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

PROJECT AND OBJECTIVES

This 'Building Innovative Green Hydrogen Systems in an Isolated Territory' (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 and has been a net exporter of electricity since 2013. Hydrogen is proposed as a solution to minimize the curtailment problems in Orkney, caused by the weak connection with the UK mainland. The hydrogen produced is used in thermal, power (cogeneration) and transport applications locally.

NON QUANTITATIVE OBJECTIVES

- Delivering the Local Authority's Orkney Hydrogen Economic Strategy
- Demonstrating replicable hydrogen economy solutions
- Bringing economic benefits to islands communities
- Improve local public acceptance of hydrogen
- Project Dissemination

PROGRESS & MAIN ACHIEVEMENTS

- HRS in Kirkwall have been already commissioned.
- Main project equipment already built: 5 H2 trailers (250kg H2 storage), H2 catalytic boiler (30 kW), 1 MW electrolyser; 5 H2 FC vans, 75 kW FC (cog)
- System design and detailed planning of sites already finished

FUTURE STEPS & PLANS

- All ground works complete and all equipment commissioned on site
- Data provision of the operation
- Business models, environmental and societal impact studies have been completed
- Exploitation and replicability studies completed and disseminated to the EU H2 community
- Conclusions and lessons learned to the 5 years project - recommendations

RELEVANCE TO FCH JU OVERARCHING OBJECTIVES

Increase the energy efficiency of production of hydrogen mainly from water electrolysis and renewable sources while reducing operating and capital costs

1,5 MW of PEME (2 units of 1MW and 0.5 MW) is directly coupled to 2 wind turbines (900 kW each) and a tidal facility (4MW) producing low price H2 and reducing the local curtailment of RES in the islands.

Demonstrate on a large scale the feasibility of using hydrogen to support integration of renewable energy sources into the energy systems

BIG HIT is the first project using renewable hydrogen (produced by electrolysis using wind and tidal power curtailed) in 3 different local applications: heat, power and transport. BIG HIT aim to increase the energy efficiency in the islands using local renewable energies and hydrogen.

QUANTITATIVE TARGETS AND STATUS

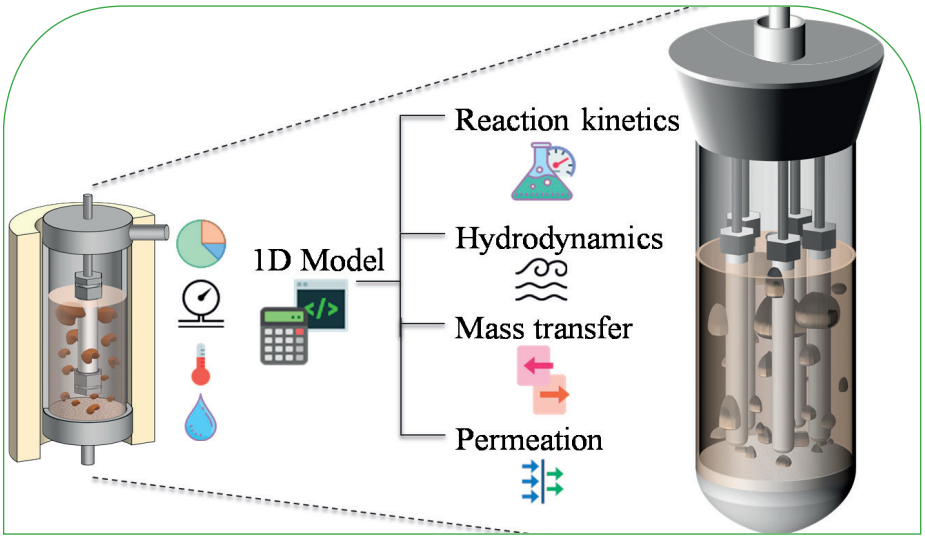
FCH JU Programme Targets*

PARAMETER	UNIT	RESULT ACHIEVED TO DATE	TARGET	TARGET ACHIEVED?	DESCRIPTION
TTW consumption NEDC	kg/100 km	0.6	1.15	✓	Symbio FCEV
FC Durability	hours	5000	5000	✓	Symbio FCEV
Rated system electrical efficiency (LHV)	%	51	42-60	✓	Stationary Unit (cold ironing)
Rated system thermal efficiency (LHV	%	49	24-42	✓	
Stack durability	hours	10,000	50,000	✗	

* As identified in MAWP Addendum 2018-2020, Target Year 2020

BIONICO

BIOGAS MEMBRANE REFORMER FOR DECENTRALIZED HYDROGEN PRODUCTION



Project ID:	**3396640**
Call topic:	**FCH-02.2-2014** - Decentralized hydrogen production from clean CO2-containing biogas
Project total costs:	**€ 3,396,640**
FCH JU max. Contribution:	**€ 3,147,64**
Project start - end:	01/09/2015 - 28/02/2019
Coordinator:	**POLITECNICO DI MILANO, IT**
Website:	**www.bionicoproject.eu**

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

PROJECT AND OBJECTIVES

BIONICO will develop, build and demonstrate at a real biogas plant a novel fluidized catalytic membrane reactor, that allows biogas reforming and hydrogen separation in a single step, increasing overall efficiency (>70%) and decreasing volumes and auxiliary heat management units. Compared with any other membrane reactor project in the past, BIONICO will demonstrate the membrane reactor at a much larger scale, with more than 100 membranes implemented in a single fluidized bed membrane reactor, producing about 100 kg/day of H2. The membrane reactor is currently under construction.

PROGRESS & MAIN ACHIEVEMENTS

- Development + scale up of fluidizable reforming catalysts tolerant to a range of biogas compositions suitable for use in a membrane reforming reactor
- Development of Pd based membranes with ceramic finger-like supports with improved flux and selectivity, suitable for fluidized bed reactors
- Design of the catalytic membrane reactor implementing more than 100 membranes

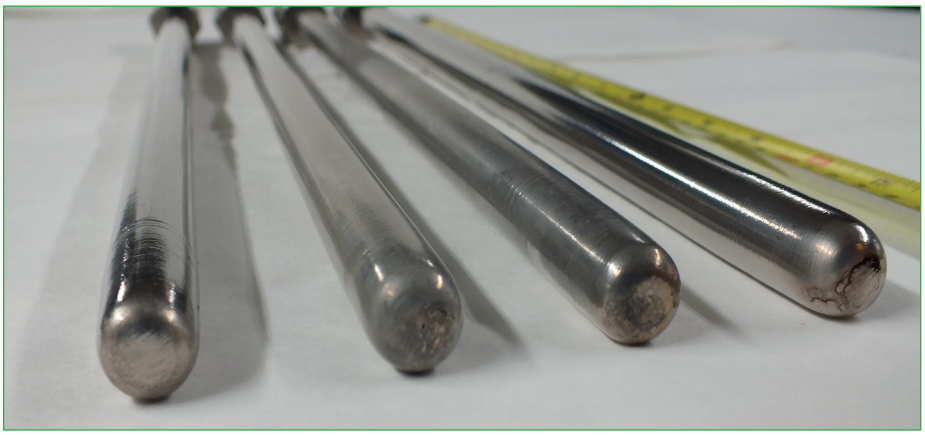
FUTURE STEPS & PLANS

- Assembly of the BIONICO reactor
- Assembly of the BIONICO system (reactor + Membranes + BOP)
- Test of the BIONICO system in the industrial facility of the manufacturer
- Shipping of the BIONICO system to the final installation site
- Installation, integration and testing of the BIONICO system in a real biogas plant

RELEVANCE TO FCH JU OVERARCHING OBJECTIVES

Increase the energy efficiency of production of hydrogen mainly from water electrolysis and renewable sources while reducing operating and capital costs

BIONICO aims at increasing the conversion efficiency from biogas to H2 thanks to process intensification using a fluidised bed catalytic membrane reactor. Hydrogen production and separation occur in a single reactor with advantages in terms of conversion efficiency (target efficiency >70%) and with reduced equipment and thus with reduced CAPEX.



QUANTITATIVE TARGETS AND STATUS

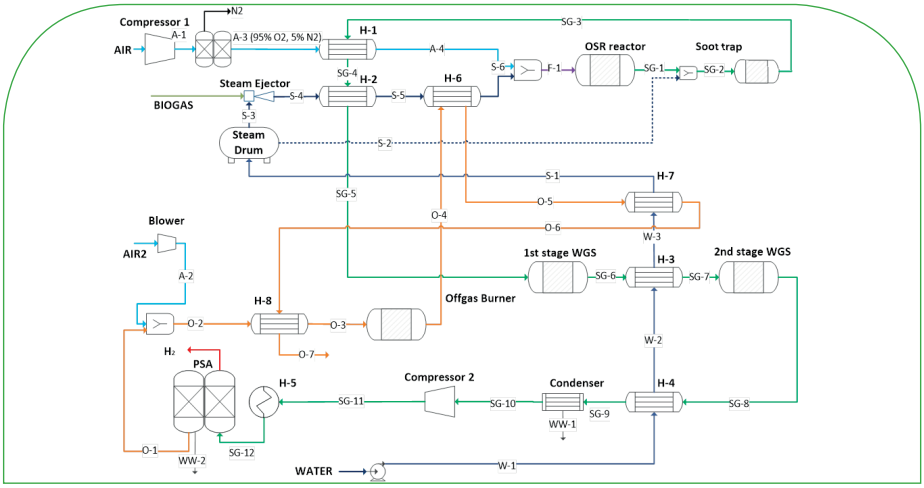
FCH JU Programme Targets*

PARAMETER	UNIT	RESULT ACHIEVED TO DATE	TARGET	TARGET ACHIEVED?	SoA RESULT ACHIEVED TO DATE BY OTHER GROUP/PROJECT (SoA YEAR)
Overall Efficiency	%	71.5	72 (HHV)	✓	40-55 (2015)
Cost of Produced hydrogen	€/kg H2	4.8	N/A	✗	7.2 (2015)

*** As identified in AWP 2014, Target Years 2018-2019**

BIOROBURplus

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



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:	**www.bioroburplus.org**

BENEFICIARIES: ACEA PINEROLESE INDUSTRIALE SPA, CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE CNRS, DBI - GASTECHNOLOGISCHES INSTITUT GGMBH FREIBERG, ENGICER SA, ETHNIKO KENTRO EREVNAS KAI TECHNOLOGIKIS ANAPTYXIS, HYSYTECH SRL, JOHNSON MATTHEY PLC, Karlsruher Institut fuer Technologie, PARCO SCIENTIFICO TECNOLOGICO PER LAMBIENTE ENVIRONMENT PARK TORINO SPA, SCUOLA UNIVERSITARIA PROFESSIONALEDELLA SVIZZERA ITALIANA, UAB MODERNIOS E-TECHNOLOGIJOS

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 CO2. The TRL6 demo-plant will deliver at least 50 Nm3/h (107 kg/day) of H2 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 CO2 removal prior to the PSA.

NON QUANTITATIVE OBJECTIVES

- Development of a compact and cost-effective fuel processor for distributed H2 production, easily scalable
- Dissemination and training activities
- LCA and Market penetration studies
- Manufacturing of support and catalyst coating process.
- Cross-cutting horizontal activities

PROGRESS & MAIN ACHIEVEMENTS

- Two OSR catalyst are being developed in parallel
  Powder scale results have shown good performances
  Innovative and suitable supports
- Technical and economical evaluation of different purification routes. Design of off-gas burner with integrated heat transfer system is in progress
- Preliminary LCA analysis study. Dissemination and training activities

FUTURE STEPS & PLANS

- Optimization of the catalyst coating process.
  Test of structured catalytic support on larger scale under more realistic conditions
- Optimization of the porous burner structure.
  Optimization of the PSA conditions
- CFD simulations results.
  To finish testing of the catalyst for WGS reactors
- LCA and PUEF draft versions to be performed.
  Dissemination and training activities

RELEVANCE TO FCH JU OVERARCHING OBJECTIVES

Increase the energy efficiency of production of hydrogen mainly from water electrolysis and renewable sources while reducing operating and capital costs

The scientific and technological objectives of BioRoburplus clearly addresses this objective, since a complete fuel processor for simply-desulphurised biogas to hydrogen is developed at TRL 6 level, thereby even exceeding the requested TRL 5 owing to the availability in the partnership of a unique test site (ACEA). The Oxidative Steam Reforming technology based on catalysts supported on cellular ceramics, originally proposed and developed in the father project BioRobur, is here employed owing to several potential advantages compared to conventional steam reformer: lower tendency to promote coke formation; fast start-up and shutdown; compactness; easy control, etc.

QUANTITATIVE TARGETS AND STATUS

FCH JU Programme Targets*

PARAMETER	UNIT	RESULT ACHIEVED TO DATE	TARGET	TARGET ACHIEVED?	SoA result achieved to date by other group/project (SoA Year)
Nominal H2 production	Nm3/h	N/A (Phase of testing campaign to be started)		✗	50 Nm3/h with an overall efficiency of the conversion of biogas to green hydrogen of 65%. (2016)
Overall plant efficiency	%	N/A (Phase of testing campaign to be started)	>80	✗	Overall Plant efficiency of 65% for a processor with a a nominal production rate of 50 Nm3/h of hydrogn (2016)
Reformer outlet CO concentration	%	Process design and simulation confirm this values. Target achieved on lab-scale. To be demonstrated at the TRL6 level.	Below 8% on a dry-basis	✓	9.99 (2016)
Cost	€/kg	N/A (Demo-plant development on-going).	< 2	✗	3 €/kg with an amortization time of 10 years (2016)
TRL	N/A	BioRoburplus plant under development. A dedicated TRL6 demo campaign will be performed.	TRL6 level	✗	TRL5 (2016)
Start-up time after stand-by	min	N/A (Phase of testing campaign to be started)	<15 min.	✗	Approx. 1 hour (2016)

*As identified in AWP 2016, Target years 2019- 2020

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

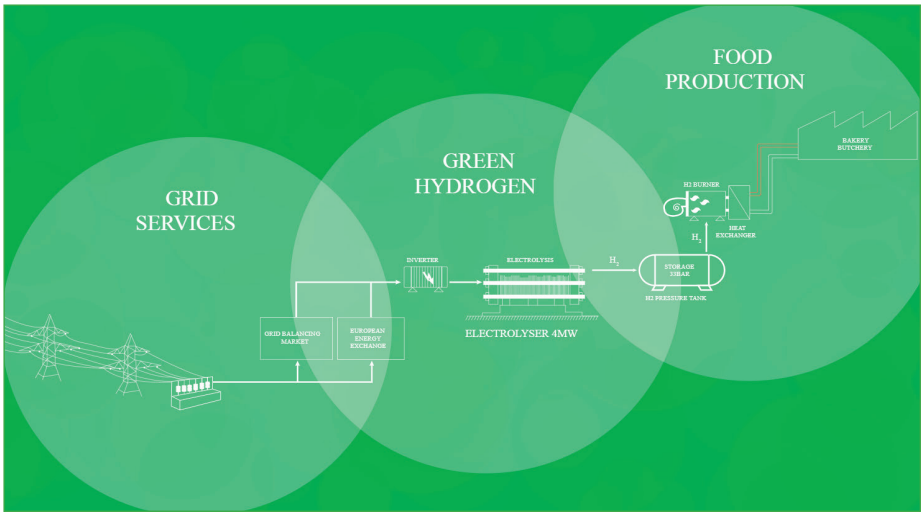
Manufacture and demonstrate an advanced 4 MW single-stack Pressurized Alkaline Electrolysers (PAE) designed for providing grid balancing services. The electrolysis plant will be installed in Völs near Innsbruck. As of 2019, the energy plant will be built and operated in the facilities of MPREIS.

PROGRESS & MAIN ACHIEVEMENTS

- Analysis of technical requirements & Analysis of RCS and safety assessment
- Engineering documents (Electrolyser and C&CS)
- Project website & dissemination tools

FUTURE STEPS & PLANS

- Construction of facilities and permits approval
- The engineering documents to implement the installation have been drafted by IHT and the final version will be executed after the HAZOP workshop
- Adapt the major changes on the Austrian power market and the regulatory energy market on Demo4Grid Business case by the end of 2018
- Demo site commissioning is staring in M2. A 6-month delay (maximum) might be due to the small delays on process design and the integration
- Demo site business operation is staring in M27 according to the initial plan



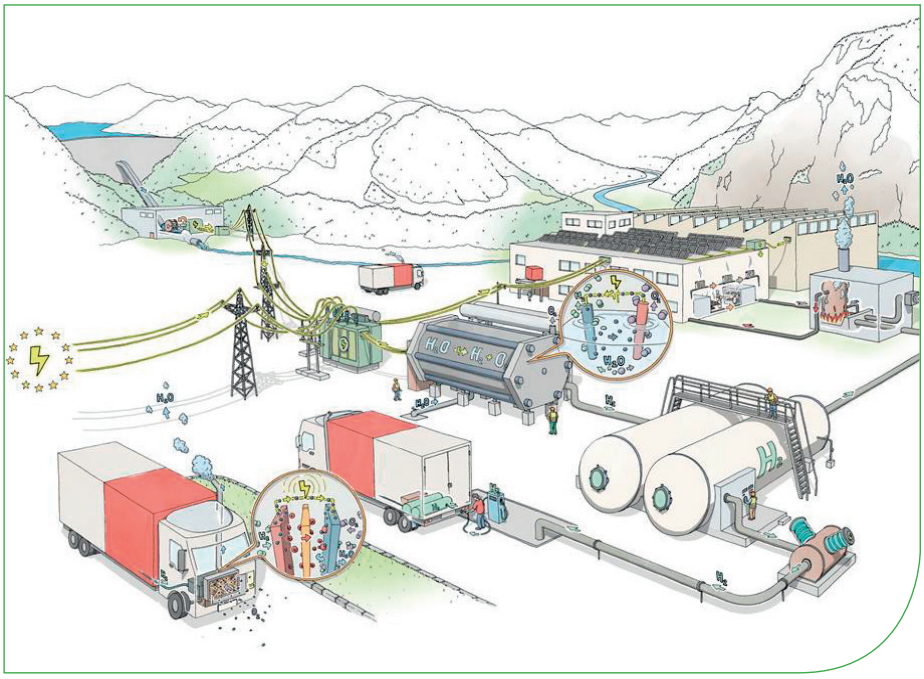
RELEVANCE TO FCH JU OVERARCHING OBJECTIVES

Increase the energy efficiency of production of hydrogen mainly from water electrolysis and renewable sources while reducing operating and capital costs

Manufacture and demonstrate an advanced 4 MW single-stack Pressurized Alkaline Electrolysers (PAE). Demonstrate a PAE system efficiency of 52 kWh/kg H2 (@ 33 bar) in compliance with MAWP 2020 KP 1.

Demonstrate on a large scale the feasibility of using hydrogen to support integration of renewable energy sources into the energy systems

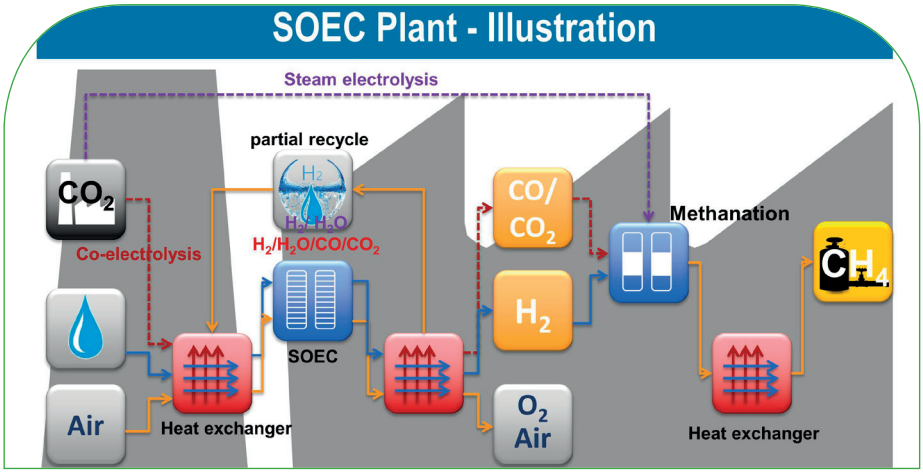
Manufacture and demonstrate an advanced 4 MW single-stack Pressurized Alkaline Electrolysers (PAE) designed for providing grid balancing services. Demo4Grid will strive to demonstrate the appropriate levels of PAE responsiveness in terms of Time Response (i.e. Hot Start, Cold Start), Variable Loads and Ramp up/Ramp-down.



ECo

EFFICIENT CO-ELECTROLYSER FOR EFFICIENT RENEWABLE ENERGY STORAGE - ECO

Project ID:	699892
Call topic:	FCH-02.3-2015 - Development of co-electrolysis using CO2 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: BELGISCH LABORATORIUM VAN DE ELEKTRICITEITSINDUSTRIE, COMMISSARIAT A L ENERGIE ATOMIQUE ET AUX ENERGIES ALTERNATIVES, ECOLE POLYTECHNIQUE FEDERALE DE LAUSANNE, EIFER EUROPAISCHES INSTITUT FUR ENERGIEFORSCHUNG EDF KIT EWIV, ENAGAS, S.A., ENGIE, FUNDACIO INSTITUT DE RECERCA DE L'ENERGIA DE CATALUNYA, HTceramix SA, VDZ gGmbH

PROJECT AND OBJECTIVES

The overall goal of ECo is to develop and validate co-electrolysis of steam & CO2 via solid oxide electrolysis for conversion of renewable electricity into distributable and storable hydrocarbons. Improved SOECs were developed through electrode optimisation. Durability was studied under realistic co-SOEC operating conditions on cells and stacks to benchmark the technology. An SOEC plant was designed and the impact of operating parameters including internal methanation on methane production rate and system efficiency evaluated. Realistic cases were identified & the life cycles analysed.

NON QUANTITATIVE OBJECTIVES

- Understanding high pressure co-electrolysis durability
- Potential practical system-design case studies
- Economic analysis
- LCA

PROGRESS & MAIN ACHIEVEMENTS

- Successful improvement of SoA cells to allow for a lower operating temperature by 50-100 oC; durability studies under relevant conditions
- Environmental benefits shown through LCA of three cases integrating the Eco concept into biomass, biogas, and cement industries
- Co-SOEC plant designed including internal methanation; high pressure & co-electrolysis provide higher system efficiency & methan yield

FUTURE STEPS & PLANS

- Completing test matrix for SoA cells/stacks
- Complete integration of improved cells into stacks and performance/durability validation
- High pressure tests on cell, SRU, and system level for performance and durability
- Measurement of impurities in flue gas (CO2) and study of effect of selected ones on cell performance
- Economic analysis of co-SOEC integrated in plants

RELEVANCE TO FCH JU OVERARCHING OBJECTIVES

Increase the electrical efficiency and the durability of the different fuel cells

The project is related to electrolysis (not fuel cell) application. However, as current SOFCs and SOECs are similar - if not the same - the improvements achieved in the ECo project will most probably also have positive impact on their use in fuel cell mode.

Increase the energy efficiency of production of hydrogen mainly from water electrolysis and renewable sources while reducing operating and capital costs

The project concept is aimed at producing easily distributable and storable hydrocarbons. However, all improvements of the co-SOEC which produces hydrogen and CO, can be utilized for the hydrogen production through SOEC as well. Furthermore, the co-SOEC plant evaluation carried out in the project also considers the cases of steam SOEC vs. co-SOEC and gives thus output about how efficiency and cost situations can be improved, also for hydrogen production through SOEC.

QUANTITATIVE TARGETS AND STATUS

FCH JU Programme Targets*

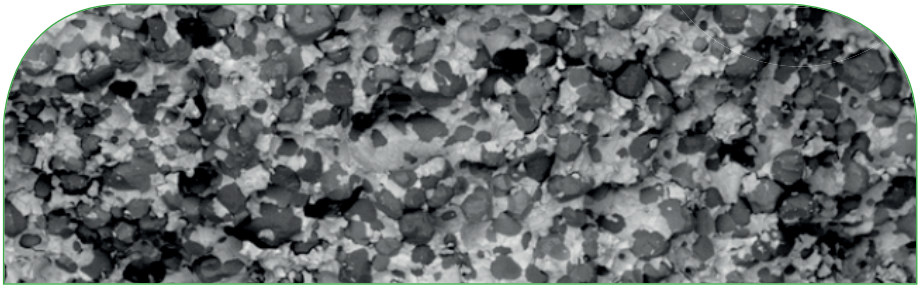
PARAMETER	UNIT	RESULT ACHIEVED TO DATE	TARGET	TARGET ACHIEVED?	DESCRIPTION
Area specific resistance at 750 oC	Ohm cm2	0.2	0.2	✓	Two improved cell version developed in the project more with promising first results
Durability	%/1000 h	1	1.2	✗	The improved cell promised smaller degradation rates, which will be studied in the coming project period
Co-electrolysis performance, temperature for -1.3 A/cm2 at 10 bar	oC	750	800-750	✓	More focus on high pressure tests in the coming project period
Stack: electrical efficiency degradation per 1000 h	%/kh	3	<1	✗	Stack (1)
Stack: electrical efficiency degradation per 1000 h	%/kh	1.3	<1	✗	Stack (2)
Stack: electrical efficiency degradation per 1000 h	%/kh	0.05	<1	✓	Stack (3)

*As identified in AWP 2016 and Project's own objectives, Target years 2019 - 2020

ELECTRA

HIGH TEMPERATURE ELECTROLYSER WITH NOVEL PROTON CERAMIC TUBULAR MODULES OF SUPERIOR EFFICIENCY, ROBUSTNESS, AND LIFETIME ECONOMY

Project ID:	**621244**
Call topic:	**SP1-JTI-FCH.2013.2.4** - New generation of high temperature electrolysers
Project total costs:	**€ 4,007,084.6**
FCH JU max. Contribution:	**€ 2,240,552**
Project start - end:	03/03/2014 - 02/06/2017
Coordinator:	**UNIVERSITETET I OSLO, NO**
Website:	**www.mn.uio.no/smn/english/research/projects/chemistry/electra/index.html**



BENEFICIARIES: ABENGOA HIDROGENO SA, AGENCIA ESTATAL CONSEJO SUPERIOR DE INVESTIGACIONES CIENTIFICAS, COORSTEK MEMBRANE SCIENCES AS, CRI EHF, MARION TECHNOLOGIES S.A., STIFTELSEN SINTEF

PROJECT AND OBJECTIVES

ELECTRA develops a tubular proton ceramic steam electrolyser based on BaZrO3 electrolyte, Ni-cermet hydrogen electrodes, and perovskite oxide steam electrodes. Utilisation of heat and steam to increase efficiency is modelled. Co-electrolysis of CO2 and steam is also investigated. Main research objectives are development of stable steam electrodes, and seals and interconnects for segmented-in-series tubes. The project aimed at demonstration of an 18-tube 1 kW module and ended medio 2017, having reached a majority of objectives except the test of the 1 kW module.

PROGRESS & MAIN ACHIEVEMENTS

- Stable steam electrodes for PCE with low polarisation resistance developed; LSM and LBGC
- Tubular segment run with high efficiency at 4 bar steam
- 1 kW multitubular module for individually monitorable and replaceable tubes designed and constructed

FUTURE STEPS & PLANS

Populating and testing the multitubular module.

RELEVANCE TO FCH JU OVERARCHING OBJECTIVES

Increase the energy efficiency of production of hydrogen mainly from water electrolysis and renewable sources while reducing operating and capital costs

ELECTRA develops stationary steam electrolysers, suing renewable electricity and steam and heat from both combustion and renewable sources (e.g. geothermal and solar-thermal)

QUANTITATIVE TARGETS AND STATUS

State of the Art (SoA)*

PARAMETER	UNIT	RESULT ACHIEVED TO DATE	SoA result achieved to date by other group/ project	SoA YEAR	SoA Source
Cell area	cm2	10	0.5	2015	E.g. Bi, L., Shafi, S. P. & Traversa, E. Y-doped BaZrO3 as a chemically stable electrolyte for proton-conducting solid oxide electrolysis cells (SOECs). Journal of Materials Chemistry A 3, 5815-5819, doi: 10.1039/C4TA07202B (2015). and Babiniec, S. M., Ricote, S. & Sullivan, N. P. Characterization of ionic transport through BaCe0.2 Zr0.7Y0.103-Ð membranes in galvanic and electrolytic operation. International Journal of Hydrogen Energy 40, 9278-9286, doi:https://doi.org/10.1016/j.ijhydene.2015.05.162 (2015)
Operated steam pressure	bar	4	1	2015	e.g. Babiniec, S. M., Ricote, S. & Sullivan, N. P. Characterization of ionic transport through BaCe0.2 Zr0.7Y0.103-Ð membranes in galvanic and electrolytic operation. International Journal of Hydrogen Energy 40, 9278-9286, doi: https://doi.org/10.1016/j.ijhydene.2015.05.162 (2015)
Efficiency	%	83 (MAWP 2020 Target achieved)	60	2012	E.g. Gan, Y. et al. Composite Oxygen Electrode Based on LSCM for Steam Electrolysis in a Proton Conducting Solid Oxide Electrolyser. Journal of The Electrochemical Society 159, F763-F767, doi:10.1149/2.018212jes (2012)
Faradaic efficiency	%	95	90	2015	E.g. Bi, L., Shafi, S. P. & Traversa, E. Y-doped BaZrO3 as a chemically stable electrolyte for proton-conducting solid oxide electrolysis cells (SOECs). Journal of Materials Chemistry A 3, 5815-5819, doi: 10.1039/C4TA07202B (2015)and Matsumoto, H., Sakai, T. & Okuyama, Y. in Pure and Applied Chemistry Vol. 85 427 (2012)
Steam electrode ASR	ohm cm2	0.2	0.2	2013	E.g. Strandbakke, R. et al. Gd- and Pr-based double perovskite cobaltites as oxygen electrodes for proton ceramic fuel cells and electrolyser cells. Solid State Ionics 278, 120-132, doi: http://dx.doi.org/10.1016/j.ssi.2015.05.014 (2015).and Li, S. & Xie, K. Composite Oxygen Electrode Based on LSCF and BSCF for Steam Electrolysis in a Proton-Conducting Solid Oxide Electrolyzer. Journal of The Electrochemical Society 160, F224-F233, doi:10.1149/2.027303jes (2013)

*** Available data provided by the project**

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- 31/03/2019
Coordinator:	**FUNDACION PARA EL DESARROLLO DE LAS NUEVAS TECNOLOGIAS DEL HIDROGENO EN ARAGON, ES**
Website:	**www.eco-soec-project.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. Demonstrative period will take place in Huesca (Spain) and will last 8 months. The progress of the project (13 months of development by 1st May) follows the schedule foreseen.

NON QUANTITATIVE OBJECTIVES

- Development of an overarching control system
- Identification of eventual RCS barriers
- To explore potential uses of H2
- New business model

PROGRESS & MAIN ACHIEVEMENTS

- Steady-state testing of the membrane and stack components at large-scale has been completed
- An in depth assessment of the best options available for the DC/DC conversion linking the PV plant with the stack has been conducted
- One specific business case related to "electrification of isolated areas" has been evaluated through time-step simulations

FUTURE STEPS & PLANS

- Assembly, erection and commissioning scheduled between June and July 2018
- Demonstration period will last from August 2018 until March 2019
- LCA and cost assessment are being developed
- 2 additional business cases will be elaborated
- 3 Technical Workshops will be organized

RELEVANCE TO FCH JU OVERARCHING OBJECTIVES

Increase the energy efficiency of production of hydrogen mainly from water electrolysis and renewable sources while reducing operating and capital costs

This topic is addressed through 1) a direct DC/DC conversion between renewable source (PV) and the stack, and 2) a very efficient PEMWE.

QUANTITATIVE TARGETS AND STATUS

FCH JU Programme Targets*

PARAMETER	UNIT	VALUE	TARGET	TARGET ACHIEVED?
Electrolyser Footprint	m2/MW	180.4	100	✗
Estimated CAPEX of electrolyser @ 100MW annual production scale	EUR/(kg/d)	800	2,000	✓ projection
OPEX @ 10 years	EUR/(kg/d)/yr	350	41	✗
Catalyst at the cathode	mg/W	0.6	1.4	✗
Catalyst at the anode	mg/W	3		

*As identified in MAWP Addendum 2018-2020, Target year 2020

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- 31/08/2018
Coordinator:	**FUNDACION PARA EL DESARROLLO DE LAS NUEVAS TECNOLOGIAS DEL HIDROGENO EN ARAGON, ES**
Website:	**www.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 H2/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. A new membrane has been tested at pilot scale (500 mm) and durability investigated by ASTs under high dynamic profiles.

NON QUANTITATIVE OBJECTIVES

- Communication and control capabilities (C&CS)
- Regulatory framework and end-user requirements
- Business models
- Dissemination of results and exploitation

PROGRESS & MAIN ACHIEVEMENTS

- New advanced materials for AWE developed at pilot scale (420 mm): 2 new membranes and 1 electrode
- Degradation studies under high dynamic profiles carried out at pilot scale, for new advanced membrane (420 mm in size)
- Grid services protocols regarding potential business models defined. Tests to be performed at industrial scale.

FUTURE STEPS & PLANS

- Estimation of durability lifetime under high dynamic profiles finished (2 new membranes + 2 new electrodes)
- Demonstration of real stacks at industrial scale providing grid services (including new advanced membrane)
- Exploitation strategy defined and at least 4 scientific publications accepted
- Design of a MW alkaline water electrolyser, capable of producing with a single stack up to 4.5 t
- LCC assessment defined and including BOP cost optimization

RELEVANCE TO FCH JU OVERARCHING OBJECTIVES

Increase the energy efficiency of production of hydrogen mainly from water electrolysis and renewable sources while reducing operating and capital costs

LCC assessment, BOP cost optimization and development of new advanced materials for AWE are addressed.

Demonstrate on a large scale the feasibility of using hydrogen to support integration of renewable energy sources into the energy systems

Demonstration of real stacks providing grid services will be carried out.

QUANTITATIVE TARGETS AND STATUS

State of the Art (SoA)*

PARAMETER	UNIT	RESULT ACHIEVED TO DATE	TARGET ACHIEVED?	SoA result achieved to date by other group/project
Reduction of CAPEX	M€/(t/d)	< 2.18	✗	2.18 (2014)
Increase of stack size	kW	target for Project 9700 (to be reached)	✗	5300 (2014)
Increase of stack capacity	t/d H2	target for Project 4.5 (to bwe reached)	✗	1.62 (2014)
Efficiency degradation	% year	Not addressed at industrial scale	✗	2 (2014)
Increase of output pressure	bar	30	✗	30 (2014)

*** As identified in MAWP Addendum 2018-2020, Target year 2020**

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/home**

BENEFICIARIES: BOEING RESEARCH & TECHNOLOGY EUROPE S.L.U., EIFER EUROPAISCHES INSTITUT FUR ENERGIEFORSCHUNG EDF KIT EWIV, POLITECNICO DI TORINO, Salzgitter Flachstahl GmbH, SUNFIRE GMBH, Teknologian tutkimuskeskus VTT Oy, Ustav fyziky materialu, Akademie Ved Ceske republiky, v.v.i.

PROJECT AND OBJECTIVES

Central elements of the GrInHy project is the manufacturing and operation of the worldwide most powerful reversible high-temperature steam-electrolyser (HTE) at an integrated iron-and-steel works. The project objectives comprises the targeted electrical system efficiency of > 80 %LHV, the upscaling of the HTE towards a power input of 150 kW AC, the field operation of >7,000 h and degradation tests at stack level of >10,000 h with a degradation rate of <1 %/kh. Since its installation in June 2017, the system reached >5,000 h of operation while proving the reversibility and 3.8 H2 quality.

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

- Start of 7,000 h test operation running the system in various test sequences; more than 5,000 hours already reached
- Proof-of-concept of a continuous hydrogen production meeting the 3.8 quality
- Start of 10,000 h stack testing; more than 8,000 hours already reached

FUTURE STEPS & PLANS

- Completion of system test operation of at least 7,000 h
- Completion of stack testing of at least 10,000 h
- Proof of system robustness for continuous operation with optimized HPU components
- Joint workshop with other FCH2 JU projects about "Route to the Industrialisation of High-Temperature Electrolysis" in September 2018
- Completion of techno-economic studies and elaboration of exploitation and development Roadmap for the SOEC/RSOC towards a marketable product

RELEVANCE TO FCH JU OVERARCHING OBJECTIVES

Increase the energy efficiency of production of hydrogen mainly from water electrolysis and renewable sources while reducing operating and capital costs

Due to a significant energy input in form of steam preferably from industrial waste heat, Steam Electrolysis (StE) achieves outstanding electrical efficiencies of more than 95 %HHV. By consuming less than 40 kWh_el per kilogram without the hydrogen processing (drying and compression), more than 20 % lower costs of operation are possible compared to low temperature electrolysis.

QUANTITATIVE TARGETS AND STATUS

FCH JU Programme Targets*

PARAMETER	UNIT	RESULT ACHIEVED TO DATE	TARGET	TARGET ACHIEVED?	SoA result achieved to date by other group/project (SoA year)	DESCRIPTION
Electrical efficiency	%HHV	92	95	✗	95	Efficiency of the RSOC unit including stacks and BoP components, excluding steam generation and compression
System capacity	kW_AC	154	150	✓	75	Rated AC power in electrolysis Mode. The corresponding power output in Fuel Cell mode is 30 kW_AC.
Lifetime	hours	5,000	7,000	✗	20,000	Expected lifetime of the RSOC unit during test operation. However, the prototype uses a robust design and enhanced cell and stack technology to enable an even longer lifetime.
Lifetime	hours	8,000	10,000	✗	20,000	Expected lifetime of separate stacks during stack testing in lab facilities.
Degradation	%/kh	0.8	1.00	✓	1.0	Voltage Degradation rate at constant temperature in electrolysis mode at 0.5 A/cm² compared to thermo-neutral voltage.
Estimated CAPEX of electrolyser @ 100MW annual production scale	EUR/(kg/d)	1500	4500	✓ Projection achieved	N/A	N/A
Electricity consumption @ nominal capacity	kWh/kg	42.7	40	✓	N/A	N/A

*** As identified in MAWP Addendum 2018-2020, AWP 2015 and Project's own objective, Target years 2018-2020**

H2Future

HYDROGEN MEETING FUTURE NEEDS OF LOW CARBON MANUFACTURING VALUE CHAINS

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:	**€ 1,7823,264.13**
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/technology**

BENEFICIARIES: AUSTRIAN POWER GRID AG, K1-MET GMBH, SIEMENS AKTIENGESELLSCHAFT, SIEMENS AKTIENGESELLSCHAFT OESTERREICH, STICHTING ENERGIEONDERZOEK CENTRUM NEDERLAND, VERBUND TRADING GMBH, VOESTALPINE STAHL GMBH

PROJECT AND OBJECTIVES

H2FUTURE is a European flagship project for the generation of green hydrogen from renewable electricity. Under the coordination of the utility VERBUND, the steel manufacturer voestalpine and Siemens, a technology provider, a large-scale 6 MW PEM electrolysis system will be installed and operated for green hydrogen production and grid services at the voestalpine Linz steel plant in Austria. Further partners are Austrian Power Grid, K1-MET and ECN part of TNO.

NON QUANTITATIVE OBJECTIVES

Industrial integration of green hydrogen production

PROGRESS & MAIN ACHIEVEMENTS

- Construction and operation permit obtained
- Detail engineering for 6MW PEM electrolyser plant performed
- KPIs for pilot tests and quasi-commercial operation defined

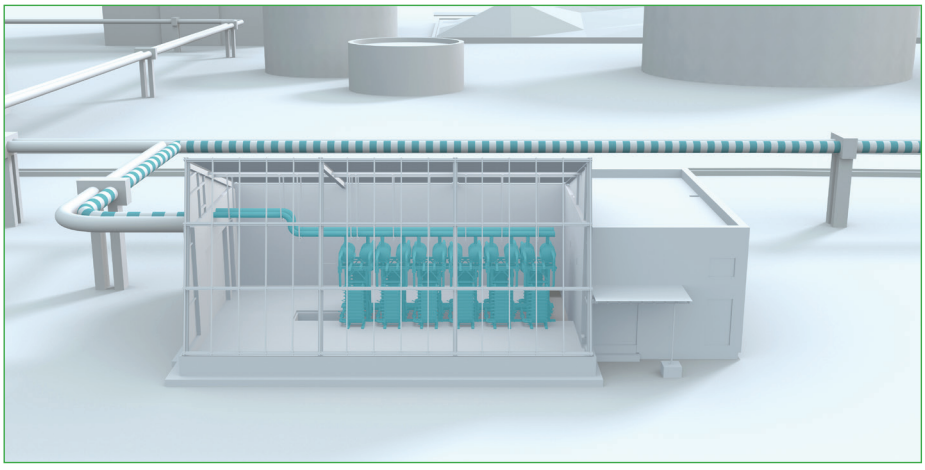
FUTURE STEPS & PLANS

- Commissioning at the beginning of 2019
- Pilot operation with various test scenarios in 2019
- Quasi commercial operation
- Operation for more than 5,000 hours as part of the project
- Accompanying analysis of roll-out and scale-up scenarios

RELEVANCE TO FCH JU OVERARCHING OBJECTIVES

Demonstrate on a large scale the feasibility of using hydrogen to support integration of renewable energy sources into the energy systems

H2FUTURE is currently the largest PEM electrolysis project which is in installation.



QUANTITATIVE TARGETS AND STATUS

FCH JU Programme Targets*

PARAMETER	UNIT	RESULT ACHIEVED TO DATE	TARGET	TARGET ACHIEVED?
Electrolyser Footprint	m2/MW	10	100	✓

*** As identified in MAWP Addendum 2018-2020, AWP 2015 and Project's own objective, Target years 2018-2020**

HELMETH

INTEGRATED HIGH-TEMPERATURE ELECTROLYSIS AND METHANATION FOR EFFECTIVE POWER TO GAS CONVERSION

Project ID:	**621210**
Call topic:	**SP1-JTI-FCH.2013.2.4** - New generation of high temperature electrolysers
Project total costs:	**€ 3,816,612.41**
FCH JU max. Contribution:	**€ 2,529,352**
Project start - end:	01/04/2014 - 31/12/2017
Coordinator:	**Karlsruher Institut fuer Technologie, DE**
Website:	**www.helmeth.eu**

BENEFICIARIES: DVGW DEUTSCHER VEREIN DES GAS- UND WASSERFACHES - TECHNISCH-WISSENSCHAFTLICHER VEREIN EV, ETHOSENERGY ITALIA SPA, European Research Institute of Catalysis A.I.S.B.L., NATIONAL TECHNICAL UNIVERSITY OF ATHENS – NTUA, POLITECNICO DI TORINO, SUNFIRE GMBH

PROJECT AND OBJECTIVES

The objective of the HELMETH project was the proof of concept of a highly efficient Power-to-Gas process by realizing the first prototype that combines a pressurized high temperature steam electrolysis with a CO2-methanation module. The project was completed at the end of 2017, demonstrating efficiencies of 76% on prototype scale and feasibility of efficiencies > 80% for large scale plants. Since the produced SNG was fully compatible with the existing natural gas grid (i.e. H2 <2 vol. %), practically no capacity limitation apply to store energy from fluctuating renewable energy sources.

NON QUANTITATIVE OBJECTIVES

- Manufacture of dedicated HTE cell and stacks for use in large systems
- Develop concepts of HTE for use with renewable energy production
- Develop concepts for pressurised electrolysis for more economical systems
- Test & evaluation of cells, stacks and systems under realistic cond

PROGRESS & MAIN ACHIEVEMENTS

- The main objective of the project to prove the feasibility of an integrated PtG process for highly efficient storage of renewable energy was achieved
- Efficiency of the integrated system of about 76 % (based on HHV) could be achieved. Efficiencies > 80% for scaled-up plants possible
- Further R&D work related to identified technical obstacles (i.e. steam mass flow control) is needed to reach higher Technology Readiness Levels

FUTURE STEPS & PLANS

Project is finished

RELEVANCE TO FCH JU OVERARCHING OBJECTIVES

Increase the energy efficiency of production of hydrogen mainly from water electrolysis and renewable sources while reducing operating and capital costs

The thermal integration of the exothermal CO2 methanation with the high temperature steam electrolyser enables much higher efficiencies (>80%) compared to the state-of-the-art utilizing low temperature electrolysis coupled to methanation.

Demonstrate on a large scale the feasibility of using hydrogen to support integration of renewable energy sources into the energy systems

The feasibility of a highly efficient Power-to-Substitute-Natural-Gas Process was demonstrated.

QUANTITATIVE TARGETS AND STATUS

FCH JU Programme Targets*

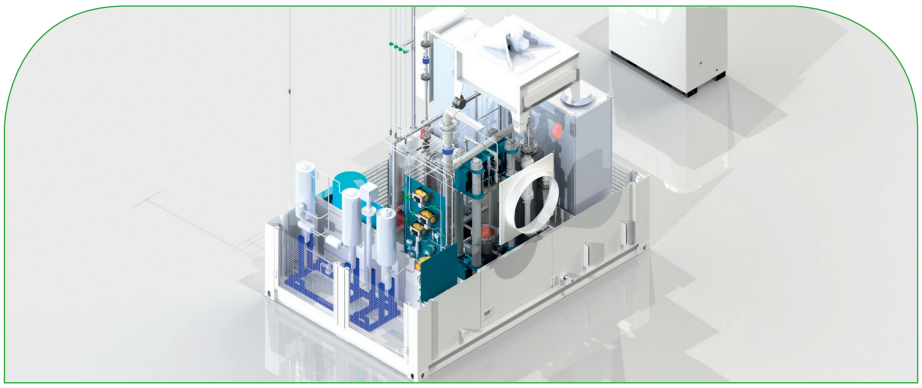
PARAMETER	UNIT	RESULT ACHIEVED TO DATE	TARGET	TARGET ACHIEVED?	SoA result achieved to date by other group/ project (SoA year)	DESCRIPTION
Current density at high-temperature (800-1000°C), pressurized cond.	A/cm²	1.0	1.0	✓	1.0 (2016)	1 A/cm² achieved with cell tests, 0.8 A/cm² at stack level
Degradation rates for short stacks	%/ 1000 h	0.43	0.5	✓	0.23 (2015)	Degradation rates < 0.5%/1000 h indirectly proven (linear extrapolation based on 320 h of tests + plausibility due to previous long term tests)
Conversion efficiencies from electricity to methane	%	76 (prototype) >80 (scale-up)	85	✗	61.8 (2016)	Efficiency of the integrated system of about 76 %HHV based on measurements of the prototype could be achieved. Efficiencies > 80% for scaled-up plants possible
Stack electricity consumption for H2 production	kWh/kg	35.5	40	✓		Electrolyser research at stack level or lower & system level

*As identified in AWP 2013, Target year 2017

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:	**www.hpem2gas.eu**



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

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 will also 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
- Successful demonstration of the electrolysis system in grid balancing
- Final event/demonstration at the field test site

PROGRESS & MAIN ACHIEVEMENTS

- Achievement of operating current density for PEM electrolysis of 3 A/cm^2 at about 80% (HHV) efficiency
- Reduction of total noble metal catalyst loading per MEA to less than 0.5 mg /cm^2
- Development of advanced stack components and design (e.g. Aquivion membranes, stable nanostructured catalysts, advanced stack design)

FUTURE STEPS & PLANS

- New PEM electrolysis technology validated at 180 kW system level with nominal hydrogen production capacity > 80 kg H2/day
- Achieving efficiency better than 82% HHV H2 at system level
- Successful demonstration of the electrolysis system in grid balancing applications

RELEVANCE TO FCH JU OVERARCHING OBJECTIVES

Increase the energy efficiency of production of hydrogen mainly from water electrolysis and renewable sources while reducing operating and capital costs

Efficiency better than 82% HHV H2 at 3 A cm-2 operating current density to reduce capital costs.

Demonstrate on a large scale the feasibility of using hydrogen to support integration of renewable energy sources into the energy systems

Demonstration of the advanced electrolysis system in grid balancing service through a field-testing campaign.

QUANTITATIVE TARGETS AND STATUS

FCH JU Programme Targets*

PARAMETER	UNIT	RESULT ACHIEVED TO DATE	TARGET	TARGET ACHIEVED?	SoA result achieved to date by other group/project (SoA year)	DESCRIPTION
Membrane conductivity for large area membranes	S/cm	0.20	0.25	✗	0.150 (2015)	Solvay Aquivion E98-09S membrane of 90 µm. Proton conductivity is >200 mS/cm-1 at T 80°C in presence of liquid water
Anode over potential vs. thermoneutral potential at 3 A cm-2 less than:	mV	200	200	✓	200 (2015)	lrRuOx solid solutions showed OER over potential of 153 mV, IR-free, at <80 °C and 3 A/cm2 with noble metal loading <0.4 mg/cm2 anode
Cathode over potential vs. , RHE at 3 A cm-2 less than:	mV	50	50	✓	100 (2015)	2 nm Pt/C catalysts showed HER over potential of 65 mV at 80 °C and 3 A/cm 2 with noble metal loading <0.1 mg/cm2
Current density at cell voltage <1.8 V under nominal operation	A/cm2	3	3	✓	N/A (2015)	3 A/cm 2 at 1.81-1.79 V at 80-90 °C, with total noble metal loading per MEA < 0.5 mg/cm2
Maximum Performance at Ucell<2 V under transient operation	A/cm2	4.5	4.5	✓	2 (2015)	4.5 A/cm2 @1.92-1.96 V at 80-90 °C, with total noble metal loading per MEA < 0.5 mg/cm2
Degradation in a 1000 h test	µV/h/cell	5	8	✓	10 (2015)	Degradation lower than 5 µV/h/cell in a 1000 h test in single cell at 3 A cm2
Gas cross over in terms of % H2 in the O2 stream (faradaic efficiency)	%	0.5	0.5	✓	1 (2015)	Achieved at nominal current density
Efficiency (HHV H2)	%	82	80	✓	77 (2015)	Voltage efficiency Achieved at cell and short stack level
Energy consumption	kWh/ kg H2	48	48	✓	52 (2015)	Achieved at cell and short stack level

*Project's own objective, Target year 2019

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:	**€ 15,631,195.73**
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: AIR LIQUIDE GLOBAL E&C SOLUTIONS FRANCE, CEMTEC FONDEN, COPENHAGEN HYDROGEN NETWORK AS, HYDROGENICS EUROPE NV, Ludwig-Boelkow-Systemtechnik GmbH, NEAS ENERGY AS

PROJECT AND OBJECTIVES

HyBalance is a project that demonstrates the use of hydrogen in energy systems. The hydrogen will be produced from water electrolysis, enabling the storage of cheap renewable electricity from wind turbines. It will thus help balance the grid, and the green hydrogen will be used for clean transportation and in the industrial sector. 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.

PROGRESS & MAIN ACHIEVEMENTS

Start-up of the hydrogen production plant

FUTURE STEPS & PLANS

- Nominal operation of the plant
- Hydrogen delivery to industry and transport market
- Demonstrate low electricity price with the help of grid balancing

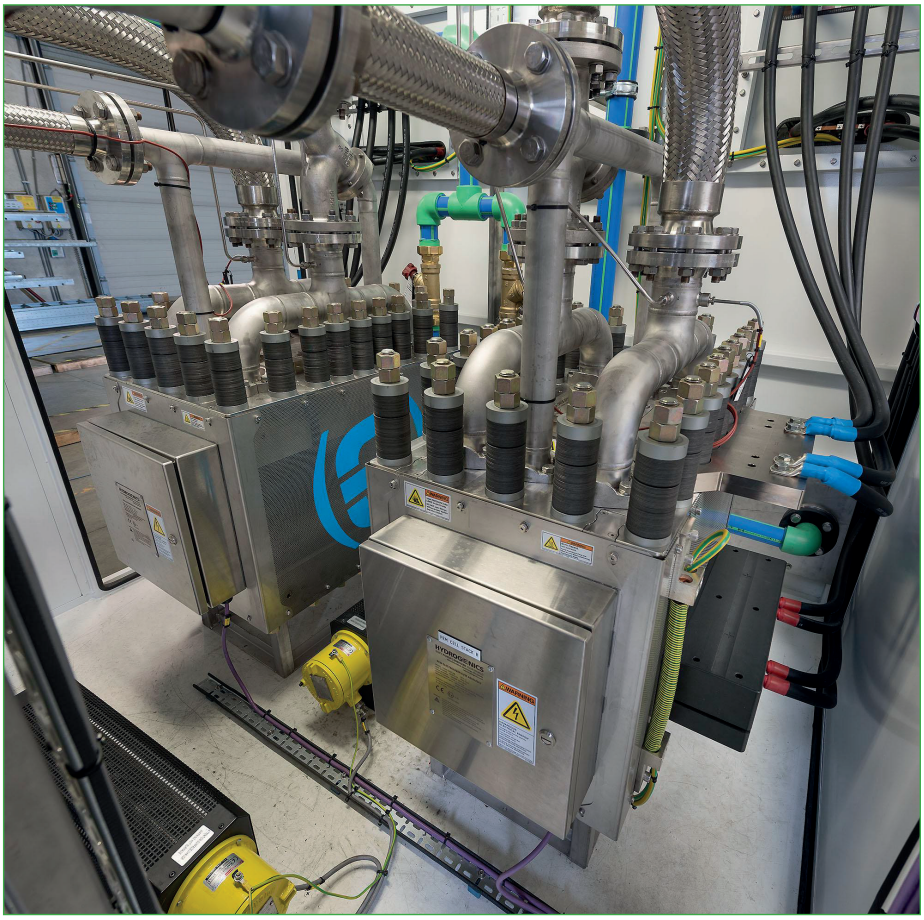
RELEVANCE TO FCH JU OVERARCHING OBJECTIVES

Increase the energy efficiency of production of hydrogen mainly from water electrolysis and renewable sources while reducing operating and capital costs

HyBalance is one step along the road to reduce electrolyser and system costs through upscaling and industrialization of power-to-hydrogen technology.

Demonstrate on a large scale the feasibility of using hydrogen to support integration of renewable energy sources into the energy systems

The operation of the plant is based on electricity spot price arbitration.



QUANTITATIVE TARGETS AND STATUS

FCH JU Programme Targets*

PARAMETER	UNIT	RESULT ACHIEVED TO DATE	TARGET	TARGET ACHIEVED?
KPI - Electrolyser Footprint	m2/MW	45	100	✓

*Project's own objective, Target year 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:	www.hydrosol-plant.certh.gr

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

PROJECT AND OBJECTIVES

Within the HYDROSOL-PLANT project (SP1-JTI-FCH.2012.2.5/ Contract No: 325361) the development and operation of a plant for solar thermoÐchemical 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 H2O 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
- Development of real size components

PROGRESS & MAIN ACHIEVEMENTS

- Durability testing of structured redox material for over 1000 h of consecutive water splitting and thermal reduction
- Achieved hydrogen production exceeding 3kg/week at the laboratory scale
- Completed construction and integration of the 750kWth solar reactors and peripherals on the solar platform. The largest solar redox reactors to date

FUTURE STEPS & PLANS

- Project is finished
- Successful operation of the platform up to 1400C. Until the date of collection of these data, only thermal tests up to 900C were achieved.
- Successful operation of the platform in hydrogen production mode. Until the date of collection of these data only thermal tests were implemented.
- Minimization of consumption of N2 during the thermal reduction step
- Successful and efficient heat recovery

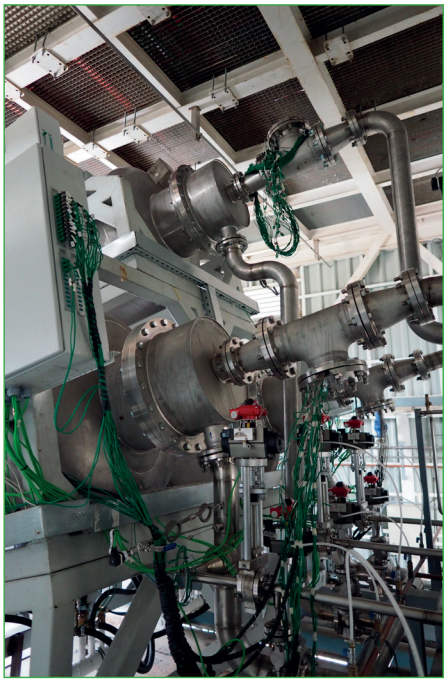
RELEVANCE TO FCH JU OVERARCHING OBJECTIVES

Increase the energy efficiency of production of hydrogen mainly from water electrolysis and renewable sources while reducing operating and capital costs

Project activities contribute in the exploitation of entirely renewable sources for the production of hydrogen from water and solar energy.

Reduce the use of the EU defined 'Critical raw materials'

No critical raw materials are used in the process.



QUANTITATIVE TARGETS AND STATUS

State of the Art (SoA)*

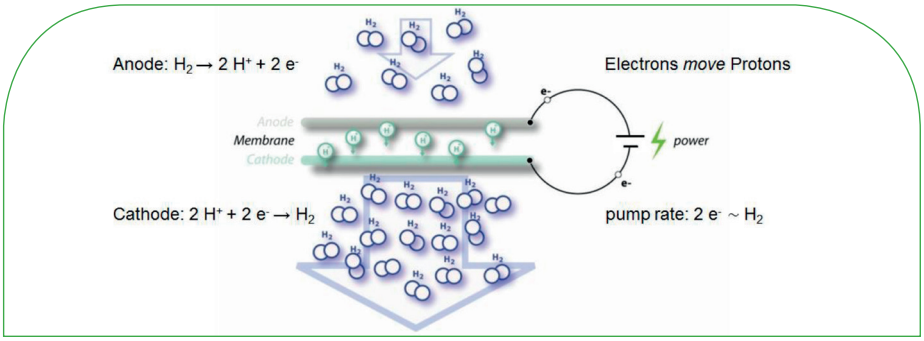
PARAMETER	UNIT	RESULT ACHIEVED TO DATE	SoA result achieved to date by other group/ project	SOA YEAR	SOA Source
Evaluation of material after multiple cyclic operation	hours	1000	283	2010	Chueh W.C., Falter C., Abbott M., Scipio D., Furler P., Haile S.M., Steinfeld A. (2010), Science, 330 (6012), pp. 1797–1801
H2 production	ml/g	7.35	4.6	2010	Chueh W.C., Falter C., Abbott M., Scipio D., Furler P., Haile S.M., Steinfeld A. (2010), Science, 330 (6012), pp. 1797–1801
Maximum H2 production rate	ml/min/g	0.45	0.1	2014	Kawakami S., Myojin T., Cho H.-S., Hatamachi T., Gokon N., Kodama T. (2014),Energy Procedia, 49, pp. 1980-1989
Solar hydrogen generator in a demonstration range Ø 0.5-2 MW scale	kW	750	100	2006	HYDROSOL II Project ID: 20030 Funded under: FP6-SUSTDEV http://cordis.europa.eu/result/rcn/47004_en.html

* Available data provided by the project

HyGrid

FLEXIBLE HYBRID SEPARATION SYSTEM FOR H2 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:	**€ 2,847,710**
FCH JU max. Contribution:	**€ 2,527,710**
Project start - end:	01/05/2016 - 30/04/2019
Coordinator:	**TECHNISCHE UNIVERSITEIT EINDHOVEN, NL**
Website:	**www.hygrid-h2.eu/**



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

PROJECT AND OBJECTIVES

The objective of the HyGrid project is to design, scale-up and demonstrate 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/kgH2 and < 1.5 €/kgH2, and a pilot designed for >25 kg/day of hydrogen production.

NON QUANTITATIVE OBJECTIVES

- Traineeships of students at TUE
- Membrane characterization (Tecnalia and TUE)
- Small scale EHP manufacturing and testing (HYET and TUE)

PROGRESS & MAIN ACHIEVEMENTS

- Palladium based membranes, carbon membranes and sealing for hydrogen separation with the recovery of hydrogen from low concentration streams developed
- A transient model for the TSA has been developed and the pilot scale TSA is now built
- A lab-scale EHP has been tested and used to validate the model and currently a pilot-scale EHP is under construction.

FUTURE STEPS & PLANS

- Simulate different configuration options to deliver a higher amount of H2 and purity within the target cost
- Proof of concept of the EHP system
- Technical economic assessment and optimization of the complete HyGrid system
- Finalize the delayed membrane module manufacturing
- Building the prototype of the HyGrid system

RELEVANCE TO FCH JU OVERARCHING OBJECTIVES

Increase the electrical efficiency and the durability of the different fuel cells

Stack characterizations under selected conditions (i.e. fuel impurities, humidity, pressures, flowrates....) is useful to improve system management (positive impact at least on efficiency).

Demonstrate on a large scale the feasibility of using hydrogen to support integration of renewable energy sources into the energy systems

HyGrid technology could provide a means of transporting/storing the produced hydrogen from peak of renewable energy or any other means by blending it to the natural gas grid and then separate it using the HyGrid technology at different sites.

QUANTITATIVE TARGETS AND STATUS

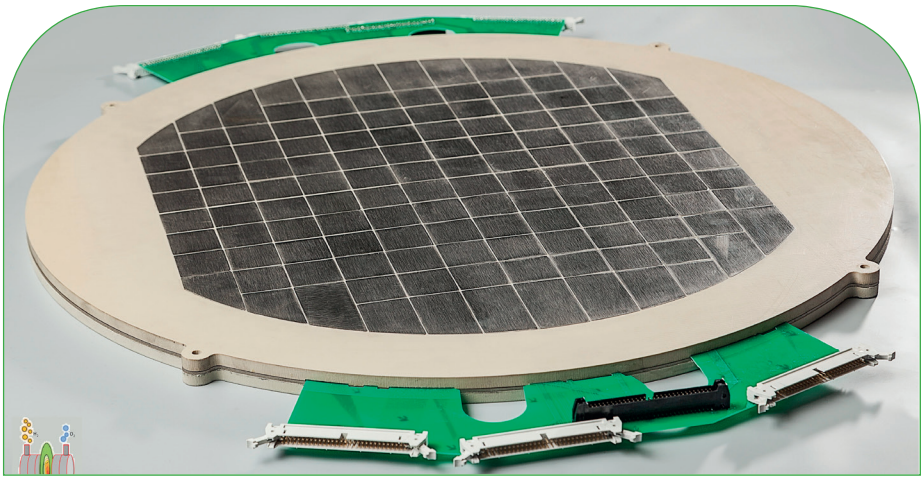
FCH JU Programme Targets *

PARAMETER	UNIT	TARGET	TARGET ACHIEVED	SoA result achieved to date by other group/ project	DESCRIPTION
Ideal selectivity	N/A	More than 10,000	✓	N/A	Development of ultra-thin Pd based membranes with selectivity (H2/CH4) ≥ 10.000 and H2 Permeance ≥ 10 x10E-7 mol m-2 s-1 Pa-1 calculated at ΔPH2 0.8 atm. Out of the tested membranes at the lab scale, few membranes achieved the specified targets
membrane H2 permeance	mol/ (m^2*s*Pa)	≥ 10 x10E-7		N/A	
Length of the membrane	cm	40-45 cm	✓	N/A	Development of long (40-45 cm) with membrane surface area of 1.26 m2 and mechanically stronger H2 selective membranes
Flow rate	Kg/day	25	🛠	N/A	A pilot scale membrane module for a hydrogen flow rate of more than 25 kg/day is under construction.
Recovery rate of H2	%	60	✓	30	Development of an electrochemical hydrogen separation compressor for low concentration stream (less than 3%) with recovery rate of 60%
Energy consumption	kWh/kgH2	4	✓	6	An electrochemical hydrogen separation compressor for low concentration stream with power consumption of lower than 5 kWh/kgH2 has been achieved
Cost	€/kgH2	less than 1.5	🛠	N/A	Manufacturing of a hybrid H2 separation, from a low hydrogen concentration stream of natural gas grid, prototype for 25 kg/day of H2 production. The preliminary cost analysis has been performed and the cost is a little bit more than what we anticipated at the beginning but further optimization in the configuration is now being carried out to fulfil the target
HRF (hydrogen recovery factor)	%	85	🛠	N/A	Overall hydrogen recovery factor of the HyGrid system
Purity	%	99.97	🛠	N/A	Overall purity of the separated hydrogen of the HyGrid system. The prototype has not yet been constructed

*Project's own objective (DoW), Target year 2019

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:	www.inside-project.eu

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

PROJECT AND OBJECTIVES

The development of diagnostics tools for three independent technologies for water electrolysis with individual properties is pursued: PEMWE, AWE, and AEMWE. The tool provides in-operando data from inside the electrolyser systems. It is based on an existing technology, which has been successfully used in the research on polymer electrolyte fuel cells. The aim is to use these diagnostics tools for online monitoring with the possibility for online adaptation of operational parameters, and for the prevention of hazardous operation modes while optimising the overall performance.

NON QUANTITATIVE OBJECTIVES

- Evaluation and verification of normal and accelerated test protocols
- Recommendation for improvements of water electrolysers

PROGRESS & MAIN ACHIEVEMENTS

- Prototype diagnostics hardware for PEMWE designed, manufactured, integrated and evaluated Enhancement in progress
- Prototype diagnostics hardware for AEMWE designed, manufactured, integrated and evaluated Enhancement in progress
- Prototype diagnostics hardware for AWE designed and manufactured. Integration and Evaluation pending

FUTURE STEPS & PLANS

- Evaluation of enhanced prototype for PEMWE
- Integration and Evaluation of prototype for AWE
- Evaluation of enhanced tools for AEMWE
- Evaluation of ASTs
- Public workshop on results and recommendations in Sept 2018

RELEVANCE TO FCH JU OVERARCHING OBJECTIVES

Increase the energy efficiency of production of hydrogen mainly from water electrolysis and renewable sources while reducing operating and capital costs

Indirectly: Project outcomes (operando Monitoring and diagnostics) contribute to more targeted development and to intelligent Operation of Water electrolysers.

QUANTITATIVE TARGETS AND STATUS

FCH JU Programme Targets*

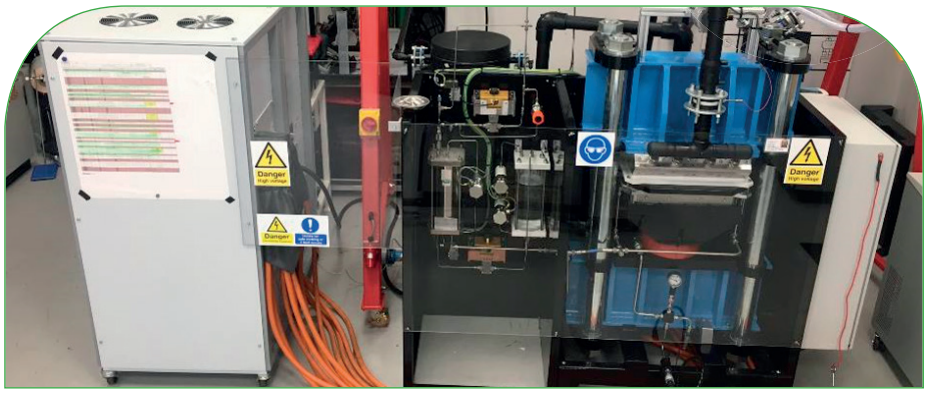
PARAMETER	UNIT	TARGET ACHIEVED	SoA result achieved to date by other group/project (SoA year)	DESCRIPTION
Diagnosis/monitoring tool availability	%	✓	2-dimensional current density monitoring was demonstrated in lab cell and industrial electrolyser /Current density monitoring was demonstrated in lab cell and industrial electrolyser (2015-2016)	Available for PEMWE electrolysis
Diagnosis/monitoring tool availability	%	⚒	N/A	Under commission
Diagnosis/monitoring tool availability	%	✓	Current density monitoring was demonstrated in industrial electrolyser	Available for AEMWE electrolysis
Evaluation and verification of normal and accelerated test protocols	N/A	⚒	N/A	Due later. Main objectives enable evaluation of test protocols. Test protocols to start with have been designed.
Recommendation for improvements of water electrolysers	N/A	⚒	N/A	

* As identified in MAIP 2008-2013 and project's own objective, Target year 2018

Megastack

STACK DESIGN FOR A MEGAWATT SCALE PEM ELECTROLYSER

Project ID:	**621233**
Call topic:	**SP1-JTI-FCH.2013.2.3** - Large capacity PEM electrolyser stack design
Project total costs:	**€ 3,912,286**
FCH JU max. Contribution:	**€ 2,168,543**
Project start - end:	01/10/2014 - 30/09/2017
Coordinator:	**STIFTELSEN SINTEF, NO**
Website:	**www.megastack.eu**



BENEFICIARIES: COMMISSARIAT A L ENERGIE ATOMIQUE ET AUX ENERGIES ALTERNATIVES, FRAUNHOFER-GESELLSCHAFT ZUR FOERDERUNG DER ANGEWANDTEN FORSCHUNG E.V, ITM POWER (TRADING) LIMITED

PROJECT AND OBJECTIVES

The main objective of MEGASTACK is to develop a cost efficient stack design for MW sized PEM electrolysers and to construct and demonstrate a prototype of this stack. The prototype will demonstrate a capability to produce hydrogen with an efficiency of at least 75% (HHV) at a current density of 1.2 Acm-2 with a stack cost below €2,500/Nm3h-1 and a target lifetime in excess of 40,000 hours (< 15 µVh-1 voltage increase at constant load). In the project we aim to take advantage of the existing PEM electrolyser stack designs of ITM power as well as novel solutions in the low-cost stack design.

PROGRESS & MAIN ACHIEVEMENTS

- MW stack design successfully completed and prototype manufactured
- Multiphysics models developed for simulation of flow distribution and stack performance
- Improved understanding of two-phase flow and wetting properties in porous transport layers, including several new measurement methods developed

FUTURE STEPS & PLANS

- Dissemination of Project results
- Prototype demonstration and commercialisation

RELEVANCE TO FCH JU OVERARCHING OBJECTIVES

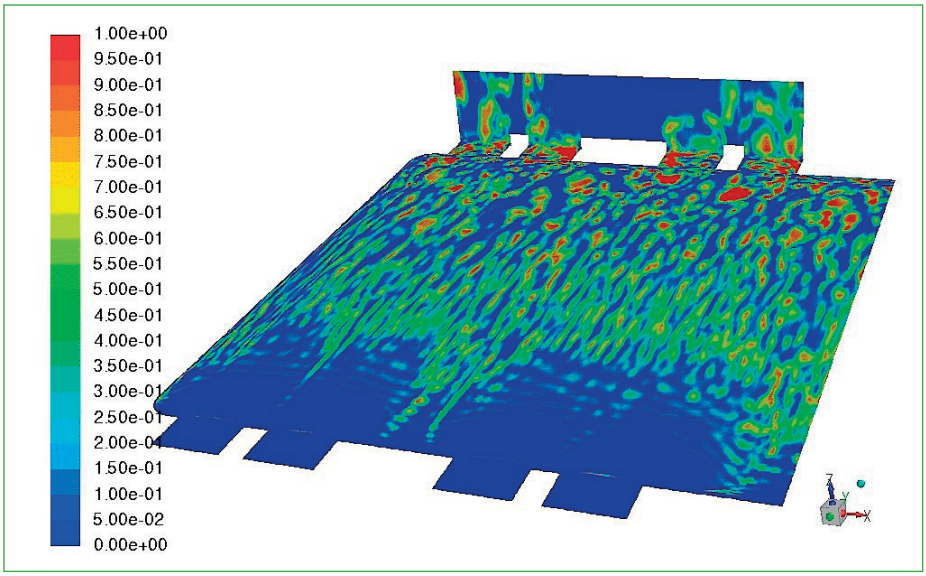
Increase the energy efficiency of production of hydrogen mainly from water electrolysis and renewable sources while reducing operating and capital costs

For large scale demonstration of hydrogen from renewables it is important to have cost effective electrolysers which megastack contributes to.

Demonstrate on a large scale the feasibility of using hydrogen to support integration of renewable energy

sources into the energy systems

For large scale demonstration of hydrogen from renewables it is important to have cost effective electrolysers which megastack contributes to.



QUANTITATIVE TARGETS AND STATUS

FCH JU Programme Targets*

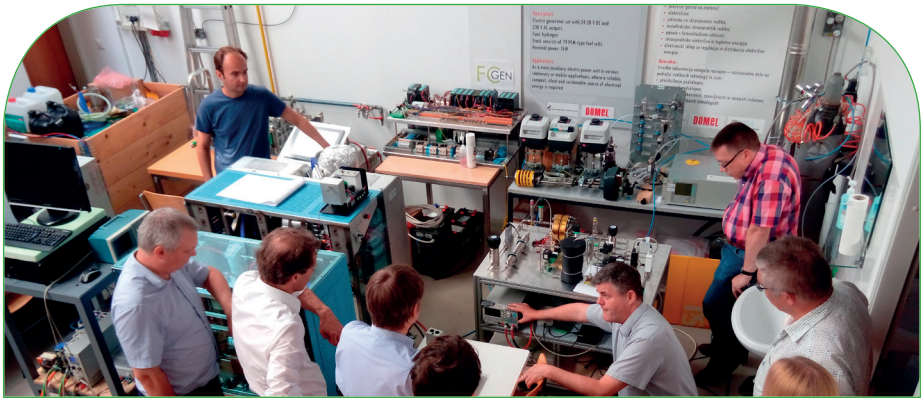
PARAMETER	UNIT	TARGET	TARGET ACHIEVED?
Stack electricity consumption for H2 production	kWh/kg	50	✓
Current density	A/cm²	0.7	✓
Efficiency degradation per 1000 h for LT Electrolyser	%/1000h	0.12	✓
Cathode catalyst loading per W	mg/cm2	3.4	✗
Anode catalyst loading per W	mg/cm2		

*As identified in MAWP Addendum 2018-2020, Target year 2020

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:	**DUALE HOCHSCHULE BADEN-WURTTEMBERG, DE**
Website:	**www.memphys.eu**



BENEFICIARIES: BORIT NV, FORSCHUNGSZENTRUM JULICH GMBH, HYET HYDROGEN BV, IMPERIAL COLLEGE OF SCIENCE TECHNOLOGY AND MEDICINE, INSTITUT JOZEF STEFAN

PROJECT AND OBJECTIVES

Project MEMPHYS, MEMbrane based Purification of HYdrogen System, targets the development of a stand-alone 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 H2/day system with an energy consumption < 5 kWh/kg H2, a hydrogen recovery rate of > 90 %, producing high purity hydrogen at a system cost of < 1,500 €/kgH2/day with an output pressure of 200 bar. The project is now at the end of the first half.

PROGRESS & MAIN ACHIEVEMENTS

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

FUTURE STEPS & PLANS

Purification and Compression in one step shall be realized with the EHP stack.

RELEVANCE TO FCH JU OVERARCHING OBJECTIVES

Increase the energy efficiency of production of hydrogen mainly from water electrolysis and renewable sources while reducing operating and capital costs

Hydrogen can be produced by biomass and with the MEMPHYS system we are able to clean and compress the hydrogen in one step.

QUANTITATIVE TARGETS AND STATUS

FCH JU Programme Targets*

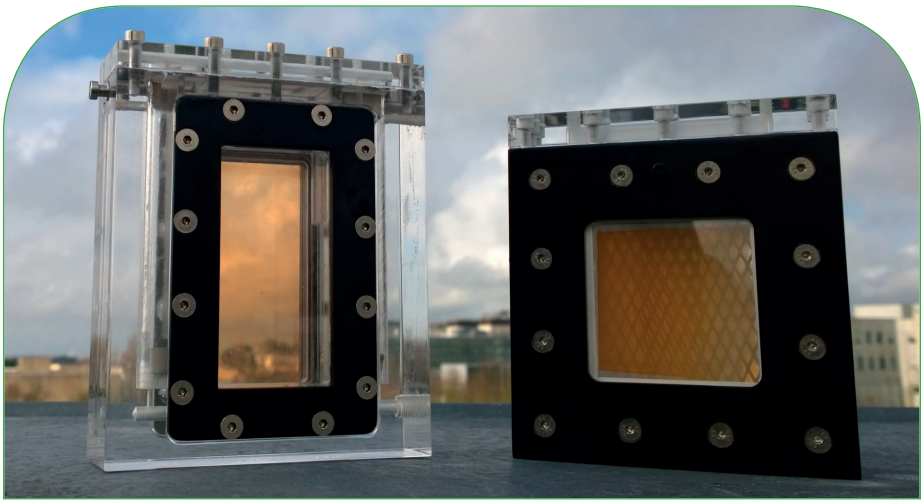
PARAMETER	UNIT	RESULT ACHIEVED TO DATE	TARGET	TARGET ACHIEVED	SoA result achieved to date by other group/project (SoA year)	DESCRIPTION
Energy Consumption of EHP Stack	kWh/kg H2	3	9.8	✗	N/A	energy consumption at the maximum reachable recovery rate of the stack
Recovery Rate EHP Stack	%	>90	78	✓	99 (2017)	N/A
Recovery Rate Single Cell	%	>90	>90	✓		N/A
Energy Consumption at Targeted Recovery Rate	kWh/kg H2	3	5	✓	N/A	For Single Cell

*** Project's own objective, Target year 2019**

PECDEMO

PHOTOELECTROCHEMICAL DEMONSTRATOR DEVICE FOR SOLAR HYDROGEN GENERATION

Project ID:	**621252**
Call topic:	**SP1-JTI-FCH.2013.2.5** - Validation of photoelectrochemical hydrogen production processes
Project total costs:	**€ 3,337,682.79**
FCH JU max. Contribution:	**€ 1,830,644**
Project start - end:	01/04/2014- 31/03/2017
Coordinator:	**HELMHOLTZ-ZENTRUM BERLIN FUR MATERIALIEN UND ENERGIE GMBH, DE**
Website:	**www.pecdemo.eu**



BENEFICIARIES: DEUTSCHES ZENTRUM FUER LUFT - UND RAUMFAHRT EV, ECOLE POLYTECHNIQUE FEDERALE DE LAUSANNE, EVONIK INDUSTRIES AG, SOLARONIX SA, TECHNION ISRAEL INSTITUTE OF TECHNOLOGY, UNIVERSIDADE DO PORTO

PROJECT AND OBJECTIVES

PECDEMO's main aim was to develop a photo electrochemical water splitting device based on low-cost and abundant materials that shows a solar-to-hydrogen efficiency of 10%, a stability of 1000 hours, and an area of at least 50 cm2. PECDEMO has addressed the challenges by focussing its efforts on three metal oxide photo electrode materials (Fe2O3, BiVO4, and Cu2O) and by combining them with a silicon- or halide perovskite-based photovoltaic cell in a tandem configuration. The highest solar-to-H2 efficiency achieved was 9.2% for BiVO4 combined with Fe2O3, the best stability was 1000 hours for Fe2O3.

NON QUANTITATIVE OBJECTIVES

- Dissemination and Outreach
- Staff exchange
- Management of IP

PROGRESS & MAIN ACHIEVEMENTS

- Solar-to-H2 efficiencies of 9.2% (HHV) for dual BiVO4/Fe2O3 photoanode in combination with Si heterojunction cell as bottom absorber
- A record stability of 1000 h was shown for Fe2O3 photoanodes
- Largest photo electrochemical metal oxide/silicon-based tandem cell ever reported (50 cm2)

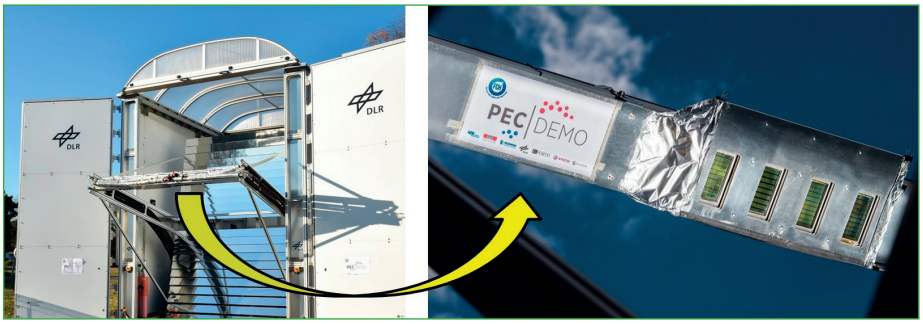
FUTURE STEPS & PLANS

Project is finished.

RELEVANCE TO FCH JU OVERARCHING OBJECTIVES

Demonstrate on a large scale the feasibility of using hydrogen to support integration of renewable energy sources into the energy systems

We achieved a ~2 orders of magnitude increase in scale for a photo electrochemical cell (from < 1 cm2 to 50 cm2).



QUANTITATIVE TARGETS AND STATUS

FCH JU Programme Targets

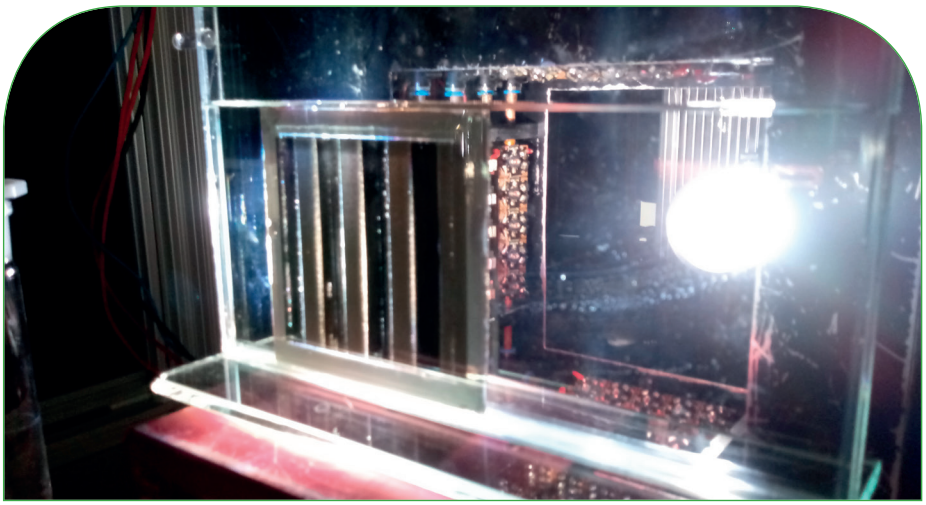
PARAMETER	UNIT	VALUE	TARGET	TARGET ACHIEVED?	DESCRIPTION
Hours of operation - cumulative	hours	1263	1000	✓	Cumulative hours for concentrated and non-concentrated (lab-scale) systems
Conversion efficiency @ start of timeframe	%	0.42 (9.2 in lab)	8	✓ (only in lab)	Outdoor test under concentrated sunlight (note: best efficiency in lab was 9.2%)

*As identified in AWP 2013, Target year 2017

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:	**www.helmholtz-berlin.de/projects/pecsys**



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

PROJECT AND OBJECTIVES

The PECSYS project aims to demonstrate a system for solar driven electrochemical hydrogen generation with an area of at least 10 m2. Initial device concepts for PV-electrochemical cell integration have been developed so that under hot temperatures, improvements in the electrochemical process overcompensate the reduced PV conversion efficiency. The concepts with the highest hydrogen production and long term stability shall be selected scaled to prototypes of at least 100 cm2. A technical economic and life cycle analysis study shall be used to select the technology used in the demonstrator.

NON QUANTITATIVE OBJECTIVES

- Interaction between partners
- Increase public awareness of hydrogen production from renewable energy sources

PROGRESS & MAIN ACHIEVEMENTS

- 12.78% STH in a lab-scale CIGS-water splitting module using non-precious catalysts under alkaline conditions
- 20 cm^2 PEM cell using 0.4 mgIr/cm^2 and 0.1 mgPt/cm^2 catalyst loadings with optimized design and operating conditions validated in outdoor test.
- 7.5% active area STH in a lab-scale thin-film-silicon water splitting module with scalable design using nickel based catalysts in alkaline conditions

FUTURE STEPS & PLANS

- By 31 Dec 2018: integrated concepts on at least 100 cm^2 with long term stability developed
- By 31 Dec 2018: Technical economic study used to choose demonstrator concept
- September 2019: Modules (each 1 m^2 or larger) for demonstrator fabricated
- December 2019: demonstrator mounted and initial tests done. By Oct 2017 validation of 6 months operation
- Efforts shall be made to catch-up the delay in implementing a crystalline silicon based integrated device to achieve milestone 1 by the end of 2018

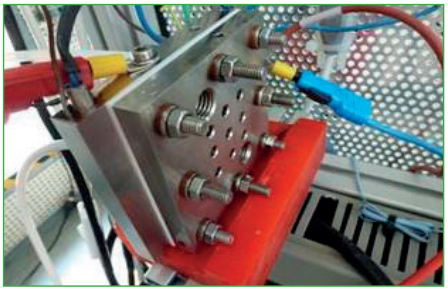
RELEVANCE TO FCH JU OVERARCHING OBJECTIVES

Increase the energy efficiency of production of hydrogen mainly from water electrolysis and renewable sources while reducing operating and capital costs,

The PV-electrochemical cell integrated device design which keeps both components in thermal contact allows possible reductions of PV output as a result of heating under high irradiation, to be compensated by the simultaneous increase in electrochemical efficiency of hydrogen production.

Demonstrate on a large scale the feasibility of using hydrogen to support integration of renewable energy sources into the energy systems

Ultimate demonstration of an installation of and validated operation in outdoor conditions of the integrated PVElectrochemical device into a module array with a total area of at least 10 m^2 at the end of the project.



QUANTITATIVE TARGETS AND STATUS

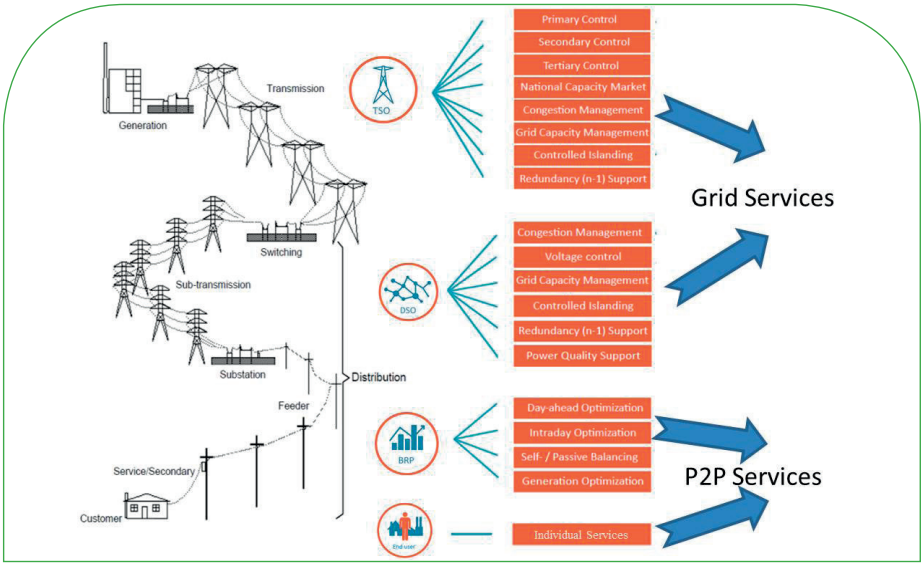
State of the Art (SoA)*

PARAMETER	UNIT	RESULT ACHIEVED TO DATE	SoA result achieved to date by other group/project	SOA YEAR	SoA Source
Solar to hydrogen efficiency	(%)	12.78 (CIGS) and 7.8 (Thin film silicon)	15.1	2017	Jan Ronge's Group at KU Leuven, Belgium. See: Sustainable Energy Fuels (2017), 1, 2061
Solar to hydrogen efficiency	(%)	12.78 (CIGS) and 7.8 (Thin film silicon)	16	2017	Todd Deutsch's group at NREL, US. See Nature Energy (2017)3, 17028
Stability	(%)	not yet tested	0% STH relative reduction(from an initial value of 3%) after 40 hours in alkaline conditions	2016	IEK-5 at FZJ, DE. See Nature Communications (2016) 7, 12681

*** Available data provided by the project**

QualyGridS

STANDARDIZED QUALIFYING TESTS OF ELECTROLYSERS FOR GRID SERVICES



Project ID:	**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, EUROPEAN FUEL CELL FORUM AG, FACHHOCHSCHULE ZENTRALSCHWEIZ - HOCHSCHULE LUZERN, FUNDACION PARA EL DESARROLLO DE LAS NUEVAS TECNOLOGIAS DEL HIDROGENO EN ARAGON, IHT INDUSTRIE HAUTE TECHNOLOGIE SA, ITM POWER (TRADING) LIMITED, NEW NEL HYDROGEN AS, STICHTING NEDERLANDS NORMALISATIE - INSTITUUT

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 50 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

- AWP 2016: definition of specific KPIs for dynamic operation to provide grid services
- AWP 2016: Development of standardized tests and protocols for assessing the capability of electrolysers to provide grid services, providing a way to compare and assess improvements for manufacturers
- Project own objective: Evaluation of business cases, sensitivities and a roadmap for the successful introduction of electrolyser technologies considering energy and grid service markets

PROGRESS & MAIN ACHIEVEMENTS

- First draft of testing protocols for electrolyser systems performing electricity grid services
- Survey of electricity grid services in Europe with prequalification information
- 3 electrolyser test benches have been set up to carry out the grid serviced tests

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 markets

RELEVANCE TO FCH JU OVERARCHING OBJECTIVES

Increase the energy efficiency of production of hydrogen mainly from water electrolysis and renewable sources while reducing operating and capital costs

OPEX cost reduction by application of grid services.

QUANTITATIVE TARGETS AND STATUS

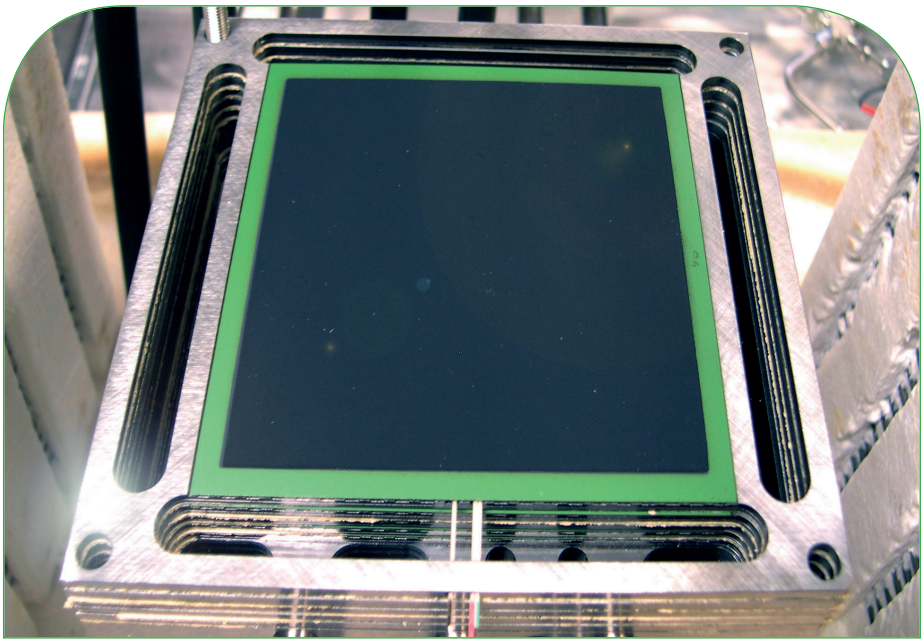
State of the Art (SoA)

PARAMETER	UNIT	RESULT ACHIEVED TO DATE	TARGET	TARGET ACHIEVED	DESCRIPTION
Current density	A/cm²	0.92-2	2.2	✗	QualyGridS - Electrolysis system -1,2, stack 2
Cold start ramp time	seconds	600-1140	30	✗	QualyGridS - Electrolysis system -1,2 & stacks
Hot idle ramp time	seconds	5	2	✗ (but achieved 2017 SoA)	QualyGridS - Electrolysis stack -2, system 2
Stack electricity consumption	kWh/kg	48.8	55	✓	QualyGridS - Electrolysis stack -2
Stack electricity consumption	kWh/kg	60.5	55	✗	QualyGridS - Electrolysis system -2

*As identified in MAWP Addendum 2018-2020, Target year 2020

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, ETHNIKO KENTRO EREVNAS KAI TECHNOLOGIKIS ANAPTYXIS, FORSCHUNGSZENTRUM JULICH GMBH, Prototech AS, PYROGENESIS SA, VYSOKA SKOLA CHEMICKO-TECHNOLOGICKA V PRAZE

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 H2O electrolysis and in a certain extent under H2O/CO2 co-electrolysis conditions. The main efforts comprise investigation of: (i) Modified SoA Ni-based cathode cermet, (ii) Alternative perovskite-type cathode materials, (iii) Thorough investigation on the O2 electrode and (iv). Development of a theoretical model for description of the performance & degradation of the SOEC H2 electrode.

NON QUANTITATIVE OBJECTIVES

- New materials and component design less prone to degradation
- Understanding of degradation mechanisms under dynamic operation
- Development of improved & robust SOEC systems (cells/stack/s)

PROGRESS & MAIN ACHIEVEMENTS

- Development and study of modified Ni-based & Ni-free cathodes and of new air electrodes with improved & "tailored" performance under SOEC operation
- "Operando" observation of Ni-based and Ni-free electrodes provided useful insight on their surface state during SOEC operation
- Thermodynamic analysis of the H2O & H2 & CO2 system towards the prediction of the most important reactions that take place under SOEC operation

FUTURE STEPS & PLANS

- Optimized cathodes (H2O electrodes) for H2O electrolysis & H2O/CO2 co-electrolysis in SOECs
- Optimized anodes (air electrodes) for H2O electrolysis SOECs
- Understanding of the underlying operation and degradation mechanisms towards improved and stable SOEC performance
- Manufacture and SOEC stability testing of high TRL cells & short stack/s, comprising the best performing electrodes in the framework of SElySOs

RELEVANCE TO FCH JU OVERARCHING OBJECTIVES

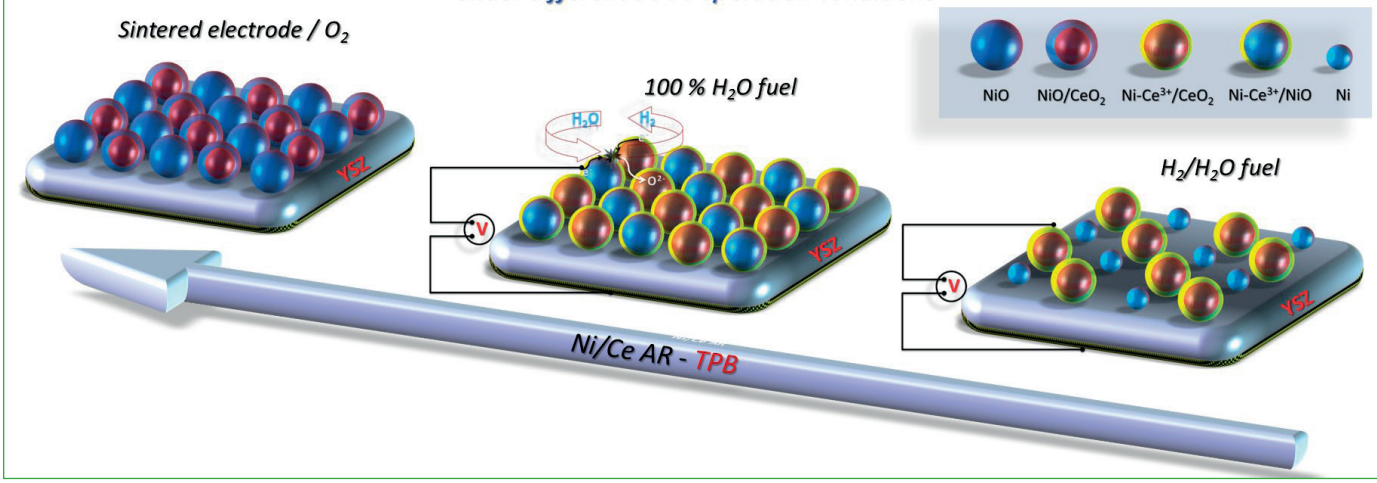
Increase the electrical efficiency and the durability of the different fuel cells

SElySOs contributes through the (i) improvement/development of new more efficient & stable electrodes and (ii) the understanding of the reaction mechanisms & processes that cause degradation on both SOEC electrodes. These will enable long-term SOEC electrical efficiency close to 90% (HHV).

Increase the energy efficiency of production of hydrogen mainly from water electrolysis and renewable sources while reducing operating and capital costs

SElySOs contributes to the identification of key operational/degradation processes, so as to assist in the development of new SOECs less prone to degradation with improved performance and stability. The latter will enable production of H2 with reduced electricity consumption.

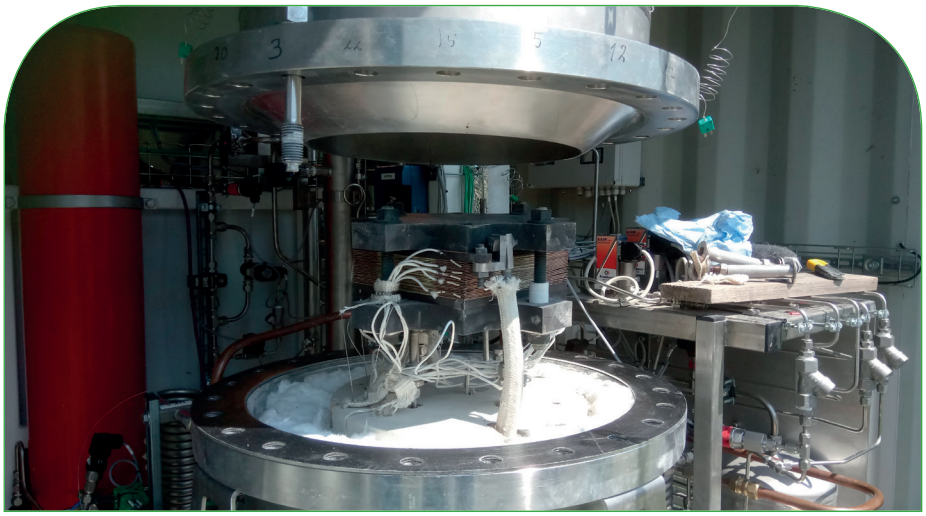
Schematic representation of a proposed nickel and ceria surface arrangement under different SOEC operation conditions



PRD 2018 PANEL
HYDROGEN FOR SECTORIAL INTEGRATION

SOPHIA

SOLAR INTEGRATED PRESSURIZED HIGH TEMPERATURE ELECTROLYSIS



Project ID:	**621173**
Call topic:	**SP1-JTI-FCH.2013.2.4** - New generation of high temperature electrolysers
Project total costs:	**€ 6,080,105.14**
FCH JU max. Contribution:	**€ 3,325,751**
Project start - end:	01/04/2014 - 30/09/2017
Coordinator:	**HyGear B.V., NL**
Website:	**www.sophia-project.eu**

BENEFICIARIES: COMMISSARIAT A L ENERGIE ATOMIQUE ET AUX ENERGIES ALTERNATIVES, DEUTSCHES ZENTRUM FUER LUFT - UND RAUMFAHRT EV, ECOLE POLYTECHNIQUE FEDERALE DE LAUSANNE, ENGIE, HTceramix SA, SOLIDPOWER SPA, TEKNOLOGIAN TUTKIMUSKESKUS VTT, Teknologian tutkimuskeskus VTT Oy

PROJECT AND OBJECTIVES

The aim of the project is to develop a solar-powered High Temperature Electrolysis system, and develop technology for co-electrolysis. The complete system, comprising of the HTE stack-subsystem and solar receiver has been tested at the Solar Simulator at DLR at 3 bar. The HTE stack-subsystem has been tested at HyGear at 15 bar.
A market analysis shows that for systems producing hydro-carbons the availability of CO2 is not limiting, but the solar power is. Various cell, SRU, and stack tests have been done in (co-)electrolysis mode.

NON QUANTITATIVE OBJECTIVES

- Develop concepts for pressurized electrolysis for more economical systems (production of hydrogen, but also methane, methanol or DME are valuable)
- Test and evaluation of cells, stacks and systems under realistic conditions
- Manufacture of dedicated HTE cells and stacks for use in large systems for the conversion of electricity from renewable sources and from nuclear power, i.e. large area cells, high durability under realistic conditions

PROGRESS & MAIN ACHIEVEMENTS

- The HTE prototype system built including a separate steam generator for stand-alone system has been tested at 15 Bara
- A performance better than 1 A/ cm2 at 1.3 V and 10 bar in co-electrolysis mode was observed
- Microscopic models, supported by innovative characterization techniques to macroscopic models have been developed

FUTURE STEPS & PLANS

Project is finished.

RELEVANCE TO FCH JU OVERARCHING OBJECTIVES

Increase the energy efficiency of production of hydrogen mainly from water electrolysis and renewable sources while reducing operating and capital costs

High temperature electrolysis technology has been tested under pressure producing hydrogen, under realistic conditions with heat and steam coming from a solar steam generator. In addition co-electrolysis for syngas production has been demonstrated at elevated pressure.

Demonstrate on a large scale the feasibility of using hydrogen to support integration of renewable energy sources into the energy systems

High temperature electrolysis has been demonstrated on a small scale but at elevated pressure.

QUANTITATIVE TARGETS AND STATUS

FCH JU Programme Targets*

PARAMETER	UNIT	RESULT ACHIEVED TO DATE	TARGET	TARGET ACHIEVED?	DESCRIPTION
Stack electricity consumption for H2 production	kWh/kg	33	40	✓	not measured
Current density	A/cm2	0.58-1	1	✓	determined in lab
Degradation	%/1000hrs	0 - 7	<0.5	✗	N/A

*As identified in MAWP Addendum 2018-2020 and AIP 2013, Target years 2017-2020

Don Quichote

DEMONSTRATION OF NEW QUALITATIVE INNOVATIVE CONCEPT OF HYDROGEN OUT OF WINDTURBINE ELECTRICITY

Project ID:	303411
Call topic:	SP1-JTI-FCH.2011.2.1 - Demonstration of MW capacity hydrogen production and storage for balancing the grid and supply to a hydrogen refuelling station
Project total costs:	€ 4,936,804.57
FCH JU max. Contribution:	€ 2,954,846
Project start - end:	01/10/2012 - 31/03/2018
Coordinator:	HYDROGENICS EUROPE NV, BE
Website:	www.don-quichote.eu

BENEFICIARIES: ETABLISSEMENTEN FRANZ COLRUYT NV, FAST - FEDERAZIONE DELLE ASSOCIAZIONI SCIENTIFICHE E TECNICHE, HYDROGEN EFFICIENCY TECHNOLOGIES (HYET) BV, ICELANDIC NEW ENERGY LTD, JRC -JOINT RESEARCH CENTRE- EUROPEAN COMMISSION, THINKSTEP AG, TUV Rheinland Industrie Service GmbH, WaterstofNet vzwy

PROJECT AND OBJECTIVES

Demonstrate the technical and economical viability of hydrogen as large scale renewable energy storage solution. Connection to a refuelling facility to investigate the commercial opportunity connecting intermittent renewable electricity to transport applications. Grid balancing using a fuel cell system. Demonstrate and validate the technology readiness. Generate facts based data for the exploitation of RE to H2.

NON QUANTITATIVE OBJECTIVES

- Study of regulatory aspects associated with this test platform
- Inventory and analyses of RCS related to the production, compression and storage of hydrogen
- Detailed analysis of LCA/LCI and total cost of ownership
- Assessment of feasibility/impact of large scale implementation
- Development of a comprehensive exploitation plan

PROGRESS & MAIN ACHIEVEMENTS

- One project covering two types of electrolysers, two types of compressors, a fuel cell system and H2 dispenser
- The hydrogen produced system is a strong example of ¨sector-coupling¨, connecting green electricity with hydrogen production
- Successfully integrated in an existing 'distribution centre' => knowledge/experience on permitting procedures and safety regulations in operation

FUTURE STEPS & PLANS

Project is finished.

RELEVANCE TO FCH JU OVERARCHING OBJECTIVES

Increase the energy efficiency of production of hydrogen mainly from water electrolysis and renewable sources while reducing operating and capital costs

A lot of effort went to optimizing the electrolyser to run on renewable source energy, intermittend and together with fuelling station where the run hours are low, so overhead energy losses are very important.

Demonstrate on a large scale the feasibility of using hydrogen to support integration of renewable energy sources into the energy systems

Separate work package to study large scale implementation.

QUANTITATIVE TARGETS AND STATUS

FCH JU Programme Targets*

PARAMETER	UNIT	RESULT ACHIEVED TO DATE	TARGET	TARGET ACHIEVED?	DESCRIPTION
Electrolyser Footprint	m2/MW	30	100	✓	PEM Electrolyser
Current Density	A/cm2	2	2.2	✗ (SoA 2017 achieved)	
Efficiency degradation per 1000 h for LT electrolysers	%/1000hrs	3.7	0.12	✗	Alkaline Electrolyser
Estimated Efficiency degradation per 1000 h @ 10 year lifespan for LT electrolysers	%/1000hrs	3.7	0.12	✗	
Current Density	A/cm2	0.44	0.7	✗	
System electrical efficiency (HHV, AC current)	%	65.3	55	✓	

* As identified in MAWP 2018-2020 and AIP 2011, Target years 2018-2020