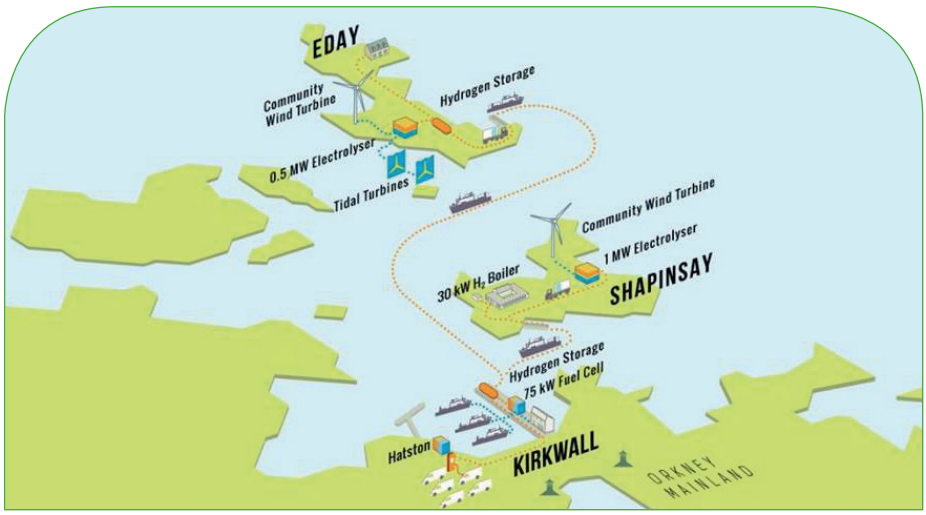
BIG HIT

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



Project ID:	**700092**
Call topic:	**FFCH-03.2-2015** - Hydrogen territories
Project total costs:	**€ 7,246,102.5**
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

This 'Building Innovative Green Hydrogen Systems in an Isolated Territory' (BIG HIT) project is a world leading pilot project, aiming to demonstrate a hydrogen territory in Orkney Islands. Curtailed energy from tidal and wind turbines (on average more than 30% of the annual renewable output in Orkney) is being used to produce 'green' hydrogen from electrolysis, which is then transported across Orkney Islands and used for local transport, heat and power end-uses. The project involves 12 partners based across six EU countries, to enhance the value of European collaborations.

NON QUANTITATIVE OBJECTIVES

- Delivering the Local Authority's Orkney Hydrogen Economic Strategy
- The project has established a new commercial entity (Orkney Hydrogen Trading) to operate the integrated hydrogen system across the islands
- The project launched the 16th of May the Hydrogen Territories Platform, a tool to replicate the BIG HIT project concepts to other territories
- Improve local public acceptance of hydrogen.

PROGRESS & MAIN ACHIEVEMENTS

- Certification for the multi element gas containers (MEGC) transporting hydrogen (specific/novel design for Orkney Ro-Ro ferries)
- HRS (350bar) and 5 RE-FCEV deployed and operating, 2 MEGCs for transporting high pressure hydrogen and a 75kW CHP FC for cold ironing commissioned
- Lessons learnt replicable to other demo projects & regions (it will be done via the Hydrogen Territories Platform that is being created in BIG HIT).

FUTURE STEPS & PLANS

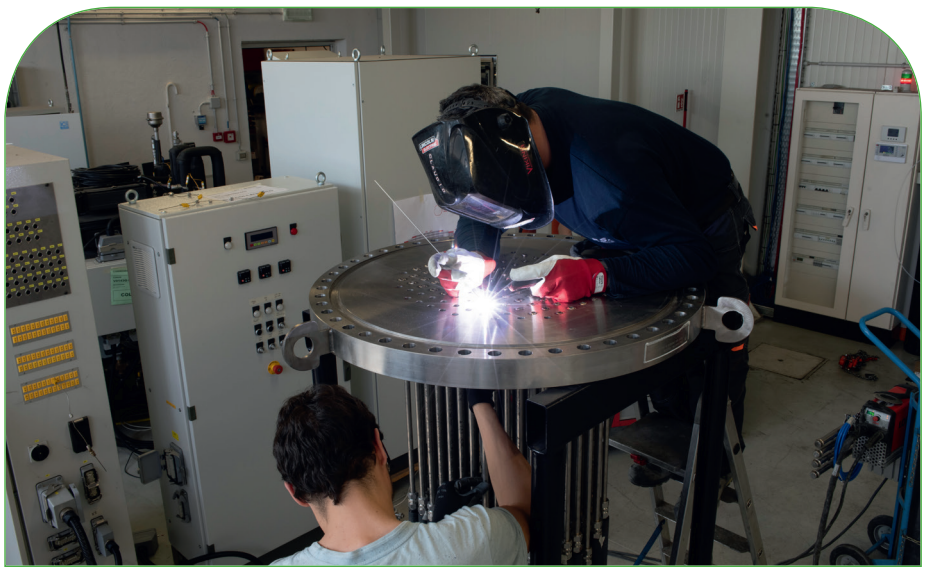
- Operation and monitoring of the fully integrated hydrogen system operation in Orkney
- Validation of commercial/business models for integration of RES locally via local hydrogen and promotion of the project replicability
- Reduces (grid) investment & improves load management
- Overcomes grid constraints and harness local (otherwise curtailed) renewable resources (wind & marine) by the integration of hydrogen technologies
- Boosts local economy including development of local skills & qualified jobs in emerging technologies like hydrogen and fuel cells.

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)	**FC VEHICLES**						
	Availability	%	98	100	✓	98	2017
	HRS						
	Energy consumption	kWh/kg	5	8.1	✗	10	2017
	Availability	%	96	85.65	✗	95	
	COMPRESSED GAS TUBE TRAILERS						
	Capacity	kg	1,000	250	✗	850	2017

BIONICO

BIOGAS MEMBRANE REFORMER FOR DECENTRALIZED HYDROGEN PRODUCTION



Project ID:	**671459**
Call topic:	**FCH-02.2-2014** - Decentralized hydrogen production from clean CO_2-containing biogas
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 & INNOVATION, I.C.I CALDAIE SPA, ABENGOA HIDROGENO SA, QUANTIS, RAUSCHERT KLOSTER VEILSDORF GMBH, ABENGOA RESEARCH SL, ENC POWER LDA, ENC ENERGY SGPS SA

PROJECT AND OBJECTIVES

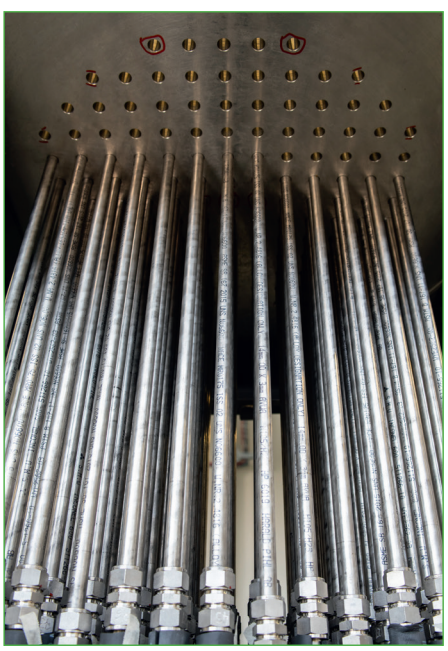
BIONICO will develop, build and demonstrate at a biogas plant a novel catalytic membrane reactor integrating H_2 production (100 kg/day) and separation in a single vessel. A significant increase of the overall efficiency (up to 72%) and decrease of volumes and auxiliary heat management units is expected.
Within the project, new ceramic supported tubular membranes operating at 550 ºC and a new reforming catalyst for H_2 production from biogas have been developed. The membrane reactor has been manufactured and integrated in ICI's labs and is going through preliminary testing.

PROGRESS & MAIN ACHIEVEMENTS

- Development and scale up of highly active, durable and stable reforming catalysts to produce H_2 from biogas
- Development and production of 120 Pd based ceramic supported tubular membranes able to work at high temperature (550°C) for the BIONICO pilot reactor
- Manufacturing of the catalytic membrane reactor and integration in ICI's laboratory for testing.

FUTURE STEPS & PLANS

Testing of the BIONICO reactor in a real biogas plant in Portugal.

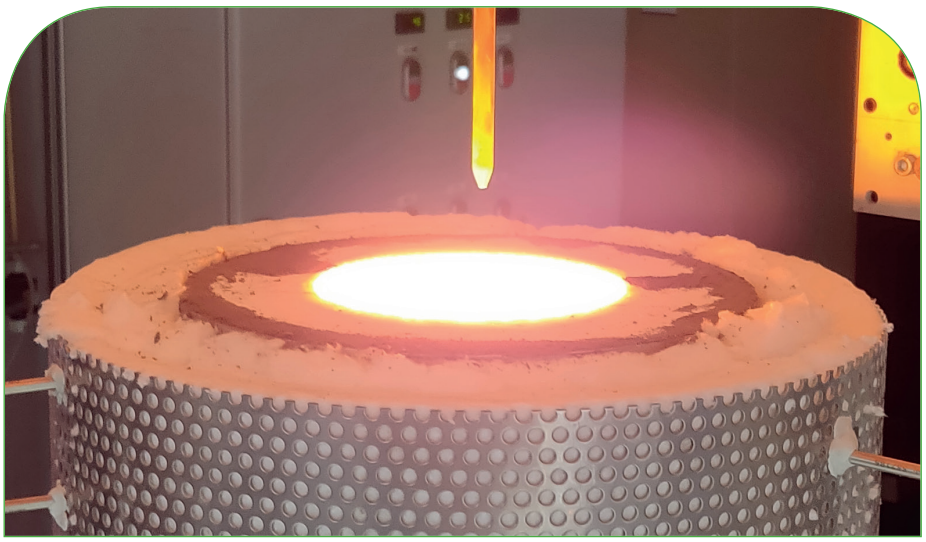


QUANTITATIVE TARGETS AND STATUS

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)	Hydrogen production efficiency	%	72.0	71.9	✓	N/A	N/A
AWP 2014	Perform hydrogen production in a single step	step	1	1	✓	4	2016

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- 30/06/2020
Coordinator:	**POLITECNICO DI MILANO, IT**
Website:	**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 LAMBIENTE 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 will develop a pre-commercial oxidative steam reformer (OSR) for sustainable and decentralized hydrogen production from biogas with no preliminary removal of CO_2. The TRL6 demo-plant will deliver at least 50 Nm3/h (107 kg/day) of H_2 at 99.9% purity and 1.5 bar with an energy efficiency conversion of 81% on a HHV basis. The ways to reach this objective are: i) high thermal integration, ii) PSA (pressure swing adsorption) off gas exploitation for reformer feed preheating, iii) power consumption minimization through CO_2 removal prior to the PSA.

NON QUANTITATIVE OBJECTIVES

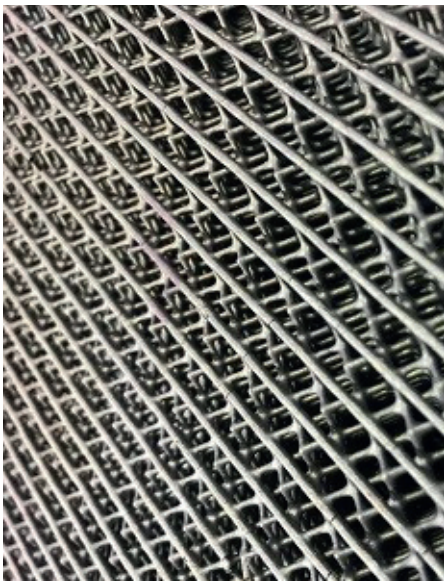
- Dissemination and training activities
- Participation in several conferences
- Improve the efficiency of hydrogen production through better heat integration of the components
- A preliminary LCA analysis of the general system has been carried out. REACH and HAZOP analysis of the BioRoburplus process has been completed. A first version of the exploitation plan has been carried out. In addition, the development of decision support schemes for BioRoburplus system implementation is going
- Coating and manufacturing process have been optimized.

PROGRESS & MAIN ACHIEVEMENTS

- Structured Nickel based-catalyst and precious-metal-based catalyst showed good performances. Most promising process for H_2purification was selected
- A dedicated innovative PSA-off-gas burner with structured components was developed
- Ceramic support structures as catalyst carriers with enhanced heat & mass transport properties were developed. LCA analysis are being performed.

FUTURE STEPS & PLANS

- Optimization of the catalyst coating process
- To complete the testing campaign of the structured catalytic support on a pilot scale under more realistic conditions
- To finish the testing of the catalyst for WGS reactors
- Manufacturing and testing the overall plant
- LCA and PUEF final versions to be performed. Techno-economic analysis will be performed.



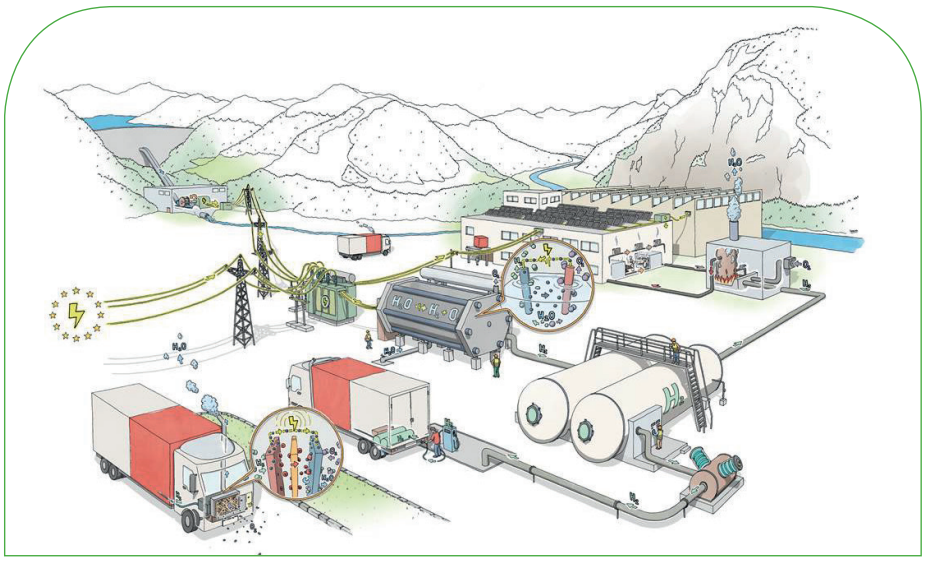
QUANTITATIVE TARGETS AND STATUS

TARGET SOURCE	PARAMETER	UNIT	TARGET	TARGET ACHIEVED?	SOA RESULT ACHIEVED TO DATE (BY OTHERS)	YEAR FOR SOA TARGET
Project's own objective	Nominal H_2 production capacity	Nm^3/h	50		50 Nm^3/h	2016
	Overall plant efficiency based on HHV	%	≥ 80		Overall Plant efficiency of 65%	
	Reformer outlet CO concentration a dry-basis	%	<8		A value of 9.99 reached with the BioRobur	
AWP 2016	H_2 purity	%	99.99		BioRobur delivered 50 Nm^3/h of 99.9% hydrogen from biogas	
	A cold-start up time of no more than	hours	2		BioRobur value 6h	

PRD 2019 PANEL
HYDROGEN FOR SECTORAL INTEGRATION

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- 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

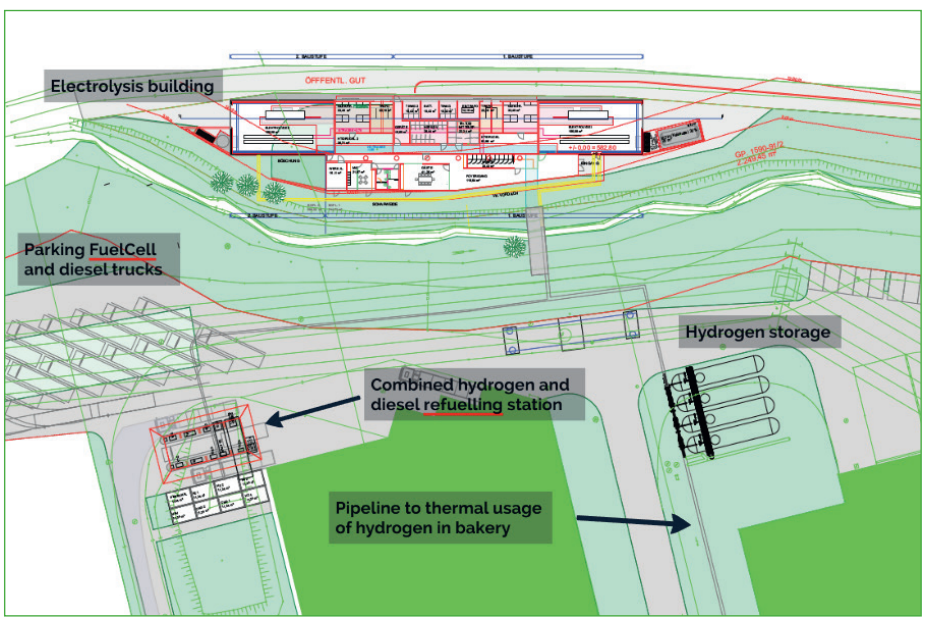
The main aim of project Demo4Grid is the commercial setup and demonstration of a technical solution utilizing "above state of the art" Pressurized Alkaline Electrolyser (PAE) technology for providing grid balancing services in real operational and market conditions. The final goal is to provide grid balancing services to the transmission system operator (primary and secondary balancing services).
The electrolysis plant will be installed in Völs near Innsbruck.

PROGRESS & MAIN ACHIEVEMENTS

- Engineering documents and analysis of RCS and Safety Requirements are in place
- Project' specific business model has been updated
- A detailed market potential assessment on different business cases of hydrogen production through alkaline electrolysers has been developed.

FUTURE STEPS & PLANS

- Permits procedures finalized by May 2020
- Building construction finished by August 2020
- Pae procurement & certification by May 2020
- Pae commissioning by December 2020
- Sat & test phase operation finished by March 2021.

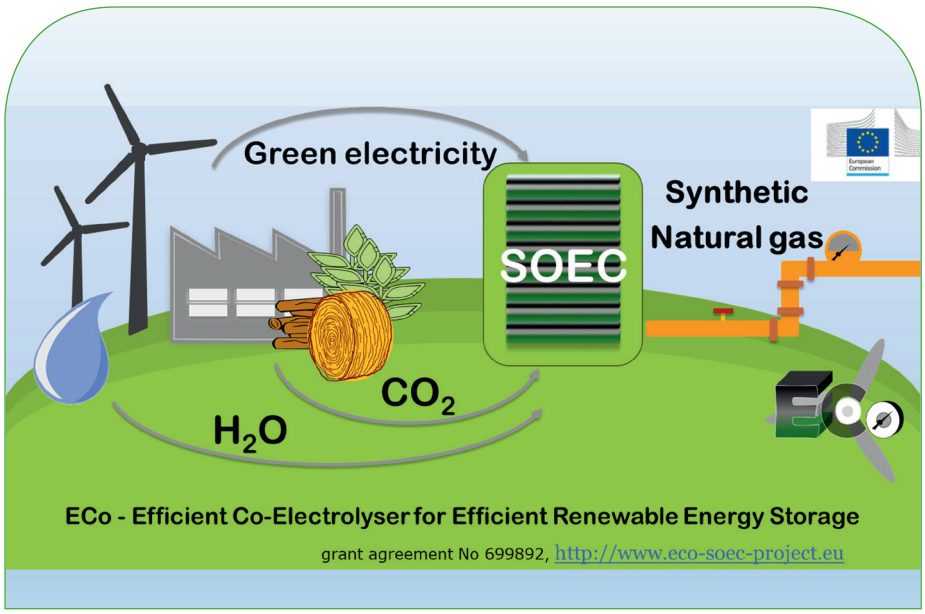


QUANTITATIVE TARGETS AND STATUS

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	Seconds	2		60	2015
	Start-up time KPIs from cold to minimum part load for Alkaline Electrolysers	Minutes	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	

ECo

EFFICIENT CO-ELECTROLYSER FOR EFFICIENT RENEWABLE ENERGY STORAGE - ECO



Project ID:	**699892**
Call topic:	**FCH-02.3-2015** - Development of co-electrolysis using CO_2 and water
Project total costs:	**€ 3,239,138.75**
FCH JU max. Contribution:	**€ 2,500,513.75**
Project start - end:	01/05/2016 - 30/04/2019
Coordinator:	**DANMARKS TEKNISKE UNIVERSITET, DK**
Website:	**www.eco-soec-project.eu**

BENEFICIARIES: COMMISSARIAT A L'ENERGIE ATOMIQUE ET AUX ENERGIES ALTERNATIVES, ECOLE POLYTECHNIQUE FEDERALE DE LAUSANNE, ENGIE, ENAGAS SA, BELGISCH LABORATORIUM VAN DE ELEKTRICITEITSINDUSTRIE LABORELEC CVBA, EIFER EUROPAISCHES INSTITUT FUR ENERGIEFORSCHUNG EDF KIT EWIV, SOLIDPOWER SA, FUNDACIO INSTITUT DE RECERCA DE L'ENERGIA DE CATALUNYA, VDZ GEMEINNUTZIGE GMBH

PROJECT AND OBJECTIVES

The overall goal of ECo is to develop and validate a highly efficient co-electrolysis process for conversion of renewable electricity into distributable and storable hydrocarbons via simultaneous electrolysis of steam and CO_2 through Solid Oxide Electrolysis Cells.
The project provided multiple generations of cells with improved performance at cell and stack level. Degradation rates under realistic co-SOE conditions reached <1%/1000 hours. Significant durability understanding was gained. A co-SOE plant was designed and integrated into existing plants for techno-economic analysis and LCA.

NON QUANTITATIVE OBJECTIVES

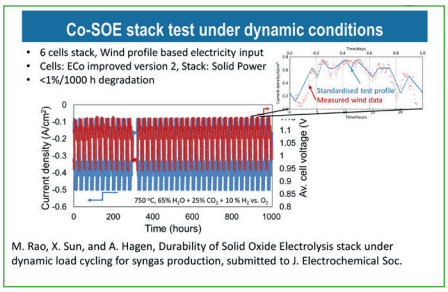
- The design of a co-SOE plant was achieved, yielding information of obtainable gas yields and efficiencies in correlation with operating conditions
- Techno-economic analysis of specific cases achieved and evaluated depending on geographic location, electricity mix, CO_2 availability, etc.
- LCA achieved based on realistic application cases and revealing benefits in case of availability of green electricity.

PROGRESS & MAIN ACHIEVEMENTS

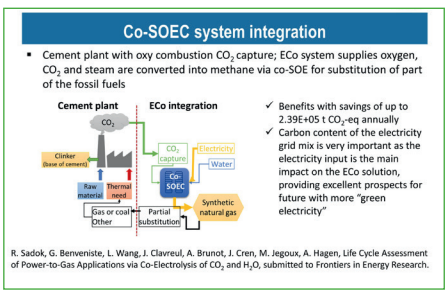
- Successful development of several cell versions to allow for a decrease of operating temperature by 50-100°C and verification at cell and stack level
- Significant detailed durability understanding under relevant conditions (dynamic, pressure, impurities) gained & degradation rates <1%/1,000 h achieved
- Co-SOEC plant designed and integrated with existing plants revealing environmental and economic benefits when green electricity is available.

FUTURE STEPS & PLANS

Project finished.



M. Rao, X. Sun, and A. Hagen, Durability of Solid Oxide Electrolysis stack under dynamic load cycling for syngas production, submitted to J. Electrochemical Soc.



R. Sadok, G. Benveniste, L. Wang, J. Clavreul, A. Brunot, J. Cren, M. Jegoux, A. Hagen, Life Cycle Assessment of Power-to-Gas Applications via Co-Electrolysis of CO_2 and H_2O, submitted to Frontiers in Energy Research.

QUANTITATIVE TARGETS AND STATUS

TARGET SOURCE	PARAMETER	UNIT	TARGET	ACHIEVED TO DATE BY THE PROJECT	TARGET ACHIEVED?
Project's own objectives	Area specific resistance	Ohm*cm²	0.2	0.2	✓
	Degradation rate	%/1,000 h	1	<1	✓
	SOE performance at 10 bar, 750°C, 1.3 V	A/cm²	-1.3	-0.9	✗

ELY4OFF

PEM ELECTROLYSERS FOR OPERATION WITH OFFGRID RENEWABLE INSTALLATIONS

Project ID:	**700359**
Call topic:	**FCH-02.1-2015** - Improved electrolysis for Off-grid Hydrogen production
Project total costs:	**€ 2,315,217.5**
FCH JU max. Contribution:	**€ 2,315,217**
Project start - end:	01/04/2016- 31/09/2019
Coordinator:	**FUNDACION PARA EL DESARROLLO DE LAS NUEVAS TECNOLOGIAS DEL HIDROGENO EN ARAGON, ES**
Website:	**www.ely4off.eu**

BENEFICIARIES: COMMISSARIAT A L'ENERGIE ATOMIQUE ET AUX ENERGIES ALTERNATIVES, EPIC POWER CONVERTERS SL, INSTRUMENTACION Y COMPONENTES SA, ITM POWER (TRADING) LIMITED

PROJECT AND OBJECTIVES

The main goal of the ELY4OFF proposal is the development and demonstration of an autonomous off-grid electrolysis system (PEMWE, 50 kW) linked to renewable energy sources (solar PV), including the essential overarching communication and control system for optimising the overall efficiency when integrated in a real installation.

NON QUANTITATIVE OBJECTIVES

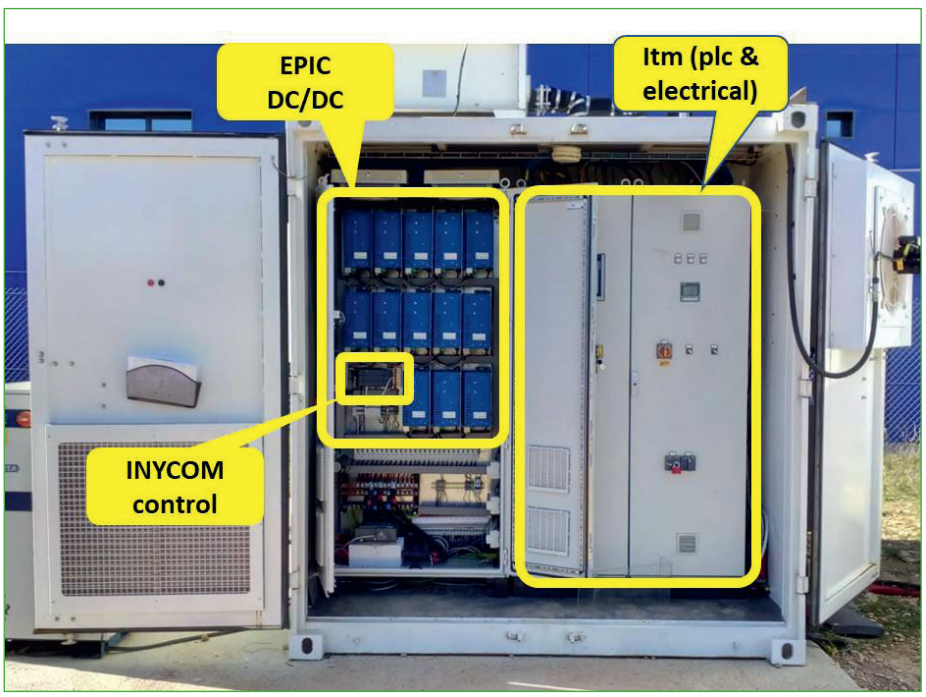
- Study covering specific national requirements and how to overcome barriers in four different countries (Denmark, Scotland, Sweden, France) has been elaborated
- The objective is to see under which conditions is possible to consider an off-grid hydrogen cycle instead of the current technologies used nowadays.

PROGRESS & MAIN ACHIEVEMENTS

- First Hydrogen production on 13 September 2018
- Demonstration period started on 11 March 2019
- Quick and efficient response of the prototype DC/DC conversion and stack to solar variability.

FUTURE STEPS & PLANS

Project finished.



QUANTITATIVE TARGETS AND STATUS

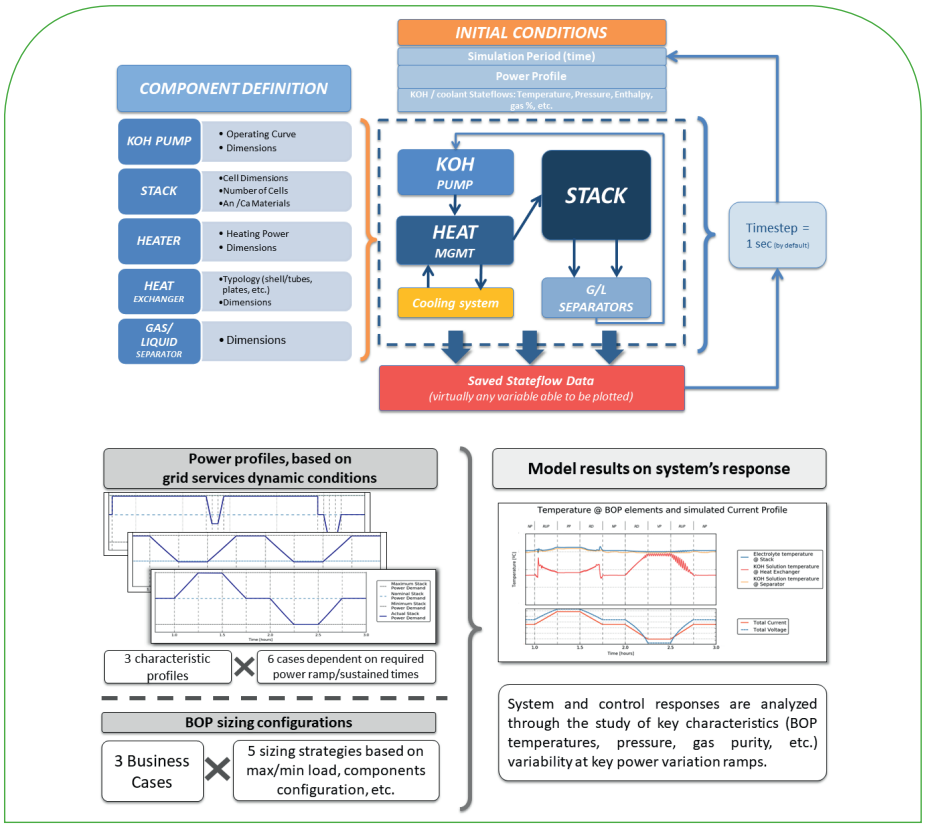
TARGET SOURCE	PARAMETER	UNIT	TARGET	ACHIEVED TO DATE BY THE PROJECT	TARGET ACHIEVED?	SOA RESULT ACHIEVED TO DATE (BY OTHERS)	YEAR FOR SOA TARGET
Project's own objectives	Efficiency at system level	kWh/kg	50	N/A	✗	48 @100kg/day	<48 @100kg/day (Neptune)
	Efficiency degradation	%/8,000h	2	Can't be measured until stack returns to lab conditions	✗	1.5%	1% (Neptune)
	CAPEX	M€/(t/d)	6	4.5 @ 100 kW scale	✓ @ 100 kW scale	3 @ 1MW scale	2.4 @10MW scale
	H_2 production flexibility (degradation <2%)	%	5-150	5-100	✓	20-300	10-400 (BEIS)
	Hot start (min to max power)	seconds	2	<2 seconds	✓	<1 second (for frequency control)	1 second

ELYntegration

GRID INTEGRATED MULTI MEGAWATT HIGH PRESSURE ALKALINE ELECTROLYSERS FOR ENERGY APPLICATIONS

Project ID:	**671458**
Call topic:	**FCH-02.8-2014** - Improvement of electrolyser design for grid integration
Project total costs:	**€ 3,301,391.25**
FCH JU max. Contribution:	**€ 1,861,309**
Project start - end:	01/09/2015- 31/05/2019
Coordinator:	**FUNDACION PARA EL DESARROLLO DE LAS NUEVAS TECNOLOGIAS DEL HIDROGENO EN ARAGON, ES**
Website:	**elyntegration.eu**

BENEFICIARIES: FRAUNHOFER GESELLSCHAFT ZUR FOERDERUNG DER ANGEWANDTEN FORSCHUNG E.V., IHT INDUSTRIE HAUTE TECHNOLOGIE SA, INSTRUMENTACION Y COMPONENTES SA, RHEINISCH-WESTFAELISCHE TECHNISCHE HOCHSCHULE AACHEN, VLAAMSE INSTELLING VOOR TECHNOLOGISCH ONDERZOEK N.V.



PROJECT AND OBJECTIVES

ELYntegration is focused in the design and engineering of a robust, flexible and cost competitive MW alkaline water electrolyser, capable of producing with a single stack up to 4.5 ton H_2/day under highly dynamic power supplies, when high renewable energies shares are considered. The most attractive business models and the assessment on market potential have been implemented. Advanced new materials (membranes and electrodes) have been developed, tested and durability investigated by ASTs at pilot scale. The most promising materials have been tested at industrial scale.

NON QUANTITATIVE OBJECTIVES

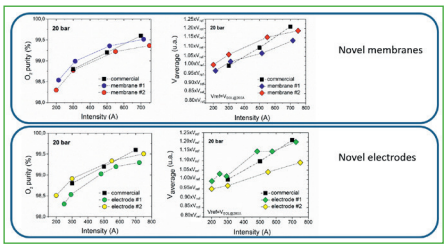
- Design and testing of Accelerated Stress Tests for AWE oriented to GS, 100% accomplished.
- An assessment of the requirements to provide GS was carried out and validated within WP5
- The regulatory frame work and end user requirements for an electrolyser providing grid services was carried out
- The most attractive business scenarios based on the utilization of the MW HP AWE for grid and energy storage devices was identified
- Dissemination through different channels and taking into account several target audiences. Several scientific publications submitted.

PROGRESS & MAIN ACHIEVEMENTS

- Demonstration of the capabilities of 4 industrial size electrolysers to provide grid services
- New materials (membranes and electrodes) developed and tested under Accelerated Stress Test (AST) conditions
- New cell assembly developed and tested.

FUTURE STEPS & PLANS

Project finished.

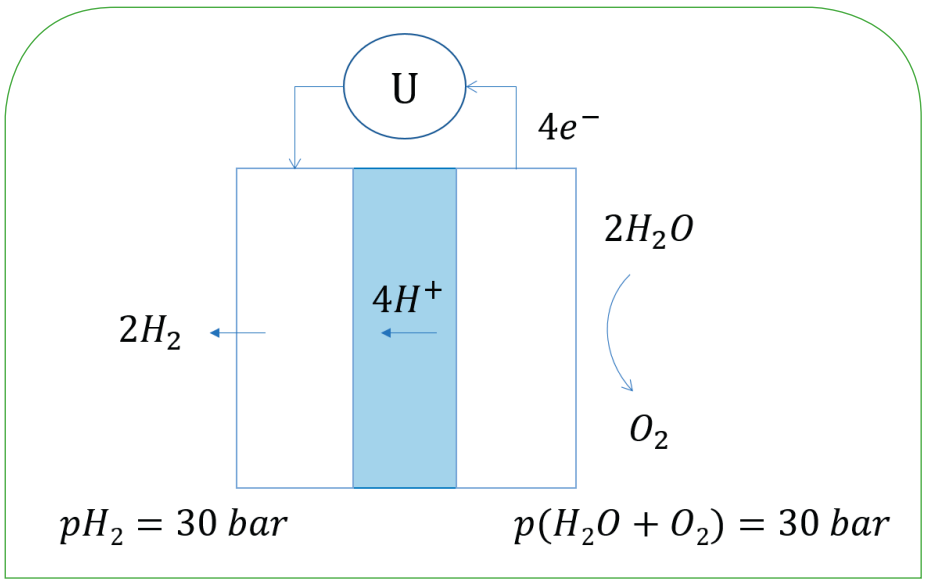


QUANTITATIVE TARGETS AND STATUS

TARGET SOURCE	PARAMETER	UNIT	TARGET	TARGET ACHIEVED?
MAWP Addendum (2018-2020)	System efficiency	kwh/kg H_2	52	✓
	H_2 production flexibility with a degradation <2%	Load spanning range (%)	0-200	✓ (Partially, project's target was 15-130%)
Project's own objective	Increase of stack size	kW	9,700	✓
	Increase of stack capacity	t/d H_2	4.2	✓
Electrolysis Study FCH-JU 2014	Reduction of CAPEX	EUR/kW	<630	✓

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**
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 that will produce pure dry pressurized 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 will develop designs of system and balance of plant components supported by advanced modelling and simulation work, flowsheets of integrated processes.

NON QUANTITATIVE OBJECTIVES

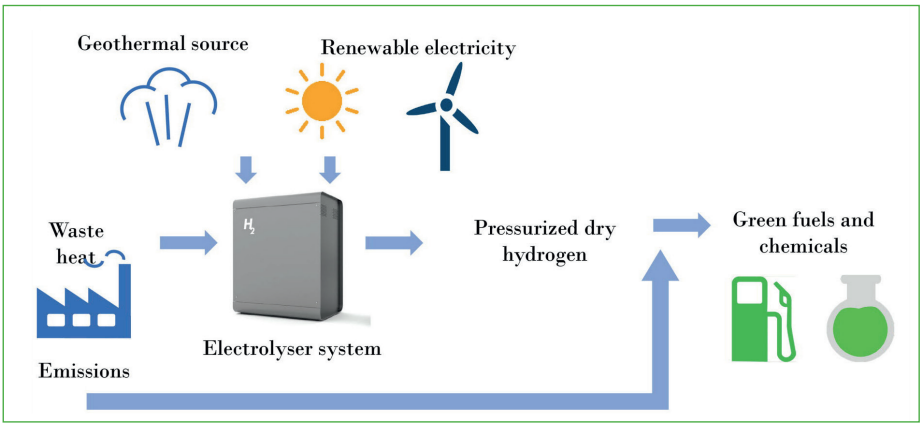
- Regular meetings are conducted with Advisory Board members to present the project's progress and define potential application scenarios for electrolyser integration
- In collaboration with industrial partners, the project has mapped relevant stakeholders for GAMER and prepared an action plan for interaction with them
- More than 11 presentations about the project have been given in open conferences. 1 flyer is also available for the project. One publication in high impact journal is accepted
- The project is currently preparing a patent for the design of the single engineering unit.

PROGRESS & MAIN ACHIEVEMENTS

- Stable operation of tubular cell at 3 bar total pressure with 1.5 bar steam on anode side measured over 700 hours at 600°C
- Novel design of single engineering unit consisting of the electrochemical cell assembled with current collectors, seals and pressurized steel vessel
- Design of 10 kW electrolyser with balance of plant defined with the development of an integrated Excel design sheet.

FUTURE STEPS & PLANS

- Experimental validation of SEU performance in relevant operating conditions
- Scaling up of SEU production for supply to electrolyser prototype
- Sub-contracting of electrolyser prototype engineering
- Installation and commissioning of electrolyser prototype at CSIC ITQ
- Testing of electrolyser system for at least 2,000 hrs operation.



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	Tubular electrochemical cell resistance	ohm * cm^2	2	4	✗	4	2018
	Stability of cell = degradation of cell potential	% /500 hr	2	2	✓	Longest test period reported for tubular PCE: 700hr	2019

GrInHy

GREEN INDUSTRIAL HYDROGEN VIA REVERSIBLE HIGH-TEMPERATURE ELECTROLYSIS

Project ID:	**700300**
Call topic:	**FCH-02.4-2015** - Proof of concept of HT electrolyser at a scale >70 kW
Project total costs:	**€ 4,498,150**
FCH JU max. Contribution:	**€ 4,498,150**
Project start - end:	01/03/2016 - 28/02/2019
Coordinator:	**SALZGITTER MANNESMANN FORSCHUNG GMBH, DE**
Website:	**www.green-industrial-hydrogen.com**

BENEFICIARIES: POLITECNICO DI TORINO, BOEING RESEARCH & TECHNOLOGY EUROPE S.L.U., EIFER EUROPAISCHES INSTITUT FUR ENERGIEFORSCHUNG EDF KIT EWIV, USTAV FYZIKY MATERIALU, AKADEMIE VED CESKE REPUBLIKY, V.V.I., SALZGITTER FLACHSTAHL GMBH, SUNFIRE GMBH, TEKNOLOGIAN TUTKIMUSKESKUS VTT OY

PROJECT AND OBJECTIVES

Central element of GrInHy is the manufacturing, integration and operation of the worldwide most powerful reversible HTE prototype at an integrated iron-and-steel works. Another focus was the technological improvement of robustness and durability on cell and stack level.
During the operation of about 10,000 h in electrolysis, fuel cell or hot-standby mode, the prototype reached electrical efficiencies of 78 %LHV (without drying and compression) in electrolysis and 52 %LHV in fuel cell mode.
In total, about 90,000 Nm³ of hydrogen were produced during electrolysis operation.

NON QUANTITATIVE OBJECTIVES

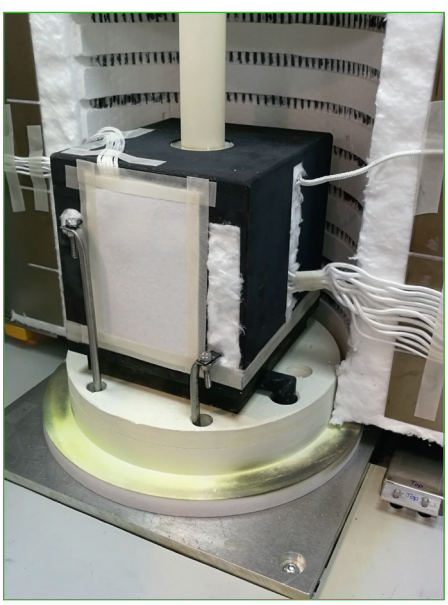
- Elaboration of an exploitation roadmap for cost reducing measures
- Development of dependable system cost data
- Integration of a reversible operation mode (fuel cell mode).

PROGRESS & MAIN ACHIEVEMENTS

- Approximately 10,000 h operation of the worldwide biggest reversible high-temperature electrolyser, fuel cell or hot-standby mode
- Production of about 90,000 Nm³ of hydrogen of which more than 41,000 Nm³ with a quality of 3.8 at 10 bar(g) were used for steel annealing processes
- Proof of electrical efficiencies of 78 %LHV (without drying and compression) in electrolysis and 52 %LHV in fuel cell mode.

FUTURE STEPS & PLANS

Project 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
AWP 2015	Electrical efficiency	%HHV	68	92	✓	95	2017
	System capacity	kW_AC	70	150		75	2017
	Lifetime	hours	2,000	10,000		20,000	2017

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: 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

The EU flagship project "H2FUTURE – Hydrogen meeting future needs of low carbon manufacturing value chains" brings together energy suppliers, the steel industry, technology providers and research partners, all jointly working on the future of energy. With a capacity of 6 megawatts and a production of 1,200 cubic meters of green hydrogen per hour, H2FUTURE is currently the world's largest and most advanced hydrogen pilot facility using PEM (proton exchange membrane) electrolysis technology for producing green hydrogen from renewable electricity.

NON QUANTITATIVE OBJECTIVES

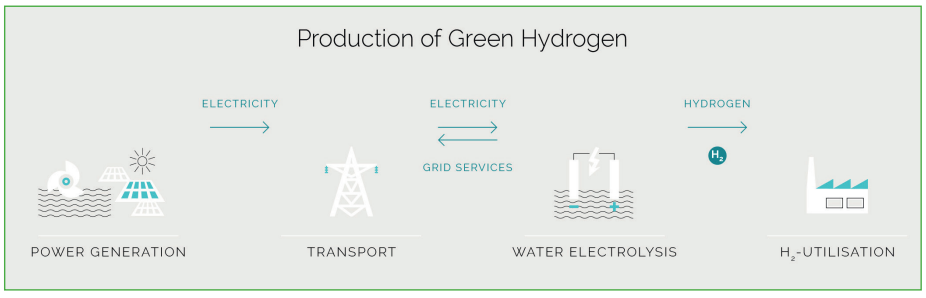
- Roll-out studies on steel & fertiliser industries
- KPIs and performance indicators grouped and defined
- Pilot tests and quasi-commercial operation planned
- Hardware tested in terms of Prequalification for grid services.

PROGRESS & MAIN ACHIEVEMENTS

- Construction permit obtained
- Electrolyser pilot plant building erected
- Optimisation tool for hydrogen/electricity markets developed.

FUTURE STEPS & PLANS

- Commissioning of pilot plant
- Pilot test Operation including testing of grid services
- Quasi-commercial operation and optimisation
- Roll-out and impact studies for steel and fertiliser industry.



QUANTITATIVE TARGETS AND STATUS

TARGET SOURCE	PARAMETER	UNIT	TARGET	ACHIEVED TO DATE BY THE PROJECT	TARGET ACHIEVED?
Project's own objectives	Time to receive construction permit	months	24 months	12 months	✓
	Communication events	Number	20	50	
	Awards won	Number	0	1	

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:	**€ 6,921,215**
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, UNIVERSITÉ DE FRANCHE-COMTE, FUNDACION TECNALIA RESEARCH & INNOVATION, UNIVERSITÉ DE TECHNOLOGIE DE BELFORT - MONTBELIARD, ECOLE NATIONALE SUPERIEURE DE MECANIQUE ET DES MICROTECHNIQUES, UNIVERSITÀ DEGLI STUDI DEL SANNIO, HYDROGENICS EUROPE NV, KES KNOWLEDGE ENVIRONMENT SECURITY SRL, NEW NEL HYDROGEN AS, COMMUNAUTE D' UNIVERSITES ET ETABLISSEMENTS UNIVERSITÉ BOURGOGNE - FRANCHE - COMTE, VARANGER KRAFTVIND AS, VARANGER KRAFTNETT AS, VARANGER KRAFT AS, VARANGER KRAFTENTERPRENOR AS, VARANGER KRAFTMARKED AS, VARANGER KRAUFTUTVIKLING AS

PROJECT AND OBJECTIVES

Combining hydrogen production and wind power can allow greater uptake of wind power, as hydrogen production functions as a controllable buffer reducing the oscillations in wind power production.
Haeolus investigates several modes of operation (re-electrification, mini-grid, fuel production) and will demonstrate them in a plant being built in Berlevåg, Norway, in a remote area with a weak grid, which is representative of many good wind power sites in Europe.

NON QUANTITATIVE OBJECTIVES

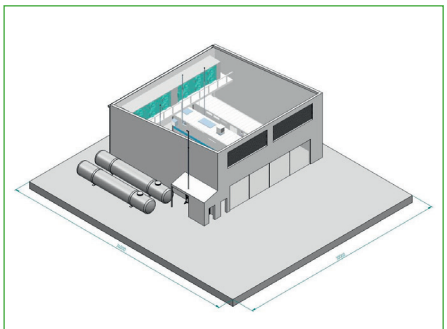
Valorisation of produced hydrogen as there is strong local interest in hydrogen projects, several exploitation actions planned.

PROGRESS & MAIN ACHIEVEMENTS

- Plant designed and site selected
- Cleared all authorisations and permits, construction scheduled for
- Engaged local authorities in several spin-off projects.

FUTURE STEPS & PLANS

- Construction and start-up of demonstration plant
- Spin-off of hydrogen exploitation actions (local initiatives, export, logistic chain)
- Testing of multiple operating modes
- Studies on LCA, business case, environmental performance, impact on energy systems & RCS.

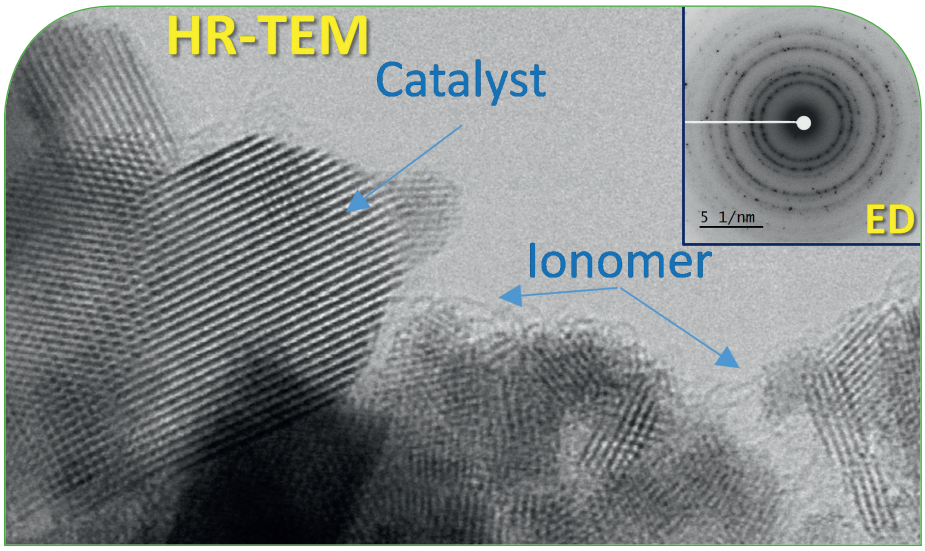


QUANTITATIVE TARGETS AND STATUS

TARGET SOURCE	PARAMETER	UNIT	TARGET	ACHIEVED TO DATE BY THE PROJECT	TARGET ACHIEVED?	SOA RESULT ACHIEVED TO DATE (BY OTHERS)	YEAR FOR SOA TARGET
AIP2012	Reactor production rate	kg/week	3	0.25		0.1	N/A
AWP 2017	Electrolyser CAPEX	M€/tpd	3	N/A		N/A	N/A
Project's Own Objective	Demonstration	years	2.5	0	✕	10	2018
MAWP Addendum (2018-2020)	Energy consumption	kWh/kg	52	N/A		45.6	2018
	Efficiency degradation	%/year	1.5	N/A		N/A	N/A

HPEM2GAS

HIGH PERFORMANCE PEM ELECTROLYZER FOR COST-EFFECTIVE GRID BALANCING APPLICATIONS



Project ID:	**700008**
Call topic:	**FCH-02.2-2015** - Improved electrolysis for Distributed Hydrogen production
Project total costs:	**€ 2,654,250**
FCH JU max. Contribution:	**€ 2,499,999**
Project start - end:	01/04/2016 - 31/03/2019
Coordinator:	**CONSIGLIO NAZIONALE DELLE RICERCHE, IT**
Website:	**hpem2gas.eu**

BENEFICIARIES: JRC -JOINT RESEARCH CENTRE- EUROPEAN COMMISSION, SOLVAY SPECIALTY POLYMERS ITALY SPA, UNIRESEARCH BV, IRD FUEL CELLS A/S, HOCHSCHULE EMDEN/LEER, ITM POWER (TRADING) LIMITED, STADTWERKE EMDEN GMBH

PROJECT AND OBJECTIVES

The HPEM2GAS project is developing a high-performance PEM electrolysis technology optimised for grid management service (power-to-gas) through both stack and balance of plant innovations, culminating in a six-month field test of an advanced 180 kW (nominal) PEM electrolyser. The project aims to contribute significantly to reducing the electrolyser CAPEX and OPEX costs. HPEM2GAS develops key technologies to bring innovative solutions from TRL 4 to 6 and will deliver a techno-economic analysis and an exploitation plan to bring the innovations to market.

NON QUANTITATIVE OBJECTIVES

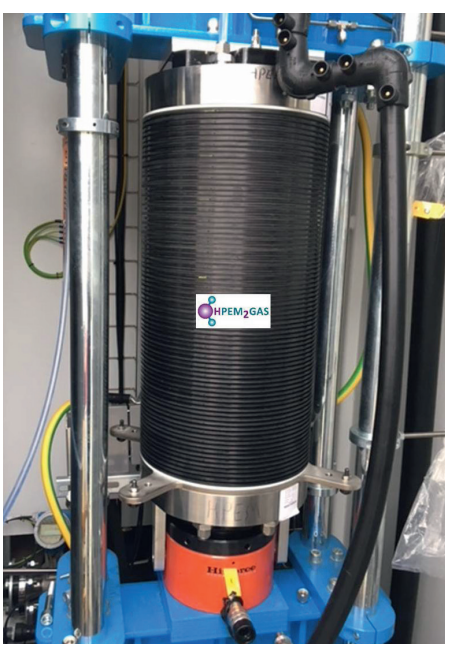
- Readiness of field testing site achieved; analysis of different test scenarios carried out and reported
- Successful demonstration of the electrolysis system in grid balancing
- Organisation of a workshop at the field testing site in Emden with participation of more than 60 stakeholders
- Participation to more than 20 conferences, publication of 4 Open Access papers in International Journals, release of flyers and brochures, radio interviews and press release
- Participation to about 3 joint workshops with other projects.

PROGRESS & MAIN ACHIEVEMENTS

- Achievement of electrolysis current density of 3 A cm^{-2} at about 77 % (HHV) stack efficiency and 75°C with reduced PGM catalyst loading (0.3 mg/W)
- Development of advanced stack components and
- Integration of the developed components and the advanced electrolysis stack in a 180kW electrolysis system validated in field testing at Emden (DE).

FUTURE STEPS & PLANS

- Completion of field testing activities
- Completion of life cycle and cost analyses
- Preparation of dissemination and exploitation plans as follow up of the project.



QUANTITATIVE TARGETS AND STATUS

TARGET SOURCE	PARAMETER	UNIT	TARGET	ACHIEVED TO DATE BY THE PROJECT	TARGET ACHIEVED?	SOA RESULT ACHIEVED TO DATE (BY OTHERS)	YEAR FOR SOA TARGET
Project's own objective	Current density at cell voltage <1.8 V under nominal operation	A/cm^2	3.0	3.0	✓	2.0	2017
	Stack degradation in a 1000 h test at 3 A cm^{-2}	%/khrs	0.280	0.21	✓	0.250	2017
	Stack efficiency at 3 A cm^{-2}	% vs. HHV	82	77	✗	N/A	N/A
	System Energy Consumption at 3 A cm^{-2}	kWh/kg H_2	48	54	✗	58	2017
	System capacity	kg/d H_2	80	83.6	✓	N/A	N/A

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 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 innovative hydrogen delivery processes involved but also demonstrate these in a real industrial environment. Another goal of the project is to improve grid balancing efficiency in order to take benefit of wind turbine electricity production in excess by producing H_2.

PROGRESS & MAIN ACHIEVEMENTS

- Successful delivery of hydrogen in challenging environment for industrial market and mobility applications
- Inauguration of the HyBalance facility on September 3, 2018
- Pipeline construction to supply a metallurgical plant through a direct connection with the HyBalance facility.

FUTURE STEPS & PLANS

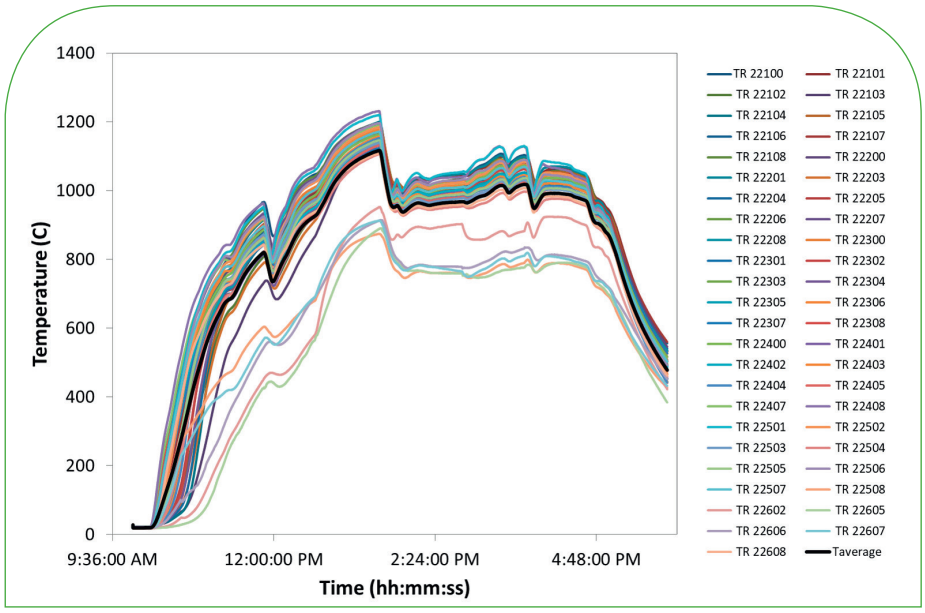
- Improve the hydrogen production efficiency to reach nominal capacity of the plant
- Implement and automate the grid balancing services over 2020
- Teething problems being solved in 2019. Close monitoring of system performance over 2019-2020.

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	58.6	✓	55.3 - 52.2	2018 - 2019
	System lifetime	hours	20,000	4,000	✓	7,000	2019

HYDROSOL-PLANT

THERMOCHEMICAL HYDROGEN PRODUCTION IN A SOLAR MONOLITHIC REACTOR: CONSTRUCTION AND OPERATION OF A 750 KWTH PLANT



Project ID:	**325361**
Call topic:	**SP1-JTI-FCH.2012.2.5** - Thermo-electrical-chemical processes with solar heat sources
Project total costs:	**€ 3,453,422.16**
FCH JU max. Contribution:	**€ 2,265,385**
Project start - end:	01/01/2014 - 30/04/2018
Coordinator:	**CENTRE FOR RESEARCH AND TECHNOLOGY HELLAS, EL**
Website:	**hydrosol-plant.certh.gr**

BENEFICIARIES: DEUTSCHES ZENTRUM FUER LUFT - UND RAUMFAHRT EV, CENTRO DE INVESTIGACIONES ENERGETICAS, MEDIOAMBIENTALES Y TECNOLOGICAS-CIEMAT, HYGEAR B.V., ELLINIKA PETRELAIA AE

PROJECT AND OBJECTIVES

Within the HYDROSOL-PLANT project the development and operation of a plant for solar thermo-chemical hydrogen production from water is pursued.
The main objectives of HYDROSOL-PLANT are to achieve a material life-time of more than 1000 operational hours and to construct a solar hydrogen production demo-plant in the 750 kWth range to verify the developed technology for solar thermochemical H_2O splitting and demonstrate hydrogen production and storage on site at levels > 3kg/week.

NON QUANTITATIVE OBJECTIVES

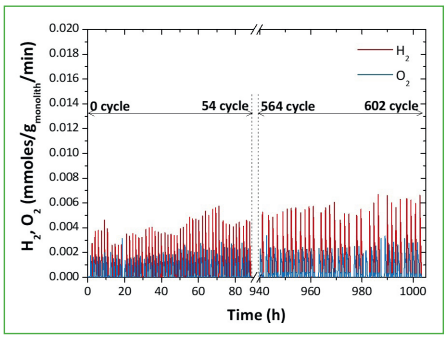
- Modelling and simulation of the plant and of key components
- Field tests of prototype plant completed via the Installation of reactors and peripherals. Thermal experiments initiated. H_2 production experiments will follow the thermal campaign
- Full size reactor components and reactors were build.

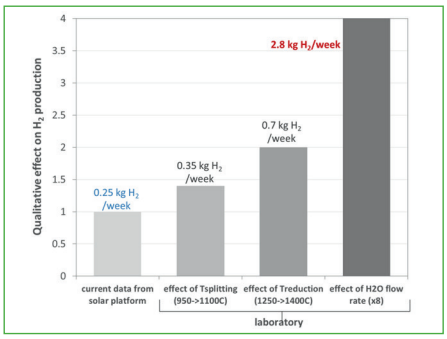
PROGRESS & MAIN ACHIEVEMENTS

- Durability testing of structured redox material for over 1,000 h of consecutive water splitting and thermal reduction
- Achieved hydrogen production from water based on redox thermochemical cycles exceeding 3kg/week at the laboratory scale
- Construction, integration and operation of the 750kWth solar reactors and peripherals on the solar platform. The largest solar redox reactors to date.

FUTURE STEPS & PLANS

Project finished.



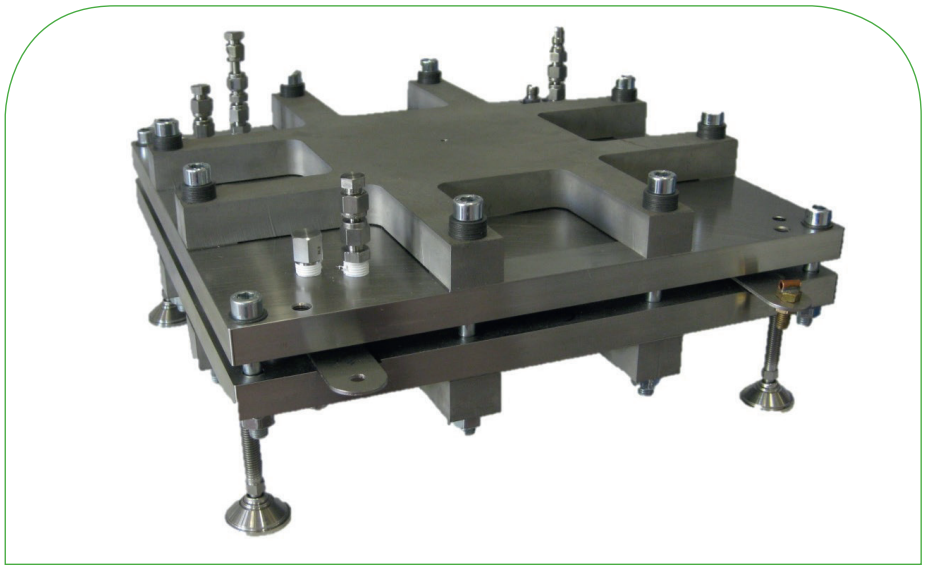


QUANTITATIVE TARGETS AND STATUS

TARGET SOURCE	PARAMETER	UNIT	TARGET	ACHIEVED TO DATE BY THE PROJECT	TARGET ACHIEVED?	SOA RESULT ACHIEVED TO DATE (BY OTHERS)	YEAR FOR SOA TARGET
AIP 2012	Material durability	hours	1,000	1,002	✓	283	2010
	Reactor production rate	kg/week	3	0.25	🛠	0.1	2012
	Solar hydrogen generator in a demonstration range @ 0.5-2 MW scale	MW	0.5-2	0.75	✓	0.10	2012
Project's Own Objectives	H_2 production	ml/g	4.6	7.35	✓	4.6	2010
	Maximum H_2 production rate	ml/min/g	0.1	0.45	✓	0.1	2014

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 will be on the hydrogen separation through a combination of membranes, electrochemical separation and temperature swing adsorption to be able to decrease the total cost of hydrogen recovery. The project targets a pure hydrogen separation system with power and cost of < 5 kWh/kgH_2 and < 1.5 $€/kgH_2$. A pilot designed for >25 kg/day of hydrogen.

NON QUANTITATIVE OBJECTIVES

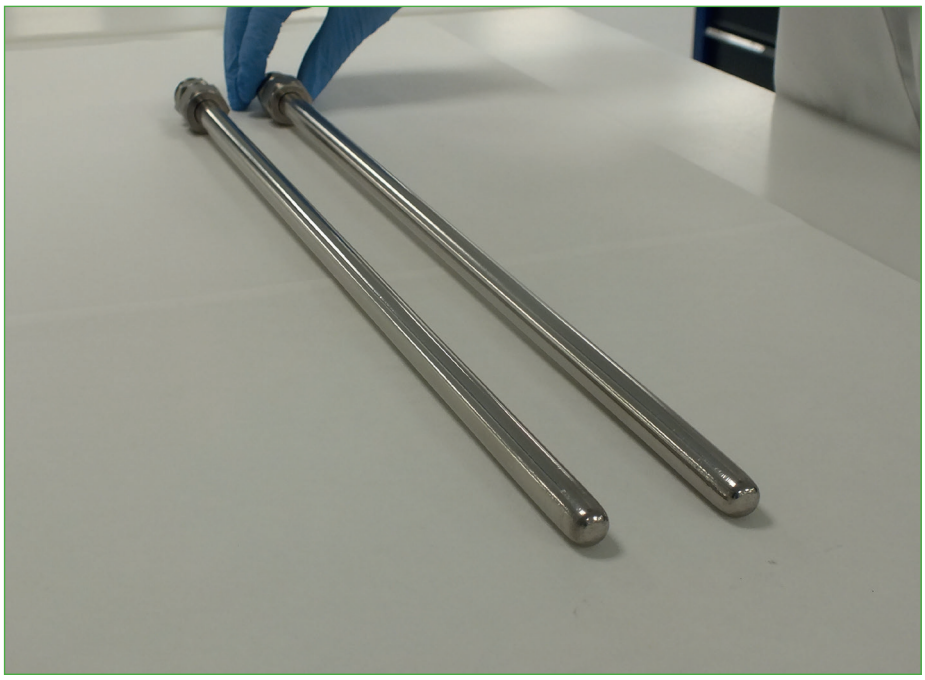
Different young researchers trained.

PROGRESS & MAIN ACHIEVEMENTS

- Patent on separation system submitted by TUE and TECNALIA
- Scale up of electrochemical compressor
- Patent on membranes to be submitted between TECNALIA and TUE.

FUTURE STEPS & PLANS

- Finalizing the prototype by 2019
- Testing of prototype by 2020.



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	4.69	✓
		$€/kgH_2$	1.5	1.6	✗
	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
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 B.V., 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 the Liquid Organic Hydrogen Carrier (LOHC) technology for distribution and storage of hydrogen to supply Hydrogen Refuelling Stations (HRS) with hydrogen meeting all quality criteria defined in ISO 14687:2-2012.
Definition of requirements, preliminary LCA, specification of the logistic concept as well as engineering of hydrogen storage-, release- and purification-systems is completed. Current focus is on assembly of the systems, layout plan for the system setup, LOHC logistics to prepare for field testing.

NON QUANTITATIVE OBJECTIVES

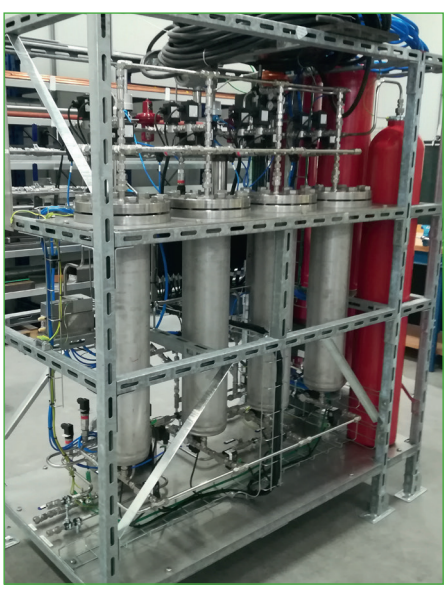
- Development of a cost-efficient, fully automated LOHC hydrogen storage system (StorageBOX) and a release system (ReleaseBOX)
- Demonstration of full systems operation for HRS supply in Finland will follow 2020.

PROGRESS & MAIN ACHIEVEMENTS

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

FUTURE STEPS & PLANS

- Delivery of LOHC-based hydrogen storage and release systems to Finland
- Demonstration of feasibility of LOHC-based hydrogen transport over long distance in Finland
- Proof that hydrogen released from LOHC meets the quality required according to 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 objective	H_2 Purity	%	ISO 14687:2	to be measured coming months	✂	99.95% purity of H_2 released from LOHC (before purification)	2019
	H_2 Input Pressure	bar	25	Design for 25 -30bar	✓	50	2017

INSIDE

IN-SITU DIAGNOSTICS IN WATER ELECTROLYZERS

Project ID:	**621237**
Call topic:	**SP1-JTI-FCH.2013.2.2** - Diagnosis and monitoring of electrolyser performance
Project total costs:	**€ 3,656,756.2**
FCH JU max. Contribution:	**€ 2,176,624.8**
Project start - end:	01/11/2014 - 31/10/2018
Coordinator:	**DEUTSCHES ZENTRUM FUER LUFT - UND RAUMFAHRT EV, DE**
Website:	**inside-project.eu**

BENEFICIARIES: CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE, ACTA SPA, HOCHSCHULE ESSLINGEN, NEW NEL HYDROGEN AS, ENAPTER SRL

PROJECT AND OBJECTIVES

A diagnostic tool for real-time monitoring of locally resolved current densities in water electrolysers was developed. Involved Electrolyser technologies are proton exchange membrane based water electrolysis (PEMWE), alkaline water electrolysis (AWE), anion exchange membrane based water electrolysis (AEMWE). Ex situ analyses accompanied the local deactivation that are visualised with the diagnostic tool. Accelerated stress tests were suggested and used and shared with FCH JU.

NON QUANTITATIVE OBJECTIVES

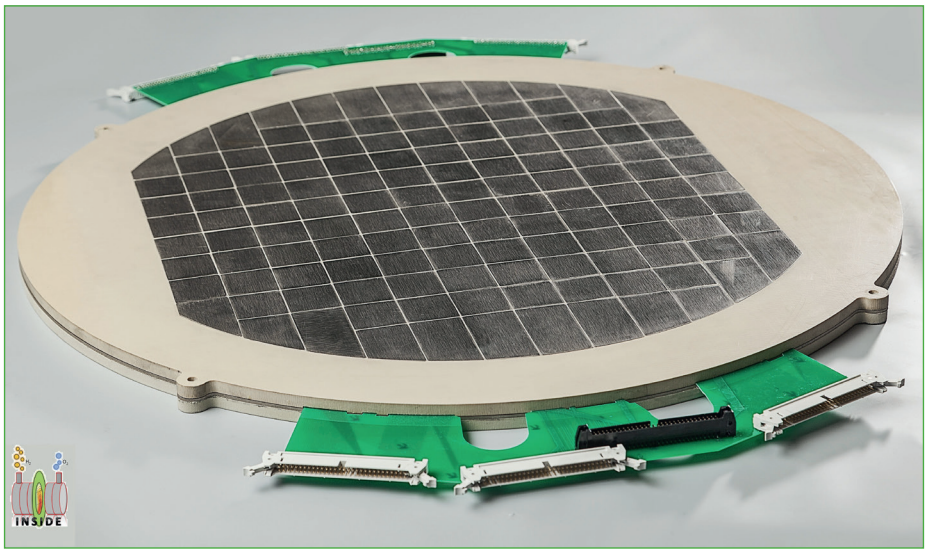
Testing protocols and ASTs for harmonised electrolyser testing. Contribution to basic harmonised electrolyser tests and testing methodology.

PROGRESS & MAIN ACHIEVEMENTS

- Tools for real-time monitoring of locally resolved current density distribution were designed for PEMWE, AEMWE and AWE
- Correlation of local electrolyser activity/ deactivation and local flow shortages / local contamination was demonstrated
- Partially harmonised accelerated stress tests for electrolysers were suggested and shared with FCH JU.

FUTURE STEPS & PLANS

- Project finished
- Reality test of diagnostics tool for AWE is planned (respective the availability of NEL testing site, or alternative).

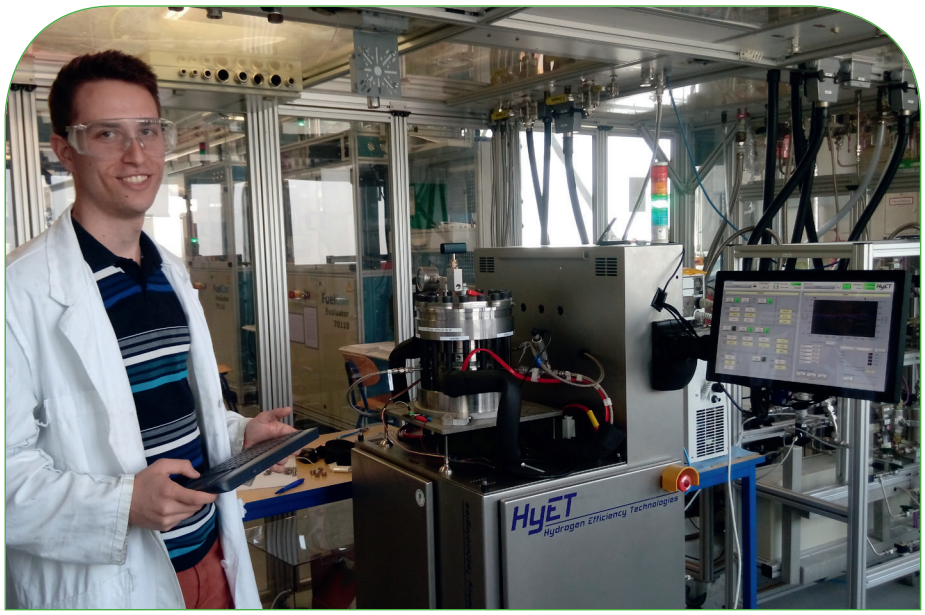


QUANTITATIVE TARGETS AND STATUS

TARGET SOURCE	PARAMETER	TARGET ACHIEVED?
MAIP (2008-2013)	Diagnosis / monitoring tool availability	✓
		✓
		✗

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
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-WURTTEMBERG, HYET HYDROGEN BV

PROJECT AND OBJECTIVES

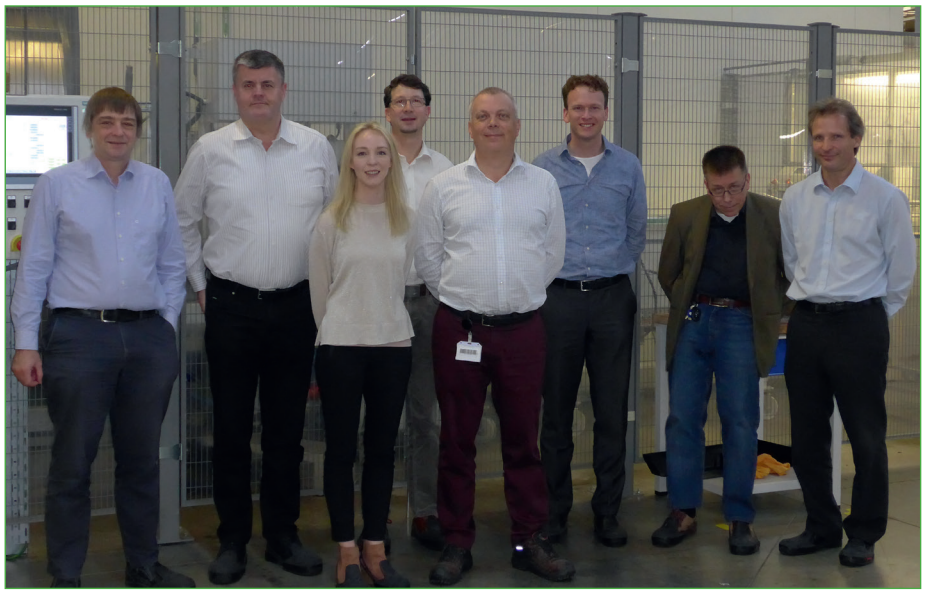
Project MEMPHYS, targets the development of a standalone hydrogen purification system based on an electrochemical hydrogen purification (EHP) system. The focus will be on high contaminant tolerance at low system cost, making the system suitable for different applications. Project MEMPHYS targets a 5 kg H_2/day system with an energy consumption < 5 kWh/kg H_2, a hydrogen recovery rate of > 90 %, producing high purity hydrogen at a system cost of < 1,500 €/kgH_2/day with a pressure of 200 bar. The project is now at the end of the first two years.

PROGRESS & MAIN ACHIEVEMENTS

- Targeted recovery rate was reached in short stack tests. Efficiency target was reached in short stack tests
- Comparable measurement results were achieved in the partners' laboratories at different institutions.

FUTURE STEPS & PLANS

- 3-month duration test
- Building up of a 5 kg/day system in the fourth quarter of the running year.



QUANTITATIVE TARGETS AND STATUS

TARGET SOURCE	PARAMETER	UNIT	TARGET	ACHIEVED TO DATE BY THE PROJECT	TARGET ACHIEVED?
Project's own objective	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

STACK DESIGN FOR A MEGAWATT SCALE PEM ELECTROLYSER

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 - 31/01/2021
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 develops a set of breakthrough solutions at materials, 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 rise in stack temperature at high current density will be managed by using Aquivion polymers for both membrane and ion exchange resin. Aquivion is characterised by enhanced conductivity, high glass transition temperature and increased crystallinity.

NON QUANTITATIVE OBJECTIVES

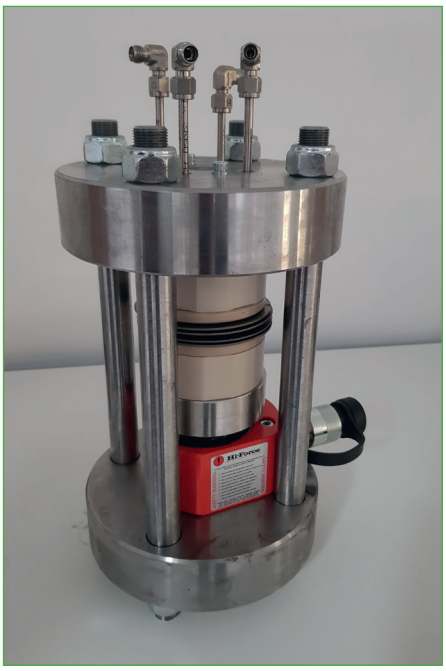
- Harmonised test protocols for assessing system components, stack and balance of plant over a wide range of operating temperature and pressure
- Website created during first three months of the project and accessible to the public
- Dissemination plan published.

PROGRESS & MAIN ACHIEVEMENTS

- Manufacture of reinforced and non-reinforced membranes with a thickness of 50 µm and a series resistance reaching project target
- Operation of an electrolysis cell at 140 °C demonstrated
- Oxygen and hydrogen evolution over potentials target reached with an MEA having low noble metal loadings.

FUTURE STEPS & PLANS

- Scaling-up and industrialisation of down-selected Aquivion membranes and ionomer dispersions
- Manufacturing of catalysts meeting the specifications and the demonstration of large-batch catalyst production
- Manufacture of enhanced MEAs for gas cross-over management at high pressure
- Advanced cost-effective PEM electrolysis stack operating at high temperature and high differential pressure
- Demonstration of advanced PEM electrolyser system for operation at high current density, temperature and pressure.

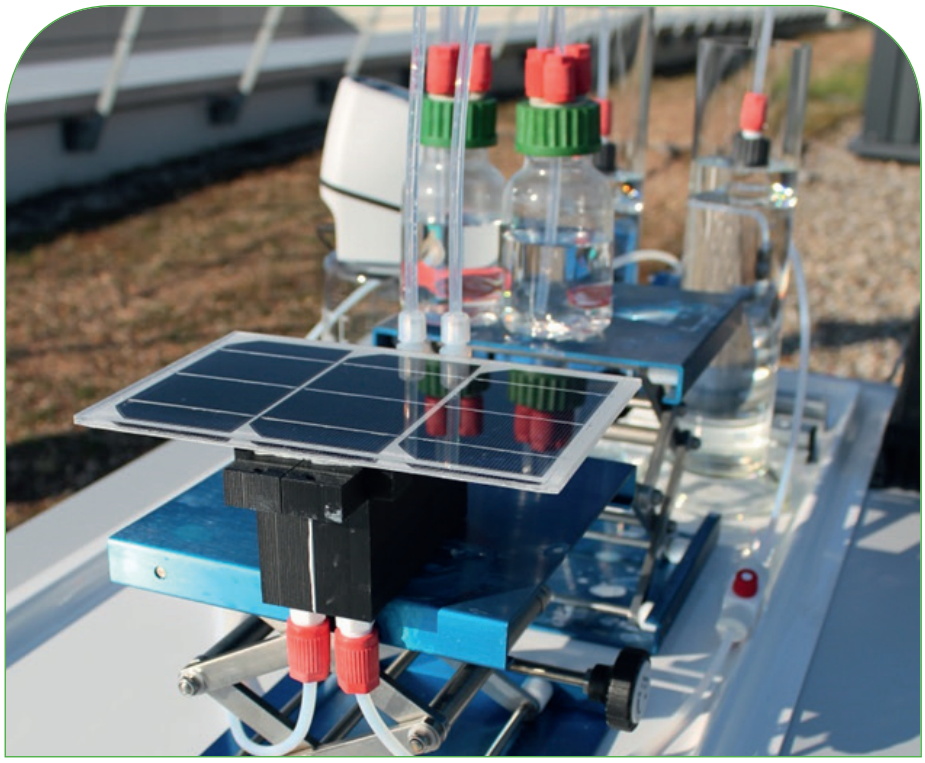


QUANTITATIVE TARGETS AND STATUS

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	Anode catalyst loading	mg/W	0.05	0.047	✓	0.23	2018
	Cathode catalyst loading	mg/W	0.0071	0.014	✗	0.035	
	Efficiency degradation per 1000 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
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:	**pecsys-horizon2020.eu**

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

PROJECT AND OBJECTIVES

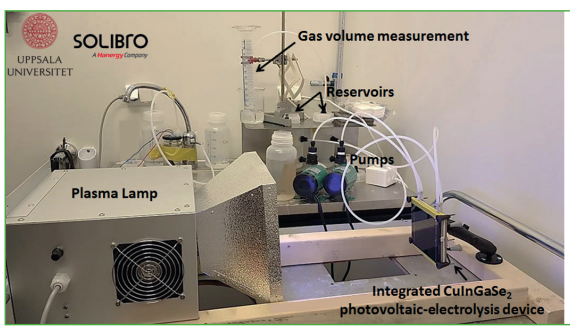
The PECSYS project is concerned with the demonstration of a solar driven electrochemical hydrogen generator using a solar collection area >10 m^2. Innovative device concepts for integrated photoelectrochemical devices with a solar collection area of at least 100 cm^2, have been implemented. Since TF Si was abandoned, only two approaches remain for consideration for deployment in the photovoltaic integrated electrolyser. Efforts are ongoing to increase the solar to hydrogen efficiency and device stability, as well as to upscale devices to ~ 1m^2 modular units that shall make up the demonstrator.

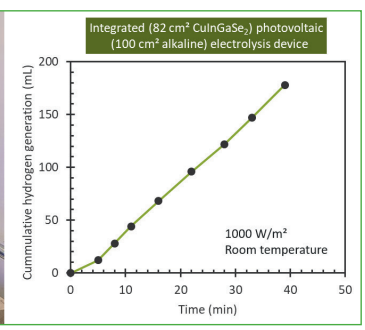
PROGRESS & MAIN ACHIEVEMENTS

- Solar to H_2 efficiency of 8.5 % at a H_2 generation rate of 2.75 g/h/m^2 (ambient conditions 1000 W/m^2, 25°C) achieved for 100 cm^2 CIGS/NiO|NiMoV unit
- Solar to H_2 efficiency of 3.7 % at a H_2 generation rate of 1.1 g/h/m^2 (outdoor conditions 1000 W/m^2) achieved for 294 cm^2 silicon/Ni|NiFeOx unit.

FUTURE STEPS & PLANS

- Further improvement of electrolyser efficiency by optimising device design to reduce resistive and mass transport losses
- Further explore cost effective alkaline resistant materials for long term stability
- Further improvement in the activity, stability and electrical conductivity of non PGM catalysts.



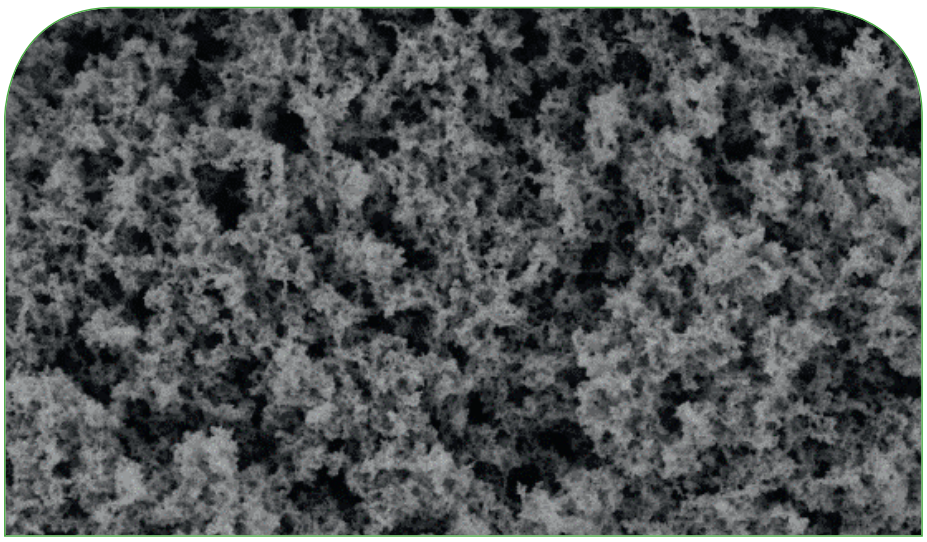


QUANTITATIVE TARGETS AND STATUS

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	m^2	10		1-2m^2
	H_2 production cost	€/kg	5		
MAWP (2014- 2020)	System capital cost	€ /(kg/d)	2,500		N/A
	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
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 is to develop an innovative PEM electrolyser that provides significant increases in efficiency and operability to satisfy emerging market demands. PRETZEL is offering a break-through in becoming game changers in the field of water electrolysers. A central objective of this project is the development of a novel PEM electrolyser system with a maximum 25 kW electrical power consumption that generates 4.5 $m^3 h^{-1}$ H_2 at rated power, at an output pressure of 100 bar and feed water temperature of maximum 90 °C.

NON QUANTITATIVE OBJECTIVES

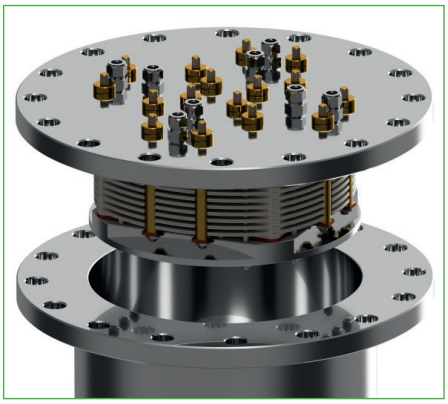
- Assessment of additional commercial opportunities that are available with the game changer electrolyser compared to current electrolysers
- Enabling additional commercial roll-out of electrolysers post 2025.

PROGRESS & MAIN ACHIEVEMENTS

- Definition of compliance test protocols and analytics for corrosion, catalytic kinetic, physical property testing etc. and material characterization
- Report on development of MEAs for 1-cell 25-100 cm^2 LP electrolysers with anode catalysts produced under task 3.3 for initial test cells
- Cell parts and CAD design of HP electrolyser stack are finalized.

FUTURE STEPS & PLANS

- Report on catalyst synthesis procedure, physical characterization of anode catalyst as well as performance and durability of components
- Component manufacture for 5-cell HP stack with 550cm^2 (Catalyst, BPP, PCD, MEAs) and HP PEM electrolyser stack prototype
- Report on the manufacturing process
- Testing protocol for electrolyser operation and report on commissioning tests.



QUANTITATIVE TARGETS AND STATUS

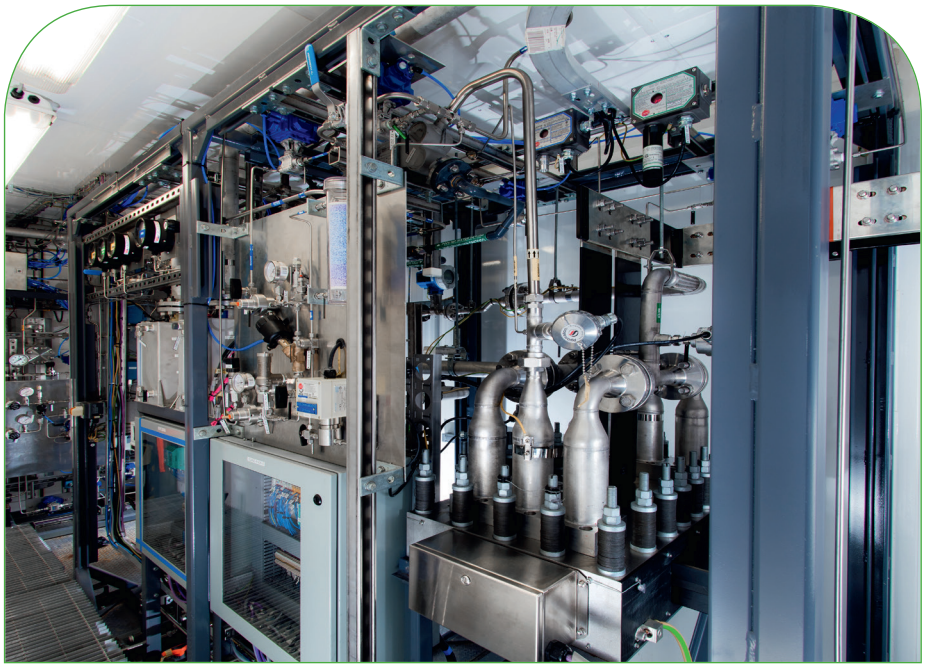
TARGET SOURCE	PARAMETER	TARGET	ACHIEVED TO DATE BY THE PROJECT
MAWP Addendum (2018-2020) and AWP 2017	New cost effective current collectors for PEM electrolysers	Reducing PEM electrolysers CAPEX costs	Initial PCD components are ready for testing in laboratory scale test devices
	25 cm^2 high pressure stack with all components tested	Development and validation of game-changer PEM electrolyser meeting the targets of 2023	Cell parts and CAD design of high pressure electrolyser stack are finalized
	Increase of catalyst activity and optimization of supporting material	Increase energy efficiency of hydrogen production	Preliminary iridium supported material (Ir/SnO_2) has been prepared Development of catalyst and aerogel support for initial MEA production
	100bar, rapid response (<1s hot start), 4A cm^{-2} nominal current density and overload of 6A cm^{-2}, Temperature T>80°C	Step change improvements	Initial cell test performing polarization curve up to 6A/cm^2 at 90°C was successful
	Cost consideration and market analysis from project results extrapolated to MW-scale	Enable additional commercial roll-out electrolyser	Not started yet

QualyGridS

STANDARDIZED QUALIFYING TESTS OF ELECTROLYSERS FOR GRID SERVICES

Project ID:	**735485 (735160 ???)**
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 - 31/12/2019
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 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 is to establish standardized testing protocols for electrolysers to perform electricity grid services. Alkaline and PEM electrolysers are both considered within this project. A variety of different grid services are addressed as well as multiple hydrogen end users. The protocols developed are applied to alkaline and PEM electrolysers systems, using electrolyser sizes from 25 kW to 300 kW. Additionally, a techno-economic analysis of business cases is performed covering the grid and market situations in the most relevant regions of Europe.

NON QUANTITATIVE OBJECTIVES

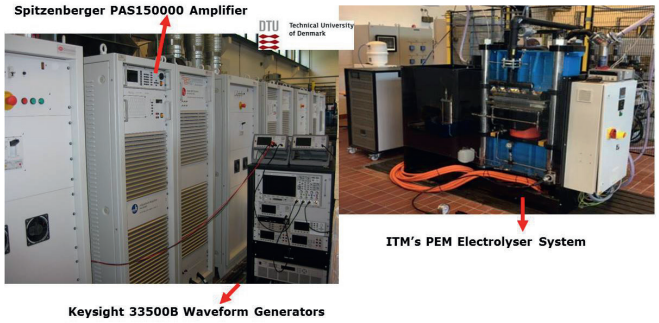
- Development of standardized protocols for electrolysers to provide grid services
- Definition of specific KPIs for dynamic operation to provide grid services
- Project own objective: Evaluation of business cases, sensitivities and a roadmap.

PROGRESS & MAIN ACHIEVEMENTS

- First draft of testing protocols for electrolyser systems performing electricity grid services
- Report on definition of selected business cases and scenarios for electrolysers performing grid services finalized, some business evaluations done
- 5 electrolyser test benches have been set up to carry out the grid service tests, grid services protocols performed in parts on 3 electrolysers.

FUTURE STEPS & PLANS

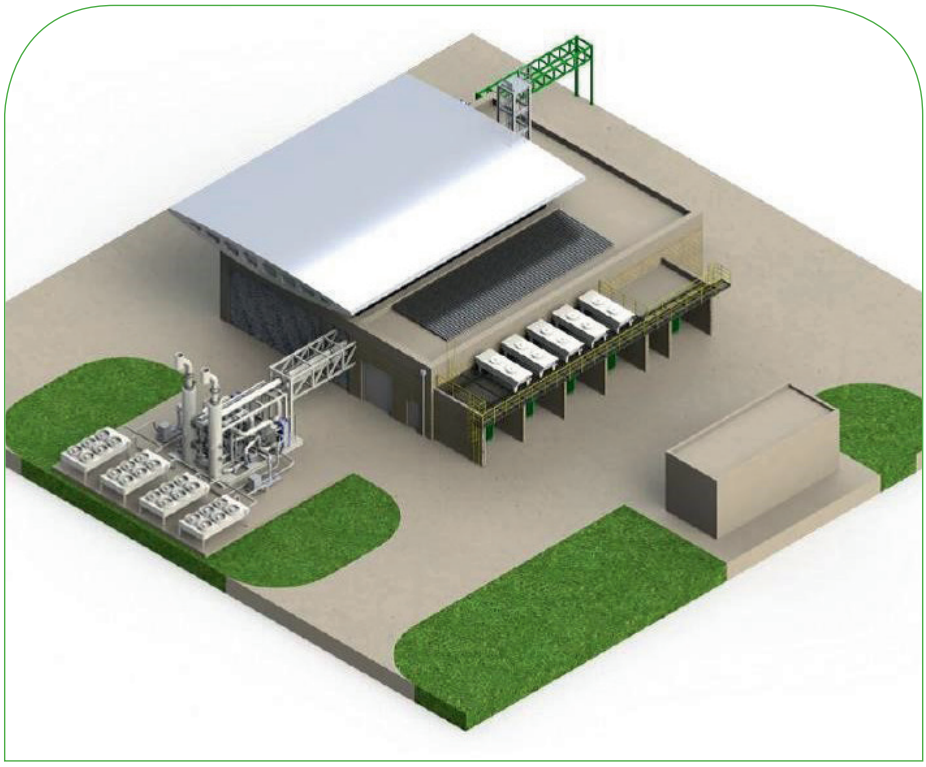
- Electrolyser testing protocols matching a selected grid service, ready for standardisation
- Electrolyser test run complying with developed testing protocol thus in principle being qualified for grid service operation
- Evaluation of business cases and a roadmap for the successful introduction of electrolyser technologies considering energy and grid service market.



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	Number of electrolysers having perfomed test run	N/A	5	Test runs with 3 electrolyser systems up to 300 kW	✗	N/A	N/A
MAWP (2014-2020)	Cost of hydrogen	(€/kg)	4.5-7.0	Cost reduction by performing FCR for certain capacity utilization scenarios can be as high as 10%	N/A	Cost of Hydrogen for mobility 6.70 €/kg status France 2017	2017
AWP 2016	Development of standardized protocols for electrolysers to provide grid Services covering EU countries-	Number of drafts and reviews	3	1	✗	N/A	N/A

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:	**€ 16,058,562.5**
FCH JU max. Contribution:	**€ 9,998,043.5**
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 10MW 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. Commissioning of the system is expected to happen in 2020.

NON QUANTITATIVE OBJECTIVES

- 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 specific analysis focussed at policy makers recommending changes to existing policies
- REFHYNE will produce a detailed assessment of the consenting process for the system and any safety or codes and standards issues encountered.

PROGRESS & MAIN ACHIEVEMENTS

- Finalised detailed engineering of the electrolyser system fulfilling the refinery requirements
- Finalised detailed design of the electrolyser building.

FUTURE STEPS & PLANS

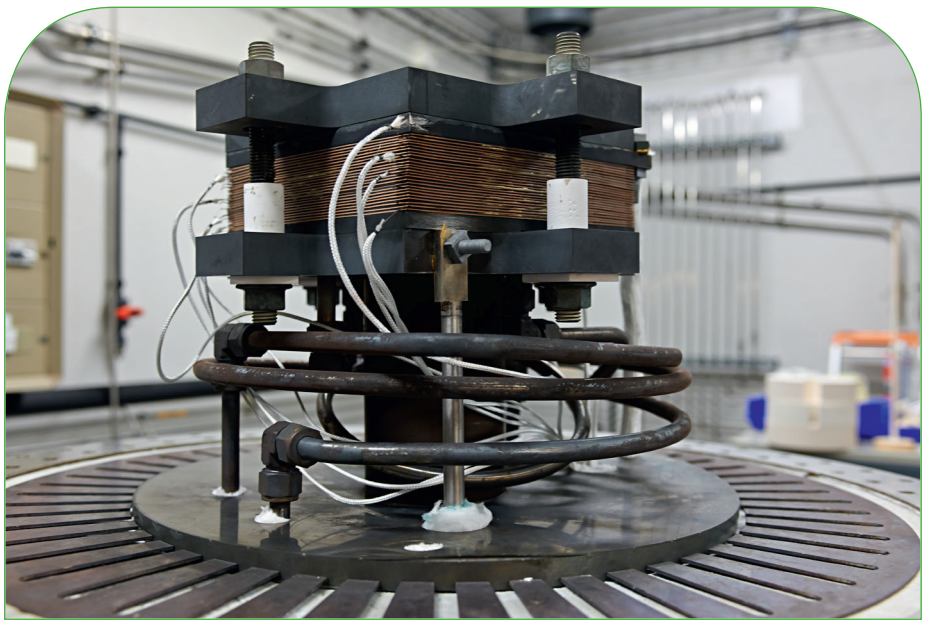
- Demonstration of the 10 MW PEM electrolyser in a refinery setting
- Techno-economic assessment of the electrolyser system and concept
- Environmental analysis of the electrolyser system and concept.

QUANTITATIVE TARGETS AND STATUS

TARGET SOURCE	PARAMETER	UNIT	TARGET	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 @ rated power	kWh/kg	52	Not yet in operation, 54 kWh/kg is expected for the whole system		57-60	2017
	CAPEX, @rated power	M€/(t/d)	2	Not yet built, 2 M€(t/d) expected		8	
	Flexibility with degradation @rated power and considering 8000 hours of operation/year	%	1.5	expected 0.54 %	✗	2-4	
	Flexibility with degradation < 2% per year	%	0-200	expected 0-100%		5-100	
	H_2 production electrolysis, hot start from min to max power	seconds	2	expected 1 sec		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: COMMISSARIAT A L'ENERGIE ATOMIQUE ET AUX ENERGIES ALTERNATIVES, DANMARKS TEKNISKE UNIVERSITET, ENGIE, UNIVERSIDAD DE SEVILLA, PARCO SCIENTIFICO TECNOLOGICO PER LAMBIENTE 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 at developing an innovative renewable energies storage solution, based on reversible Solid Oxide Cell technology, able to operate either in electrolysis mode to store excess electricity to produce H_2, or in fuel cell mode when energy needs exceed local production, to produce electricity and heat again from H_2 or any other fuel locally available.
It integrates improvements of rSOC components (cells, stacks, power electronics, heat exchangers) and system, and the definition of advanced operation strategies. An in-field demonstration will be performed.

NON QUANTITATIVE OBJECTIVES

- Stack modified to achieve high performance in both SOEC and SOFC mode with project cells
- Among different topologies, the best electrical architecture has been selected.

PROGRESS & MAIN ACHIEVEMENTS

- Optimisation of Solid Oxide Cell in order to improve the performance for rSOC operation, and the durability
- Optimisation of the stack design in order to increase the operating window and to include the modified cells
- System design definition and power electronics architecture for modules made of several stacks to reach the best overall efficiency.

FUTURE STEPS & PLANS

- Assemble all components to build the system, manufacture the stacks for the demo system
- Perform long term testing in rSOC operation in lab
- Finalise the site preparation
- Install and operate the system in-field
- Perform the techno-economic analysis and the upscaling study to 1 MWe.

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/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
	Current density in SOFC mode	A/cm²	0.6 at 700°C	0.65	✓	0.4 A/cm² at 700°C	2015
AWP 2017	Power	kW	50 in electrolysis	80 (at the stage of design)	✓ (at the design)	150	2018
	Fuel utilisation	%	80-85	85	✓	70	2015
	Cost	%	System cost increase due to addition hardware for MDLT less than 3%	Evaluation in 2019	✗	N/A	N/A

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 - 01/11/2019
Coordinator:	**FOUNDATION FOR RESEARCH AND TECHNOLOGY HELLAS, EL**
Website:	**selysos.iceht.forth.gr**

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

PROJECT AND OBJECTIVES

SElySOs focuses on understanding of the degradation & lifetime fundamentals on both of the SOEC electrodes, for minimization of their degradation & improvement of their performance and stability mainly under H_2O electrolysis and in a certain extent under H_2O/CO_2 co-electrolysis conditions. The main efforts comprise investigation of: (i) Modified SoA Ni-based cathode cermets, (ii) Alternative perovskite-type cathode materials, (iii) Thorough investigation on the O_2 electrode and (iv) Development of a theoretical model for description of the performance & degradation of the SOEC H_2 electrode.

NON QUANTITATIVE OBJECTIVES

- New materials and component design less prone to degradation. During the 3rd year of SElySOs a series of modified Ni-based & 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.
- Understanding of degradation mechanisms under dynamic operation. Mathematical modelling is under development for both of the SOEC H_2O electrolysis and H_2O/CO_2 co-electrolysis processes.

PROGRESS & MAIN ACHIEVEMENTS

- Development of promising modified Ni-based & Ni-free cathodes and of new air electrodes with improved & "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 & electrochemical modelling of the H_2O & H_2 & CO_2 system by combining theoretical with experimental data, under SOEC operation.

FUTURE STEPS & PLANS

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

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 a 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 a Au-Mo-Ni/GDC modified fuel electrode and LSCoF as air electrode		0.22	
	Decrease of the catalyst (fuel electrode) loading per H_2 capacity	$g/(kgH_2/day)$	N/A	18.5 for a Au-Mo-Ni/GDC modified fuel electrode and LSCoF as air electrode		50.3	