BIG HIT
Building Innovative Green Hydrogen systems in an Isolated Territory: a pilot for Europe

Panel 5 — Hydrogen production, distribution and storage: research and validation

Acronym:	BIG HIT
Project ID:	700092
Title:	Building Innovative Green Hydrogen systems in an Isolated Territory: a pilot for Europe
Call Topic:	FCH-03.2-2015
Project total costs (€):	€ 7,2 million
FCH JU maximum contribution (€):	€ 5,0 million
Project start/end:	01 May 2016 - 30 Apr 2021
Coordinator:	Fundacion para Desarrollo de las Nuevas Tecnologias del Hidrogeno en Aragon, Spain
Beneficiaries:	Calvera Maquinaria E Instalaciones, The Scottish Hydrogen And Fuel Cell Association Ltd, Danmarks Tek. Uni., Shapinsay Development Trust, Community Energy Scotland Ltd, Ministry for Transport and Infrastructure, Malta, Orkney Islands Council, Giacomini, Symbiofcell, ITM Power (Trading), The European Marine Energy Centre Ltd
Website:	https://www.bighit.eu/
Linkedin:	BIG HIT
Twitter:	@H2BIGHIT

Project and objectives

BIG HIT will create a replicable hydrogen territory in Orkney (Scotland) by implementing a fully integrated model of hydrogen production, storage, transportation and utilisation for heat, power and mobility. It will absorb curtailed energy from two wind turbines and tidal turbines and use 1.5MW of PEM electrolysis to convert it into ~50 t/year of hydrogen. This will be used to heat two local schools, and transported by sea to Kirkwall in hydrogen trailers where it will be used to fuel a 75kW fuel cell and a refuelling station.

Major project achievements

- None reported

Future steps

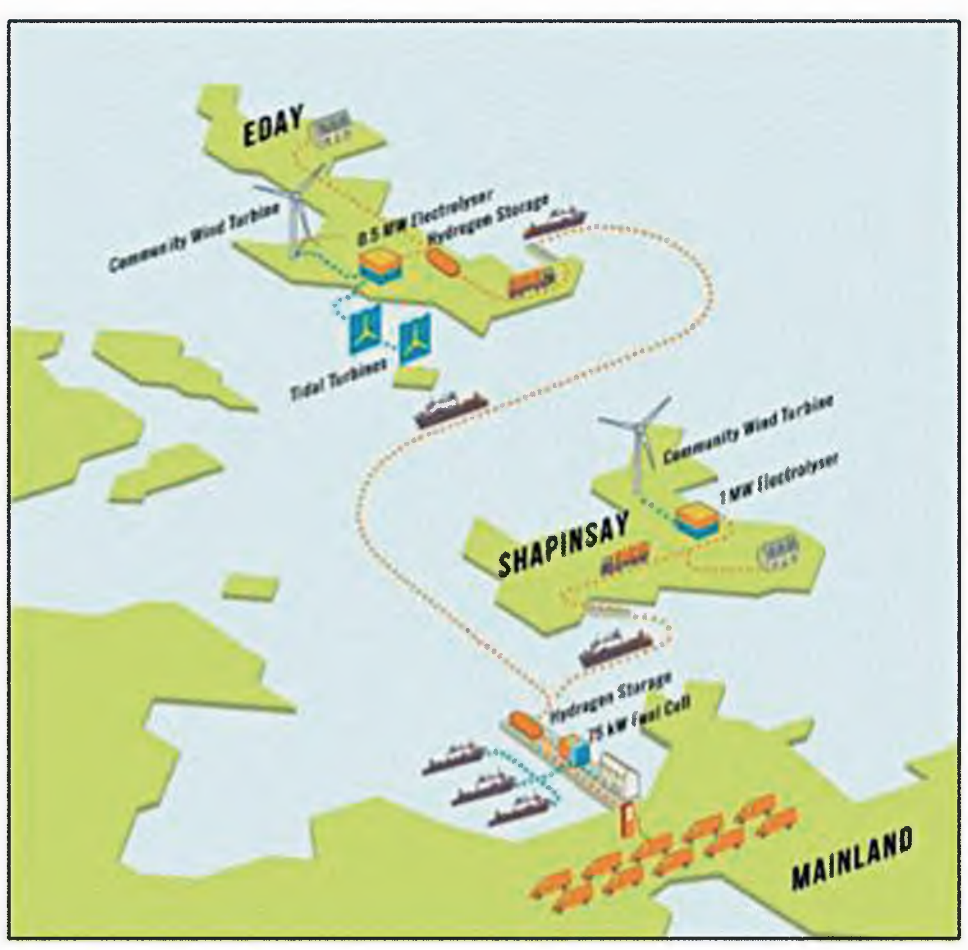
- None reported

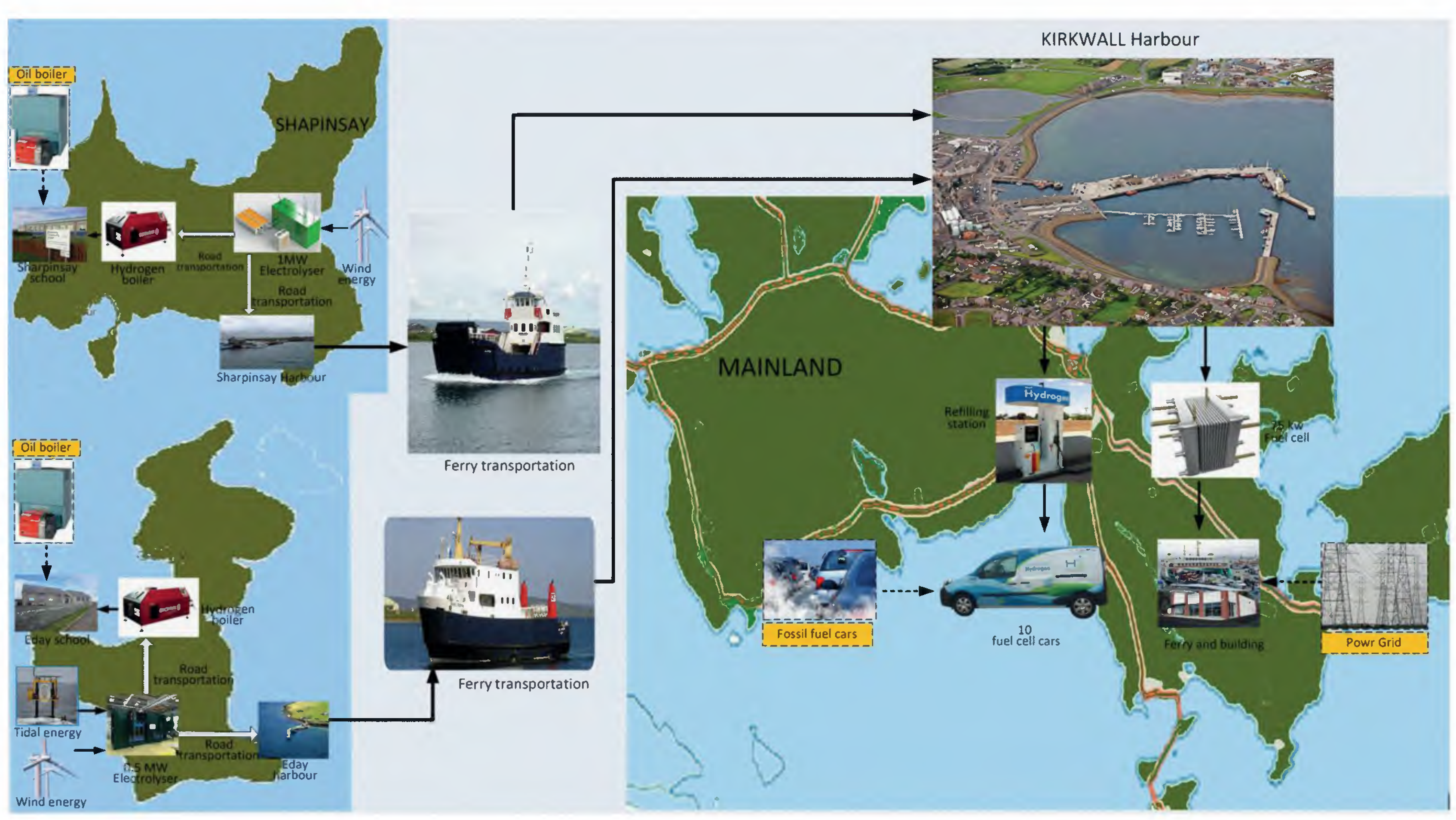
Relevant to FCH JU overarching objectives

- Increase the electrical efficiency and the durability of the different fuel cells used for power production to levels which can compete with conventional technologies, while reducing costs
- Increase the energy efficiency of production of hydrogen mainly from water electrolysis and renewable sources while reducing operating and capital costs, so that the combined system of the hydrogen production and the conversion using the fuel cell system can compete with the alternatives for electricity production available on the market
- Demonstrate on a large scale the feasibility of using hydrogen to support integration of renewable energy sources into the energy systems, including through its use as a competitive energy storage medium for electricity produced from renewable energy sources

Quantitative targets and status

Target Source	Parameter	Unit	Starting point	Target for project	Achieved to date in project	Best est. of final project result	Target: status on May 1st 2017	Description
AIP 2015	Develop a Hydrogen Territory in at least one EU isolated territory	1	0	1	0.2	1	Due later	New possibility to Orkney in order to increase RES penetration by H_2
AIP 2015	Co-involve at least 1 follower territory	1	0	1	0	1	Due later	Malta
AIP 2015	Electrolysis power	MW	0	1.5	0.50	1.5	Due later	One electrolyser built (0.5MW). 1MW PEMWE delayed in the groundworks for commissioning
AIP 2015	HRS in operation	1	0	1	0	1	Due later	The HRS is built but is delayed in the groundworks for commissioning
Project's own	2 x 30 kW catalytic H_2 boilers for heating 2 Orkney schools	kW	0	60	0	60	Due later	First boiler built and tested, to be sent when groundworks at the Shapinsay school are finished
Project's own	Nr electric vans with FC range extender		0	10	5	10	Due later	First five H_2 vans are in Orkney
Project's own	75kW FC in operation in Orkney harbour	kW	0	75	75	75	Achieved	Built, waiting for H_2 production to start operation
Project's own	2 Multi Element Gas Containers - H_2 storage		0	2	2	2	Achieved	Built (200 bar & 270 kg), waiting for H_2 production to start
Project's own	Reduction of curtailed energy	GWh/yr	0	-2.7	0	-2.7	Due later	Through conversion of wind & tidal generation
Project's own	Reduction of GHG emissions by 330 t/year	t/yr	0	-330	0	-330	Due later	Through reduction of diesel





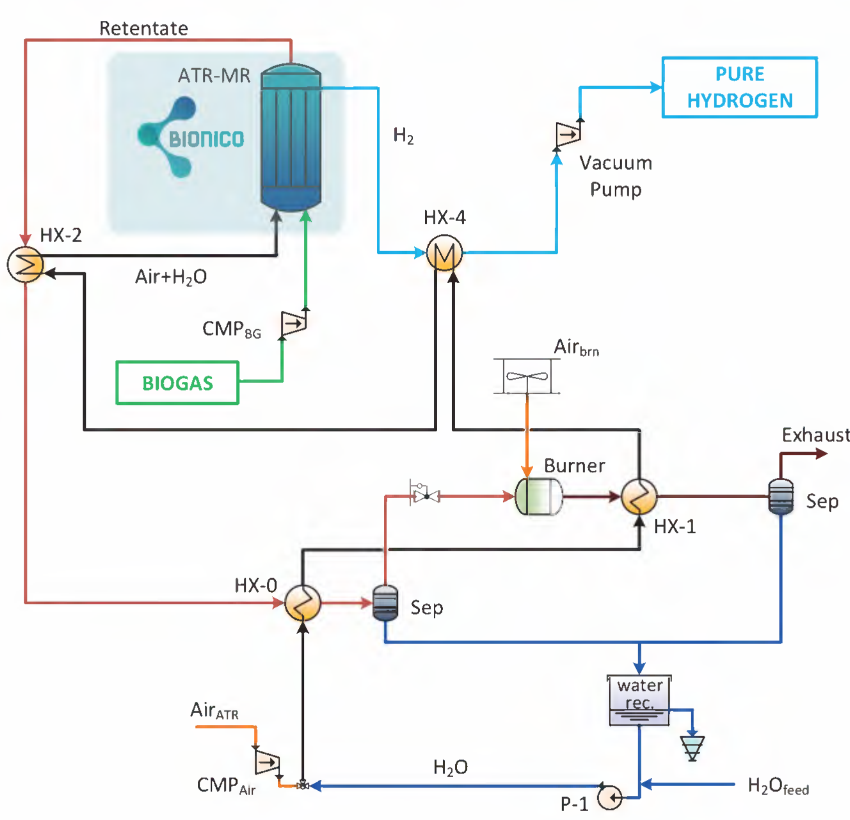
BIONICO
BIOgas membrane reformer for deceNtralIzed hydrogen produCtiOn

Panel 5 — Hydrogen production, distribution and storage: research and validation

Acronym:	**BIONICO**
Project ID:	671459
Title:	BIOgas membrane reformer for deceNtralIzed hydrogen produCtiOn
Call Topic:	FCH-02.2-2014
Project total costs (€):	€ 3,4 million
FCH JU maximum contribution (€):	€ 3,1 million
Project start/end:	01 Sep 2015 - 28 Feb 2019
Coordinator:	Politec. Milano, Italy
Beneficiaries: Rauschert Kloster Veilsdorf, Abengoa Hidrogeno, ICI Caldaie, Fundacion Tecnalia Research & Innovation, Johnson Matthey, Tech. Uni. Eindhoven, ENC Energy, ENC Power Lda, Abengoa Research, Quantis	
Website:	http://www.bionicoproject.eu/
Linkedin:	Membrane Reactors

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. Currently, new highly active PGM doped alumina reforming catalysts to produce H_2 from diverse biogas mixtures has been developed, together with new ceramic-supported tubular membranes stable at high temperature (550-600 °C). The membrane reactor is in the preliminary design phase.

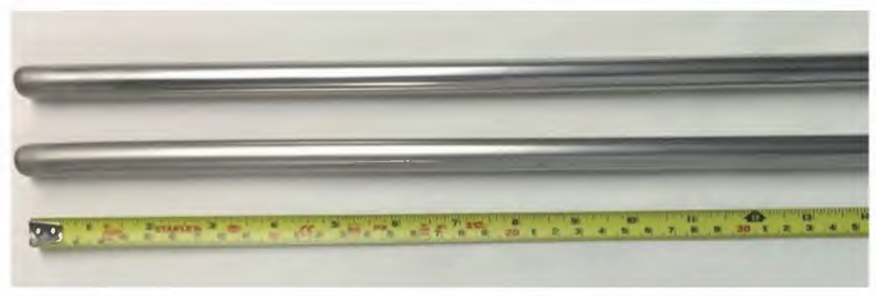


Major project achievements

- Development of highly active, durable and stable reforming catalysts to produce hydrogen from diverse biogas mixture coupled with steam (and air)
- Development of Palladium-based tubular supported membranes, for application in biogas reforming catalytic membrane reactors
- Identification of the state-of-the-art performance of conventional system for hydrogen production from biogas

Future steps

- Catalyst production for the pilot plant
- Membrane production for the pilot plant
- Design of the pilot plant and definition of the operating conditions
- Assembly of the reactor at the manufacturer site



Quantitative targets and status

Target Source	Parameter	Unit	Starting point	Target for project	Achieved to date in project	Best est. of final project result	Target: status on May 1st 2017	Description
MAWP 2014-2020	H_2 production efficiency	%	59.2	72		70.8	To be addressed	Preliminary simulation results
AIP 2014	H_2 production in a single step	step	4	1	1	1	Achieved	Demonstrated at lab scale
AIP 2014	Demonstrate BIONICO concept at a landfill plant delivering 100 kg/day	kg/day	0	100		100	To be addressed	
Project's own	Development, test, manufacturing and scale up of novel Membranes						Due later	Manufacturing and scale up is ongoing
Project's own	Develop, test, manufacturing and scale up of novel catalyst						Due later	Manufacturing and scale up is ongoing

Non-quantitative objectives and status

- Strengthen collaboration between partners
  Master student exchange between Politecnico di Milano and TUE

Relevant 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, so that the combined system of the hydrogen production and the conversion using the fuel cell system can compete with the alternatives for electricity production available on the market

BIOROBUR
Biogas robust processing with combined catalytic reformer and trap

Panel 5 — Hydrogen production, distribution and storage: research and validation

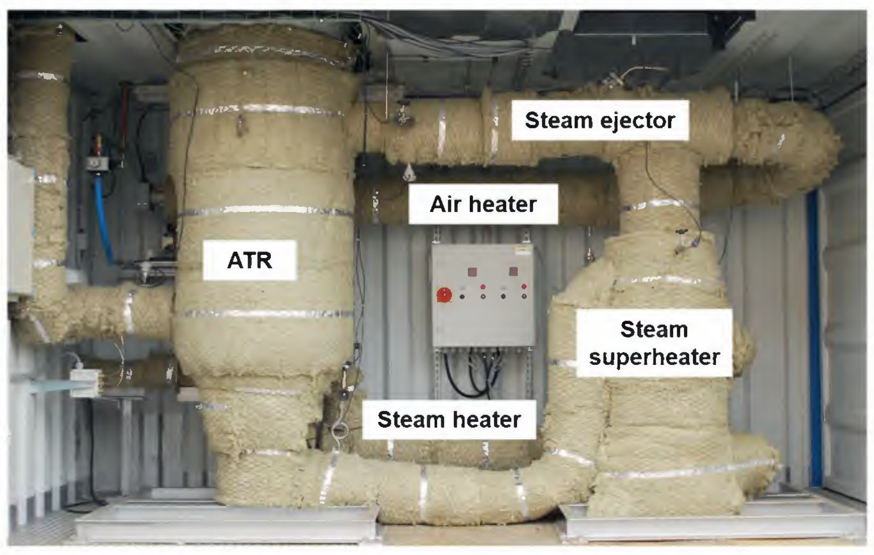
Acronym:	**BIOROBUR**
Project ID:	325383
Title:	Biogas robust processing with combined catalytic reformer and trap
Call Topic:	SP1-JTI-FCH.2012.2.3
Project total costs (€):	€ 3,8 million
FCH JU maximum contribution (€):	€ 2,4 million
Project start/end:	01 May 2013 - 31 Aug 2016
Coordinator:	Politec. Torino, Italy
Beneficiaries: Erbicol, Pirelli & C. Eco Technology Ro, Scuola Universitaria Professionale Svizzera It., Tech. Uni. Bergakademie Freiberg, Centre for Research and Technology Hellas, Centre National de la Recherche Scientifique CNRS, Hysytech, Uab Modernios E-Technologijos	
Website:	http://www.biorobur.org/

Project and objectives

The BioRobur project developed and tested a robust and efficient biogas reformer for hydrogen (H_2) production, with a nominal production rate of 50 Nm3/h (107 kg/h) and an energy efficiency of 65%. The fuel processor employs a catalytic autothermal reforming (ATR) process using a structured catalyst to convert biogas (with no preliminary CO_2 separation) into H_2, with the adoption of a catalytic wall-flow filter located downstream from the ATR processor to effectively filter and gasify in-situ the carbon emissions eventually generated.

Major project achievements

- Development and testing of a robust and efficient decentralised processor based on the ATR of biogas with a nominal production rate of 50Nm3/h of H_2
- System energy efficiency of biogas conversion into green hydrogen of 65%
- Excellent material supports and catalysts with excellent performances were proposed and tested



Future steps

- Project finished

Quantitative targets and status

Target Source	Parameter	Unit	Starting point	Target for project	Achieved to date in project	Best est. of final project result	Target: status on May 1st 2017	Description
MAIP 2008-2013	Scalability: lab scale to H_2 production level	Nm3/h		50	50	50	Achieved	High thermal conductivity of cellular materials and internal heat generation in the process allowed perfect scale-up
AIP 2012	Nominal production rate pure hydrogen (50-250 kg/day)	kg/day		50-250	107	107	Achieved	Using noble metal - based coated monolith.
AIP 2012	Biogas to hydrogen conversion efficiency	%		65	65	65	Achieved	Target reached in the BioRobur testing campaign
AIP 2012	Materials costs for 50 Nm3/h hydrogen production rate	€		25,000	200,000		Achieved	Reused test rig for pilot scale reformers of up to 250 Nm3/h developed within FP6 EU project
AIP 2012	CO concentration at the reformer exit	% vol	10	9.9	9.9	9.9	Achieved	Target reached with the BioRobur technology.

Non-quantitative objectives and status

- Scale-up: high performance materials supports and catalysts
  Cellular materials adopted and synthesised catalysts for the ATR support and soot trap allowed to a perfect scale-up of the unit
- Manufacture of new supports for biogas ATR
  Innovative supports were designed and tested
- Development and testing a pre-commercial plant for 50Nm3/h of hydrogen
  Developed and tested a pre-commercial plant for H_2 production from the biogas ATR. Plant flexibility demonstrated
- High degree of reactor compactness & design simplification
  Good functionality and proper interaction of the main components demonstrated

Relevant 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, so that the combined system of the hydrogen production and the conversion using the fuel cell system can compete with the alternatives for electricity production available on the market
- Demonstrate on a large scale the feasibility of using hydrogen to support integration of renewable energy sources into the energy systems, including through its use as a competitive energy storage medium for electricity produced from renewable energy sources
- Reduce the use of the EU defined 'Critical raw materials', for instance through low-platinum or platinum-free resources and through recycling or reducing or avoiding the use of rare earth elements

DON QUICHOTE
Demonstration of new qualitative concept of hydrogen out of wind turbine electricity

Panel 5 — Hydrogen production, distribution and storage: research and validation

Acronym:	**DON QUICHOTE**
Project ID:	303411
Title:	Demonstration of new qualitative concept of hydrogen out of wind turbine electricity
Call Topic:	SP1-JTI-FCH.2011.2.1
Project total costs (€):	€ 4,8 million
FCH JU maximum contribution (€):	€ 2,9 million
Project start/end:	01 Oct 2012 - 31 Mar 2018
Coordinator:	Hydrogenics Europe, Belgium
Beneficiaries:	Thinkstep, Etablissementen Franz Colruyt, Fast - Federazione delle Associazioni Scientifiche e Tecniche, Hydrogen Efficiency Technol. (Hyet), Tuv Rheinland Industrie Service, Waterstofnet, Icelandic New Energy Ltd, JRC -Joint Research Centre, European Commission
Website:	http://www.don-quichote.eu/

Project and objectives

Don Quichote demonstrates the technical and economic viability of an integrated hydrogen storage system for renewables linked to H_2 refuelling and re-electrification assets. The commercial opportunity connecting intermittent renewable electricity to transport applications is assessed by Total Cost of Ownership analysis (TCO). By demonstrating the impact on efficiency and costs of the operations of a logistics centre, the project demonstrates the market readiness of the H_2-components needed for storing renewable energy. The innovative components are a 150kW PEM electrolyser and a 120kW PEM fuel cell.

Major project achievements

- Development, construction, delivery and site operation of a PEM electrolyser (30 Nm³/h, 10 bar)
- Development, construction and operation of a Fuel Cell outdoor system (120kW)
- LCA analysis performed

Future steps

- Continuous monitoring of extension including PEM electrolyser and fuel cell stack
- Construction and on-site installation of a new compressor
- Performance monitoring of the system with a new compressor (final Phase)
- Complete outstanding deliverables
- Closing event

Quantitative targets and status

Target Source	Parameter	Unit	Starting point	Target for project	Achieved to date in project	Best est. of final project result	Target: status on May 1st 2017	Description
AIP 2011	Well to tank efficiency	%		55	58	60	Achieved	Electrolyser system: 70% (full production); compressor: 85% in steady state
AIP 2011	Cost of hydrogen delivered	€/kg		15	13	11	Achieved	Intermittent operation & low H_2 demand → > energy/cost overhead vs optimal case.
AIP 2011	ISO/DIS 14786-2 compliant	Y/N		no	no	yes	Achieved	H_2 quality compliant to fuelling standard
AIP 2011	Availability	%		95	94	97	Due later	Up-time not yet achieved in all (monthly) periods due to corrective maintenance measures/inactivity
Select	Operational hours	hr	0	25,000	16,000	22,000	Due later	Mission time (ready for production) not sufficient
AIP 2011	durability	yrs		10	3	4	Not yet addressed	Post-project lifetime assured

Non-quantitative objectives and status

- Develop a portfolio of sustainable hydrogen production
  Power based (energy supply side) steering of both PEM and alkaline water electrolysis
- R&D in innovative hydrogen production and supply chains
  PEM and FC units constructed and in operation
- Storage processes meeting increasing H_2-demand
  High pressure (450 bar) carbon fibre storage solution implemented
- Distribution processes for end-use
  80-100 refuelling every month since start of operation

Relevant 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, so that the combined system of the hydrogen production and the conversion using the fuel cell system can compete with the alternatives for electricity production available on the market
- Demonstrate on a large scale the feasibility of using hydrogen to support integration of renewable energy sources into the energy systems, including through its use as a competitive energy storage medium for electricity produced from renewable energy sources

ECo
Efficient Co-Electrolyser for Efficient Renewable Energy Storage

Panel 5 — Hydrogen production, distribution and storage: research and validation

Acronym:	ECo
Project ID:	699892
Title:	Efficient Co-Electrolyser for Efficient Renewable Energy Storage
Call Topic:	FCH-02.3-2015
Project total costs (€):	€ 3,2 million
FCH JU maximum contribution (€):	€ 2,5 million
Project start/end:	01 May 2016 - 30 Apr 2019
Coordinator:	Danmarks Tek. Uni., Denmark
Beneficiaries: Vdz G, Htceramix, Belgisch Laboratorium van de Elektriciteitsindustrie, Enagas, Fundacio Inst. De Recerca de L'Energia De Catalunya, Eifer Europaisches Inst. fur Energieforschung, ENGIE, Ecole Polytechnique Federale de Lausanne, Commissariat à l'Energie Atomique et aux Energies Alternatives CEA	
Website:	http://www.eco-soec-project.eu/
Twitter:	@ECo_SOEC

Project and objectives

The ECo Project aims at utilising electricity from renewable sources for production of storage media via electrolysis of steam & CO_2 through solid oxide electrolysis.

Objectives/Status:

- Cell improvement/First candidates through design of structures developed
- Durability under realistic co-electrolysis operating conditions/ Benchmark tests performed in different operation modes
- Integration of the SOEC with input electricity & CO_2 and catalytic hydrocarbon production & economic evaluation/Model established
- LCA: Ongoing
- Test of a co-electrolysis system under realistic conditions/Under development

Major project achievements

- Solid oxide cells were developed based on electrode structure design
- Benchmark co-electrolysis durability tests were carried out at different operation modes
- System layout of power-to-methane system including realistic CO_2 sources and capture technologies was established

Future steps

- Verification of improved cells
- Durability mapping under relevant conditions
- High pressure performance and durability testing
- Analysis and optimization of most promising specific system designs

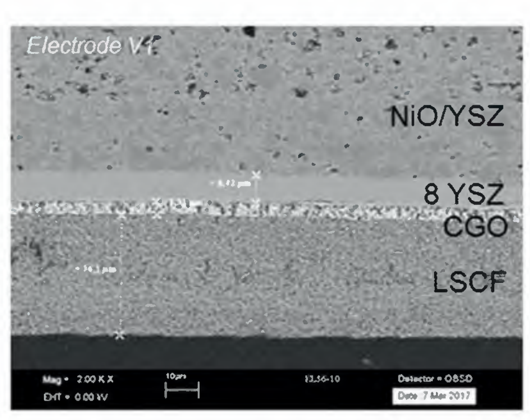
Relevant to FCH JU overarching objectives

- Increase the energy efficiency of production of hydrogen mainly from water electrolysis and renewable sources while reducing operating and capital costs, so that the combined system of the hydrogen production and the conversion using the fuel cell system can compete with the alternatives for electricity production available on the market
- Demonstrate on a large scale the feasibility of using hydrogen to support integration of renewable energy sources into the energy systems, including through its use as a competitive energy storage medium for electricity produced from renewable energy sources

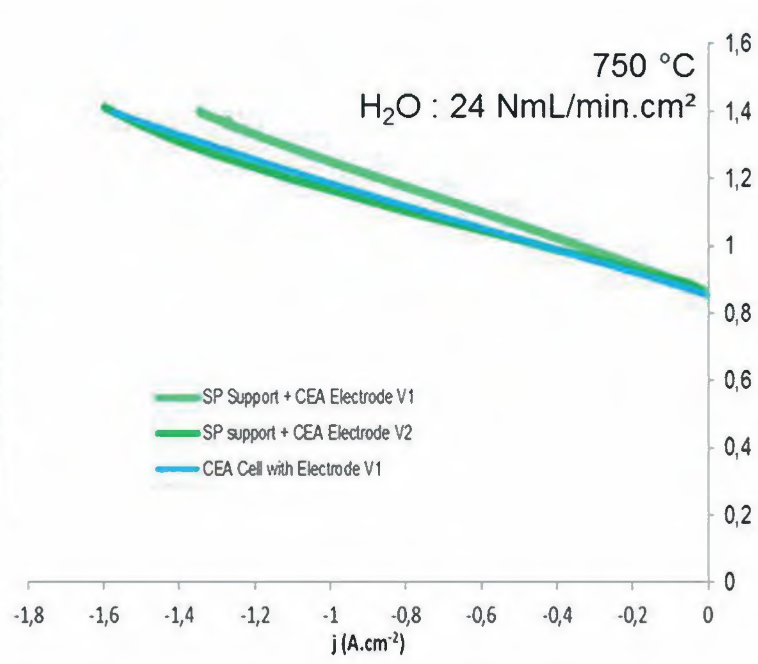
Quantitative targets and status

Target Source	Parameter	Unit	Starting point	Target for project	Achieved to date in project	Best est. of final project result	Target: status on May 1st 2017	Description
Project's own	Area specific resistance at 750 °C	Ohm cm²	0.60	0.20	0.34	0.2	Due later	Materials development and structural optimisation
Project's own	Durability	%/1000 h	3	1	2	1	Due later	Development of more stable cells and mapping of critical (for degradation) operation parameters
Project's own	Co-electrolysis temperature for -1.3 A/cm² at 10 bar	°C	800	750		750	Due later	No results published (only in house reports), project will deliver first results
Project's own	High pressure co-electrolysis durability	% realised	0	100	10	100	Due later	No durability results published, project will deliver first results
Project's own	System test	% realised	0	100	0	100	Not yet addressed	No durability results published, project will deliver first results
Project's own	Potential practical system-design case studies	% realised	0	100	20	100	Due later	Development of process concepts for specific cases - power to gas (or liquid) incl. all sources & final hydrocarbon production
Project's own	Economic analysis	% realised	0	100	0	100	Due later	Case and competition analysis for the proposed plant
Project's own	LCA	% realised	0	100	10	100	Due later	Consideration of various CO_2 and electricity sources of fossil or renewable origin

First improved cell version



- Optimization of microstructure of oxygen electrode



EDEN
High energy density Mg-based metal hydrides storage system

Panel 5 — Hydrogen production, distribution and storage: research and validation

Acronym:	**EDEN**
Project ID:	303472
Title:	High energy density Mg-based metal hydrides storage system
Call Topic:	SP1-JTI-FCH.2011.2.4
Project total costs (€):	€ 2,6 million
FCH JU maximum contribution (€):	€ 1,5 million
Project start/end:	01 Oct 2012 - 30 Jun 2016
Coordinator:	Fondazione Bruno Kessler, Italy
Beneficiaries: Mbn Nanomaterialia, Panco - Physikalische Technik Anlagenentwicklung & Consulting, Uni. La Laguna, Cidete Ingenieros, JRC -Joint Research Centre, European Commission, Matres	
Website:	http://www.h2eden.eu/

Project and objectives

The EDen project aimed to develop a POWER-to-POWER system consisting of:

(1) a new storage material with high hydrogen storage capacity, for distributed level applications, included on

(2) a specifically designed storage tank, integrated with

(3) an energy provision system able to match local energy sources with energy demand in form of reversible solid oxide cell.

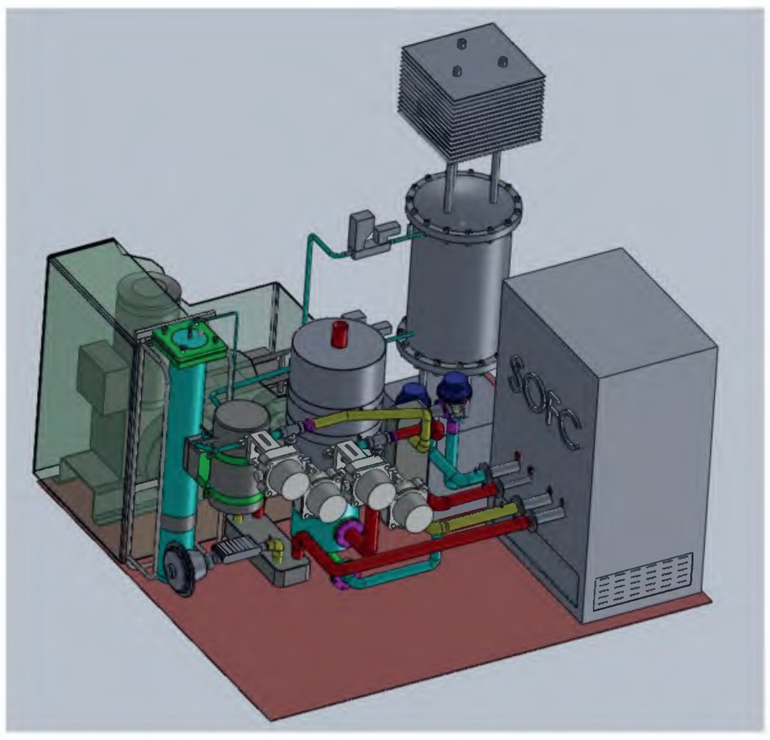
The technology was demonstrated in Barcelona, installed in a facility of the Energy Agency of the City. The final net cycle efficiency of the system was 25%

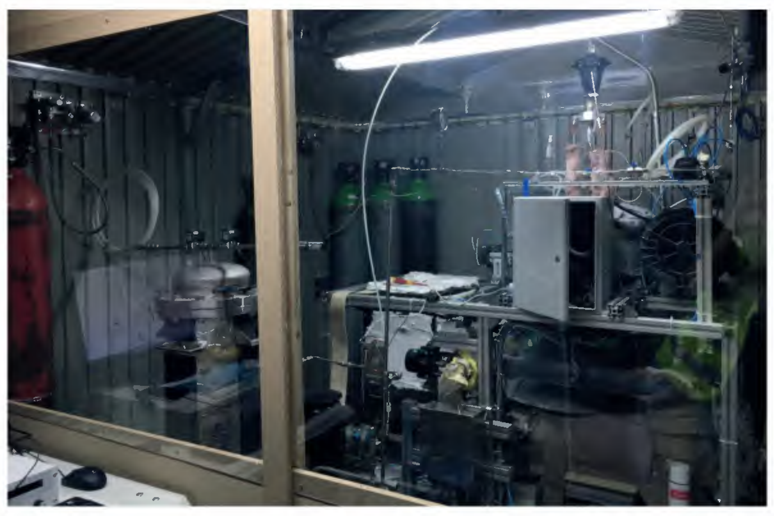
Major project achievements

- Mg-based powder produced by High Energy Ball Milling, with 7.1 wt.% H_2/MH storage capacity and desorption rate > 1 gH2/min/kg at 320 °C and 1.2 bar
- Intermediate and full storage tanks realized, integrated of thermal and hydrogen management able to release more than 1,5 litres per minute
- Full scale POWER TO POWER system, using HT electrolyser / fuel cell and solid state integrated storage, with integrated fuel and thermal management

Future steps

- Project finished





Quantitative targets and status

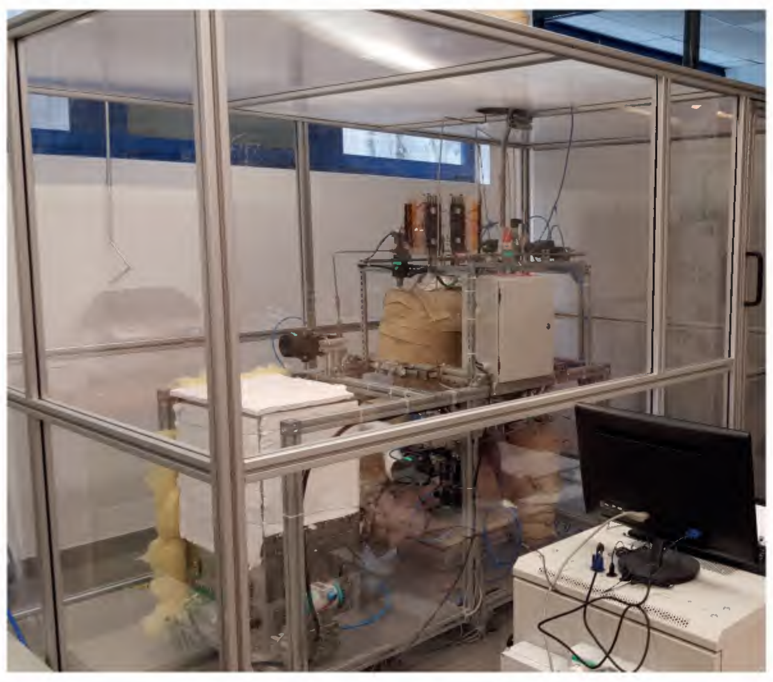
Target Source	Parameter	Unit	Starting point	Target for project	Achieved to date in project	Best est. of final project result	Target: status on May 1st 2017	Description
Project's own	Cost of hydrogen storage considering 100 cycles	€/kg	800	500	500	300	Achieved	Nr of performed cycles to increase in last demo period
AIP 2011	Material storage capacity	wt. %	5.50	6.00	7.10	7.10	Achieved	Target material also with H_2 sorption density > 80 kgH2/m³, desorption rate > 3g/min
AIP 2011	Material cost	€/kg		30	42	28	Achieved	Demonstrated it could be achieved through hydride mass production (several tons/year)
AIP 2011	H_2 desorption rate	g/min		3	1.50	1.70	Achieved	Important to feed the FC and maintain the power output
AIP 2011	Absorption heat recovery	%		25	26.50	26.50	Achieved	Heat recovered during the electrolysis mode
AIP 2011	Total hydrogen stored	kg		0.60	0.82	0.82	Achieved	Hydrogen stored in the tank at maximum capacity
AIP 2011	Hydrogen volumetric density, material	kg/l		0.08	0.13	0.13	Achieved	Volumetric density of Mg hydride at max. performance
AIP 2011	Hydrogen volumetric density, tank	kg/l		0.04	0.04	0.04	Achieved	H_2 volumetric density including tank structures

Non-quantitative objectives and status

- Training and education of professionals
  PhD Student trained in the electrochemical characterization of SOFC units. He performed physicochemical SOFC studies for EDEN.
- Safety, Regulations, codes and standards
  FCH JU Joint Workshop on Hydrogen Storage, 02/10/13
- Assessment of safety regulations, networking with institutes as PTB, firefighters of Barcelona
- Public awareness
  Five events, including ES and IT press release, interview at RAI and ADA Channel. Special issue "Tutto Scienze" in La Stampa, EU press release on Build up

Relevant to FCH JU overarching objectives

- Reduce the production cost of fuel cell systems to be used in transport applications, while increasing their lifetime to levels which can compete with conventional technologies
- Increase the energy efficiency of production of hydrogen mainly from water electrolysis and renewable sources while reducing operating and capital costs, so that the combined system of the hydrogen production and the conversion using the fuel cell system can compete with the alternatives for electricity production available on the market
- Demonstrate on a large scale the feasibility of using hydrogen to support integration of renewable energy sources into the energy systems, including through its use as a competitive energy storage medium for electricity produced from renewable energy sources



EG-04-17-700-EN-P

ELECTRA

High temperature electrolyser with novel proton ceramic tubular modules of superior efficiency, robustness, and lifetime economy

Panel 5 — Hydrogen production, distribution and storage: research and validation

Acronym:	ELECTRA
Project ID:	621244
Title:	High temperature electrolyser with novel proton ceramic tubular modules of superior efficiency, robustness, and lifetime economy
Call Topic:	SP1-JTI-FCH.2013.2.4
Project total costs (€):	€ 4,0 million
FCH JU maximum contribution (€):	€ 2,2 million
Project start/end:	03 Mar 2014 - 02 Jun 2017
Coordinator:	Uni. et I Oslo, Norway
Beneficiaries: Abengoa Hidrogeno, Agencia Estatal Consejo Superior de Investigaciones Cientificas, Coorstek Membrane Sciences, Marion Technol., CRI EHF, Stiftelsen Sintef	
Website:	http://www.mn.uio.no/smn/english/research/projects/chemistry/electra/index.html

Project and objectives

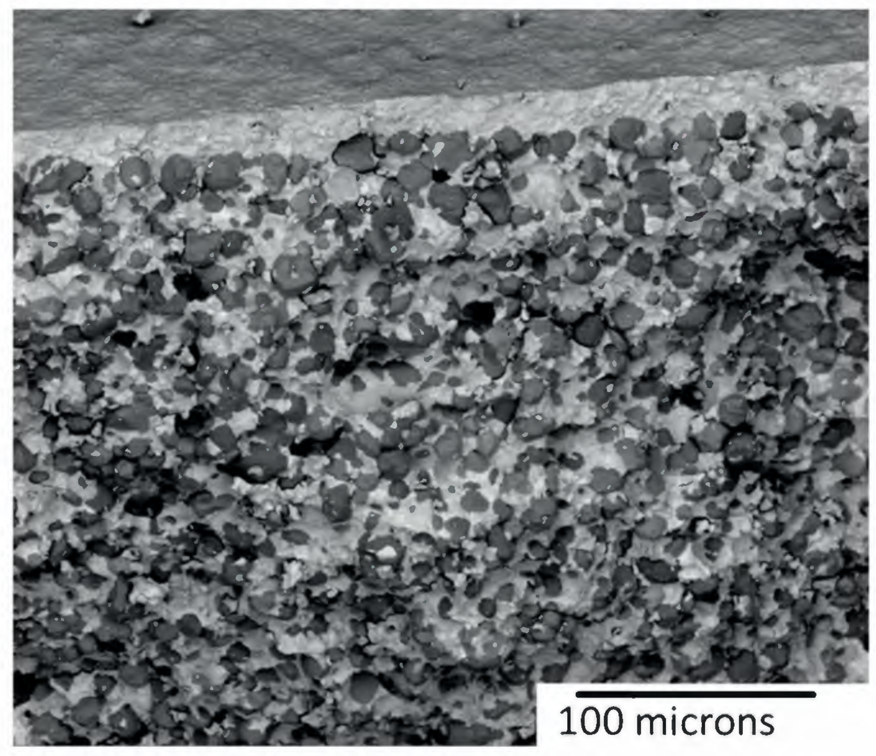
The main objective of the ELECTRA project is to develop robust tubular proton ceramic electrolysers (PCEs) that can produce dry pressurised hydrogen directly from steam, alleviating downstream separation and compression. A scalable and cost-efficient process for producing large quantities of tubular Ni-BZCY/BZCY half-cells has been developed. These have been used to produce fully assembled tubular PCEs with the highest hydrogen production rate reported thus far, implementing a novel steam anode. A techno-economic study of integration with renewable energy sources has been completed.

Major project achievements

- A robust, scalable and cost-efficient processing route for tubular PCE half-cells has been developed to produce high quality tubular segments
- A steam anode material with state-of-the-art performance has been successfully developed and demonstrated with ASR < 0.2 Ohm cm^2 at 700°C
- Step-change improvement in both scale and electrical efficiency of PCE technology using tubular geometry and high steam pressure

Future steps

- Project finishes early June 2017. Mainly final test of co-electrolysis and test of kW-size multi-tubular module remains



Quantitative targets and status

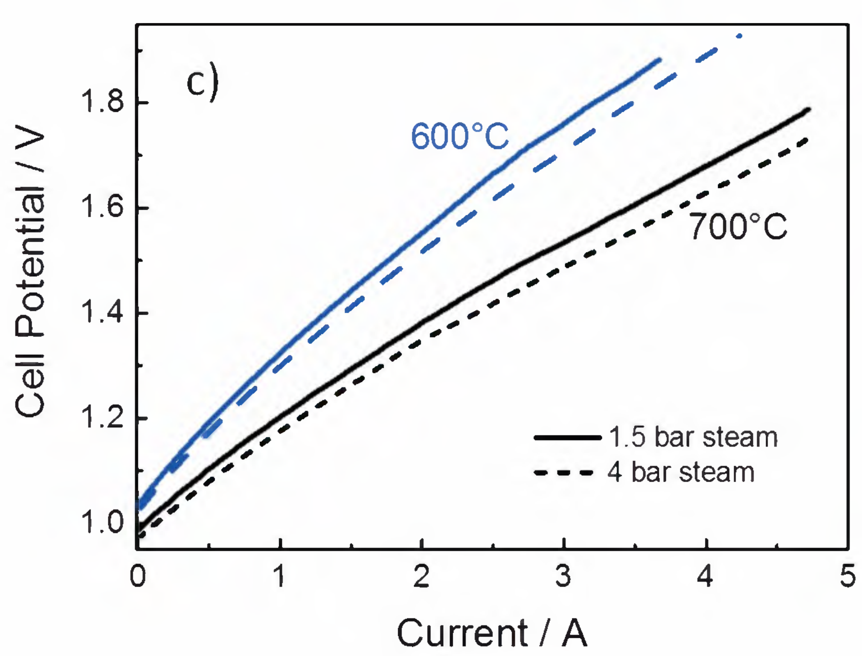
Target Source	Parameter	Unit	Starting point	Target for project	Achieved to date in project	Best est. of final project result	Target: status on May 1st 2017	Description
MAIP 2008-2013	Module capacity	L/h	0	250	0	125	Due later	Module designed & commissioned, construction imminent
MAIP 2008-2013	Electrical efficiency	%	30	80	80	80	Achieved	Electrical efficiency for single cell at 0.2 Acm^-2
AIP 2013	Area Specific Resistance (ASR) of cell	Ohm cm^2	10	1	2	2	Delayed	Total ASR over 10 cm^2 tubular cell at 700C
Project's own	Anode ASR	Ohm cm^2	3	0.20	0.20	0.20	Achieved	Polarisation resistance of steam anode at 700°C
Project's own	Conductivity	S cm-1	1	300	1000	1000	Achieved	Conductivity of current collection material
Project's own	Module power	kW	0	1	1	0.50	Due later	Limited by production of tubes

Non-quantitative objectives and status

- Robust and scalable production of tubular PCE half-cells
  Fully optimised production process of extrusion and spray-coating in a cost-efficient process with high yield of defect-free half-cells
- Techno-economic evaluation of PCE integration with renewable energy
  Techno-economic analysis completed
- Proof-of-concept of co-ionic co-electrolysis of CO_2 and H_2O
  Under testing
- Design, commissioning and construction of multi-tube module
  Finalised design in terms of thermal zones and gas flow optimisation, fully commissioned and construction almost completed

Relevant 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, so that the combined system of the hydrogen production and the conversion using the fuel cell system can compete with the alternatives for electricity production available on the market
- Reduce the use of the EU defined 'Critical raw materials', for instance through low-platinum or platinum-free resources and through recycling or reducing or avoiding the use of rare earth elements



ELY4OFF
PEM ElectroLYsers FOR operation with OFFgrid renewable installations

Panel 5 — Hydrogen production, distribution and storage: research and validation

Acronym:	**ELY4OFF**
Project ID:	700359
Title:	PEM ElectroLYsers FOR operation with OFFgrid renewable installations
Call Topic:	FCH-02.1-2015
Project total costs (€):	€ 2,3 million
FCH JU maximum contribution (€):	€ 2,3 million
Project start/end:	01 Apr 2016 - 31 Mar 2019
Coordinator:	Fundacion para Desarrollo de las Nuevas Tecnologias del Hidrogeno en Aragon, Spain
Beneficiaries: Instrumentacion y Componentes, EPIC Power Converters, ITM Power (Trading), Commissariat à l'Energie Atomique et aux Energies Alternatives CEA	
Website:	www.ely4off.eu

Project and objectives

The main goal of the ELY4OFF 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. Demonstration in Huesca (Spain) will last 8 months. The progress of the project (13 months of development as of May 1st, 2017) follows the schedule foreseen.

Major project achievements

- Thin membranes have been successfully tested at ITM facilities
- The definitive topology for the DC/DC converter to directly link the PV field with the PEMWE has been identified
- A computer model has been elaborated with Odyssey tool and allows predicting behaviour of the system in different conditions

Future steps

- Completion of PEMWE fabrication
- Completion of DC/DC converter
- Commissioning of all the components of the system at demo site
- Execution of demonstrative period
- Development of the exploitation strategy and business plan

Non-quantitative objectives and status

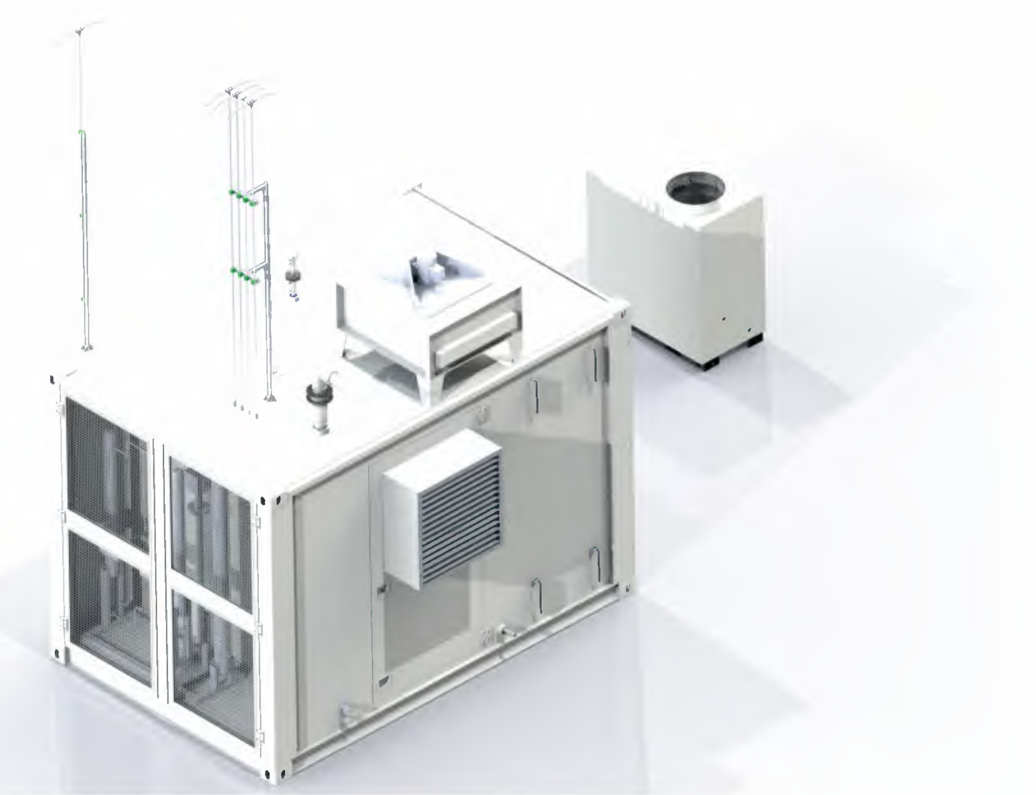
- Development of an overarching control system
  The main specifications were established and more details are in progress
- Identification of eventual RCS barriers
  RCS at demo site were identified, and at EU and international level are expected in the last stage of the project
- To explore potential uses of H_2
  The H_2 produced will be linked to another project were electrical mini buses with H_2 range extender are expected to be deployed in Huesca
- New business model
  Replicable to EU and international environments. To be started during 2017

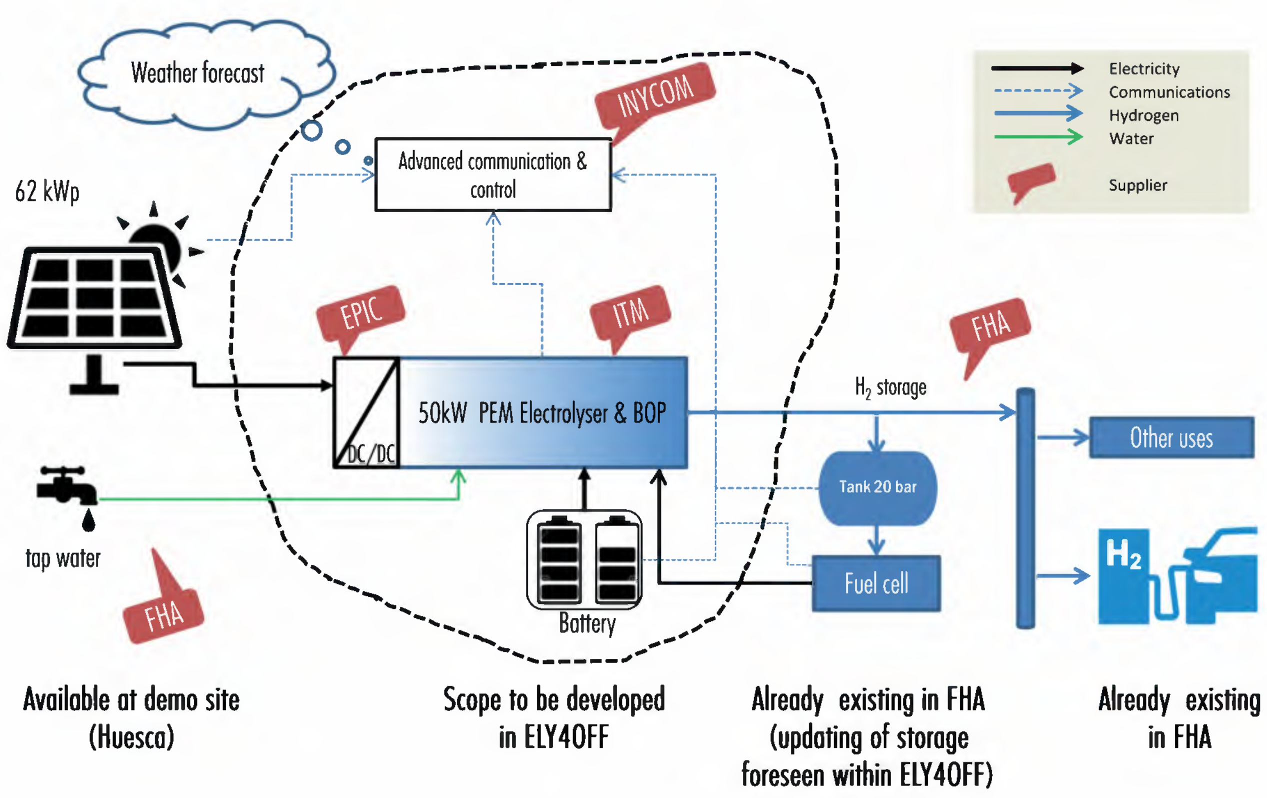
Relevant to FCH JU overarching objectives

- Increase the energy efficiency of production of hydrogen mainly from water electrolysis and renewable sources while reducing operating and capital costs, so that the combined system of the hydrogen production and the conversion using the fuel cell system can compete with the alternatives for electricity production available on the market

Quantitative targets and status

Target Source	Parameter	Unit	Starting point	Target for project	Best est. of final project result	Target: status on May 1st 2017
MAWP 2014-2020	Efficiency at system level	kWh/kg	55	50	50	Not yet addressed
MAWP 2014-2020	Efficiency degradation	%/8000h	2	2	2	Not yet addressed
MAWP 2014-2020	CAPEX	M€/(t/d)	3.7	6	6	Not yet addressed
MAWP 2014-2020	H_2 production flexibility (degradation <2%)	%	5-150	5-150	5-150	Not yet addressed
MAWP 2014-2020	Hot start (min to max power)	seconds	10	2	<3	Not yet addressed
MAWP 2014-2020	Cold start (min to max power)	seconds	<120	<300	<300	Not yet addressed
Project's own	Stack lifetime	h	40000	60000	60000	Not yet addressed
Project's own	Stack capacity	Nm3/h	14	>13	14.2	Not yet addressed
Project's own	Output pressure	bar	20	20	20	Not yet addressed
Project's own	Ramp up (min to full load)	%/s		50	100	Not yet addressed





ELYntegration
Grid Integrated Multi Megawatt High Pressure Alkaline Electrolysers for Energy Applications

Panel 5 — Hydrogen production, distribution and storage: research and validation

Acronym:	**ELYntegration**
Project ID:	671458
Title:	Grid Integrated Multi Megawatt High Pressure Alkaline Electrolysers for Energy Applications
Call Topic:	FCH-02.8-2014
Project total costs (€):	€ 3,3 million
FCH JU maximum contribution (€):	€ 1,8 million
Project start/end:	01 Sep 2015 - 31 Aug 2018
Coordinator:	Fundacion para Desarrollo de las Nuevas Tecnologias del Hidrogeno en Aragon, Spain
Beneficiaries:	Instrumentacion y Componentes, Iht Industrie Haute Technol., Rheinisch-Westfaelische Tech. Hochschule Aachen, Vlaamse Instelling voor Technol. Onderzoek, Fraunhofer Gesellschaft zur Foerderung der Angewandten Forschung
Website:	http://www.elyntegration.eu

Project and objectives

ELYntegration is focused in the design and engineering of a robust, flexible and cost-competitive MW-scale alkaline water electrolyser, capable of producing with a single stack up to 4.5 ton /day hydrogen under highly dynamic power supply when high renewable energies shares are considered. The most attractive business models and the assessment on market potential have been implemented. Advanced materials have been developed and tested at micro pilot level. Degradation tests at pilot scale level and demonstration of the industrial prototype in real conditions are planned.

Major project achievements

- Implementation of test bench for testing at pilot scale and design of AST protocols for degradation assessment
- Novel advanced materials for AWE developed (eight structures as separators and two set of electrodes), tested at micropilot scale
- Communication protocols for grid services defined and new potential business models identified

Future steps

- C&CS validated at industrial scale
- Commissioning of advanced stacks: 3 for pilot scale and at least 2 for industrial scale tests
- Accelerated stress tests at pilot scale
- Demonstration of technology at industrial scale and under dynamic profiles coupled to a RE system
- Design of multi MW high pressure alkaline water electrolysis

Non-quantitative objectives and status

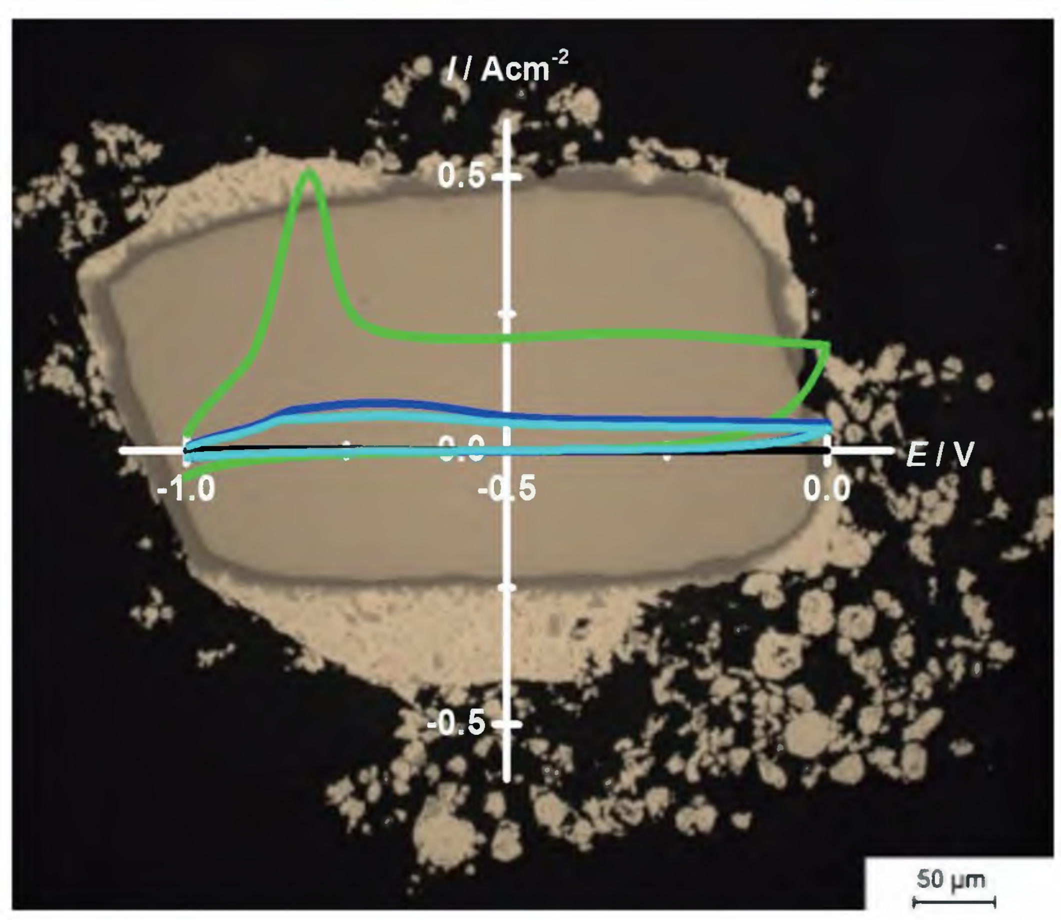
- Communication and control capabilities (C&CS)
  An assessment of the requirements to provide grid and balancing services has been carried out. C&CS will be validated in summer 2017 within WP5
- Regulatory framework and end-user requirements
  The regulatory framework and end user requirements for an electrolyser providing grid services have been carried out
- Business models
  The most attractive business scenarios based on the utilization of the MW HP AWE for grid and energy storage devices have been identified
- Dissemination of the results
  The communication is being made through different channels and taking into account several target audiences in order to maximize the impact

Relevant 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, so that the combined system of the hydrogen production and the conversion using the fuel cell system can compete with the alternatives for electricity production available on the market
- Demonstrate on a large scale the feasibility of using hydrogen to support integration of renewable energy sources into the energy systems, including through its use as a competitive energy storage medium for electricity produced from renewable energy sources

Quantitative targets and status

Target Source	Parameter	Unit	Starting point	Target for project	Achieved to date in project	Best est. of final project result	Target: status on May 1st 2017	Description
MAWP 2014-2020	Efficiency degradation	%/year	2	1.5		1.5	Not yet addressed	Accelerated stress protocols (AS) defined. Test bench implemented
MAWP 2014-2020	Reduction of CAPEX	M€/(t/d)	2.18	1.30	<2.18	<1.30	Due later	Through improvements on stack design, BOP optimisation and manufacturing processes
Project's own	Increase of stack size	kW	3500	9700	0	9700	Not yet addressed	Once validated and demonstrated at prototype level, all advanced constructive features will be integrated in the design of a MW HP AWE system
Project's own	Increase of stack capacity	t/d H_2	1.62	4.50	0	4.50	Not yet addressed	Development of final design according to incremental results from various project tasks
Project's own	Increase of out-put pressure	bar	33	35-60	33	35 (60)	Not yet addressed	60 bar to be tested at pilot scale first. Materials development crucial



GrInHy
Green Industrial Hydrogen via Reversible High-Temperature Electrolysis

Panel 5 — Hydrogen production, distribution and storage: research and validation

Acronym:	**GrInHy**
Project ID:	700300
Title:	Green Industrial Hydrogen via Reversible High-Temperature Electrolysis
Call Topic:	FCH-02.4-2015
Project total costs (€):	€ 4,5 million
FCH JU maximum contribution (€):	€ 4,5 million
Project start/end:	01 Mar 2016 - 28 Feb 2019
Coordinator:	Salzgitter Mannesmann Forschung, Germany
Beneficiaries: VTT, Sunfire, Salzgitter Flachstahl, Politec. Torino, Ustav Fyziky Materialu, Akademie Ved Ceske Republiky, Eifer Europaisches Inst. fur Energieforschung, Boeing Research & Technology Europe	
Website:	http://www.green-industrial-hydrogen.com/home/

Project and objectives

Central to the GrInHy project is the manufacturing, integration and operation of the worldwide most powerful reversible high-temperature steam-electrolyzer (HTE) at an integrated iron-and-steel works.

The project objectives comprise 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 at least 7,000 h and degradation tests at stack level of > 10,000 h with a degradation rate of < 1 %/1,000 h.

The on-site installation of the GrInHy system started in June. Test operation is planned for July 2017.

Major project achievements

- Separate lab commissioning of both the RSOC and HPU container
- Start of 10,000 h stack testing
- First test results at cell and stack level regarding glass sealing and thermo-mechanical strength; fuel reforming/cleaning test results

Future steps

- Finishing of on-site installation and commissioning of the GrInHy system - both RSOC and Hydrogen Processing Unit container - by end of June 2017
- Starting of test operation in July 2017
- Finishing the 7,000 h test operation in June 2018
- Finishing the 10,000h stack testing in the end of 2018
- Report on techno-economic evaluation of GrInHy concept on cost targeting and evaluation in March 2018

Non-quantitative objectives and status

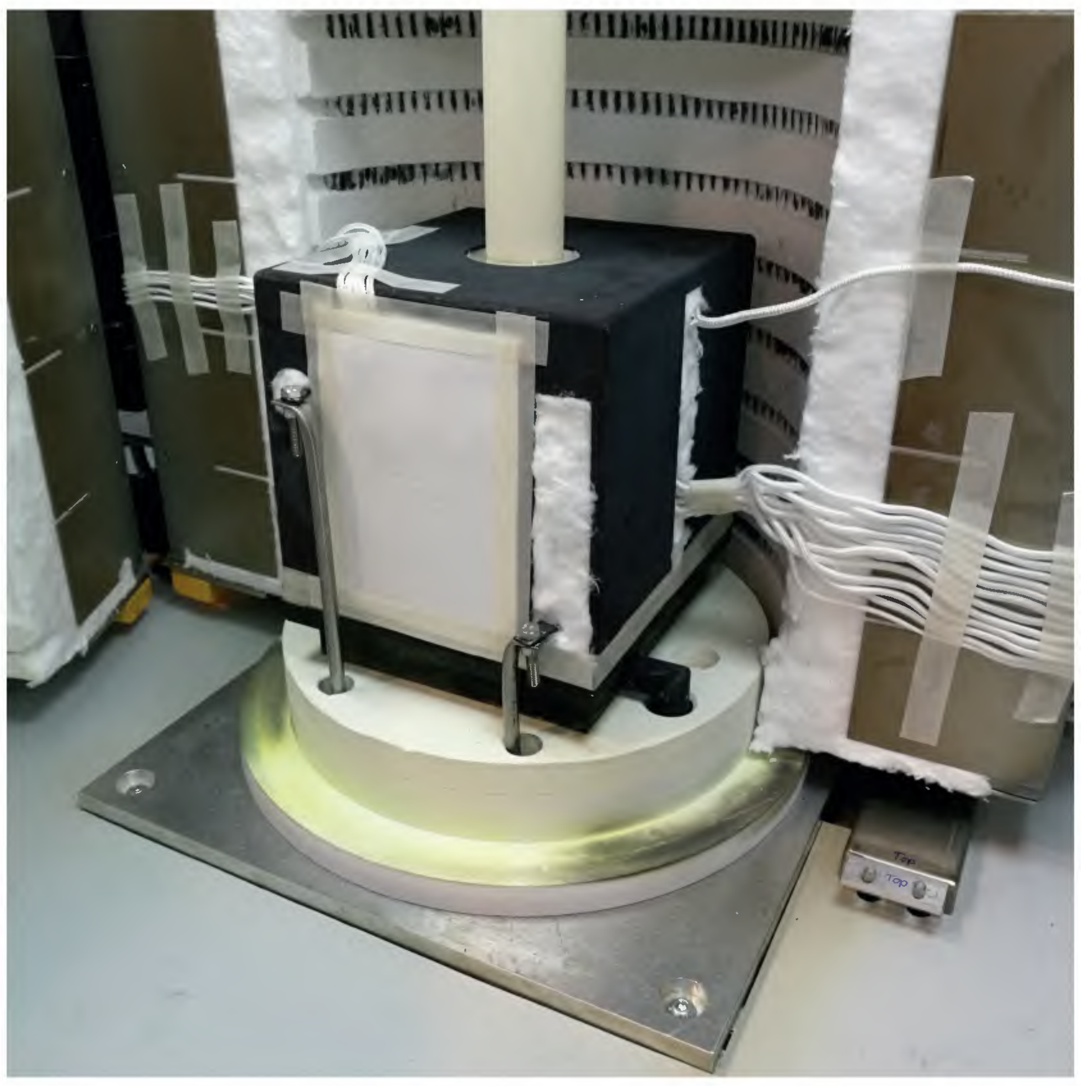
- Elaboration of an exploitation roadmap for cost reducing measures
  A draft exploitation roadmap has been prepared. It will be updated during the second half of the project
- Development of dependable system cost data
  The first prototype has been set up. Its costs will be analysed in detail to compile a reliable database for future cost estimations
- Integration of a reversible operation mode (fuel cell mode)
  The prototype is designed with the ability to operate in reverse mode as power generator with H2 or NG. This will be proofed during onsite tests

Relevant 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, so that the combined system of the hydrogen production and the conversion using the fuel cell system can compete with the alternatives for electricity production available on the market
- Demonstrate on a large scale the feasibility of using hydrogen to support integration of renewable energy sources into the energy systems, including through its use as a competitive energy storage medium for electricity produced from renewable energy sources

Quantitative targets and status

Target Source	Parameter	Unit	Starting point	Target for project	Achieved to date in project	Best est. of final project result	Target: status on May 1st 2017	Description
MAWP 2014-2020	Overall electrical efficiency	%HHV	68	95		95	Due later	The use of HTE and steam from waste heat will enable the system to achieve highest efficiencies
MAWP 2014-2020	System capacity	kW	75	150		150	Due later	The prototype will comprise a newly designed larger RSOC module
MAWP 2014-2020	Lifetime	h	2000	7000		15000	Due later	The prototype uses a robust design and enhanced cell and stack technology to enable a longer lifetime
Project's own	Degradation	%/kh	1	1		1	Due later	The prototype uses an enhanced cell and stack technology to enable low degradation



HELMETH
Integrated High-Temperature electrolysis and methanation for effective power to gas conversion

Panel 5 — Hydrogen production, distribution and storage: research and validation

Acronym:	**HELMETH**
Project ID:	621210
Title:	Integrated High-Temperature electrolysis and methanation for effective power to gas conversion
Call Topic:	SP1-JTI-FCH.2013.2.4
Project total costs (€):	€ 3,8 million
FCH JU maximum contribution (€):	€ 2,5 million
Project start/end:	01 Apr 2014 - 31 Dec 2017
Coordinator:	Karlsruher Inst. Technol., Germany
Beneficiaries: Ethosenergy Italia, European Research Inst. of Catalysis, Nat. Tech. Uni. Athens, Politec. Torino, Sunfire, DVGW Deutscher Verein des Gas- und Wasserfaches - Technisch-Wissenschaftlicher Verein	
Website:	http://www.helmeth.eu/

Project and objectives

The objective of the HELMETH project is the proof of concept of a highly efficient Power-to-Gas technology with methane as chemical storage and by thermally integrating high temperature electrolysis (SOEC technology) with CO2 methanation. The aim is to prove and demonstrate that high temperature electrolysis and methanation can be coupled and thermally integrated towards conversion efficiencies > 85 % from renewable electricity to methane. So far, promising results have been obtained. Pressurized SOEC module has been successfully operated. Methanation module is in commissioning phase.

Major project achievements

- SOEC short stacks tests have been performed at 800°C and pressurised conditions. Degradation rates < 0.5 %/ 1000 h and feasibility of co-electrolysis
- Efficiencies > 85% for large-scale plants based on realistic assumptions and lab tests. SNG quality is met with reactor concept based on lab experiments
- The world's first pressurized SOEC module has been successfully operated. Methanation module is in commissioning phase

Future steps

- Completion of studies related to scale-up and technical harmonization & regulation
- Characterisation of methanation module
- Coupling of methanation and SOEC module. Operation of coupled prototype in the last quarter of 2017

Non-quantitative objectives and status

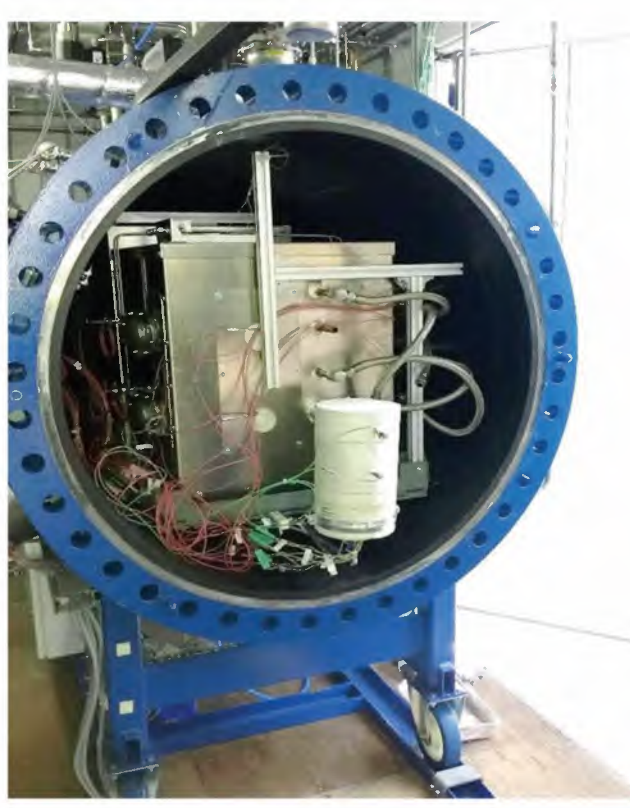
- Manufacture of dedicated HTE cell and stacks for use in large systems
  The developed HTE cells and stack within HELMETH are the suitable basis for upscaling to large systems
- Develop concepts of HTE for use with renewable energy production
  This is the major target of HELMETH. So far promising results have been obtained as described
- Develop concepts for pressurised electrolysis for more economical system
  Pressurized SOEC module has been successfully operated.
- Test & evaluation of cells, stacks and systems under realistic conditions

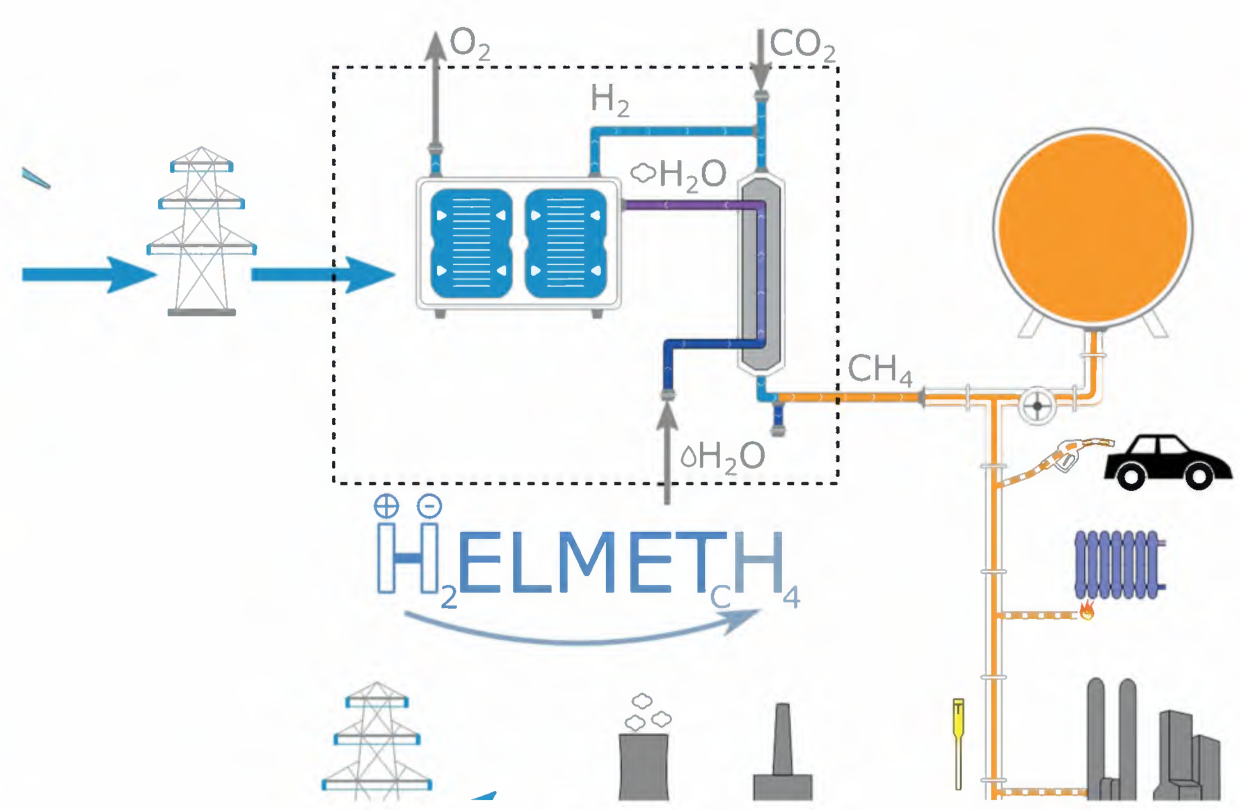
Relevant to FCH JU overarching objectives

- Increase the energy efficiency of production of hydrogen mainly from water electrolysis and renewable sources while reducing operating and capital costs, so that the combined system of the hydrogen production and the conversion using the fuel cell system can compete with the alternatives for electricity production available on the market
- Demonstrate on a large scale the feasibility of using hydrogen to support integration of renewable energy sources into the energy systems, including through its use as a competitive energy storage medium for electricity produced from renewable energy sources

Quantitative targets and status

Target Source	Parameter	Unit	Starting point	Target for project	Achieved to date in project	Best est. of final project result	Target: status on May 1st 2017	Description
AIP 2013	Current density @ 800-1000°C & pressurised cond.	A/cm²		1	1	1	Achieved	1 A/cm² achieved on cell tests, 0.8 A/cm² at stack level
AIP 2013	Degradation rates for short stacks	%/ 1000 h		0.5	0.43	0.43	Achieved	Degradation rates < 0.5%/1000 h indirectly proven by linear extrapolation based on 320 h of tests + plausibility due to previous long-term tests
AIP 2013	Conversion efficiency from electricity to methane	%		85	86	86	Due later	Detailed simulations including BoP predict a total conversion efficiency of 86% (large scale plant). Operation of final prototype at end of 2017





HPEM2GAS
High Performance PEM Electrolyzer for Cost-effective Grid Balancing Applications

Panel 5 — Hydrogen production, distribution and storage: research and validation

Acronym:	**HPEM2GAS**
Project ID:	700008
Title:	High Performance PEM Electrolyzer for Cost-effective Grid Balancing Applications
Call Topic:	FCH-02.2-2015
Project total costs (€):	€ 3,8 million
FCH JU maximum contribution (€):	€ 2,5 million
Project start/end:	01 Apr 2016 - 31 Mar 2019
Coordinator:	Consiglio Nazionale delle Ricerche CNR, Italy
Beneficiaries: EStadtwerke Emden, Solvay Specialty Polymers Italy, ITM Power (Trading), Hochschule Emden/Leer, Ewii Fuel Cells, Uniresearch, JRC -Joint Research Centre, European Commission	
Website:	www.hpem2gas.eu

Project and objectives

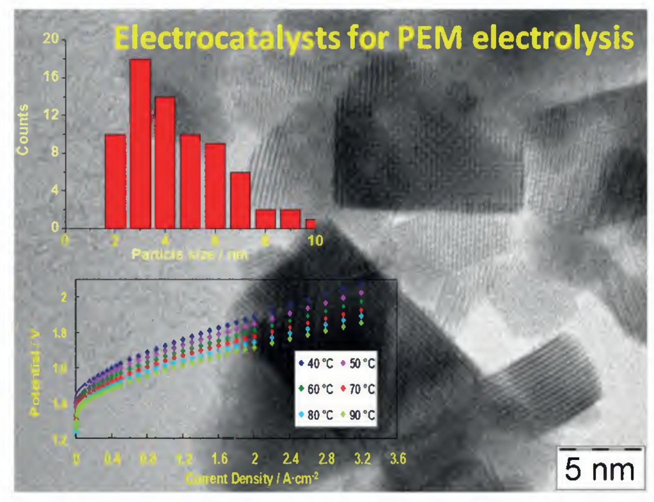
The HPEM2GAS project is developing a high performance PEM electrolysis technology optimised for grid management service (power-to-gas) through both stack and balance of plant innovations, culminating in a six-month field test of an advanced 180 kW (nominal) PEM electrolyser. The project will also contribute 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.

Major project achievements

- Achievement of operating current density for PEM electrolysis of 3 A cm-2 at about 80% 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

- Validation of the conventional PEM electrolysis system (298 kW) used as baseline to assess the progress achieved in this project
- Large area MEA manufacturing for final PEM electrolysis stack
- Assembling and testing of the final PEM electrolysis stack
- Completion of the BoP for the new system
- Test-site completed



Quantitative targets and status

Target Source	Parameter	Unit	Starting point	Target for project	Achieved to date in project	Best est. of final project result	Target: status on May 1st 2017	Description
Project's own	Membrane conductivity for large area membranes	S cm-1	0.15	0.20	0.20	0.25	Achieved	Solvay Aquivion E98-09S membrane of 90 µm. Proton conductivity is >200 mS/cm-1 at T >80°C in presence of liquid water
Project's own	Anode overpotential vs. thermoneutral potential	mV	300	200	200	150	Achieved	IrRuOx solid solutions showed OER overpotential of 153 mV, IR-free, at <80 °C and 3 A/cm2 with noble metal loading <0.4 mg/cm² anode
Project's own	Cathode overpotential vs. RHE at 3 A cm-2 less than:	mV	100	50	50	50	Achieved	2 nm Pt/C catalysts showed HER overpotential of 65 mV at 80 °C and 3 A/cm² with noble metal loading <0.1 mg/cm²
Project's own	Performance of 3 A cm-2 at Ucell<1.8 V under nominal operation	A/cm2	2	3	3	3	Achieved	3 A/cm² @1.81-1.79 V at 80-90 °C, with total noble metal loading per MEA < 0.5 mg/cm²
Project's own	Performance of 4.5 A cm-2 at Ucell<2 V under transient operation	A/cm2	3	4.5	4.5	4.5	Achieved	4.5 A/cm2 @1.92-1.96 V at 80-90 °C, with total noble metal loading per MEA < 0.5 mg/cm²
Project's own	Degradation lower than 5 µV/h/cell in a 1000 h test	µV/h/cell	10	5	5	3	Achieved	Degradation < 5 µV/h/cell in 1000 h test in single cell at 1 A/cm²
Project's own	Electrolysis system with hydrogen capacity > 80 kg H_2/day	kg H2/day		80	80	80	Due later	New HPEM2GAS system under development. Conventional system, 134.4 kg H_2/day operating at a current density about 1 A/cm² reported (TRUST)
AIP 2015	Efficiency better than 82% HHV H_2	%	74	82	82	82	Due later	Target achieved at present only in terms of cell voltage efficiency at 3 A/cm². Complete system testing foreseen later
AIP 2015	Energy consumption lower than 48 kWh/kg H_2.	kWh/kg H2	51.10	48	48	48	Due later	Target achieved at present only in terms of cell voltage efficiency at 3 A/cm². Complete system testing foreseen later
Project's own	Gas cross over <0.5 vol % H_2 in the O_2 stream (faradaic effciency)	%	1	0.5	0.5	0.5	Achieved	Achieved at nominal (not yet at very low) current density. Mitigation strategy addressed for the low current range (recombination cat.)

Non-quantitative objectives and status

- Readiness of setup field testing site
  Detailed engineering and approval by local authorities achieved; analysis of different test scenarios carried out and reported
- Successful demonstration of the electrolysis system in grid balancing
  Planning of the field-test site is progressing well, as well as system and components development
- Final event/demonstration at the field test site
  Organisation of the final event planned in terms of period, location and stakeholders to invite is ongoing

Relevant 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, so that the combined system of the hydrogen production and the conversion using the fuel cell system can compete with the alternatives for electricity production available on the market
- Demonstrate on a large scale the feasibility of using hydrogen to support integration of renewable energy sources into the energy systems, including through its use as a competitive energy storage medium for electricity produced from renewable energy sources
- Reduce the use of the EU defined 'Critical raw materials', for instance through low-platinum or platinum-free resources and through recycling or reducing or avoiding the use of rare earth elements

HyBalance

Panel 5 — Hydrogen production, distribution and storage: research and validation

Acronym:	**HyBalance**
Project ID:	671384
Title:	HyBalance
Call Topic:	FCH-02.10-2014
Project total costs (€):	€ 15,6 million
FCH JU maximum contribution (€):	€ 8 million
Project start/end:	01 Oct 2015 - 30 Sep 2020
Coordinator:	Air Liquide Advanced Business, France
Beneficiaries: Neas Energy, Copenhagen Hydrogen Network, Hydrogenics Europe, Ludwig-Boelkow-Systemtechnik, Air Liquide Global E&C Solutions France, Cemtec Fonden	
Website:	www.hybalance.eu
Linkedin:	HyBalance

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 the highly dynamic PEM electrolysis technology and innovative hydrogen delivery processes involved but also demonstrate these in a real industrial environment by applying high pressure hydrogen production and delivery equipment. The plant is under construction. The electrolyser has been delivered.

Major project achievements

- Factory Acceptance Test validated
- Electrolyser delivered onsite

Future steps

- Site Acceptance Test of the electrolyser
- Site Acceptance Test of the entire plant
- Opening Event

Relevant 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, including through its use as a competitive energy storage medium for electricity produced from renewable energy sources

Quantitative targets and status

Target Source	Parameter	Unit	Starting point	Target for project	Achieved to date in project	Best est. of final project result	Target: status on May 1st 2017	Description
MAWP 2014-2020	Cost goal	€/kW	0	2570	1810	1000	Achieved	Target achieved for installation from 2.5 MW onwards
AIP 2014	Efficiency	kWhel/ kgH_2		57.5	54	54	Achieved	Unit is designed for >20 khrs performance within this target
AIP 2014	System lifetime	hours		20,000		20,000	Due later	Unit designed for 20 000 hrs with 10% degradation

HYDROSOL-PLANT

Thermochemical hydrogen production in a solar monolithic reactor: construction and operation of a 750 kWth plant

Panel 5 — Hydrogen production, distribution and storage: research and validation

Acronym:	**HYDROSOL-PLANT**
Project ID:	325361
Title:	Thermochemical hydrogen production in a solar monolithic reactor: construction and operation of a 750 kWth plant
Call Topic:	SP1-JTI-FCH.2012.2.5
Project total costs (€):	€ 3,5 million
FCH JU maximum contribution (€):	€ 2,2 million
Project start/end:	01 Jan 2014 - 31 Dec 2017
Coordinator:	Centre for Research and Technology Hellas, Greece
Beneficiaries: Hygear, Centro de Investigaciones Energeticas, Medioambientales y Tecnologicas-Ciemat, Helmholtz-Zentrum Berlin fur Materialien und Energie, Ellinika Petrelaia	
Website:	http://www.hydrosol-plant.certh.gr/

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 lifetime exceeding 1000 operational hours and to construct a solar hydrogen production demonstration plant in the 750 kWth range to verify the developed technology for solar thermochemical water splitting and demonstrate hydrogen production and storage on site at levels above 3kg/week.

Major project achievements

- Manufacturing of novel redox structures
- Durability testing of structured redox material for over 1000 h of consecutive water splitting and thermal reduction
- Scale-up of reactors. The largest solar redox reactors to date

Future steps

- Completion of solar reactors and peripherals installation, solar plant operation and evaluation of results
- LCA and identification of points for minimal environmental impact of further commercialisation
- Workshop organization

Non-quantitative objectives and status

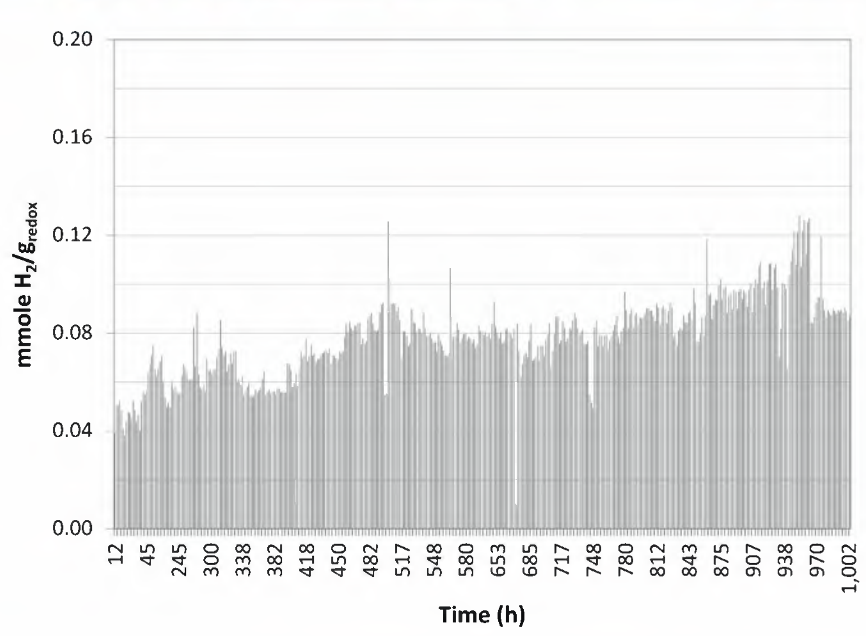
- Modelling and simulation of the plant and of key components
  Objective completed: covers reactants and products conditioning, heat recovery, use of excess/waste heat, monitoring and control
- Field tests of prototype plant
  Installation of the reactors and all peripherals in progress. Thermal and H_2 production experiments will be implemented until the end of the project

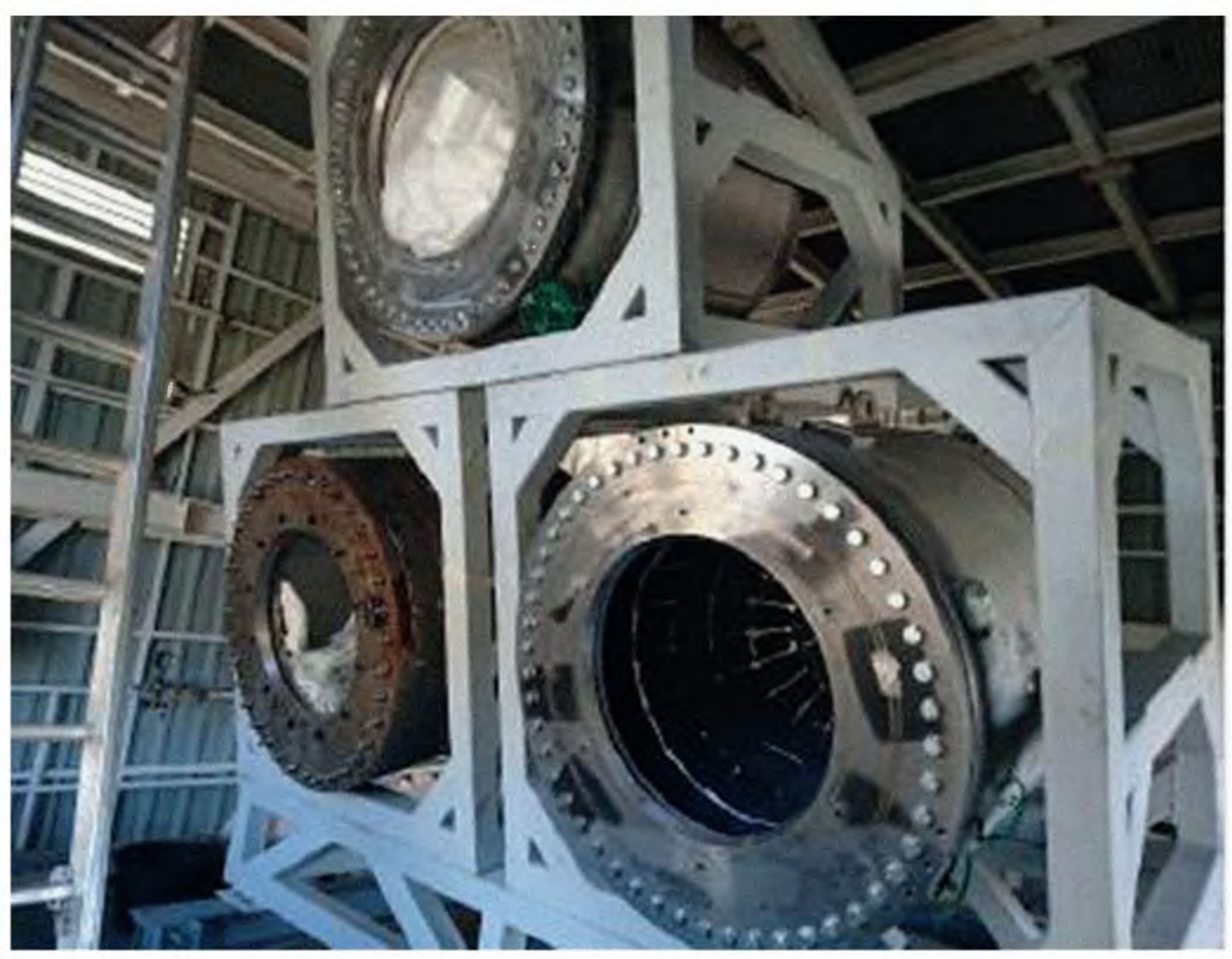
Relevant to FCH JU overarching objectives

- Increase the energy efficiency of production of hydrogen mainly from water electrolysis and renewable sources while reducing operating and capital costs, so that the combined system of the hydrogen production and the conversion using the fuel cell system can compete with the alternatives for electricity production available on the market

Quantitative targets and status

Target Source	Parameter	Unit	Starting point	Target for project	Achieved to date in project	Best est. of final project result	Target: status on May 1st 2017	Description
AIP 2012	Material lifetime	h	20	1000	1002		Achieved	Structured monolithic bodies entirely of the redox material
AIP 2012	Solar hydrogen generator scale	MW	0.10	0.75	0.10	0.75	Due later	Lab-scale evaluation corresponding to >6months on-sun operation
AIP 2012	Demonstration of hydrogen production and storage on site	Kg/week	0.1	3.00	3.30	3.00	Due later	Largest solar thermochemical H_2 production facility to date





FUEL CELLS AND HYDROGEN JOINT UNDERTAKING

HyGrid
Flexible Hybrid separation system for H_2 recovery from NG Grids

Panel 5 — Hydrogen production, distribution and storage: research and validation

Acronym:	**HyGrid**
Project ID:	700355
Title:	Flexible Hybrid separation system for H_2 recovery from NG Grids
Call Topic:	FCH-02.5-2015
Project total costs (€):	€ 2,8 million
FCH JU maximum contribution (€):	€ 2,5 million
Project start/end:	01 May 2016 - 30 Apr 2019
Coordinator:	Tech. Uni. Eindhoven, The Netherlands
Beneficiaries: Hygear Technology and Services, Hydrogen Efficiency Technol. (Hyet), Hygear Fuel Cell Systems, Hygear, Saes Getters, Naturgas Energia Distribucion, Quantis, Fundacion Tecnalia Research & Innovation	
Website:	http://www.green-industrial-hydrogen.com/home/

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.

Major project achievements

- New type of sealing produced and patented
- New membranes produced and tested
- Models have been validated

Non-quantitative objectives and status

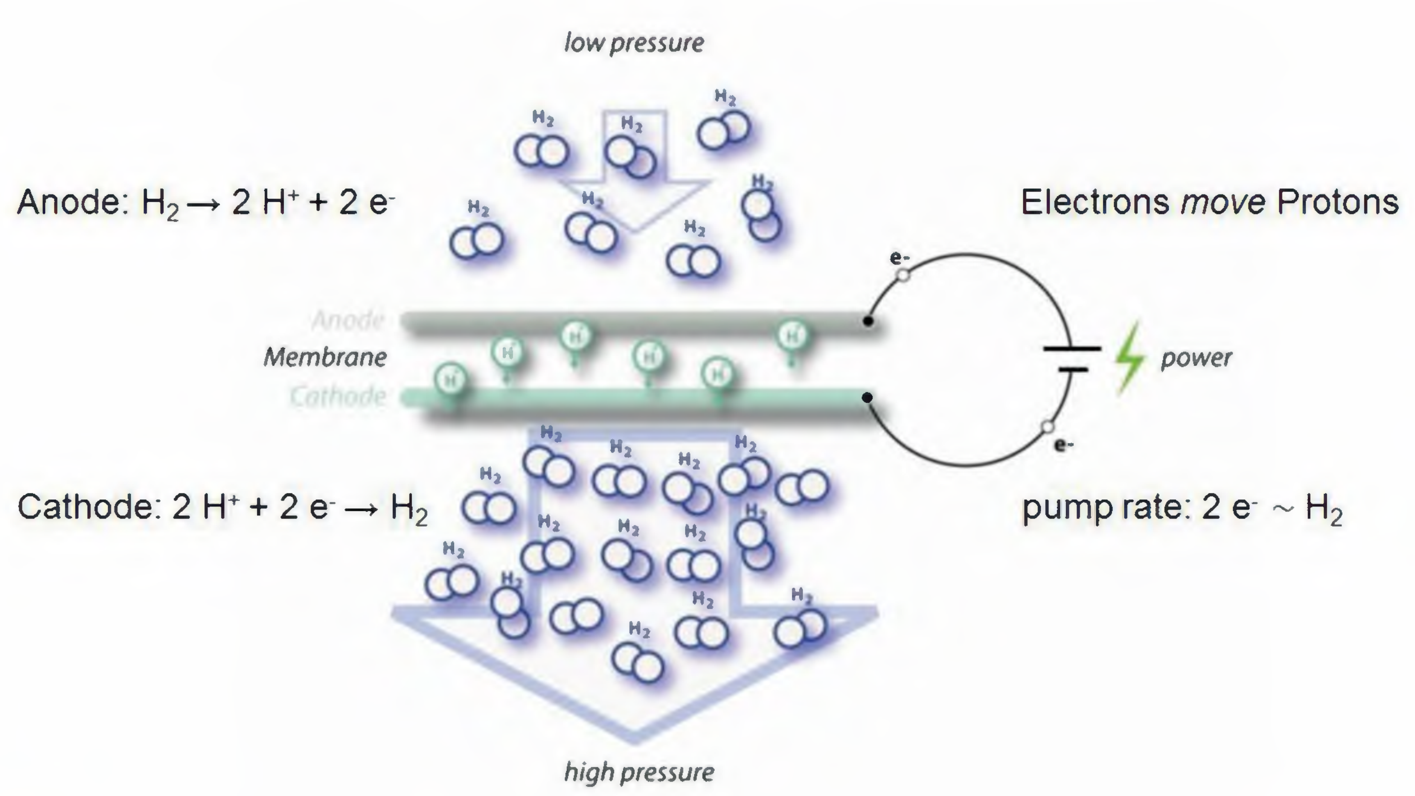
- New types of membrane sealings
  We have developed a new kind of sealing that is more resistant than the standard one. We have patented the new sealing

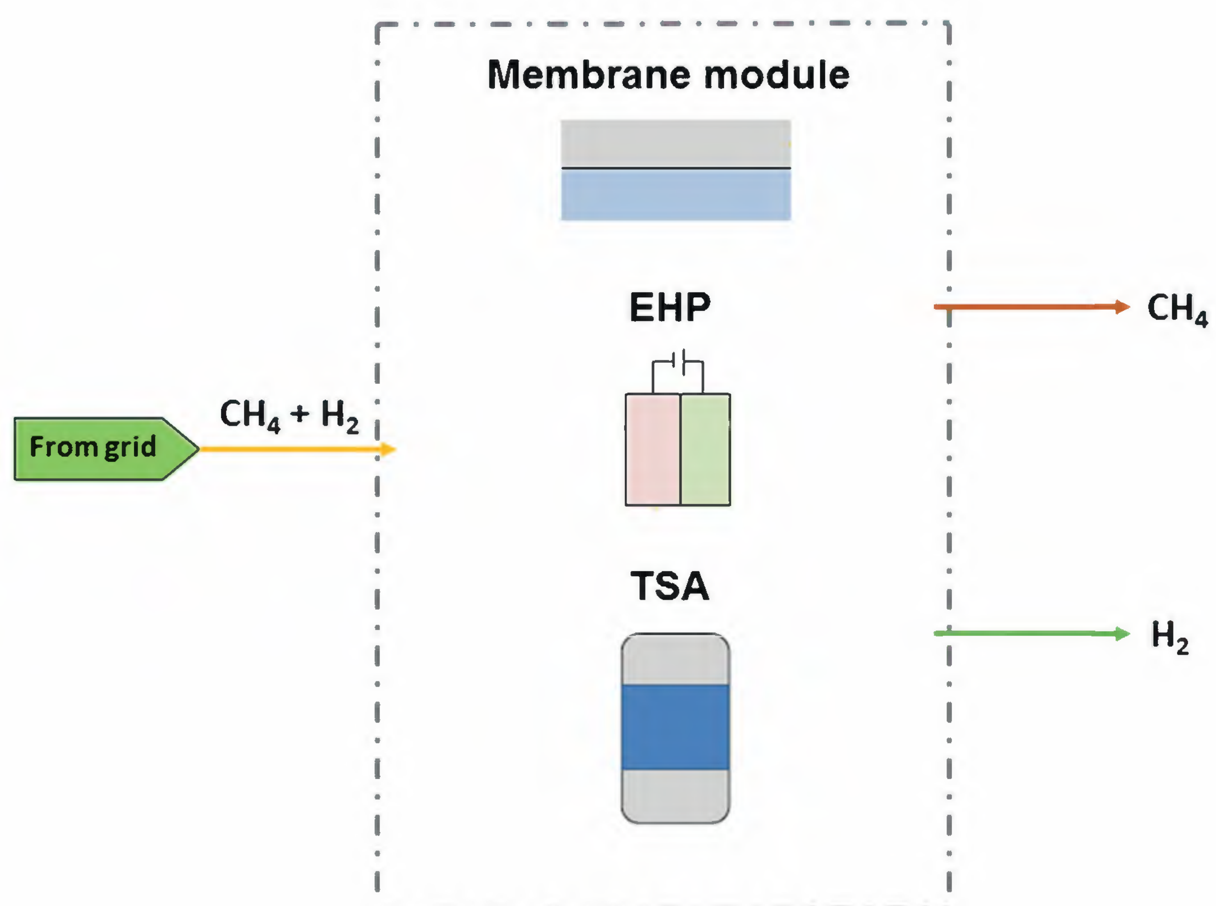
Relevant to FCH JU overarching objectives

- Increase the electrical efficiency and the durability of the different fuel cells used for power production to levels which can compete with conventional technologies, while reducing costs
- Demonstrate on a large scale the feasibility of using hydrogen to support integration of renewable energy sources into the energy systems, including through its use as a competitive energy storage medium for electricity produced from renewable energy sources

Quantitative targets and status

Target Source	Parameter	Unit	Starting point	Target for project	Achieved to date in project	Best est. of final project result	Target: status on May 1st 2017
AIP 2015	Pure hydrogen separation system with low power	kWh/kgH_2	-	5			Due later
AIP 2015	pure hydrogen separation system with low cost	€/kgH_2	-	1.5			Due later
AIP 2015	Pure hydrogen production	kg/day	0	25			Due later
AIP 2012	P rototype unit	TRL	3	5	3	5	Due later





FUEL CELLS AND HYDROGEN JOINT UNDERTAKING

HYTRANSFER
Pre-normative research for thermodynamic optimization of fast hydrogen transfer

Panel 5 — Hydrogen production, distribution and storage: research and validation

Acronym:	**HYTRANSFER**
Project ID:	325277
Title:	Pre-normative research for thermodynamic optimization of fast hydrogen transfer
Call Topic:	SP1-JTI-FCH.2012.2.6
Project total costs (€):	€ 3,1 million
FCH JU maximum contribution (€):	€ 1,6 million
Project start/end:	01 Jun 2013 - 31 Dec 2016
Coordinator:	Ludwig-Boelkow-Systemtechnik, Germany
Beneficiaries: Honda R&D Europe (Deutschland), Centre National de la Recherche Scientifique CNRS, Raufoss Fuel Systems, Testnet Engineering, JRC -Joint Research Centre, European Commission, L'Air Liquide, The CCS Global Group Ltd	
Website:	http://www.hytransfer.eu/

Project and objectives

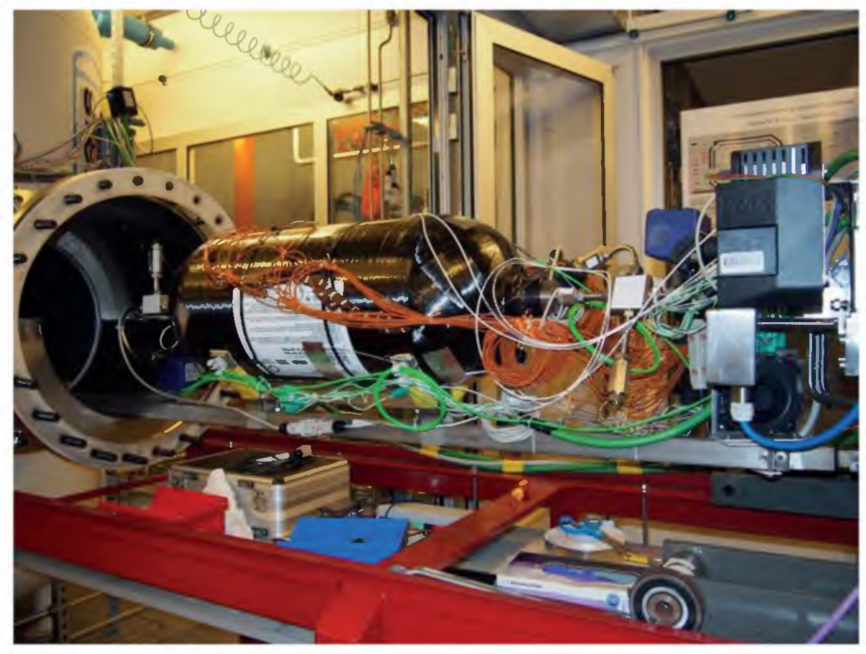
HyTransfer developed and experimentally validated an innovative approach for optimised fast filling of compressed hydrogen, meeting the material temperature limits of the tanks taking into account the container and system's thermal behaviour. The new approach enables faster filling in combination with reduced pre-cooling requirements. Relevant cost savings were identified. The project was concluded in December 2016.

Major project achievements

- Knowledge on thermodynamic effects and behaviour inside pressure vessels during and after fast hydrogen transfer was created
- An innovative new hydrogen refuelling approach was developed. This approach enables faster refuelling by also enabling reduced costs at the HRS

Future steps

- Project finished



Quantitative targets and status

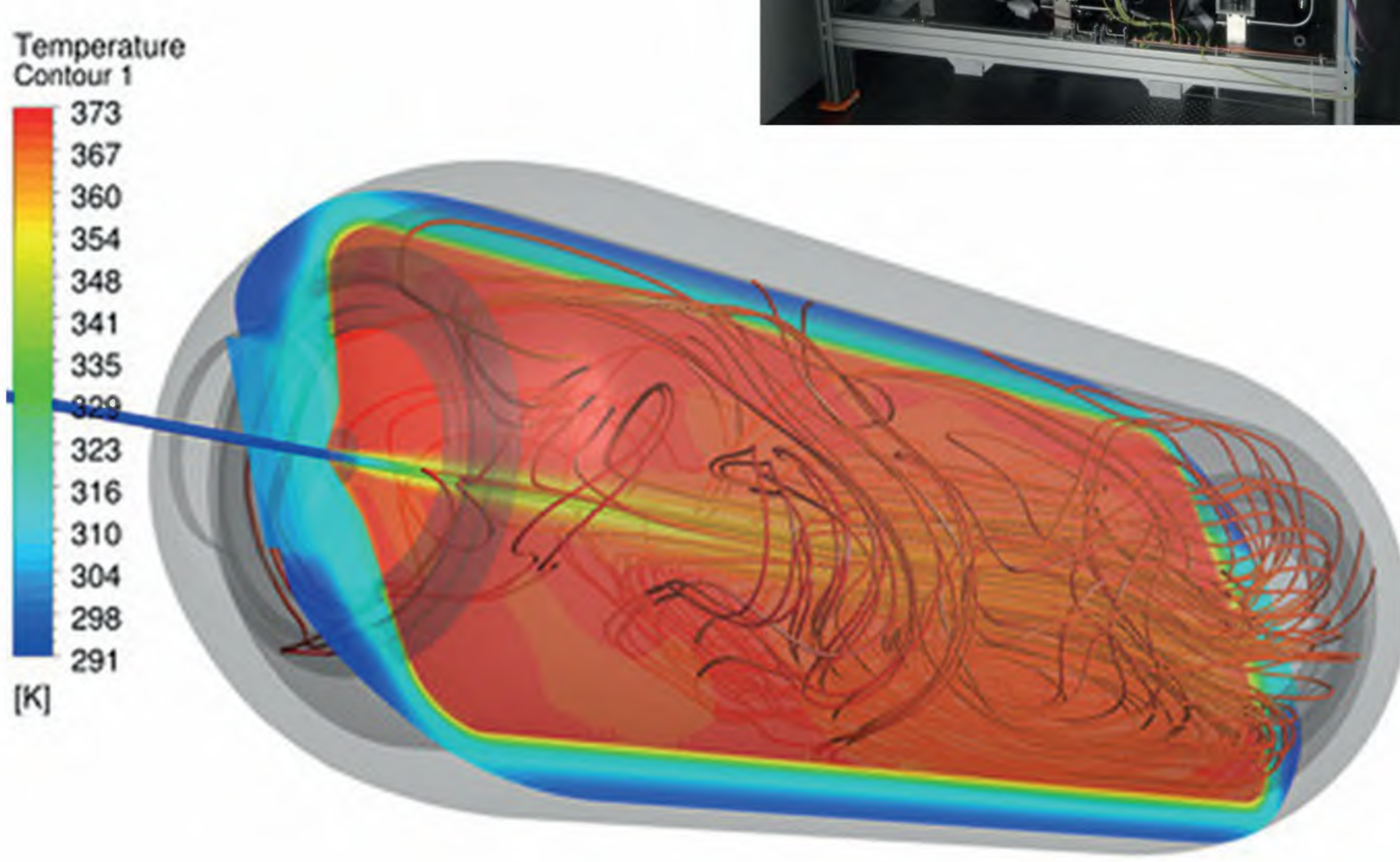
Target Source	Parameter	Unit	Starting point	Target for project	Achieved to date in project	Best est. of final project result	Target: status on May 1st 2017	Description
Project's own	typical refuelling duration	minutes	5	3	3	3	Achieved	3 minutes or below for all relevant refuelling conditions

Non-quantitative objectives and status

- Improve thermodynamic knowledge on fast hydrogen refuelling
  Objective achieved. Large-scale experimental campaigns were performed. Different tank sizes and refuelling conditions were considered
- Develop model to predict thermodynamic conditions during refuelling
  Objective achieved. Software model was validated using extensive data from the experimental campaigns
- Develop innovative approach for fast hydrogen refuelling
  Objective achieved. New approach was developed and confirmed by software modelling
- Quantify improvements of new refuelling approach
  Objective achieved. Refuelling time can be reduced while also reducing pre-cooling requirements. Relevant cost savings were identified

Relevant to FCH JU overarching objectives

- Reduce the production cost of fuel cell systems to be used in transport applications, while increasing their lifetime to levels which can compete with conventional technologies
- Increase the energy efficiency of production of hydrogen mainly from water electrolysis and renewable sources while reducing operating and capital costs, so that the combined system of the hydrogen production and the conversion using the fuel cell system can compete with the alternatives for electricity production available on the market



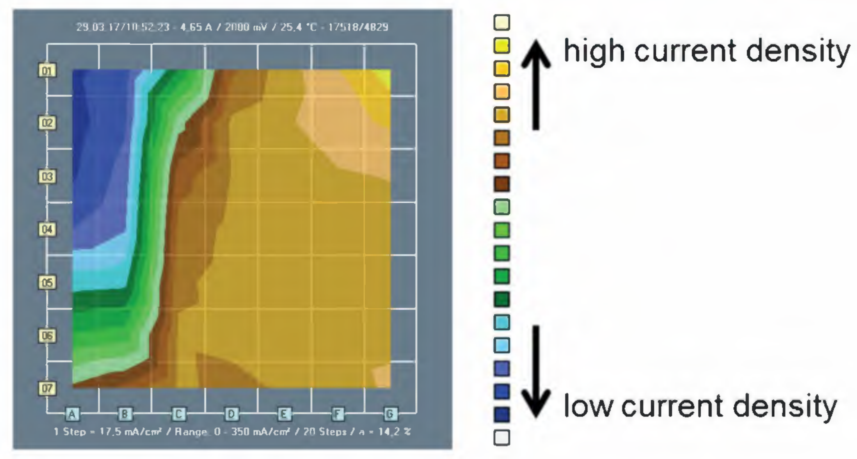
INSIDE
In-situ Diagnostics in Water Electrolyzers

Panel 5 — Hydrogen production, distribution and storage: research and validation

Acronym:	**INSIDE**
Project ID:	621237
Title:	In-situ Diagnostics in Water Electrolyzers
Call Topic:	SP1-JTI-FCH.2013.2.2
Project total costs (€):	€ 3,6 million
FCH JU maximum contribution (€):	€ 2,1 million
Project start/end:	01 Nov 2014 - 31 Oct 2018
Coordinator:	DLR, Deutsches Zentrum fuer Luft und Raumfahrt, Germany
Beneficiaries: Acta, Heliocentris Italy, Centre National de la Recherche Scientifique CNRS, New Nel Hydrogen, Hochschule Esslingen	
Website:	www.inside-project.eu

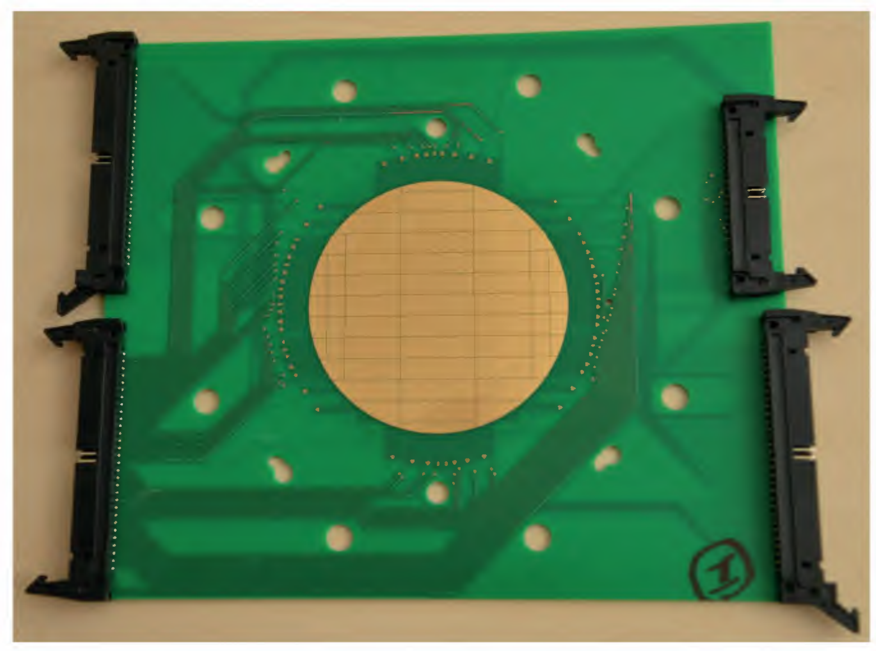
Project and objectives

The development of diagnostics tools for three independent water electrolysis technologies with individual properties is pursued: polymer-electrolyte membrane (PEM WE), alkaline (AWE) and anion exchange membrane (AEM WE) water electrolysis. 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.



Major project achievements

- Applicability for in-operando current densities were evaluated in PEMWE test cell operation for various scenarios
- Prototype diagnostics hardware for AEMWE designed, manufactured and integrated. Evaluation pending



Future steps

- Evaluation of 1st prototype for AEM WE (July 2017)
- Manufacturing and integration of 1st prototype for PEMWE until Sept 2017
- Manufacturing and integration of 1st prototype for AWE until Sept 2017
- Design for 2nd generation prototypes until Nov 2017; for 3rd generation prototypes until Mar 2018
- Public workshop on results and recommendations in Sept 2018

Quantitative targets and status

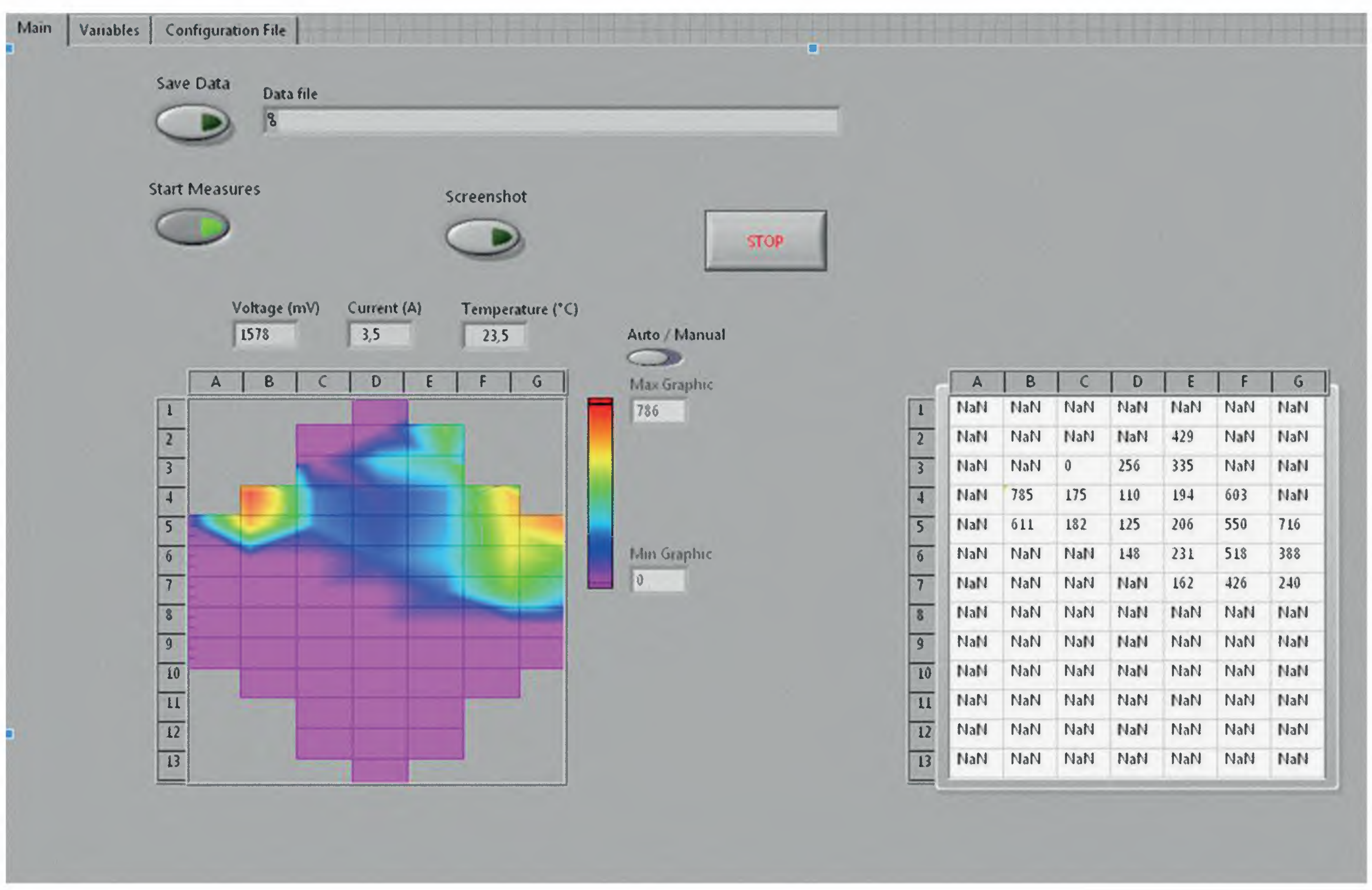
Target Source	Parameter	Unit	Starting point	Target for project	Achieved to date in project	Best est. of final project result	Target: status on May 1st 2017	Description
MAIP 2008-2013	PEM WE Diagnosis/monitoring tool availability						Delayed	
MAIP 2008-2013	AWE Diagnosis/monitoring tool availability						Delayed	
MAIP 2008-2013	AEM WE Diagnosis/monitoring tool availability						Achieved	

Non-quantitative objectives and status

- Evaluation and verification of normal and accelerated test protocols
  Due later. Main objectives enable evaluation of test protocols. Test protocols to start with have been designed
- Recommendation for improvements of water electrolysers
  Due later. Public summary on the lessons learned for electrolyser design/development, which were learned during the use of the diagnostics prototypes

Relevant 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, so that the combined system of the hydrogen production and the conversion using the fuel cell system can compete with the alternatives for electricity production available on the market



MEGASTACK
Stack design for a Megawatt scale PEM electrolyser

Panel 5 — Hydrogen production, distribution and storage: research and validation

Acronym:	**MEGASTACK**
Project ID:	621233
Title:	Stack design for a Megawatt scale PEM electrolyser
Call Topic:	SP1-JTI-FCH.2013.2.3
Project total costs (€):	€ 3,9 million
FCH JU maximum contribution (€):	€ 2,1 million
Project start/end:	01 Oct 2014 - 30 Sep 2017
Coordinator:	Stiftelsen Sintef, Norway
Beneficiaries: Commissariat à l'Energie Atomique et aux Energies Alternatives CEA, Fraunhofer Gesellschaft zur Foerderung der Angewandten Forschung, ITM Power (Trading)	
Website:	www.megastack.eu

Project and objectives

The project 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 concepts developed in FCH JU projects NEXPEL and NOVEL. To up-scale the design concept from a 10-50 kW to a MW-sized stack, we will perform integrated two-phase flow and structural mechanics modelling together with optimisation of stack components such as MEAs, current collectors and sealings. The stack design will have ease of manufacture and stack assembly as a major goal, with necessary quality control processes and robust supply chains.

Major project 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

- Prototype demonstration
- Dissemination of project results

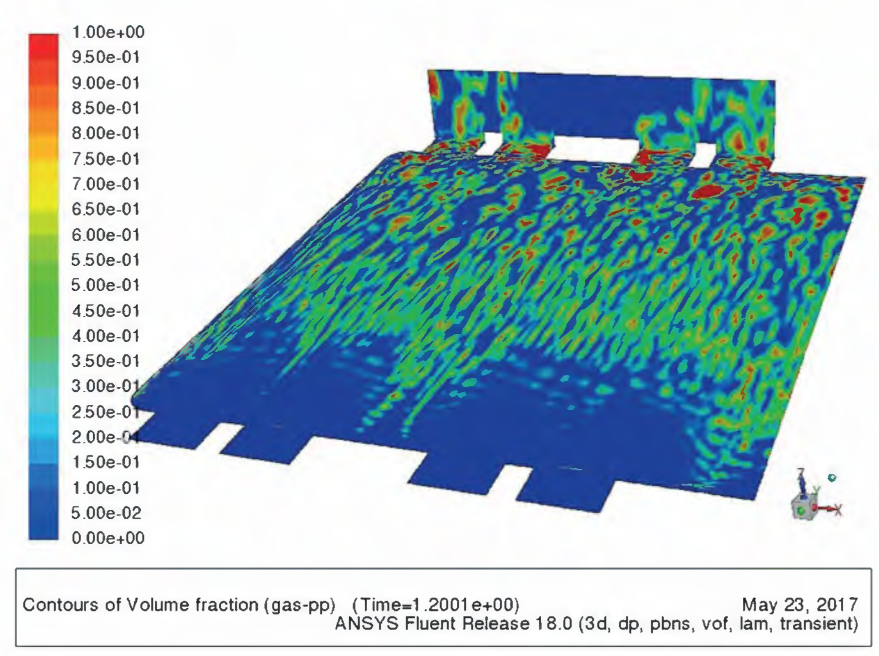
Relevant to FCH JU overarching objectives

- Increase the energy efficiency of production of hydrogen mainly from water electrolysis and renewable sources while reducing operating and capital costs, so that the combined system of the hydrogen production and the conversion using the fuel cell system can compete with the alternatives for electricity production available on the market

EG-04-17-700-EN-P

Quantitative targets and status

Target Source	Parameter	Unit	Starting point	Target for project	Achieved to date in project	Best est. of final project result	Target: status on May 1st 2017	Description
MAIP 2008-2013	Stack cost	€/(Nm3/h)	4000	2500	2500	2500	Achieved	Upscale and design improvements
MAIP 2008-2013	Current density	A/cm²	1	1.2	1.5	1.5	Achieved	MEA and PTL improvement
AIP 2013	Hydrogen production capacity	Nm3/h	20	60	60	60	Achieved	
AIP 2013	Stack availability	%	99	99		99	Not yet addressed	
AIP 2013	Lifetime	h	40,000	40,000	200	40,000	Not yet addressed	Lifetime will not be measured in this project. Extrapolation of 3- month test will be used



NOVEL
Novel materials and system designs for low cost, efficient and durable PEM electrolysers

Panel 5 — Hydrogen production, distribution and storage: research and validation

Acronym:	**NOVEL**
Project ID:	303484
Title:	Novel materials and system designs for low cost, efficient and durable PEM electrolysers
Call Topic:	SP1-JTI-FCH.2011.2.7
Project total costs (€):	€ 5,9 million
FCH JU maximum contribution (€):	€ 2,6 million
Project start/end:	01 Sep 2012 - 30 Nov 2016
Coordinator:	Stiftelsen Sintef, Norway

Beneficiaries:
Areva Stockage d'Energie, Areva H2Gen, Beneq, Commissariat à l'Energie Atomique et aux Energies Alternatives CEA, Fraunhofer Gesellschaft zur Foerderung der Angewandten Forschung, Johnson Matthey Fuel Cells Ltd, Paul Scherrer Inst., Teer Coatings Ltd

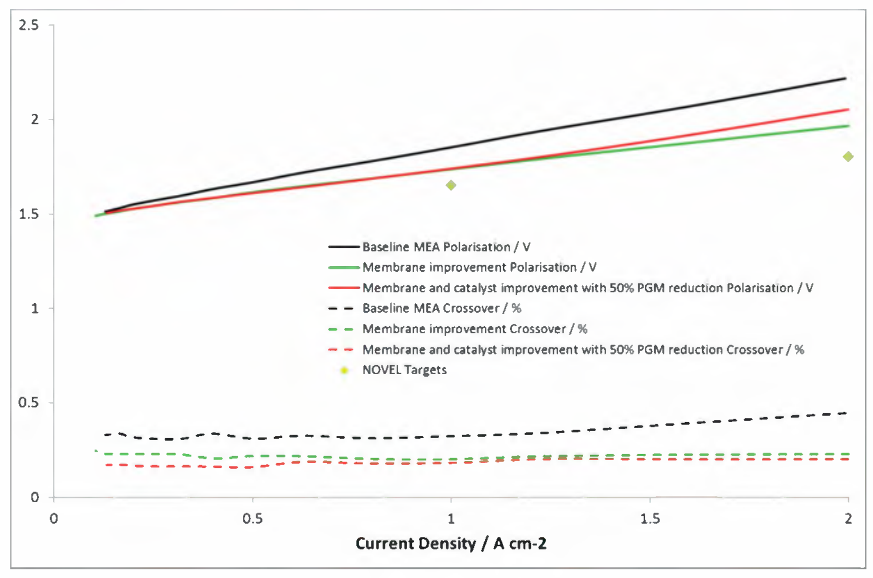
Website: www.novelhydrogen.eu

Project and objectives

The main objective of NOVEL was to develop and demonstrate an efficient and durable PEM water electrolyser utilising the new, beyond the state of the art materials developed within the project. The electrolyser would demonstrate the capability to produce hydrogen with an efficiency of at least 75% (LHV) at rated capacity with a stack cost below €2,500/(Nm3/h and a target lifetime in excess of 40,000 hours (< 15 μVh-1 voltage increase at constant load).

Major project achievements

- Identified degradation mechanisms in PEM electrolysers
- Membranes and MEAs with lower H_2 crossover and lower costs
- Oxygen electrocatalysts with higher activity



Quantitative targets and status

Target Source	Parameter	Unit	Starting point	Target for project	Achieved to date in project	Best est. of final project result	Target: status on May 1st 2017	Description
MAIP 2008-2013	stack CAPEX	€/(Nm3/h)		2000	1500	1500	Achieved	
AIP 2011	Lifetime	h		40,000			Not yet addressed	Lifetime target not met: No time in project to verify + some material solutions do not have the lifetime needed
AIP 2011	Efficiency	% (LHV)		75	68	68		Efficiency target will not be reached, but not needed to reach the related programme objectives
MAIP 2008-2013	Cost of hydrogen	€/kg		5	3.55	3.55	Achieved	Cost calculations - for an electricity price of 0.057€/kWh

Non-quantitative objectives and status

- Alternative materials for bipolar plates and current collectors
  Development of coatings. The goal is to reduce the contact resistance of Titanium decreasing the passivation of titanium to increase the electrolyser lifetime
- Polymer membranes with improved conductivity
  Thinner, more conductive and reinforced PFSA membranes.
- More efficient catalysts for the oxygen evolution reaction
  Catalysts with 300% mass activity vs. state of the art demonstrated ex situ

Relevant 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, so that the combined system of the hydrogen production and the conversion using the fuel cell system can compete with the alternatives for electricity production available on the market
- Demonstrate on a large scale the feasibility of using hydrogen to support integration of renewable energy sources into the energy systems, including through its use as a competitive energy storage medium for electricity produced from renewable energy sources
- Reduce the use of the EU defined 'Critical raw materials', for instance through low-platinum or platinum-free resources and through recycling or reducing or avoiding the use of rare earth elements

PECDEMO
Photoelectrochemical demonstrator device for solar hydrogen generation

Panel 5 — Hydrogen production, distribution and storage: research and validation

Acronym:	**PECDEMO**
Project ID:	621252
Title:	Photoelectrochemical demonstrator device for solar hydrogen generation
Call Topic:	SP1-JTI-FCH.2013.2.5
Project total costs (€):	€ 3,4 million
FCH JU maximum contribution (€):	€ 1,8 million
Project start/end:	01 Apr 2014 - 31 Mar 2017
Coordinator:	Helmholtz-Zentrum Berlin fur Materialien und Energie, Germany
Beneficiaries: Evonik Industries, DLR, Deutsches Zentrum fuer Luft und Raumfahrt, Solaronix, Ecole Polytechnique Federale de Lausanne, Uni. Porto, Technion Israel Inst. Technol	
Website:	www.pecdemo.eu

Project and objectives

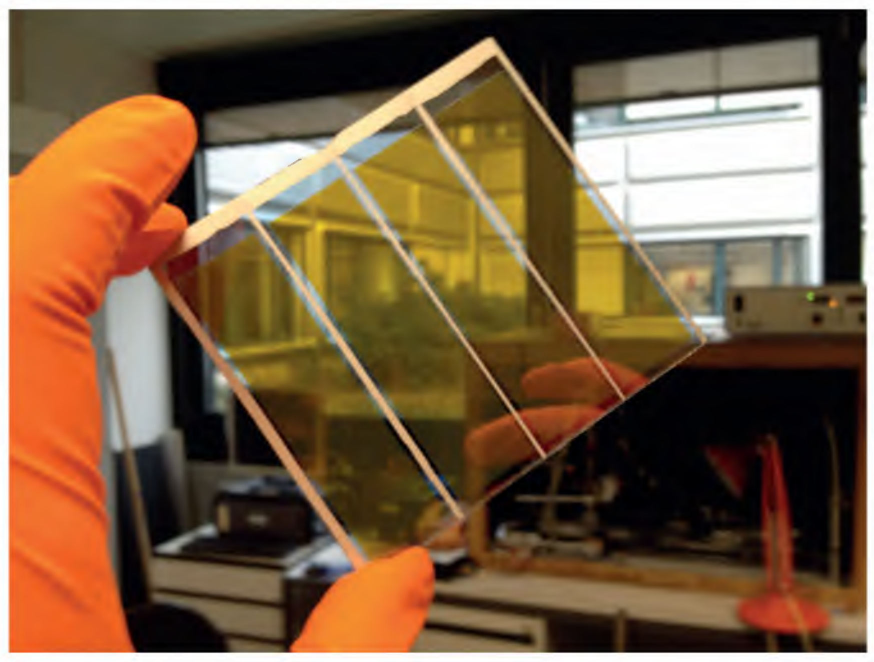
PECDEMO's aim is to develop a hybrid photo-electrochemical-photovoltaic tandem device for light-driven water splitting based on wide-bandgap metal oxide absorbers and thin film photovoltaic cells. Innovative cell designs are used to address critical scale-up issues, such as mass transport limitations and resistive losses. A >50 cm2 cell design is used to construct a water splitting module that has been tested in the field. In parallel, extensive techno-economic and lifecycle analyses based on actual performance characteristics have been carried out.

Major project achievements

- Highest efficiencies (up to 16.2% HHV) ever reported for metal oxide/silicon based PEC/PV tandem devices
- Largest PEC/PV demonstrator (4 x 50 cm2) tested outside under concentrated sunlight
- Innovative novel device concepts demonstrated and published in high impact journals

Future steps

- Project finished



Quantitative targets and status

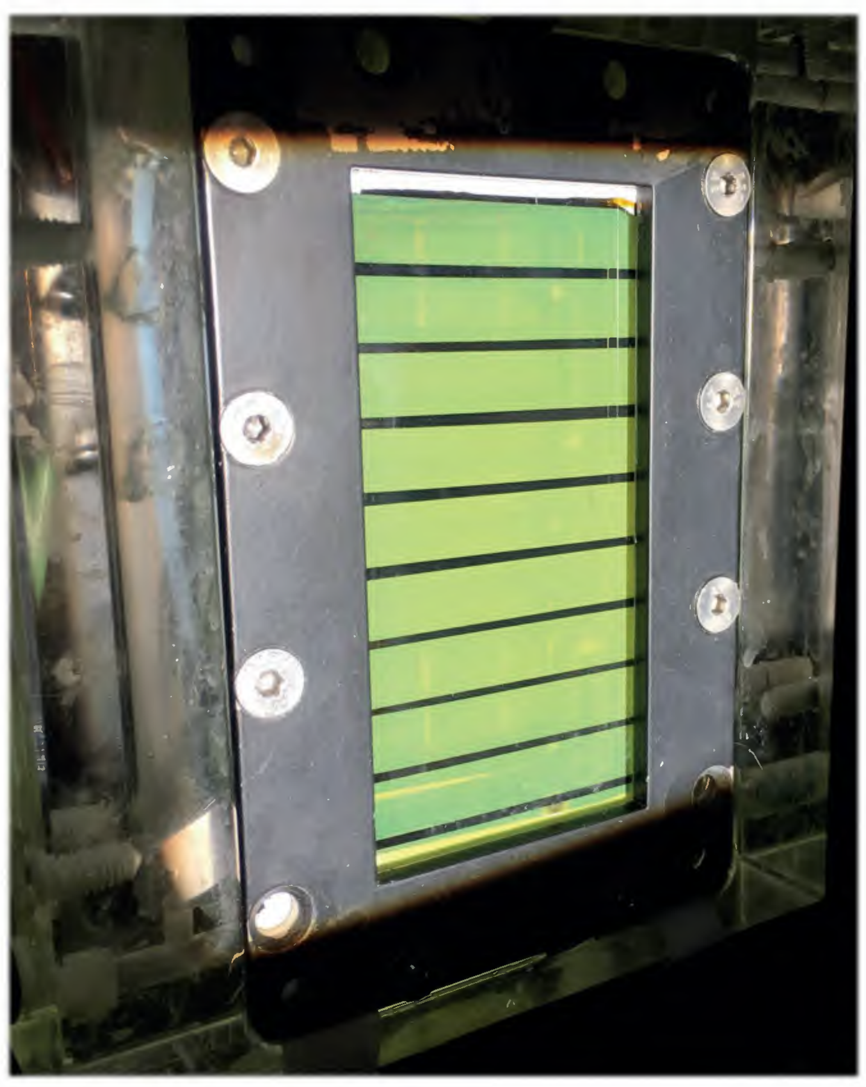
Target Source	Parameter	Unit	Starting point	Target for project	Achieved to date in project	Best est. of final project result	Target: status on May 1st 2017	Description
Project's own	Stability	hours		1000	1000		Achieved	Measured in lab for Fe2O3 photo-anodes
Project's own	Photoelectrode area	cm^2	1	50	50		Achieved	Largest BiVO4 area ever reported, achieved with optimised spray recipe in combination with novel electro-deposition recipe for Ni grid on FTO
Project's own	Solar-to-hydrogen efficiency	% (HHV)	7.30	10	16.20		Achieved	Achieved with novel Ga2O3/ Cu2O nanowire electrode coupled to silicon PV cell with dichroic mirror for photon management

Non-quantitative objectives and status

- Demonstration of prototype water splitting devices
  Hybrid photo-electrochemical / photovoltaic module for water splitting with total area of 200 cm2 has been demonstrated
- Estimate feasibility to meet EU target cost of 5 €/kg H_2
  Cost estimates made for three different production scenarios, value of 9 €/kg was estimated for single home application based on 8% efficient devices
- Design innovative device architectures for efficient light harvesting
  Novel light management concepts based on dual photo-anodes, dichroic mirrors, and rotatable photo-electrodes have been demonstrated
- Develop diagnostic methods to identify energy losses and degradation
  Opto-electrical studies revealed critical loss mechanisms in semiconductor/catalyst interfaces, active power management used to enhance efficiencies

Relevant 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, so that the combined system of the hydrogen production and the conversion using the fuel cell system can compete with the alternatives for electricity production available on the market
- Demonstrate on a large scale the feasibility of using hydrogen to support integration of renewable energy sources into the energy systems, including through its use as a competitive energy storage medium for electricity produced from renewable energy sources
- Reduce the use of the EU defined 'Critical raw materials', for instance through low-platinum or platinum-free resources and through recycling or reducing or avoiding the use of rare earth elements



SElySOs

Development of new electrode materials and understanding of degradation mechanisms on Solid Oxide High Temperature Electrolysis Cells

Panel 5 — Hydrogen production, distribution and storage: research and validation

Acronym:	**SElySOs**
Project ID:	671481
Title:	Development of new electrode materials and understanding of degradation mechanisms on Solid Oxide High Temperature Electrolysis Cells
Call Topic:	FCH-02.1-2014
Project total costs (€):	€ 2,9 million
FCH JU maximum contribution (€):	€ 2,9 million
Project start/end:	02 Nov 2015 - 01 Nov 2019
Coordinator:	Foundation for Research and Technol. Hellas, Greece
Beneficiaries: Prototech, Pyrogenesis, Forschungszentrum Julich, Ethniko Kentro Erevnas Kai Technologikis Anaptyxis, Vysoka Skola Chemicko-Technologicka V Praze, Centre National de la Recherche Scientifique CNRS	
Website:	http://selysos.iceht.forth.gr/
Linkedin:	SElySOs Project

Project and objectives

SElySOs focuses on understanding of the degradation & lifetime fundamentals on both of the SOEC electrodes, for minimisation of their degradation & improvement of their performance and stability mainly under water electrolysis and to a certain extent under water/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

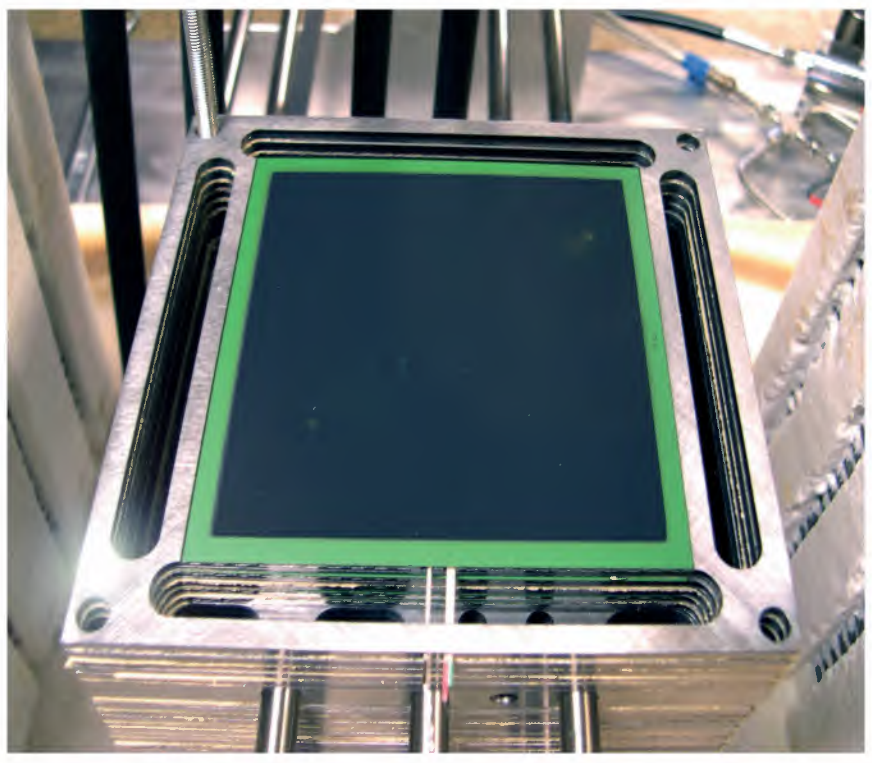
(iv) Development of a theoretical model for description of the performance & degradation of the SOEC H_2 electrode

Major project achievements

- The first results with modified Ni-based & Ni-free cathodes and studies on conventional O_2 cermets in H_2O electrolysis conditions are quite promising
- Very interesting remarks have been derived via operando observations of nickel/ceria electrode surfaces during HT electrolysis measurements
- A 0-D kinetic model of the solid oxide steam electrolysis on the cathode electrode has been developed

Future steps

- Optimized cathodes (H_2O electrodes) for H_2O electrolysis SOECs
- Optimized cathodes (H_2O electrodes) for H_2O/CO_2 co-electrolysis SOECs
- Optimized anodes (O_2 electrodes) for H_2O electrolysis SOECs
- Stack connection for 100 mbar pressure fluctuations and > 1 Mohm electrical insulation successfully verified



Quantitative targets and status

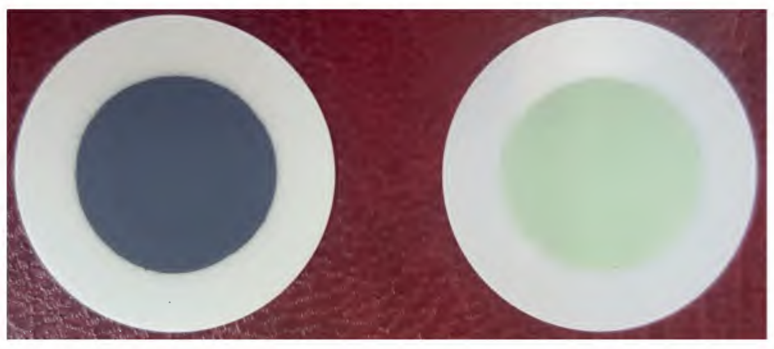
Target Source	Parameter	Unit	Starting point	Target for project	Achieved to date in project	Best est. of final project result	Target: status on May 1st 2017	Description
MAWP 2014-2020	Long term electrical system efficiency (HHV)	%	74	>90			Not yet addressed	Conclusions for the specific objective are not available yet
MAWP 2014-2020	Improvement on the efficiency degradation rate	%/year	2-5	<1			Not yet addressed	Conclusions for the specific objective are not available yet
MAWP 2014-2020	Increase of TRL		3	5	3	5	Due later	Conclusions for the specific objective are not available yet

Non-quantitative objectives and status

- New materials and component design less prone to degradation
During the 1st year of operation a series of Ni-based and Ni-free electrodes started to be investigated under various SOEC H_2O electrolysis conditions
- Understanding of degradation mechanisms under dynamic operation
During the 1st year of operation a mathematical model has been developed particularly for the SOEC H_2O electrolysis reaction.
- Reduction of electricity consumption for H_2 production by 10% by 2025
SElySOs is on its first year of operation and conclusions for the specific objective are not available yet
- Development of improved & robust SOEC systems (cells/stack/s)
SElySOs is on its first year of operation and conclusions for the specific objective are not available yet

Relevant to FCH JU overarching objectives

- Increase the electrical efficiency and the durability of the different fuel cells used for power production to levels which can compete with conventional technologies, while reducing costs
- Increase the energy efficiency of production of hydrogen mainly from water electrolysis and renewable sources while reducing operating and capital costs, so that the combined system of the hydrogen production and the conversion using the fuel cell system can compete with the alternatives for electricity production available on the market
- Reduce the use of the EU defined 'Critical raw materials', for instance through low-platinum or platinum-free resources and through recycling or reducing or avoiding the use of rare earth elements



SOL2HY2
Solar to hydrogen hybrid cycles

Panel 5 — Hydrogen production, distribution and storage: research and validation

Acronym:	**SOL2HY2**
Project ID:	325320
Title:	Solar to hydrogen hybrid cycles
Call Topic:	SP1-JTI-FCH.2012.2.5
Project total costs (€):	€ 3,7 million
FCH JU maximum contribution (€):	€ 2,0 million
Project start/end:	01 Jun 2013 - 30 Nov 2016
Coordinator:	Enginsoft, Italy

Beneficiaries:
Aalto-Korkeakoulusaatio, ENEA, Agenzia Nazionale per le Nuove Tecnologie, l'Energia e lo Sviluppo Economico Sostenibile, Erbicol, DLR, Deutsches Zentrum fuer Luft und Raumfahrt, Oy Woikoski, Outotec (Finland)

Website: sol2hy2.eucoord.com

Project and objectives

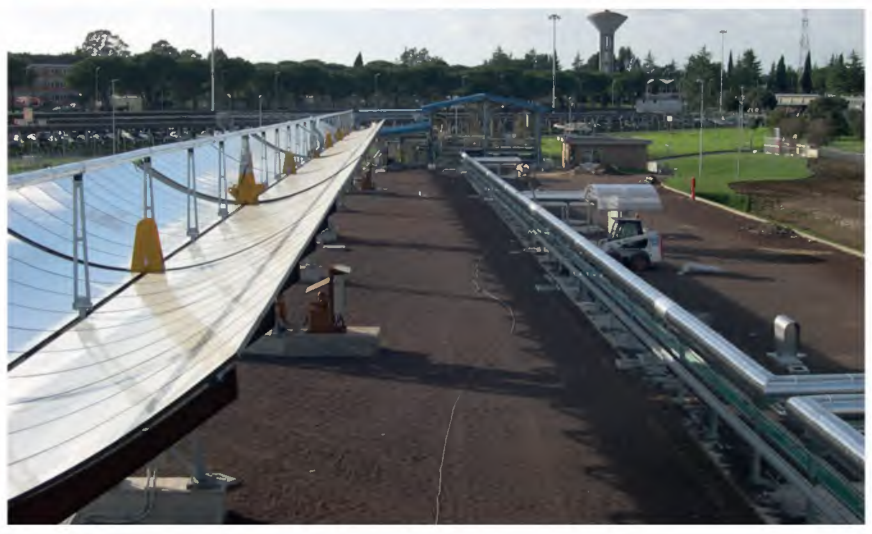
Solar-powered thermo-chemical cycles are capable to directly transfer concentrated sunlight into chemical energy by a series of chemical and electro-chemical reactions, and of these cycles, the hybrid-sulphur (HyS) cycle was identified as the most promising one. The project focus was on bottlenecks solving materials R&D and demonstration of the key components of the solar-powered, CO_2-free hybrid water splitting cycles, complemented by their advanced modelling and process simulation, with conditions and site-specific technical-economical assessment optimization, quantification and benchmarking.

Major project achievements

- The final flowsheets and software for SOL2HY2 plant were developed and analyzed with the flowsheets including solar power input for key units
- New SO_2 depolarized electrolyser was designed, built and tested
- For high temperature solar operations the stability tests at 1000°C for the tailored higher-temperature catalysts were carried out

Future steps

- Project finished



Quantitative targets and status

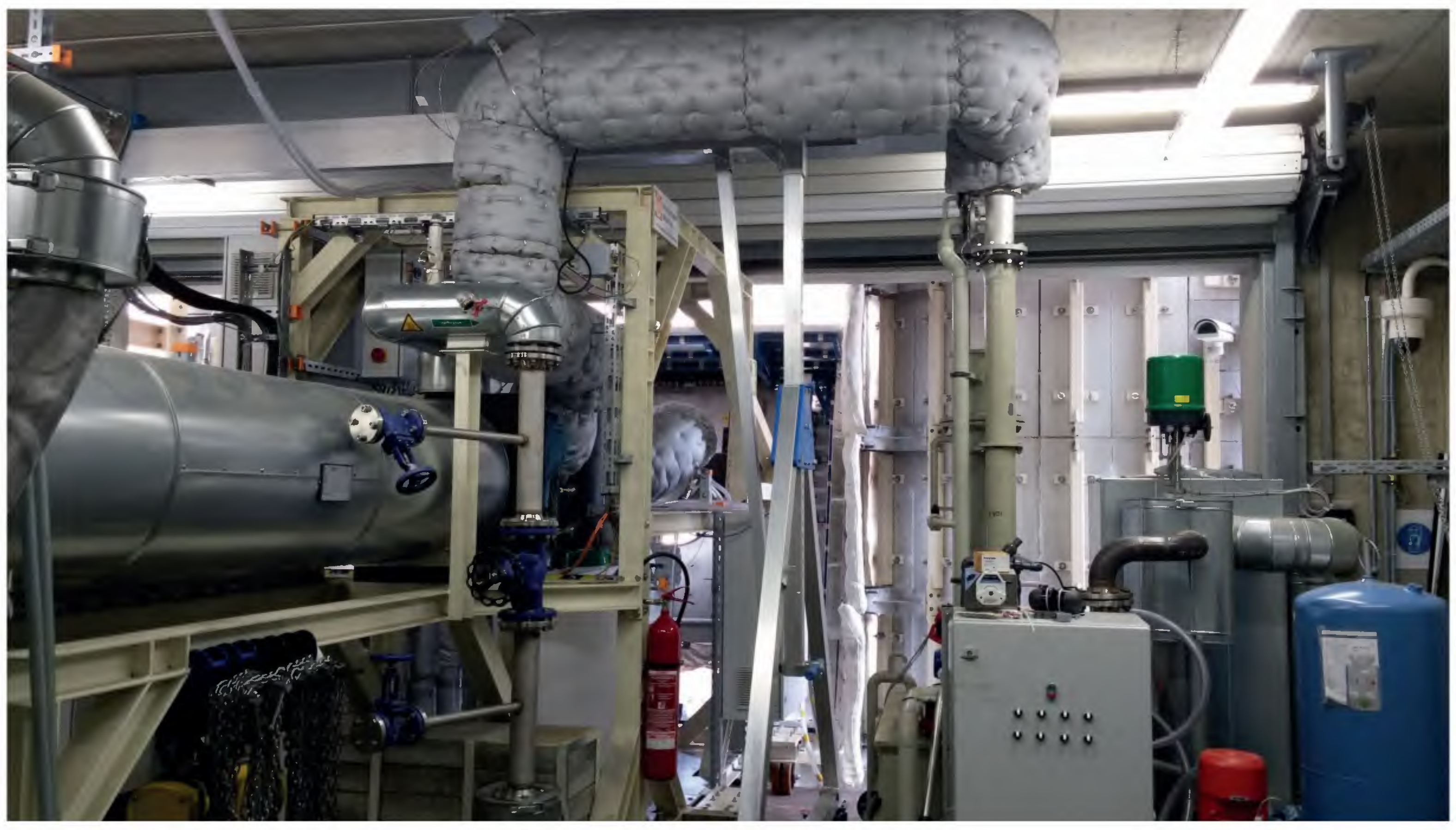
Target Source	Parameter	Unit	Starting point	Target for project	Achieved to date in project	Best est. of final project result	Target: status on May 1st 2017	Description
MAIP 2008-2013	Cost of H_2 delivered at refuelling station	€/kg		5			Not addressed	Not directly addressed
AIP 2012	Catalysts with better activities +30%	%	30	50	30	30	Achieved	Electro-catalysts with 50% better efficiency vs. Pt/Pd. will be not used in final design
AIP 2012	Redox materials with doubled conversion rate	times	2.00				Achieved	Redox materials are not used

Non-quantitative objectives and status

- Integration of HyS cycle features to semi-centralised H_2 production
  Design and development of the components for electrolyser stack, cracker and plant for test facility at Solar Tower Julich (capacity ~1 MW)
- New materials solutions
  Development and optimization of SDE catalysts, ceramics solar components, protective corrosion-resistant coatings
- New software for virtual plants
  For the first time, MODAO+FEM+CFD was integrated with and the plant predictions were made

Relevant 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, so that the combined system of the hydrogen production and the conversion using the fuel cell system can compete with the alternatives for electricity production available on the market
- Reduce the use of the EU defined 'Critical raw materials', for instance through low-platinum or platinum-free resources and through recycling or reducing or avoiding the use of rare earth elements



SOPHIA
Solar integrated pressurized high temperature electrolysis

Panel 5 — Hydrogen production, distribution and storage: research and validation

Acronym:	**SOPHIA**
Project ID:	621173
Title:	Solar integrated pressurized high temperature electrolysis
Call Topic:	SP1-JTI-FCH.2013.2.4
Project total costs (€):	€ 6,0 million
FCH JU maximum contribution (€):	€ 3,3 million
Project start/end:	01 Apr 2014 - 30 Sep 2017
Coordinator:	Hygear, The Netherlands
Beneficiaries: Commissariat à l'Energie Atomique et aux Energies Alternatives CEA, DLR, Deutsches Zentrum fuer Luft und Raumfahrt, Ecole Polytechnique Federale de Lausanne, Htceramix, Solidpower, VTT, VTT, ENGIE	
Website:	http://www.sophia-project.eu/

Project and objectives

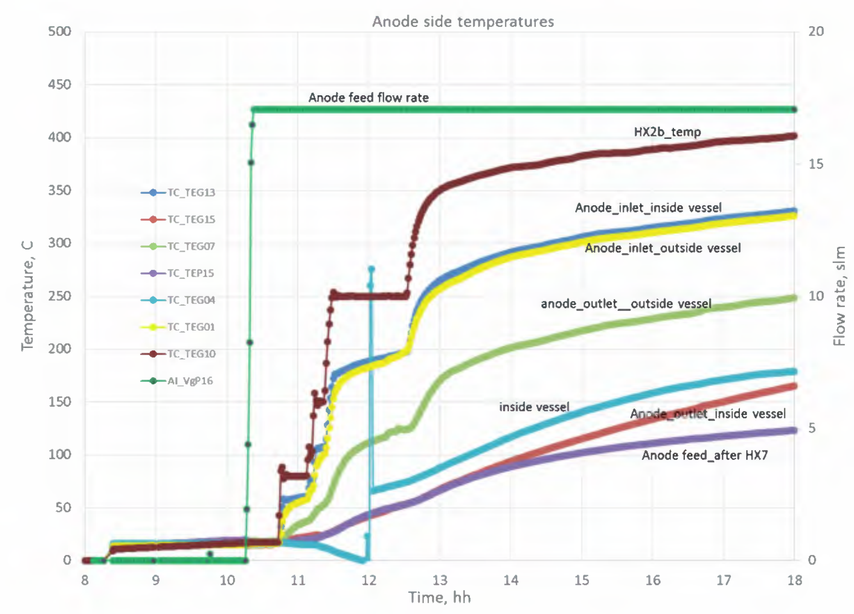
The aim of the SOPHIA project was to develop a solar-powered High Temperature Electrolysis (HTE) system, and develop technology for co-electrolysis. The technology is prototyped on a 3 kW-scale, and designed for operation at 15 bar. The complete system, comprising of the HTE stack-subsystem and solar receiver has been tested at the Solar Simulator at DLR (Deutsches Zentrum fuer Luft und Raumfahrt). Testing at HyGear will follow. A market analysis shows that for systems producing hydrocarbons the availability of CO_2 is not limiting, but the solar power is. Various cell, Single Repeat Units (SRU), and stack tests have been done in (co-)electrolysis mode.

Major project achievements

- High pressure operation of short stacks up to 15 bar
- Co-electrolysis operation proven, producing H_2 and CO plus some CH_4 depending on conditions
- Development of a system for pressurised operation

Future steps

- Final testing of complete system at a pressure of 15 bar



Quantitative targets and status

Target Source	Parameter	Unit	Starting point	Target for project	Achieved to date in project	Best est. of final project result	Target: status on May 1st 2017	Description
MAIP 2008-2013	Degradation	%/1000hr	2	0.50	4.50	1.00	Due later	Operation mode and microstructure improvement
MAIP 2008-2013	Current density	A/cm^2	0.70	1	1	1	Achieved	Operation mode and microstructure improvement

Non-quantitative objectives and status

- PoP of a HT SOE system at kW size under realistic conditions
  System has been tested in combination with a simulated solar heat source
- Develop cells and up-scaling the production of such cells
  Cells have been developed and applied; cell production has been upscaled
- Develop concepts for high pressure electrolysis for more economical systems
  Fuel production via co-electrolysis SOEC and syngas upgrading has been studied by a techno-economic analysis

Relevant 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, so that the combined system of the hydrogen production and the conversion using the fuel cell system can compete with the alternatives for electricity production available on the market