-1-2016** - Development of innovative hydrogen purification technology based on membrane systems
PRD 2020 Panel:	5 - Hydrogen for Sectoral Integration
Project total costs:	**€2 088 195**
FCH JU max. contribution:	**€1 999 925**
Project start - end:	01/01/2017- 31/12/2019
Coordinator:	**INSTITUT JOZEF STEFAN, SI**
Website:	**www.memphys.eu**

BENEFICIARIES: IMPERIAL COLLEGE OF SCIENCE, TECHNOLOGY AND MEDICINE, FORSCHUNGSZENTRUM JULICH GMBH, BORIT NV, DUALE HOCHSCHULE BADEN-WUERTTEMBERG, HYET HYDROGEN BV

PROJECT AND OBJECTIVES

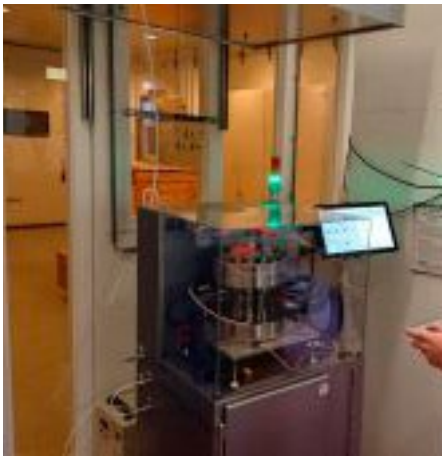
Project MEMPHYS targeted the development of a stand-alone hydrogen purification system based on electrochemical hydrogen purification (EHP). The focus was on high contaminant tolerance at low cost, making the system suitable for different applications. MEMPHYS targeted a 5 kg H_2/day system with an energy consumption of <5 kWh/kg H_2, a hydrogen recovery rate of >90 %, producing high-purity hydrogen at a system cost of <1 500 €/kg H_2/day with a pressure of 200 bar. The project ended in December 2019.

PROGRESS AND MAIN ACHIEVEMENTS

- Targeted recovery rate and efficiency targets were reached in short-stack tests
- Extensive experimentation was performed and comparable measurement results were achieved in the partner's laboratories at different institutions
- A study to determine the optimum catalyst, fluid dynamic model and balance-of-plant components was conducted.

FUTURE STEPS AND PLANS

- Project finished by 31 December 2020. However, several partners expressed the intention to continue providing support to industrial partner HyET
- Building up of a 5 kg/day system in 2020
- Further development of diagnostic algorithms by partner JSI in 2020.



QUANTITATIVE TARGETS AND STATUS

TARGET SOURCE	PARAMETER	UNIT	TARGET	ACHIEVED TO DATE BY THE PROJECT	TARGET ACHIEVED?
Project's own objectives	Energy consumption of EHP stack	kWh/kg H_2	3	3	✓
	Recovery rate EHP short stack	%	>90	90	
	Recovery rate single cell	%	>90	90	
	Energy consumption at targeted recovery rate	kWh/kg H_2	3	5	✗

NEPTUNE
NEXT GENERATION PEM ELECTROLYSER UNDER NEW EXTREMES

Project ID:	**779540**
Call topic:	**FCH-02-1-2017** - Game-changer water electrolysers
PRD 2020 Panel:	5 - Hydrogen for Sectoral Integration
Project total costs:	**€1 927 335.43**
FCH JU max. contribution:	**€1 926 221.25**
Project start - end:	01/02/2018 - 31/01/2021
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 that will be 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 at <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)
- Deliverables report published.

PROGRESS AND MAIN ACHIEVEMENTS

- Manufacture large-area membranes at 50 µm thickness, and electro catalysts in large batch sizes, meeting the project targets
- MEA degradation rate achieved at 80 °C, 4.4 µV/h/cell at 4 Acm^{-2} in a test >2000 h (single cell level)
- At 90 °C, cell voltage of 1.74 V and 1.98 V at 4 and 8 Acm^{-2}, respectively, with noble metal loading of 0.34 mg cm^{-2} anode and 0.1 mg cm^{-2} cathode.

FUTURE STEPS AND PLANS

- Design and build a new, simplified balance-of-plant for PEM electrolysis to extend operating conditions
- Demonstrate an advanced, cost-effective PEM electrolysis stack operating at high temperature and under high differential pressure
- Validation of PEM electrolysis stack durability in endurance tests and under dynamic operating conditions
- Conduct a market analysis and draft supporting documents on policies, codes and standards required for enhanced PEM electrolysis systems
- Perform a techno-economic assessment and life cycle analysis on the advanced PEM electrolyser.

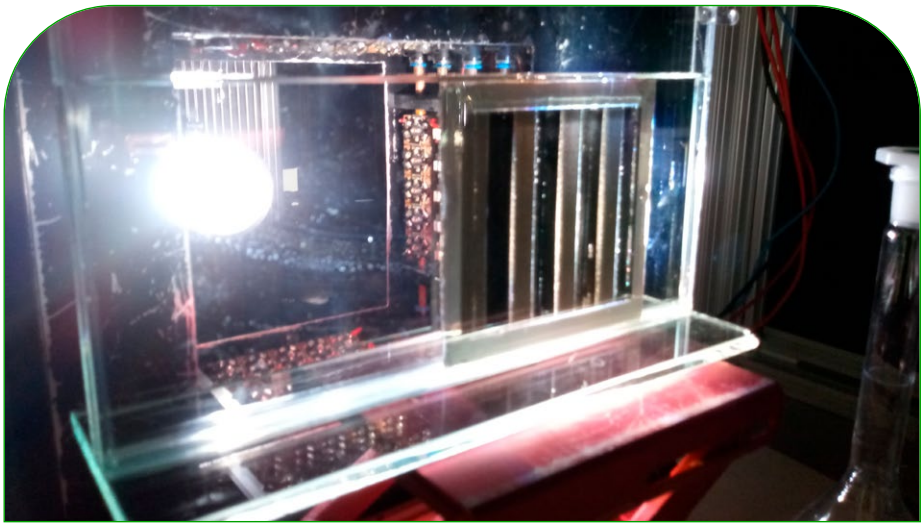
QUANTITATIVE TARGETS AND STATUS

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	

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
PRD 2020 Panel:	5 - Hydrogen for Sectoral Integration
Project total costs:	**€2 499 992.50**
FCH JU max. contribution:	**€2 499 992.50**
Project start - end:	01/01/2017- 31/12/2020
Coordinator:	**HELMHOLTZ-ZENTRUM BERLIN FUER MATERIALIEN UND ENERGIE GMBH, DE**
Website:	**pecsys-horizon2020.eu**



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

PROJECT AND OBJECTIVES

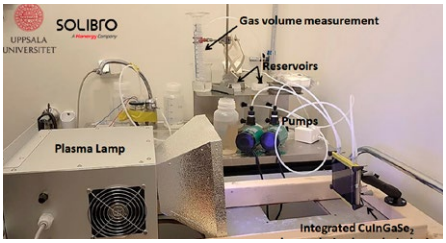
The PECSYS project is aimed at demonstrating a solar-powered electrochemical hydrogen generator using a solar collection area (A_sol) >10 m². Photovoltaic (PV) integrated electrolysers with A_sol ≥100 cm² now achieve a solar-to-hydrogen (STH) efficiency of 10 %. Efforts are ongoing to scale the devices to ~1 m² modular units for the demonstrator. For comparison, a reference system with full-sized silicon heterojunction and CuInGaSe PV modules with a total A_sol of 8.2 m² connected to detached PEM electrolysers (water-fed only at the cathode) with STH ~ 10 % has also been installed.

PROGRESS AND MAIN ACHIEVEMENTS

- An electrolyser integrated with 100 cm² CuInGaSe PV generates 25 mg-H_2/h with STH of 9.7 % under 1 000 W/cm² irradiation
- An electrolyser integrated with 294 cm² silicon heterojunction PV generates 60 mg-H_2/h at 800 W/m² and 18 °C with STH of 3-10 % outdoors
- SHJ and CuInGaSe PV modules (A_sol = 8.2 m²) connected to detached PEM electrolysers generated 26 g-H_2/h averaging 10 % STH outdoors in Julich (DE).

FUTURE STEPS AND PLANS

- Catch up in delays in scaling the integrated silicon heterojunction approach to ~1 m² for installation in the test field at Julich
- Complete 80 cm² solar collection area CuInGaSe PV-integrated electrolyser, to be installed in the test field at Julich, in lieu of planned 1 m²
- Demonstrate the stable outdoor operation of both the detached and integrated PV-coupled electrolysers over six months
- Use final design components and experimental performance data as inputs for calculations in the techno-economic and life cycle analysis
- Write a business plan for the project's exploitation after December 2020.



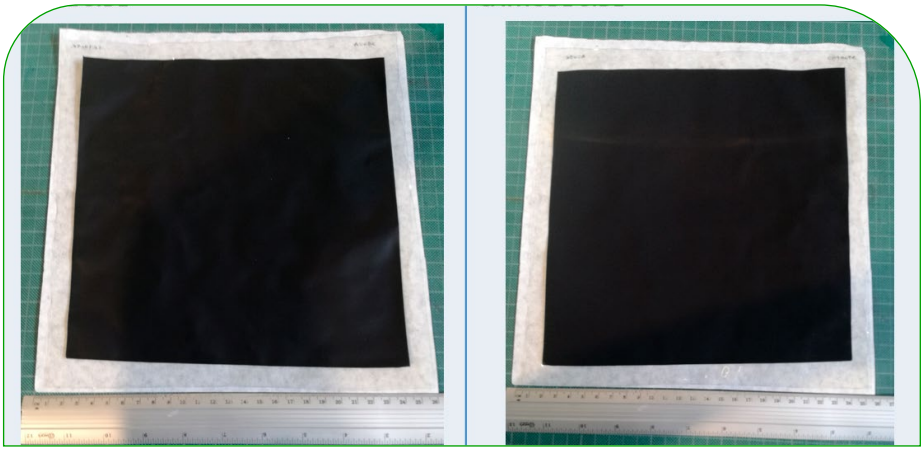
QUANTITATIVE TARGETS AND STATUS

TARGET SOURCE	PARAMETER	UNIT	TARGET	TARGET ACHIEVED?	SOA RESULT ACHIEVED TO DATE (BY OTHERS)
Project's own objectives	Hydrogen production rate	L/day	22		250 l/day
	Solar collection area	m²	10		1.6
	H_2 production cost	€/kg	5		N/A
	System capital cost	€ /(kg/d)	2 500		
	System energy use	kWh/kg	100		

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
PRD 2020 Panel:	5 - Hydrogen for Sectoral Integration
Project total costs:	**€1 999 088.75**
FCH JU max. contribution:	**€1 999 088.75**
Project start - end:	01/01/2018 - 31/12/2020
Coordinator:	**DEUTSCHES ZENTRUM FUER LUFT - UND RAUMFAHRT EV, DE**
Website:	**pretzel-electrolyzer.eu/**



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

PROJECT AND OBJECTIVES

The overall goal of PRETZEL is to develop an innovative, game-changer polymer electrolyte membrane electrolyser (PEMEL) that provides significant increases in efficiency and operability to satisfy emerging market demands. A central objective is the development of a novel PEMEL system with max. 25 kW electrical power consumption generating 4.5 $m^3 h^{-1} H_2$ at rated power, output pressure of 100 bar and feed water temperature of max. 90 °C. The components have been tested and are currently in manufacturing. The system will be tested for 2 000 h.

NON-QUANTITATIVE OBJECTIVES

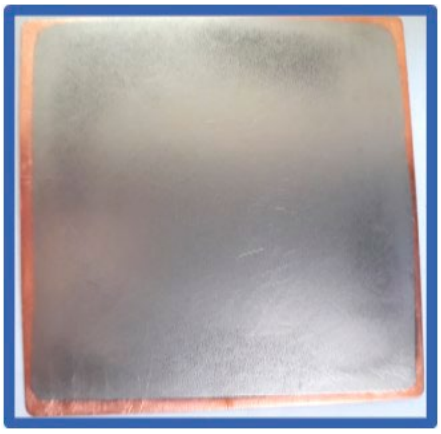
- Assess additional commercial opportunities available to the game-changer electrolyser compared with those currently available: not started yet
- Enable additional commercial roll-out of electrolysers post-2025: not started yet.

PROGRESS AND MAIN ACHIEVEMENTS

- Catalysts and coated components pass compliance tests, revealing high activity, stability and excellent corrosion resistance properties
- Summary report written on the entire manufacturing processes of PRETZEL stack components, specifically the BPP, PCD and MEA
- Catalyst synthesis was successfully scaled up to produce the amounts needed for 500cm^2 MEAs.

FUTURE STEPS AND PLANS

- Testing protocol for electrolyser operation and report on commissioning tests
- Install and put HP stack into operation
- Start 2 000 h final test.

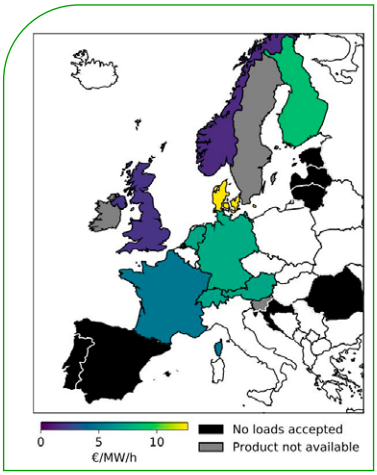


QUANTITATIVE TARGETS AND STATUS

TARGET SOURCE	PARAMETER	ACHIEVED TO DATE BY THE PROJECT
AWP 2017	New cost-effective current collectors for PEM electrolysers for hydrogen generation from renewable energies.	500 cm^2 manufactured PCD are ready for implementation and testing in high-pressure stack.
	25 cm^2 high-pressure stack with all components tested	Cell parts and CA-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 is developed in the publicly funded projects VOMPELS (EFRE-0800099) and MoDePEM (EFRE-0400094).
	Increase catalyst activity and optimise supporting material.	Iridium-supported material (Ir/SnO_2) has been prepared and evaluated for catalytic activity and economic feasibility for scaling up. Catalyst has been developed with adequate metal content and aerogel support for 500 cm^2 MEA production.
	100 bar, rapid response (<1 s hot start), 4 Acm^{-2} nominal current density and overload of 6 Acm^{-2}, temperature >80 °C.	Initial cell test performing polarisation curve up to 6 Acm^2 at 90 °C was successful.
	Cost consideration and market analysis from project results extrapolated to MW-scale.	Market analysis started by investigating possible user for produced gases.

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
PRD 2020 Panel:	5 - Hydrogen for Sectoral Integration
Project total costs:	**€2 811 262.50**
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 objective of the QualyGridS project was to establish standardised testing protocols for electrolysers used in electricity grid services. Alkaline and PEM electrolysers were both considered within this project. A variety of different grid services were addressed, as well as multiple hydrogen end-users. The protocols developed were applied to alkaline and PEM electrolyser systems, using electrolyser sizes ranging from 25 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

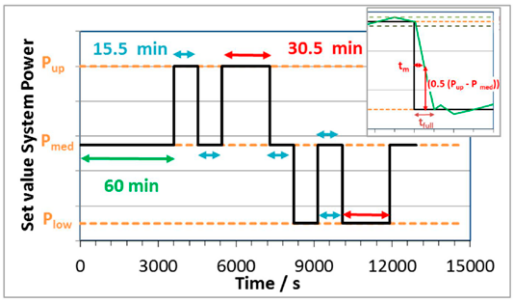
- AIP 2016: develop standardised protocols for electrolysers to provide grid services
- 80 %. Updated draft available, invited as ISO technical report new work item proposal
- AIP 2016: Definition of specific KPIs for dynamic operation to provide grid services
- 60 %. Draft available
- Project's own objectives: evaluation of business cases, sensitivities and a roadmap
- 90 %. Business cases evaluated, final recommendations drafted.

PROGRESS AND MAIN ACHIEVEMENTS

- Draft of testing protocols for electrolysers performing grid services presented to ISO TC197 Hydrogen, invited to produce an ISO technical report
- Business case definition and detailed business case evaluation done
- Two 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

- Organise an ISO working group for the technical report based on QualyGridS testing protocols, work out the technical report and submit to ISO
- Identify limitations and main characteristics of SoA electrolysers and include improvements in electrolyser systems for use in grid services
- Further dissemination of project results.

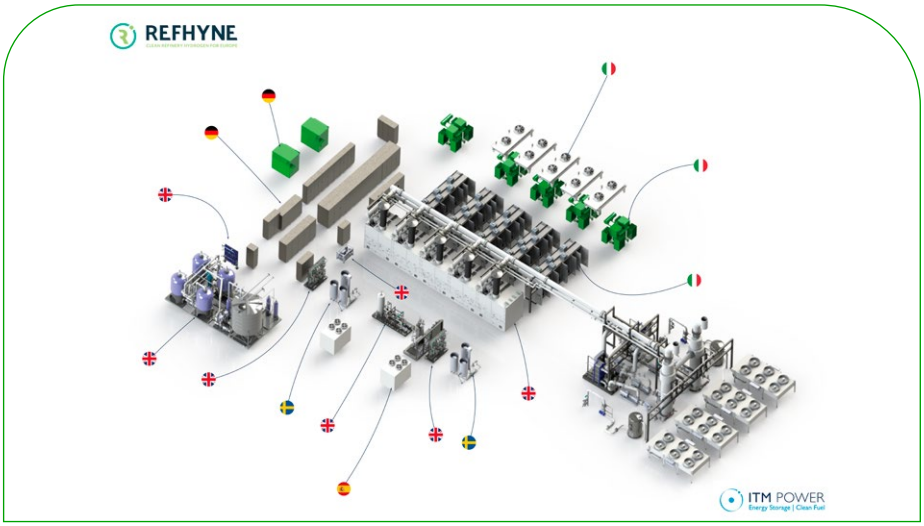


QUANTITATIVE TARGETS AND STATUS

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 having performed test run	N/A	5	Five 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 grid services could reach between 0.5 €/kg and 1 €/kg (derived from theoretical analysis of market data)	N/A	Cost of hydrogen for mobility: 11 €/kg in 2020, 9 €/kg in 2024	2018
AWP 2016	Development of standardised protocols for electrolysers to provide grid services covering EU countries	Number of drafts and reviews of these drafts	3	2	✓	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
PRD 2020 Panel:	5 - Hydrogen for Sectoral Integration
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: STIFTELSEN SINTEF, ELEMENT ENERGY LIMITED, ITM POWER (TRADING) LIMITED, THINKSTEP AG, SHELL DEUTSCHLAND OIL GMBH, SHELL ENERGY EUROPE LIMITED

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. In doing this, REFHYNE will validate the business model for using large-scale electrolytic hydrogen as an input to refineries, prove 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. Detailed design of the system is complete, permit application has been approved and construction work at the refinery began in Q3 2019.

NON-QUANTITATIVE OBJECTIVES

- Draw up recommendations for policy makers and regulators on measures required to stimulate the market for these systems
- One of the key project outputs a suite of reports providing an evidence base for changes to existing policies. This will include specific analyses for policymakers, containing recommended changes to existing policies
- Assess 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, codes and standards encountered.

PROGRESS AND MAIN ACHIEVEMENTS

- Finalised detailed design of the electrolyser system plant and its adaption to the refinery
- Permit application approved by local authorities
- All electrolyser stacks have been manufactured and have successfully completed testing to 85 % full load, ahead of their installation in the modules.

FUTURE STEPS AND PLANS

- Demonstration of the 10 MW PEM electrolyser in a refinery setting
- Techno-economic assessment of the electrolyser system and concept
- Environmental analysis of the electrolyser system and concept.

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)	Energy consumption @ rated power	kWh/kg	52		57-60	2017
	CAPEX, @rated power	M€/(t/d)	2		8	
	Flexibility with degradation @ rated power and considering 8 000 hours of operation/year	%	1.5		2-4	
	Flexibility with degradation <2 % per year	%	0-200		5-100	
	H_2 production electrolysis, hot start from min. to max. power	sec	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
PRD 2020 Panel:	5 - Hydrogen for Sectoral Integration
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: COMMISSARIAT A L'ENERGIE ATOMIQUE ET AUX ENERGIES ALTERNATIVES, DANMARKS TEKNISKE UNIVERSITET, ENGIE, UNIVERSIDAD DE SEVILLA, PARCO SCIENTIFICO TECNOLOGICO PER L'AMBIENTE ENVIRONMENT PARK TORINO SPA, GREEN POWER TECHNOLOGIES SL, AKTSIASELTS ELCOGEN, ENGIE SERVIZI SPA, TEKNOLOGIAN TUTKIMUSKESKUS VTT OY, SYLFEN

PROJECT AND OBJECTIVES

The REFLEX project aims to develop an innovative renewable energy storage solution based on reversible solid oxide cell technology. It should be able to operate in either electrolysis mode to store excess electricity to produce H_2, or in fuel cell mode, when energy demand exceeds local production, to produce electricity and heat from H_2 or any other locally available fuel.
REFLEX integrates improvements to rSOC components (cells, stacks, power electronics, heat exchangers) and systems, and the definition of advanced operation strategies. A field demonstration will be performed.

NON-QUANTITATIVE OBJECTIVES

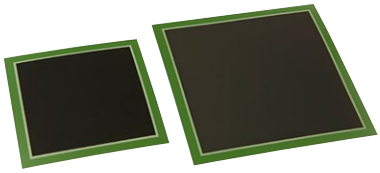
- Tech-eco assessment
- Ongoing for different market segments.

PROGRESS AND MAIN ACHIEVEMENTS

- Performance and durability improved in rSOC operation thanks to second-generation cells developed in the project, confirmed at cell and stack level
- Power electronics designed and high efficiency confirmed with lab test
- Validation of modified stack design, manifolded and electrically insulated, to connect two stacks in series.

FUTURE STEPS AND PLANS

- Assemble all components to build the system
- Manufacture the stacks for the demo system
- Install the system to operate in the field.



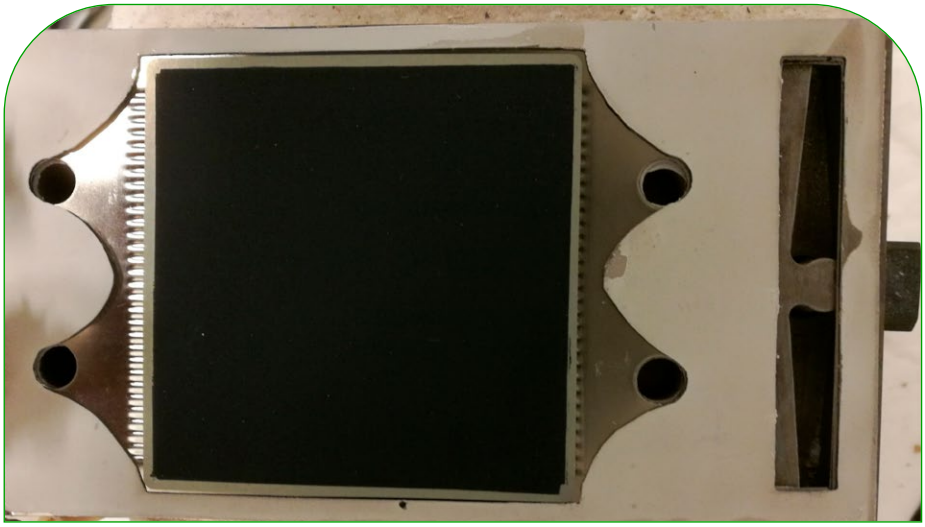
QUANTITATIVE TARGETS AND STATUS

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	Current density in SOEC mode	A/cm²	-1.2 at 700 °C in SOEC mode	-1.25	✓	-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 %	%/kh	2	1.2	✗	2.3 %/1 000 h for current densities of 0.6-0.7 A/cm² and SC = 50 %	2015
AWP 2017	Steam conversion rate	%	80-85	85	✓	70	2015
	Cell active area	cm²	200	200	✓	128	2014

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
PRD 2020 Panel:	5 - Hydrogen for Sectoral Integration
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 focuses on understanding the degradation and lifetime fundamentals on both SOEC electrodes, to minimise their degradation and improve their performance and stability, mainly under H_2O electrolysis and, to a certain extent; under H_2O/CO_2 co-electrolysis conditions. The main efforts comprise investigation of:

- modified SoA Ni-based cathode cermets
- alternative perovskite-type cathode materials
- the O_2 electrode
- development of a theoretical model for description of the performance and degradation of the SOEC H_2 electrode.

NON-QUANTITATIVE OBJECTIVES

- New materials and component design less prone to degradation
- During the fourth year of SElySOs, a series of modified Ni-based and Ni-free electrodes and a series of new air electrodes were investigated under various SOEC H_2O electrolysis and H_2O/CO_2 co-electrolysis conditions. The obtained results are quite promising and specific electrodes have been selected and are currently being further examined, as larger-size cells, for long-term stability and in short-stack tests, under SOEC operation
- Understanding degradation mechanisms under dynamic operation
- Mathematical modelling is under development and close to completion for both the SOEC H_2O electrolysis and H_2O/CO_2 co-electrolysis processes. One key objective achieved is the correlation of the model/s with experimental data, provided by the measurements performed in the framework of the project
- Development of improved and robust SOEC systems (cells/stack/s)
- The performance and tolerance of the newly developed electrodes in complete cells is under investigation. In parallel, the cells are tested in long-term stability measurements of single large-area cells and through the manufacture and test of a short stack.

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 insight on their surface state during SOEC operation
- Thermodynamic and electrochemical modelling of the H_2O, H_2 and CO_2 system by combining theoretical with experimental data under SOEC operation.

FUTURE STEPS AND PLANS

- Understanding the underlying operation and degradation mechanisms for improved and stable SOEC performance
- Validation of the electrochemical model for SOEC single cell operation
- Long-term stability testing, in SOE operation, of large-sized cells comprising the best-performing fuel/air electrodes
- Stability testing in SOE operation, of a manufactured short stack comprising large-sized cells of the best-performing fuel/air electrodes.

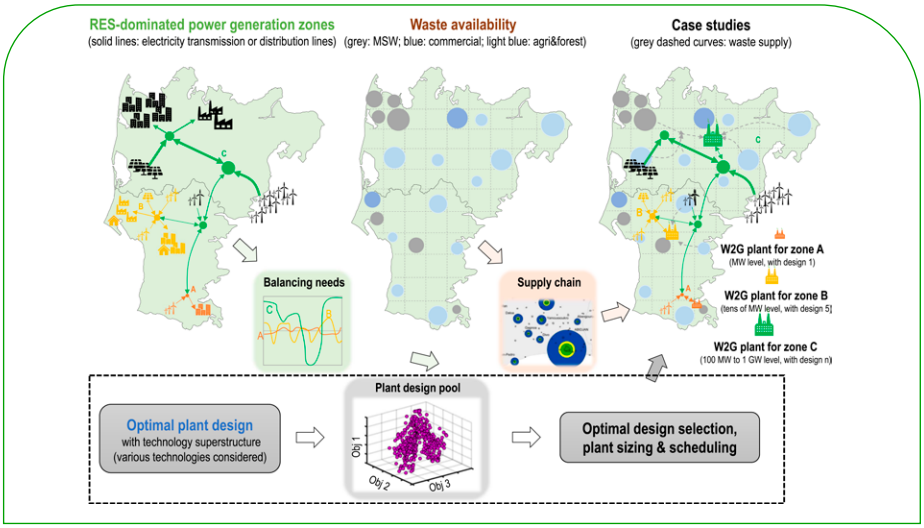
QUANTITATIVE TARGETS AND STATUS

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	Decrease the area-specific resistance on the fuel electrode compared with 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	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	
	Decrease the catalyst (fuel electrode) loading per H_2 capacity	$g/(kgH_2/day)$	N/A	18.5 for an Au-Mo-Ni /GDC modified fuel electrode and LSCoF as air electrode		50.3	

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
PRD 2020 Panel:	5 - Hydrogen for Sectoral Integration
Project total costs:	**€528 750**
FCH JU max. contribution:	**€528 750**
Project start - end:	01/01/2019 - 30/06/2020
Coordinator:	**ECOLE POLYTECHNIQUE FEDERALE DE LAUSANNE, CH**
Website:	**www.waste2grids-project.net/**



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

PROJECT AND OBJECTIVES

The WASTE2GRIDS project has investigated the waste gasifier and reversible solid-oxide cell stack combined plant for power-balancing services. An interdisciplinary team from Switzerland, Denmark, and Italy has studied the long-term techno-economic feasibility of such plants to meet different grid-balancing needs and to identify several promising business cases. The project started in January 2019 and will end in December 2020. It has passed the mid-term review. The grid flexibility need and plant concept designs have been completed. Plant integration and economic evaluation are ongoing.

NON-QUANTITATIVE OBJECTIVES

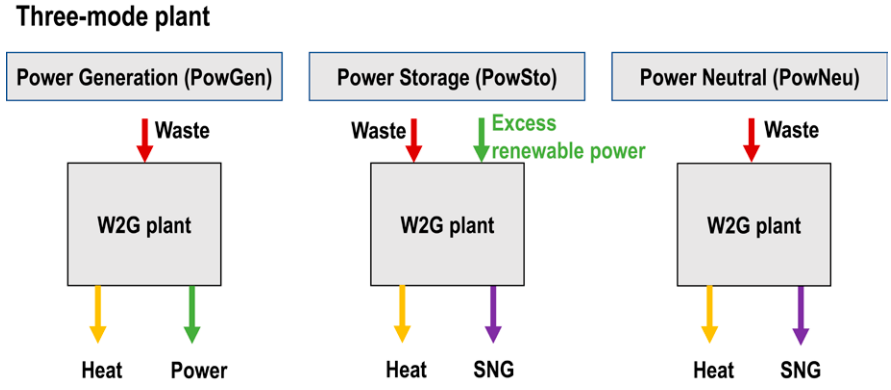
- Future grid-balancing needs
- Power profiles to be balanced in 2030 obtained at hour/day/week/month time scale and 1/10/100/1 000 MWe capacity for wind- and/or PV-dominated zones
- Future available wastes
- Waste type, amount and location identified at different granularities for power-balancing needs at different capacities by 2030
- Balancing plant design
- A set of promising conceptual plant designs with high accumulated overall efficiency has been obtained for different balancing scenarios.

PROGRESS AND MAIN ACHIEVEMENTS

- The grid flexibility needs in renewable-energy dominated zones in Denmark and southern Italy have been identified and hourly profiles and statistical analyses drawn up
- The exploitable waste potential for the identified zones has been investigated, along with detailed waste type and geographical distribution
- Conceptual designs of the plants with different types of gasifier have been investigated, resulting in a pool of many trade-off plant designs.

FUTURE STEPS AND PLANS

- Plant grid integration: identify the best plant, from among the pool of designs, for various grid flexibility needs by considering the waste supply chain
- Identify specific requirements for successful grid integration, including auxiliary oxygen supply devices
- Perform an economic evaluation once the plant sizes, deployment and waste supply chains have been identified
- Identify major constraints, at each level of practical application, on such plants providing grid-balancing services
- Catch up dissemination activities postponed due to COVID-19.



QUANTITATIVE TARGETS AND STATUS

TARGET SOURCE	PARAMETER	TARGET	TARGET ACHIEVED?	SOA RESULT ACHIEVED TO DATE (BY OTHERS)	YEAR FOR SOA TARGET
Project's own objectives	Future grid flexibility needs	Hourly profiles	✓	Not available for specific zones	2020
	Future waste potential	Type and distribution		No geo-referenced aggregated data of waste and agro-forestry residues production at national/ local level	
	Plant conceptual design	Design pool		No trade-off designs investigated in literature or other project	