ArtipHyction

Fully Artificial Photo-Electrochemical Device for Low Temperature Hydrogen Production

AIP / APPLICATION AREA	AIP 2011 / AA 2: Hydrogen Production and Distribution
CALL TOPIC	SP1-JTI-FCH.2011.2.6: Low-temperature H_2 production processes
START & END DATE	01 May 2012 - 31 Oct. 2015
TOTAL BUDGET	€ 3,594,580.50
FCH JU CONTRIBUTION	€ 2,187,040.00
PANEL	Panel 5 - Hydrogen Production, Distribution and Storage

PARTNERSHIP/CONSORTIUM LIST

Coordinator: Politecnico di Torino

Partners: HySyTech srl, Commissariat à L'Energie Atomique, Chemical Process Engineering Research Institute, Solaronix SA, Lurederra Foundation for Technical and Social Development, Tecnologia Navarra de Nanoproductos SL, Pyrogenesis SA

PROJECT WEBSITE/URL

www.artiphyction.org

PROJECT CONTACT INFORMATION

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MAIN OBJECTIVES OF THE PROJECT

The project aims at developing a Photo-Electro-Chemical Reactor for H_2 production capable of 5% conversion of solar energy into hydrogen (LHV) with:

1. Improved and novel nano-structured materials for photo-activated processes comprising photo catalysts, photo anodes interfaced with liquid or new polymer electrolytes
2. Chemical systems for highly efficient low temperature water splitting using solar radiation
3. a projected durability of >10,000 h
4. a modular approach capable to cope with small to medium scale applications ranging from 100 W for domestic use (ca. 3 g/h H_2 equivalent) to 100 kW (ca. 3 kg/h H_2 equivalent) for commercial use.

PROGRESS/RESULTS TO-DATE

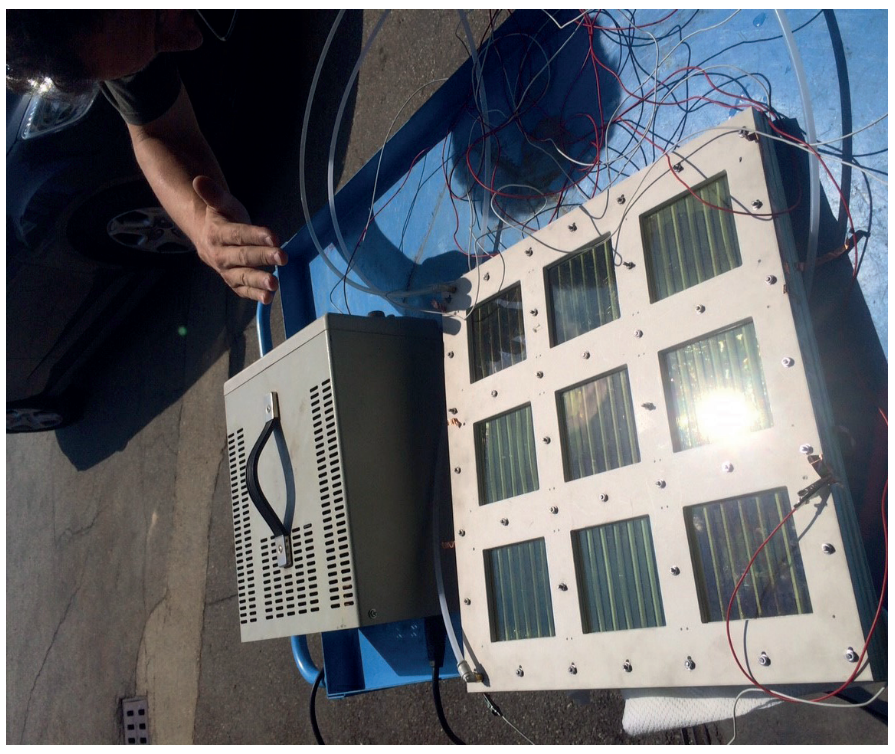
- anodic and cathodic (photo) electro-catalysts identified and providing satisfactory activity in a non-optimised form.
- transparent conducting oxide precursors, powders and porous layers developed as electrode main structures supporting the electrocatalysts
- effect of pulsation of the electrolyte assessed
- final prototype modules (9 10x10 cm^2 modules each) designed and tested
- overall reactor prototype being assembled based on 12 parallel modules

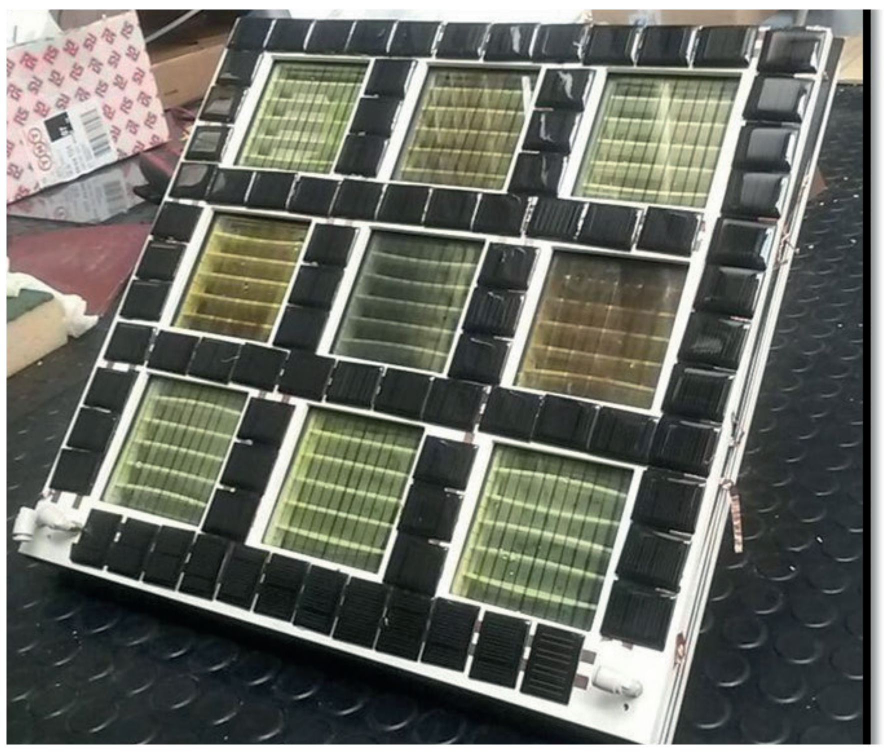
FUTURE STEPS

- test complete prototype
- determine deactivation of performance degradation behaviour
- disseminate the results

CONCLUSIONS, MAJOR FINDINGS AND PERSPECTIVES

- The partnership can anticipate that the original efficiency targets will be only partially achieved (50%).
- The main findings of the project lie in the assessment of the numerous efficiency drop causes that appear from lab scale to full scale; just to mention a few:
  - limited electron transfer through wider electrode surfaces based on transparent conducting oxides layers;
  - Impossibility to reduce the gap between the electrodes to minimise ohmic drops for large scale electrodes
  - ohmic losses linked to the Cu wires embedded in the prototype frame to connect the single photoactive electrode couples in parallel;
  - need to provide a bias through Si PV hosted in the area around the photoactive windows.
- These pieces of information will be quite fruitful to those that will attempt similar scale-up tasks in the near future.





CONTRIBUTION TO THE PROGRAMME OBJECTIVES

SOURCE OF OBJECTIVE/ TARGET (MAIP, AIP)	ASPECT ADDRESSED	PROGRAMME OBJECTIVE/ QUANTITATIVE TARGET	PROJECT OBJECTIVES/ QUANTITATIVE TARGETS	CURRENT STATUS/ ACHIEVEMENTS TO-DATE
MAIP 2008-2013	Scale-up to cost effective capacity, as well more cost efficient, high performance materials for renewables based H_2 production	Applications ranging from 100 W for domestic use (ca. 3 g/h H_2 equivalent) to 100 kW (ca. 3 kg/h H_2 equivalent) for commercial use.	Test the smallest scale of the range aside.	A single module with 9 10x10 cm^2 electrodes has been produced. 12 of such modules are being assembled to produce the full scale ArtipHyction photoreactor.
AIP 2011	Sun-to-hydrogen conversion efficiency	5%	5%	2,5% efficiency achieved at small scale (2x2cm^2 electrodes) 1,5% achieved at full prototype scale (the above mentioned 9 tiles module).
AIP 2011	Durability	10000 h	10000 h	N/A (prototype will be tested for 1000 h (at the end of the project)

BioRobur

Biogas Robust Processing with Combined Catalytic Reformer and Trap

AIP / APPLICATION AREA	AIP 2012 / AA 2: Hydrogen Production and Distribution
CALL TOPIC	SP1-JTI-FCH.2012.2.3: Biogas reforming
START & END DATE	01 May 2013 - 30 Apr. 2016
TOTAL BUDGET	€ 3,843,868.40
FCH JU CONTRIBUTION	€ 2,486,180
PANEL	Panel 5 - Hydrogen Production, Distribution and Storage

PARTNERSHIP/CONSORTIUM LIST

Coordinator: Politecnico di Torino

Partners: Technische Universität Bergakademie Freiberg (DE), Scuola universitaria professionale della Svizzera italiana (CH), Institut de recherches sur la catalyse et l'environnement de Lyon (FR), Chemical Process Engineering Research Institute / Centre for Research and Technology Hellas (GR), Erbicol SA (CH), HySyTech srl (IT) and UAB Modernios E-Technologijos (LT).

PROJECT WEBSITE/URL

http://www.biorobur.org

PROJECT CONTACT INFORMATION

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MAIN OBJECTIVES OF THE PROJECT

BioRobur project will develop a robust and efficient biogas reformer aimed at covering a wide span of potential applications, from fuel cells feed (both high temperature SOFC or MCFC fuel cells and low temperature PEM ones, requiring a significantly lower inlet CO concentration) up to the production of pure, PEM-grade hydrogen.

PROGRESS/RESULTS TO-DATE

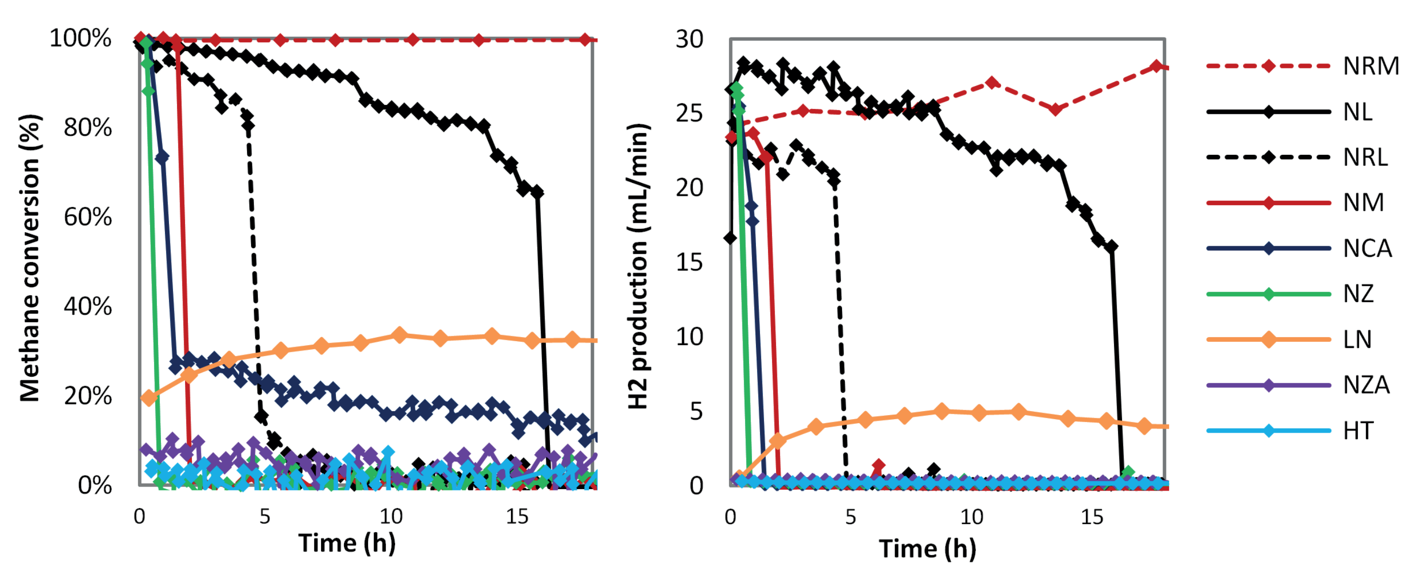
- Two biogas ATR catalysts and two soot trap catalysts have been selected for the final pilot plant testing and related coating routes for the selected.
- Innovative and suitable cellular ceramic supports for ATR catalyst support.
- Lab-scale reactor developed
- Control System and BOP components for the final pilot plant finalized
- LCA analysis (energy)

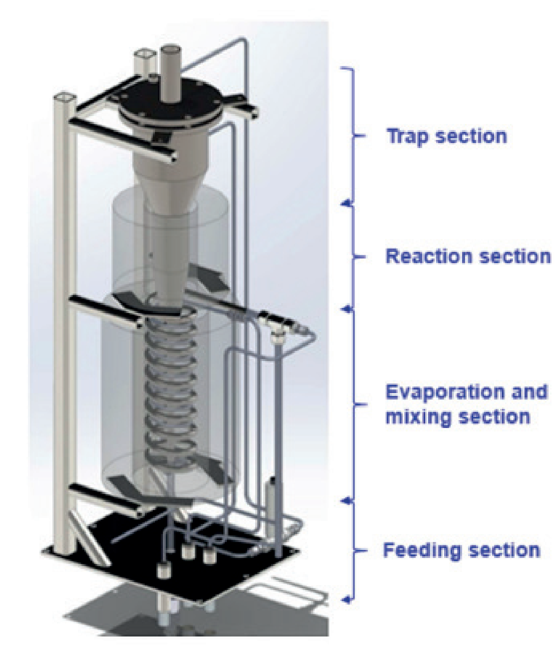
FUTURE STEPS

- Catalyst coating on ATR and Soot Trap supports from lab-scale to the final scale size to test the final Biorobur plant configuration.
- Pilot plant final adaptation.
- Biorobur demonstration plant testing campaign
- LCA analysis completed (energy & materials)
- Dissemination and training activities

CONCLUSIONS, MAJOR FINDINGS AND PERSPECTIVES

- 15%Ni-0.05%Rh/$MgAl_2O_4$ formulation for ATR is very efficient. High methane conversion even at severe GHSV conditions reached.
- $LiFeO_2$ and $LiCoO_2$ formulations were selected as the most prominent candidates toward to soot gasification.
- Innovative cellular ceramic for ATR catalyst supports selected and tested in two different lab-scale reactors.
- Feed system control strategy, including biogas pre-treatment finalized
- CFD Simulations of the Micro-structural Design of the Cellular Material





CONTRIBUTION TO THE PROGRAMME OBJECTIVES

SOURCE OF OBJECTIVE/ TARGET (MAIP, AIP)	ASPECT ADDRESSED	PROGRAMME OBJECTIVE/ QUANTITATIVE TARGET	PROJECT OBJECTIVES/ QUANTITATIVE TARGETS	CURRENT STATUS/ ACHIEVEMENTS TO-DATE
MAIP 2008-2013	e.g. FC system life time (h)	>5,000	>10,000	N/A (test not finalized)
AIP 2012	Nominal production rate of pure hydrogen (kg/day)	50-250	100	N/A (test not finalized)
AIP 2012	CO concentration at the reformer exit (vol%) (dry basis)	<10	<10	N/A (test not finalized)
AIP 2012	Biogas to hydrogen conversion efficiency (%)	>65	>65	N/A (test not finalized)
AIP 2012	Materials costs for a 50 Nm^3/h hydrogen production rate (€)	<250.000	150.000	N/A (test not finalized)

FUEL CELLS AND HYDROGEN JOINT UNDERTAKING

BOR4STORE

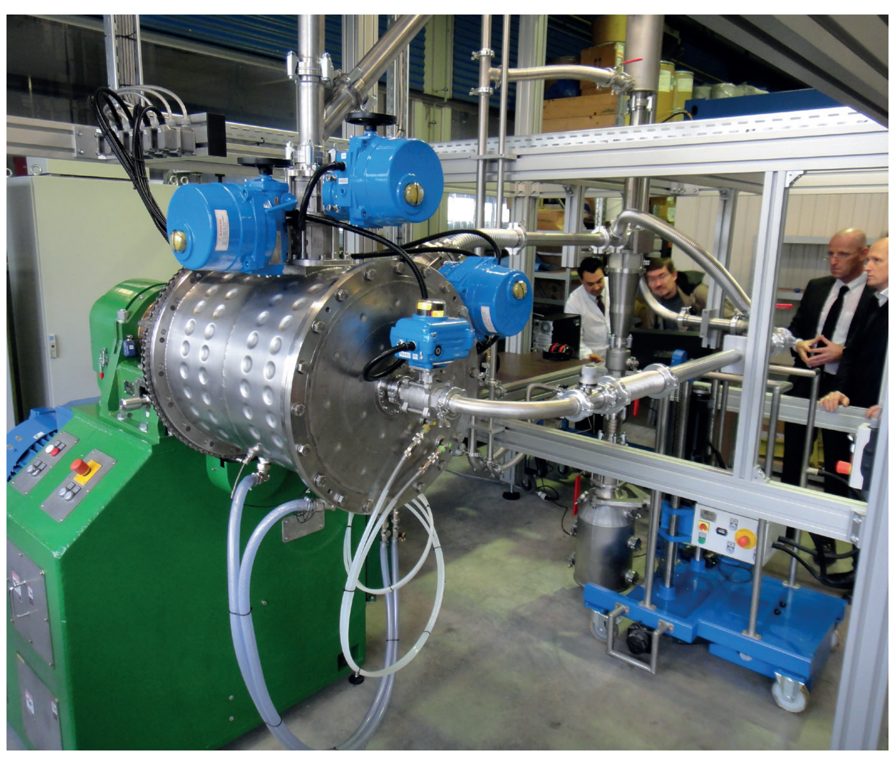
Fast, Reliable and Cost Effective Boron Hydride Based High Capacity Solid State Hydrogen Storage Materials

AIP / APPLICATION AREA	AIP 2011 / AA 2: Hydrogen Production and Distribution
CALL TOPIC	SP1-JTI-FCH.2011.2.4: Novel H_2 storage materials for stationary and portable applications
START & END DATE	01 Apr. 2012 - 30 Sep. 2015
TOTAL BUDGET	€ 4,070,711.30
FCH JU CONTRIBUTION	€ 2,273,682
PANEL	Panel 5 - Hydrogen Production, Distribution and Storage

PARTNERSHIP/CONSORTIUM LIST

Coordinator: Helmholtz-Zentrum Geesthacht GmbH

Partners: Abengoa Hidrógeno SA, Zoz Gmbh, Katchem spol. s.r.o., Aarhus Universitet, Institutt for Energieteknikk, Università degli Studi di Torino, Eidgenössische Materialprüfungs- und Forschungsanstalt, National Centre for Scientific Research "Demokritos"



PROJECT WEBSITE/URL

www.bor4store.eu

PROJECT CONTACT INFORMATION

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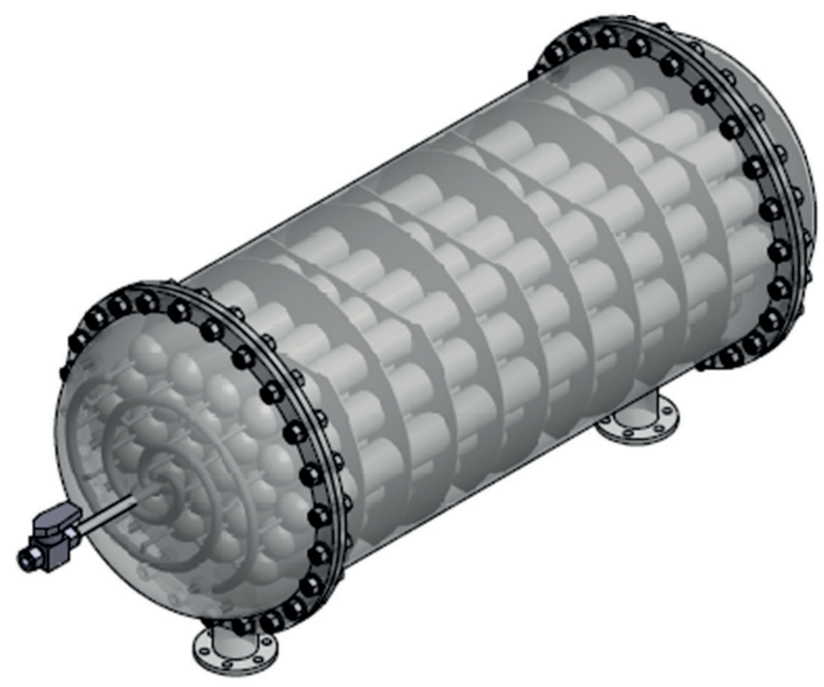
MAIN OBJECTIVES OF THE PROJECT

Development and testing of novel, optimised and cost-efficient boron hydride based hydrogen storage materials with superior performance (materials capacity more than 8 wt.% and 80 kg H_2/m^3) for SOFC applications.

Integration and experimental validation of the performance of a solid state hydrogen storage tank (containing ca. 10 kg storage material, ca. 1 kg H_2) with an SOFC in different conditions of operation.



PROGRESS/RESULTS TO-DATE

- Characterisation of a range of different high capacity boron hydride based hydrogen storage materials
- Characterisation of thermodynamic, kinetic and cycling properties. Scientific understanding of solid state reactions during hydrogenation.
- Selection of most suitable material for storage tank: $LiBH_4/MgH_2$ RHC.: ca. 10 wt.%, ca. 100 kg H_2/m^3. Loading time @ 50 bar < 1 h. Suitable temperature of operation 350 – 600°C, ie. suitable for SOFC application
- Establishment of simulation model of integrated SOFC – metal hydride tank systems. Analysis of different options for heat transfer between SOFC.
- Optimised version of heat exchange for integrated system established. Integrated system under construction.

FUTURE STEPS

- Optimisation of simulation system and verification by experiments
- Testing of prototype of 1.3 kW SOFC –metal hydride tank system with respect to functionality and cycling behaviour of storage material.

CONCLUSIONS, MAJOR FINDINGS AND PERSPECTIVES

- Cyclable boron hydride based material with high capacity exists, suitable for construction of solid state hydrogen storage integrated with SOFC, SOEC or other high temperature applications.
- Mechano-chemical processing of storage materials possible below 1 €/kg. Cheaper routes for synthesis of boron containing compounds from e.g. borax ores have to be developed in order to decrease raw materials cost. Also e.g. by use of waste and recycling alloys (e.g. Mg, Al).
- Simulation of material in storage tank and optimisation of thermal integration with SOFC shows feasibility and high energy efficiency of integrated system.
- Application perspectives: hydrogen supplied high temperature fuel cells, power – to – power applications with SOEC and SOFC or reversible SOC systems. Main advantage: high capacity at low refuelling pressures < 100 bar, provision of extra heating and cooling power due to chemical reactions in metal hydride.

CONTRIBUTION TO THE PROGRAMME OBJECTIVES

SOURCE OF OBJECTIVE/ TARGET (MAIP, AIP)	ASPECT ADDRESSED	PROGRAMME OBJECTIVE/ QUANTITATIVE TARGET	PROJECT OBJECTIVES/ QUANTITATIVE TARGETS	CURRENT STATUS/ ACHIEVEMENTS TO-DATE
MAIP 2008-2013	High capacity hydrogen storage Storage of hydrogen in solid materials: 2010: 3 t cap. | 5 M€/t 2015: 5 t cap. | 1.5 M€/t 2020: 10 t cap. | 0.85 M€/t	Potential for cost below 500 €/kg of stored hydrogen	Capacity 1 kg of hydrogen, potential for cost below 500 €/kg = 5 M€/t	Capacity of several tons of hydrogen (exact number secret) in metal hydride tanks demonstrated in German FC powered submarines before 2010. BOR4STORE storage system will be modular. I.e. can be simply scaled up by multiplying number of modules to required capacity. Current materials cost level ca. 5000€/kg of stored hydrogen. Potential for further cost reduction by using waste and/or recycling materials, mechano-chemical materials processing, series production of storage tank system.
AIP 2011	Capacity	Storage materials with capacities ≥ 6 wt.%, ≥ 60 kg H_2/m^3	capacities of > 80 kg H_2/m^3 and > 8 wt.%	Ca. 100 kg H_2/m^3, 9 – 10 wt.% on materials basis. Capacities on system level to be calculated from final tank system construction.
AIP 2011	Temperature of operation	reversibly releasing hydrogen at operating temperatures compatible e.g. with PEM FC, HT PEM FC or SOFC / MCFC	Release temperature ≤ 450°C (compatible with SOFC)	Release temperature 350 – 450°C. Due to safety considerations, final tank system is designed for a maximum temperature of operation of 650°C.
AIP 2011	Loading and unloading speed	appropriate hydrogen loading and unloading kinetics for the envisaged application	Loading time < 1 h	Loading time < 1 h in materials testing, loading time of storage tank tbd. Tank system constructed such to guarantee a hydrogen flow of ca. 20 Nl/min over several hours of operation.
AIP 2011	Validation	Small scale prototype storage systems with significantly improved storage capacity compared to compressed gas storage (≥ 4 wt.%, ≥ 40 kg H_2/m^3)	Same	Storage system under construction
AIP 2011	Cost	Demonstrate the potential up-scaling for reaching in the long run a target cost of 500 €/kg of stored H_2 at the system level with a significant decrease of overall lifetime cost compared to the state-of-the-art in the special application. Possible integration of thermal energy to the storage system has to be taken into account in the economic assessment	Same	Prototype under construction

CoMETHy

Compact Multifuel-Energy to Hydrogen Converter

AIP / APPLICATION AREA	AIP 2010 / AA 2: Hydrogen Production and Distribution
CALL TOPIC	SP1-JTI-FCH.2010.2.2: Development of fuel processing catalyst, modules and systems; SP1-JTI-FCH.2010.2.3: Development of gas purification technologies.
START &END DATE	01 Dec. 2011 - 31 Dec. 2015
TOTAL BUDGET	€ 4,933,250.39
FCH JU CONTRIBUTION	€ 2,484,095.00
PANEL	Panel 5 - Hydrogen Production, Distribution and Storage

PARTNERSHIP/CONSORTIUM LIST

Coordinator: ENEA

Partners: Processi Innovativi Srl., Acktar Ltd., Technion, Fraunhofer IKTS, University of Salerno, CERTH, Aristotle University of Thessaloniki, University "La Sapienza", ECN, GKN Sinter Metals Engineering GmbH, University Campus Bio-medico" of Rome

PROJECT WEBSITE/URL

www.comethy.enea.it

PROJECT CONTACT INFORMATION

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MAIN OBJECTIVES OF THE PROJECT

CoMETHy aims at developing a flexible membrane reformer operating at "low temperatures" (< 550°C), to convert different fuels (methane, ethanol, etc.) and adaptable to different heat sources (solar, biomass, fossil, etc.). Molten salts (MS) are used to collect and store the heat from concentrating solar plants (CSP) or alternative sources like biomass or Refuse Derived Fuel (RDF). The MS stream provides the process heat to the steam reformer, steam generator, and other unit operations.

This low temperature steam reforming (400-550°C rather than conventional 850-950°C) allows material cost reduction and leads to a compact device for multi-fuelled hydrogen production.

PROGRESS/RESULTS TO-DATE

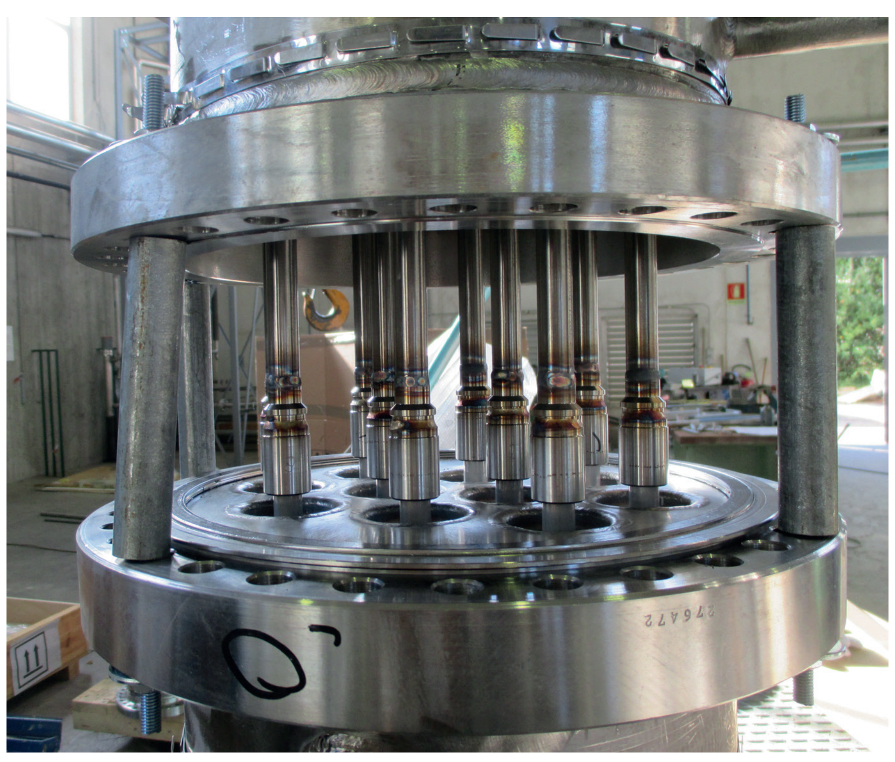
- Advanced multi-fuel catalysts for methane/biogas and ethanol steam reforming at 400-550°C developed with enhanced heat transfer, low pressure drops, satisfactory catalytic activity.
- Suitable Pd-based hydrogen selective membranes identified and tested.
- Innovative molten salts heated membrane reformer designs developed and reactor prototypes successfully tested at the bench scale under representative operative conditions
- Pilot plant (2 Nm3/h of pure hydrogen production) constructed and ready for operation
- Techno-economic evaluation on CoMETHy solar steam reforming process resulted in competitive hydrogen production costs

FUTURE STEPS

- Completing operational tests of the pilot membrane reformer (2 Nm^3/h of pure hydrogen production) for PoC
- Completing the techno-economic optimization of the process under different operative conditions

CONCLUSIONS, MAJOR FINDINGS AND PERSPECTIVES

- CoMETHy is successfully achieving its objectives
- Besides the specific application to solar reforming, CoMETHy's findings have impact on catalyst and membrane technology, innovative reactor design, and small reformers
- Demonstration in relevant industrial environments is expected: industrial large scale hydrogen production by solar steam reforming and decentralized (small/medium scale) hydrogen production in refuelling stations



CONTRIBUTION TO THE PROGRAMME OBJECTIVES

SOURCE OF OBJECTIVE/ TARGET (MAIP, AIP)	ASPECT ADDRESSED	PROGRAMME OBJECTIVE/ QUANTITATIVE TARGET	PROJECT OBJECTIVES/ QUANTITATIVE TARGETS	CURRENT STATUS/ ACHIEVEMENTS TO-DATE
MAIP 2008-2013	H_2 production from RES	Up to 50% of the H_2 energy suplied from RES; decarbonisation of transport; CO_2 lean or CO2 free H_2	38% up to 100% reduction of CO_2 emissions and fossil fuel use in steam reforming processes using RES	Reactor prototypes proved the feasibility of the solar SMR, with 38-53% CO_2 emissions saving with respect to the traditional route. Reforming of biofuels (biogas, bioethanol) proved too, obtaining 100% renewable H_2.
MAIP 2008-2013	Materials performance	For decentralized production ... more cost efficient, high performance materials (e.g. membranes)	Proof of catalysts and membranes stability over 250 hours	Developed catalysts and membranes proved stable over 250 hours-on-stream. However, long-term durability of membranes needs to be improved.
MAIP 2008-2013	SMR process efficiency	By 2020: centralized SMR (CCS ready) efficiency > 72% and decentralized biogas SMR efficiency > 67%	SMR efficiency >70%	Process evaluations and experimental results lead to SMR efficiency (LLV base) > 70% when the plant capacity is > 5,000 Nm^3/h
AIP 2010	Simplification and compactness of reactor design	Scalability from 2 to 750 Nm^3/h (hydrogen production rate)	PoC of one module with > 2 Nm^3/h hydrogen production	A compact reactor developed: one unit to achieve reforming, water-gas shift and H_2 separation. PoC with small prototypes successful, pilot reformer constructed.
AIP 2010	High performance reforming catalysts	Reforming catalysts with shift activity to get CO concentration < 10 vol%	CO concentration < 10 vol% in the gas product	Developped SMR catalysts lead to CO content < 5%vol, thus avoiding the need of shift reactors.
AIP 2010	Replacement of components	Catalyst replacement time < 4 hours	Catalyst replacement time < 4 hours	Replacement time for all catalysts and membranes in the pilot reactor lasted < 2 hours.

FUEL CELLS AND HYDROGEN JOINT UNDERTAKING

Don Quichote

Demonstration of New Qualitative Innovative Concept of Hydrogen Out of Wind Turbine Electricity

AIP / APPLICATION AREA	AIP 2011 / AA 2: Hydrogen Production and Distribution
CALL TOPIC	SP1-JTI-FCH.2011.2.1: Demonstration of MW capacity hydrogen production and storage for balancing the grid and supply to a hydrogen refuelling station
START & END DATE	01 Oct. 2012 - 30 Sep. 2017
TOTAL BUDGET	€ 4,946,134
FCH JU CONTRIBUTION	€ 2,954,846
PANEL	Panel 5 - Hydrogen Production, Distribution and Storage

PARTNERSHIP/CONSORTIUM LIST

Coordinator: Hydrogenics Europe NV

Partners: Hydrogen Efficiency Technologies (HyET) BV, WaterstofNet vzw, Etablissementen Franz Colruyt NV, TUV Rheinland Industrie Service GmbH, Joint Research Centre – European Commission, Thinkstep, Icelandic New Energy Ltd, Federazione delle Associazioni Scientifiche e Techniche (FAST)

PROJECT WEBSITE/URL

http://www.don-quichote.eu/

PROJECT CONTACT INFORMATION

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MAIN OBJECTIVES OF THE PROJECT

The Don Quichote project complements and expands existing hydrogen refuelling system in Halle, Belgium, with innovative, components: a PEM electrolyser, a fuel cell re-electrification unit and an electrochemical compressor. Integration with a windmill, realizes hydrogen based energy storage. The hydrogen refuels forklifts at 350bar or produces electricity. The whole system is evaluated in terms of performance, carbon footprint, regulation issues and business potential. It combines targets on increasing renewable electricity, grid balancing, sustainable mobility and using 100% green hydrogen in an obvious way.

PROGRESS/RESULTS TO-DATE

- Regular performance and cost monitoring via validated LCA (Life Cycle Analyses) software
- Development, construction, delivery and site operation of a PEM electrolyser (30 Nm^3/h, 10 bar)
- Development and construction of a Fuel Cell outdoor system (120kW)
- LCA analysis performed
- Development of registration plan and operational diary for TCO (Total Cost of Ownership)

FUTURE STEPS

- Continuous monitoring of extension including PEM electrolyser and fuel cell stack
- Construction and on-site installation of the electrochemical compressor, 60 kg/day, 450 bar
- Continuous performance monitoring of the system with electrochemical compression included (final Phase)
- Detailed yearly datasets on the performance of the plant

CONCLUSIONS, MAJOR FINDINGS AND PERSPECTIVES

- Good view of regulatory hurdles
- Realistic costing of hardware and installation
- Excellent performance of PEM electrolyser and ease of operation
- Prospect on detailed data for TCO assessment

CONTRIBUTION TO THE PROGRAMME OBJECTIVES

SOURCE OF OBJECTIVE/ TARGET (MAIP, AIP)	ASPECT ADDRESSED	PROGRAMME OBJECTIVE/ QUANTITATIVE TARGET	PROJECT OBJECTIVES/ QUANTITATIVE TARGETS	CURRENT STATUS/ ACHIEVEMENTS TO-DATE
AIP 2011	efficiency (WtT; well to tank) > 55 %	> 10 years	electrolyser 69% compressor 85	Stack at 77% efficiency (full production). BOP: to be monitored
AIP 2011	cost of hydrogen delivered	<15€/kg	<13€/kg	Related to cost of renewable energy. Phase 2 TCO analysis in progress Phase 3 demo cost unclear
AIP 2011	Hydrogen production facility turn-key CAPEX (capital expenditures):	3.5 M€/(t/d) (i.e. 1.7 M€/MWel)	3.5 M€/(t/d) (i.e. 1.7 M€/MWel)	To be assessed during economical evaluation end project
AIP 2011	hydrogen quality	ISO/DIS 14786-2 compliant	ISO/DIS 14786-2 compliant	PEM unit qualified Compressor to be done
AIP 2011	Availability	>95%	>95%	Succesfull site acceptance test. Measurements phase II starting Q3,2015

EDEN

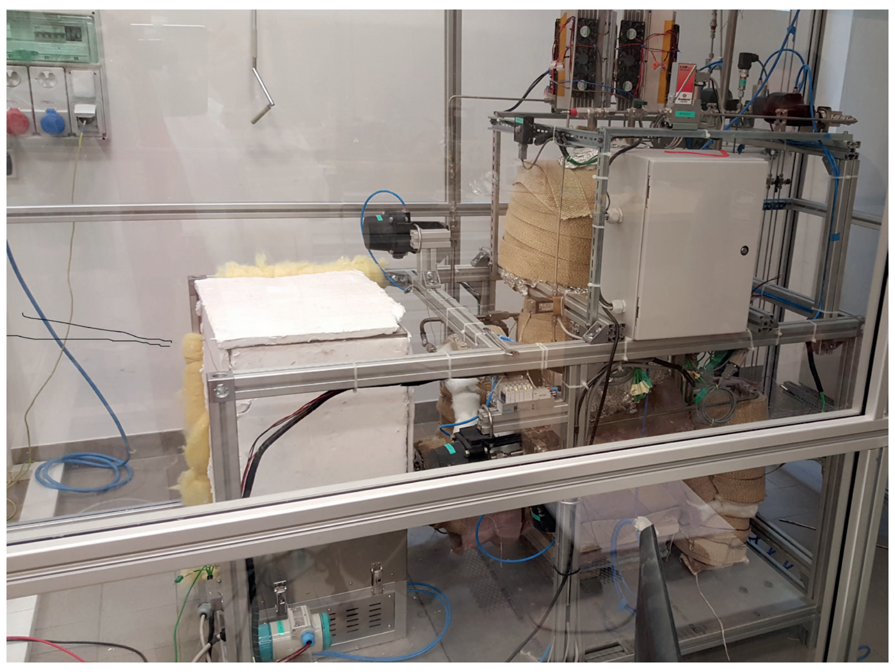
High Energy Density Mg-Based Metal Hydrides Storage System

AIP / APPLICATION AREA	AIP 2011 / AA 2: Hydrogen Production and Distribution
CALL TOPIC	SP1-JTI-FCH.2011.2.4: Novel H2 storage materials for stationary and portable applications
START & END DATE	01 Oct. 2012 - 31 Jan. 2016
TOTAL BUDGET	€ 2,653,574.00
FCH JU CONTRIBUTION	€ 1,524,900.00
PANEL	Panel 5 - Hydrogen Production, Distribution and Storage

PARTNERSHIP/CONSORTIUM LIST

Coordinator: Fondazione Bruno Kessler

Partners: MBN Nanomaterialia SPA, Cidete Ingenieros SL, Matres SCRL, Panco GmbH, Universidad de la Laguna, Joint Research Centre – Institute for Energy and Transport



PROJECT WEBSITE/URL

www.h2eden.eu

PROJECT CONTACT INFORMATION

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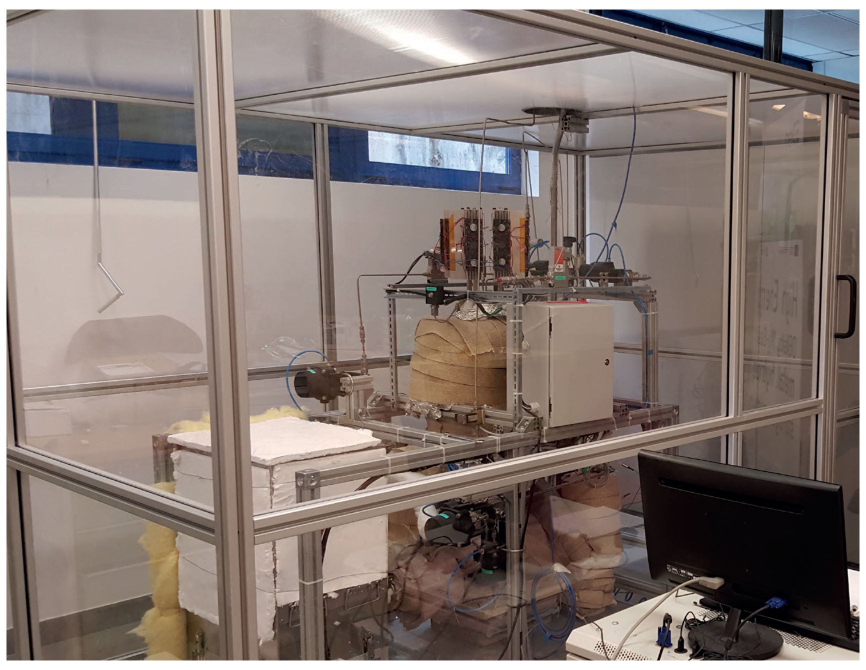
MAIN OBJECTIVES OF THE PROJECT

Main objective of EDen project: develop a new storage material with high hydrogen storage capacity, manageable in real-time, for distributed applications, on a storage tank. It will be interlinked to an energy provision system able to match intermittent sources with local energy demand. The target values are:

- Material: Storage capacity: >6.0 wt.%, Density : >80 g/l, Desorption rate : >3 g/min, Cost : <30€/kg;
- Tank: Storage capacity: 4.0 wt.%, Density : 40 g/l, Absorption heat recovery : 25%, Hydrogen stored : 600g, Desorption rate : 1,5g/min
- System : Heat recovery, Safety, SOFC performance : >300 mW/cm^2 , Performance loss : <10%/year



PROGRESS/RESULTS TO-DATE

- The improved material has been realized both with standard and sputtered catalysts added;
- Intermediate and full Storage Tanks realized, integrated of all thermal and hydrogen management components, able to release more than 1,5 litres per minute;
- System integration layout comprised of all auxiliaries to properly manage hydrogen and thermal power between the hydrogen tank and the SOFC;
- Full scale POWER TO POWER system, using HT electrolyzer / fuel cell and solid state integrated storage

FUTURE STEPS

- Test and validate the material in the full scale storage tank along long term tests
- Demonstrate the power to power technology in real environment

CONCLUSIONS, MAJOR FINDINGS AND PERSPECTIVES

- The Mg-metal hydride has been demonstrated to have 7,1 % weight of storage capacity and a reaction kinetic able to release 2,0 litres per minute of hydrogen
- Innovative catalyst addition process realized, qualified and first samples realized and validated with improved reaction kinetic
- The tank has been realized integrating innovative layout with enhanced transfer medium as expanded natural graphite and heat pipes, with less than 1 °C of internal temperature gradient
- Full management and control of the power to power technology was realized

CONTRIBUTION TO THE PROGRAMME OBJECTIVES

SOURCE OF OBJECTIVE/ TARGET (MAIP, AIP)	ASPECT ADDRESSED	PROGRAMME OBJECTIVE/ QUANTITATIVE TARGET	PROJECT OBJECTIVES/ QUANTITATIVE TARGETS	CURRENT STATUS/ ACHIEVEMENTS TO-DATE
MAIP 2008-2013	Stationary storage (of H2 from renewable electricity), by 2015 Capacity per site / CAPEX per site	5 t / 1,5 M€ per t	NOT APPLICABLE	NOT APPLICABLE
AIP 2011	Hydrogen storage capacity	>6% w	>6% w	7,0% w
AIP 2011	Tank system storage capacity	>4% w	4% w	Around 2,0% w
AIP 2011	Compatibility with FC systems	Any FC	SOFC/SOE	confirmed
AIP 2011	Long term run cost	<500€/kg	300€/kg	N/A (test not finalized)

ELECTRA

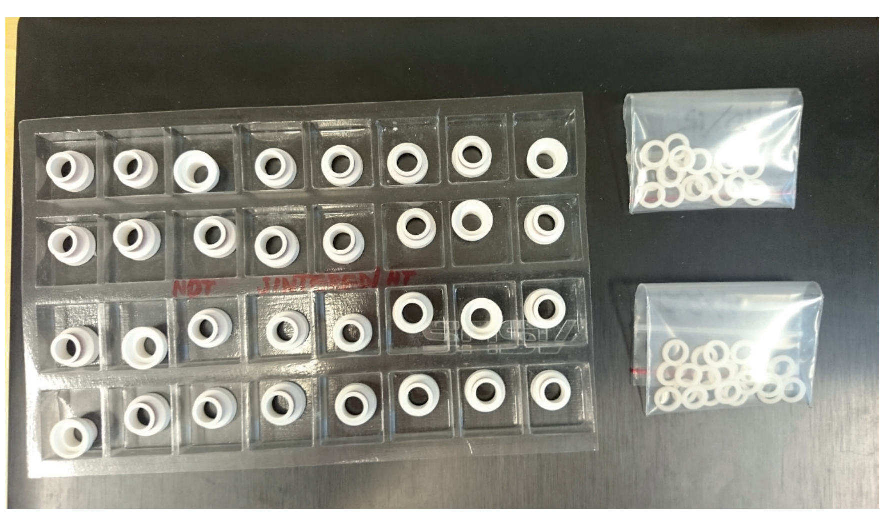
High Temperature Electrolyser with Novel Proton Ceramic Tubular Modules of Superior Efficiency, Robustness and Lifetime Economy

AIP / APPLICATION AREA	AIP 2013 / AA 2: Hydrogen Production and Distribution
CALL TOPIC	SPI-JTI-FCH-2013.2.4: New generation of high temperature electrolyser
START & END DATE	03 Mar. 2014 - 02 Mar. 2017
TOTAL BUDGET	€ 4,007,084.60
FCH JU CONTRIBUTION	€ 2,240,552.00
PANEL	Panel 5 - Hydrogen Production, Distribution and Storage

PARTNERSHIP/CONSORTIUM LIST

Coordinator: University of Oslo (NO)

Partners: CSIC (ES), SINTEF (NO), MARION (FR), PROTIA (NO), Abengoa Hidrigeno (ES), CRI (IC)



PROJECT WEBSITE/URL

http://www.mn.uio.no/smn/english/research/projects/electra

PROJECT CONTACT INFORMATION

Professor Truls Norby, Univ. Oslo
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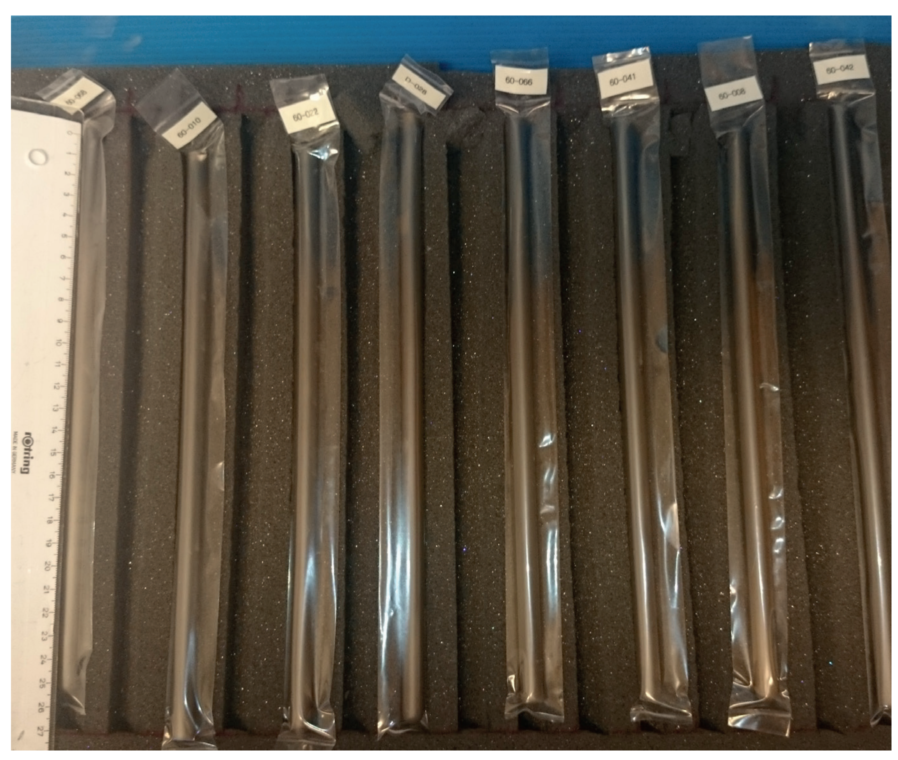
MAIN OBJECTIVES OF THE PROJECT

This project seeks to design, build and test a kW size multi-tubular proton ceramic high temperature electrolyser for production of hydrogen from steam and renewable energy. The project also aims to develop efficient and stable oxygen side electrodes with integrated current collection, segmented-in-series proton ceramic tubular cells, and design of a multi-tubular module with its necessary peripherals. The project will test the multi-tubular unit for production of 250 L_n/h hydrogen, and test the single tube unit in co-ionic mode for production of syngas and di-methyl ether (DME) from CO2 and steam.



PROGRESS/RESULTS TO-DATE

- Successful production of 1^{st} and 2^{nd} gen. tubes
- Stable and compatible component materials identified
- Anode layers with required performance have been developed
- Single-tube and multi-tube module designs conceived
- Techno-economic modelling on integration with renewable energy sources initiated

FUTURE STEPS

- Further development and production of 2^{nd} and 3^{rd} generation, segmented tubes
- Deposition and characterization of anode electrodes and interconnects on tube segments
- Electrolysis tests of fully assembled 1^{st}, 2^{nd}, and/or 3^{rd} generation cells
- Development of compatible current collection layers
- System design and techno-economic studies for process integration with renewable power sources

CONCLUSIONS, MAJOR FINDINGS AND PERSPECTIVES

- Work progresses as planned at month 16
- 1^{st} generation tubes fabricated and in use
- 2^{nd} generation stacked tubes demonstrated
- Oxygen electrodes (anodes) identified and tested OK
- 3^{rd} generation segmented tubes challenging

CONTRIBUTION TO THE PROGRAMME OBJECTIVES

SOURCE OF OBJECTIVE/ TARGET (MAIP, AIP)	ASPECT ADDRESSED	PROGRAMME OBJECTIVE/ QUANTITATIVE TARGET	PROJECT OBJECTIVES/ QUANTITATIVE TARGETS	CURRENT STATUS/ ACHIEVEMENTS TO-DATE
MAIP 2008-2013	Unit capacity	~1.5 t/day	250 L_n/hour	Test not scheduled yet
MAIP 2008-2013	Efficiency	68 %	68 %	Test not scheduled yet
AIP 2013	Cell and stack properties	I > 1 Acm^{-2} Area Specific Resistance < 1 Ωcm^2	I > 1 Acm^{-2} ASR < 1 Ωcm^2	Individual MEA layers OK
AIP 2013	Degradation rate	< 0.5% per 1,000 hours	< 0.5% per 1,000 hours	Test not scheduled yet
AIP 2013	Durability	Pressure tolerance under realistic conditions	Long term operation at 20 bar. Robust solutions for lifetime economy.	Design conceived for individual tube monitoring and replacement. Pressure and long term test not scheduled yet.
AIP 2013	Module power	kW range	Multi-tubular module of ~1kW	Design conceived. Not built or tested yet.
AIP 2013	Co-electrolysis proof-of-concept	85-90 % efficiency	Syngas and DME production -> 85% efficiency	Test not scheduled yet.

ELECTROHYPEM

Enhanced Performance and Cost-Effective Materials for Long-Term Operation of PEM Water Electrolysers Coupled to Renewable Power Sources

AIP / APPLICATION AREA	AIP 2011 / AA 2: Hydrogen Production and Distribution
CALL TOPIC	SP1-JTI-FCH.2011.2.7: Innovative Materials and Components for PEM electrolysers
START & END DATE	01 Jul. 2012 - 30 Jun. 2015
TOTAL BUDGET	€ 2,842,312
FCH JU CONTRIBUTION	€ 1,352,771
PANEL	Panel 5 - Hydrogen Production, Distribution and Storage

PARTNERSHIP/CONSORTIUM LIST

Coordinator: CONSIGLIO NAZIONALE DELLE RICERCHE (CNR-ITAE)

Partners: JOINT RESEARCH CENTRE, INSTITUTE FOR ENERGY AND TRANSPORT (JRC-IET), CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE (CNRS), SOLVAY SPECIALTY POLYMERS ITALY S.P.A. (SLX), ITM Power (Trading) Ltd (ITM), TOZZI RENEWABLE ENERGY (TRE)

PROJECT WEBSITE/URL

http://www.electrohypem.eu

PROJECT CONTACT INFORMATION

Dr. Antonino Salvatore Arico'
Tel. +39090624237

MAIN OBJECTIVES OF THE PROJECT

The overall objective of the ELECTROHYPEM project is to develop cost-effective components for PEM electrolysers with enhanced activity and stability in order to reduce stack and system costs and to improve efficiency, performance and durability. The focus of the project is on low-cost electrocatalyst, low-noble metal loading electrodes and membrane development. The project addresses the development of PEM electrolysers based on such innovative components for residential applications in the perspective of a suitable integration with renewable power sources. The aim is to contribute to the road-map addressing the achievement of a wide scale decentralised hydrogen production infrastructure.

PROGRESS/RESULTS TO-DATE

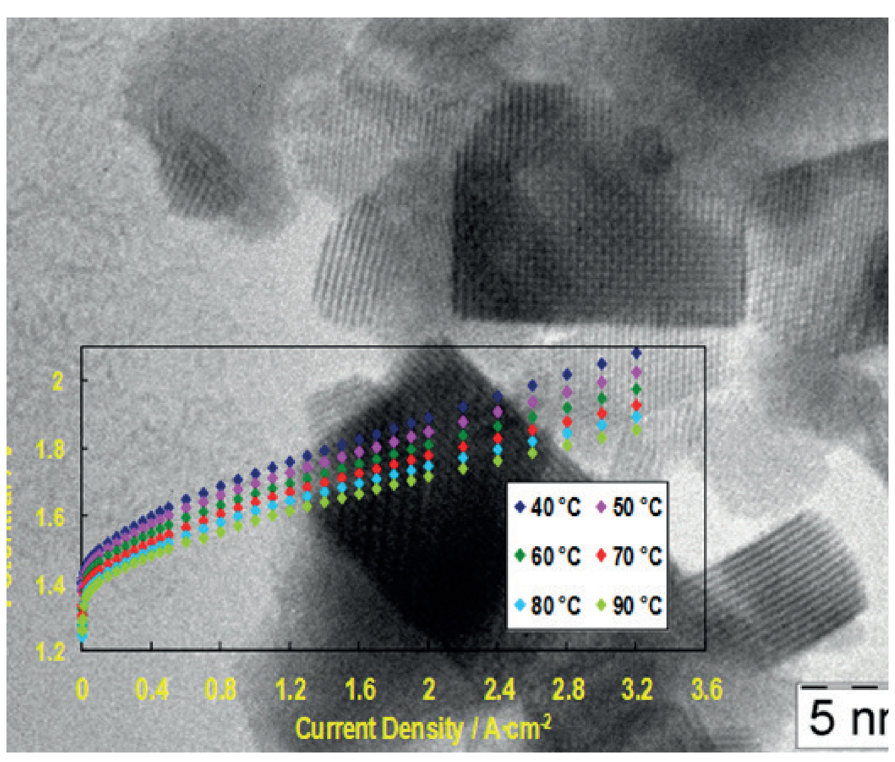
- Innovative membranes with enhanced conductivity and reduced hydrogen cross over for wide temperature operation have been developed
- Enhanced nanosised solid solution mixed oxide electrocatalysts demonstrated
- Membrane-electrode assembly (MEA) performance of 1.8 V at 3 A cm^{-2} achieved at 130 °C (0.5 mg cm^{-2} noble metal loading)
- MEA performance decay with time ~8 μV/h (1200 hrs test)
- Power consumption of 3.53 kWh/Nm^3 H_2 for 1.2 Nm^3/h capacity water electrolysis stack

FUTURE STEPS

- Use the developed components in 100 Nm^3/h capacity electrolysers
- Achieving similar efficiencies in large size PEM stacks (0.5 MW)
- Set-up of processes for volume manufacturing of the membranes and electro-catalysts
- Scaling-up of the MEA active area
- Dissemination and exploitation of project results

CONCLUSIONS, MAJOR FINDINGS AND PERSPECTIVES

- In order to be competitive within the field of decentralised hydrogen production, the PEM electrolyser must be reasonably cheap; moreover, it should be compact, characterised by high durability and capable of producing hydrogen at high efficiency and at suitable pressure.
- Enhanced materials and components (catalyst, membranes, MEAs and stacks) have been developed providing performance better than the state of the art at lower precious metal loading
- Novel materials have been validated in stacks of 1.2 Nm^3 H_2/h capacity and promising efficiency levels have been achieved
- These devices are promising for small scale applications especially under operation with renewable power sources and for grid-balancing service



CONTRIBUTION TO THE PROGRAMME OBJECTIVES

SOURCE OF OBJECTIVE/ TARGET (MAIP, AIP)	ASPECT ADDRESSED	PROGRAMME OBJECTIVE/ QUANTITATIVE TARGET	PROJECT OBJECTIVES/ QUANTITATIVE TARGETS	CURRENT STATUS/ ACHIEVEMENTS TO-DATE
MAIP 2008-2013	Cost-competitive, high energy efficient and sustainable hydrogen production	Cost-efficient low-temperature electrolysers	Development of enhanced performance and cost-effective materials for long-term operation of PEM water electrolysers coupled to renewable power sources	High performance novel membranes and electrodes with cost effective characteristics have been demonstrated
AIP 2011	PEM electrolyser capacity	Hydrogen production capacity > 1 Nm^3/h	Innovative electrolyser with rated production capacity > 1 Nm^3/h	Innovative electrolyser with production capacity 1.2 Nm^3/h
AIP 2011	PEM electrolyser stack efficiency/ energy consumption	Efficiency of 75% (LHV)	Stack energy consumption < 4 kWh/Nm^3 H_2 @ 1 Nm^3 h^{-1}	Stack energy consumption 3.53 kWh/Nm^3 H_2 at 1.2 Nm^3 h^{-1}
AIP 2011	PEM electrolyser durability/stability	High stability at constant load	Voltage increase < 15 μV/h at 1 A cm^{-2}	Stability > 1200 hrs, 8 μV/h at 1 A cm^{-2}
AIP 2011	PEM electrolyser capital costs	Stack cost <2.500 €/Nm^3 H_2 in series production;	Aimed stack cost <<2.500 €/Nm^3 H_2 using novel membranes and electrocatalysts	Cost effective novel membranes and electrocatalysts demonstrated

FUEL CELLS AND HYDROGEN JOINT UNDERTAKING

ELYGRID

Improvements to Integrate High Pressure Alkaline Electrolysers for Electricity/H2 Production from Renewable Energies to Balance the Grid

AIP / APPLICATION AREA	AIP 2010 / AA 2: Hydrogen Production and Distribution
CALL TOPIC	SP1-JTI-FCH.2010.2.1: Efficient alkaline electrolyzers
START & END DATE	01 Nov. 2011 - 31 Dec. 2014
TOTAL BUDGET	€ 3,701,178.33
FCH JU CONTRIBUTION	€ 2,105,017
PANEL	Panel 5 - Hydrogen Production, Distribution and Storage

PARTNERSHIP/CONSORTIUM LIST

Coordinator: FHA

Partners: IHT, EMPA, AREVA, JÜLICH, VITO, LAPESA, INYCOM, INGETEAM, CEA

PROJECT WEBSITE/URL

www.elygrid.com

PROJECT CONTACT INFORMATION

Coordinator: Foundation for Hydrogen in Aragon
info@hidrogenoaragon.org

MAIN OBJECTIVES OF THE PROJECT

ELYGRID project aims at contributing to the reduction of the Total Cost of hydrogen produced via electrolysis coupled to Renewable Energy Sources, mainly wind turbines, and focusing on mega watt size electrolyzes (from 0,5 MW and up). The objectives are to improve the efficiency related to the complete system by 20% and to reduce costs by 25%. The work will be structured in cell improvements, power electronics and balance of plant (BOP).

PROGRESS/RESULTS TO-DATE

- New materials for separator developed and tested
- Full BOP containerized redesign (cost reduction)
- Long term tests at real scale (1.600 mm membrane diameter)
- Dynamic model for electrolyser coupled to RE
- Improved control system for the electrolyser

CONCLUSIONS, MAJOR FINDINGS AND PERSPECTIVES

- Redesign of BOP: 20% of cost reduction (against baseline case)
- High capacity units could be produced increasing the current density
- New power electronics based on IGBTs
- New plug&play design and control system could reduce the Total Cost of Ownership (TCO)

CONTRIBUTION TO THE PROGRAMME OBJECTIVES

SOURCE OF OBJECTIVE/ TARGET (MAIP, AIP)	ASPECT ADDRESSED	PROGRAMME OBJECTIVE/ QUANTITATIVE TARGET	PROJECT OBJECTIVES/ QUANTITATIVE TARGETS	CURRENT STATUS/ ACHIEVEMENTS TO-DATE
MAIP 2008-2013	2015 target: Unit capacity	1.5 Ton/d	3 Ton/d	3 Ton/d
AIP 2013	Efficiency	80% HHV (0,75 A/cm^2)	90%HHV (0,5 A/cm^2)	78% HHV (0,4 A/cm^2)
AIP 2013	Durability	10 years lifespan	10 years lifespan	Critical factor: membrane. AST or extrapolation of behaviour needed
AIP 2013	Modular system cost	3000€/Nm^3	25% cost reduction	Final cost reduction 20% taking into account the baseline of the previous technology at the beginning of the project

HELMETH

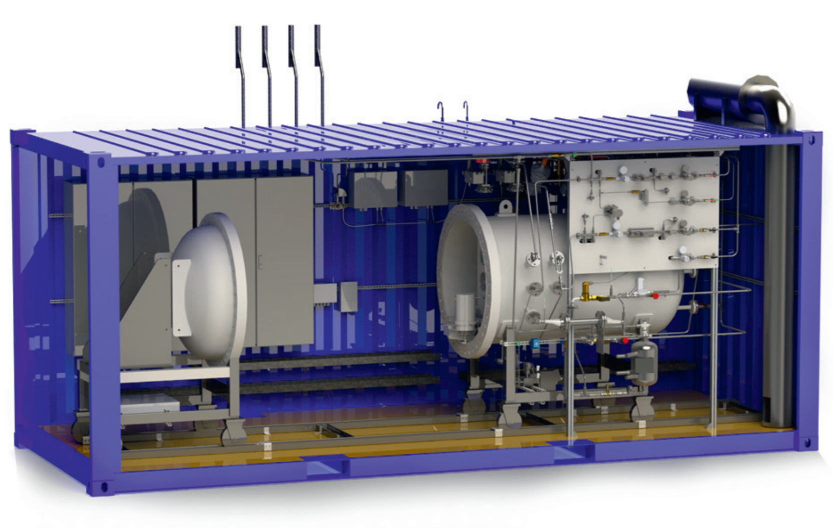
Integrated High-Temperature Electrolysis and Methanation for Effective Power to Gas Conversion Sources

AIP / APPLICATION AREA	AIP 2013 / AA 2: Hydrogen Production and Distribution
CALL TOPIC	SP1-JTI-FCH.2013.2.4: New generation of high temperature electrolyser
START & END DATE	01 Apr. 2014 - 31 Mar. 2017
TOTAL BUDGET	€ 3,809,972.00
FCH JU CONTRIBUTION	€ 2,529,352.00
PANEL	Panel 5 - Hydrogen Production, Distribution and Storage

PARTNERSHIP/CONSORTIUM LIST

Coordinator: Karlsruhe Institute of Technology (Germany)

Partners: Politecnico di Torino (Italy), Sunfire GmbH (Germany), European Research Institute of Catalysis A.I.S.B.L. (Belgium), Ethos Energy Italy (Italy), National Technical University of Athens (Greece), DVGW - German Technical and Scientific Association for Gas and Water (Germany)



PROJECT WEBSITE/URL

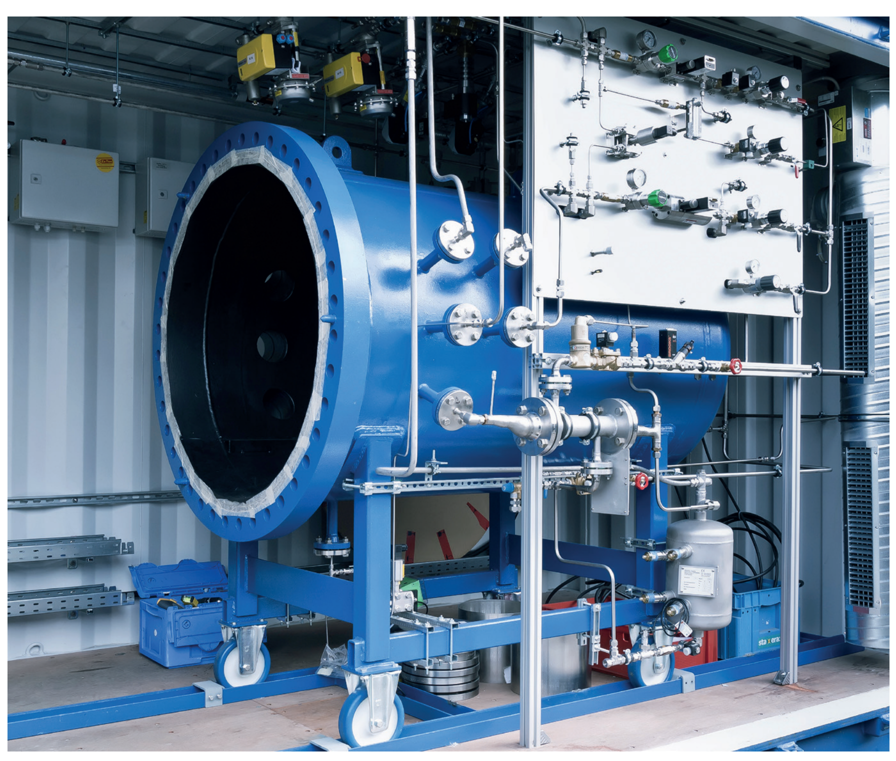
www.helmeth.eu

PROJECT CONTACT INFORMATION

Dimosthenis Trimis
dimosthenis.trimis@kit.edu

MAIN OBJECTIVES OF THE PROJECT

The objective of the HELMETH project is the proof of concept of a highly efficient Power-to-Gas (P2G) technology with methane as a chemical storage and by thermally integrating of 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 highest conversion efficiencies > 85 % from renewable electricity to methane by utilizing the process heat of the exothermal methanation reaction in the high temperature electrolysis process.



PROGRESS/RESULTS TO-DATE

- System specifications of SOEC and methanation module fixed
- Pressurised high-temperature electrolysis system is completed and already realised. First test results with preliminary SOEC stack correspond to the expectations
- Tests on co-electrolysis conducted. Results will be published in September 2015 as Deliverable 2.2
- Novel design of SOEC heat exchangers by using Direct Laser Metal Sintering technology is almost finished
- Decision of optimal methanation module concept consisting of 3 reactors, combined in one pressure vessel (86% process simulation efficiency)

FUTURE STEPS

- Results of pressurized catalytic tests will be published in September 2015 as Deliverable 3.2
- Construction of methanation module starts in autumn 2015
- Hazard and operability study is currently ongoing in order to assure the SOEC and methanation module safety concept

CONCLUSIONS, MAJOR FINDINGS AND PERSPECTIVES

- Total efficiency of coupled SOEC and methanation module is expected to exceed 85 % at a SOEC steam conversion of 80 %
- Higher efficiencies can be reached with higher SOEC steam conversions and/or with SOEC co-electrolysis
- Optimal reaction temperature concerning the methanation is 300°C for an integrated system (SOEC + Methanation)
- Minimal heat losses can be reached by combining catalytic reactors in one pressure vessel

CONTRIBUTION TO THE PROGRAMME OBJECTIVES

SOURCE OF OBJECTIVE/ TARGET (MAIP, AIP)	ASPECT ADDRESSED	PROGRAMME OBJECTIVE/ QUANTITATIVE TARGET	PROJECT OBJECTIVES/ QUANTITATIVE TARGETS	CURRENT STATUS/ ACHIEVEMENTS TO-DATE
AIP 2013	Development of cells and stacks designed for high-temperature and high current density, pressurised conditions	High-temperature (800-1000 °C), high current density (>1 A/cm2), pressurised conditions	High-temperature (800-1000 °C), high current density (>1 A/cm2), pressurised conditions	Electrodes and interconnector protection layers feasible for HTE under pressurized conditions
AIP 2013	Manufacture of dedicated HTE cells and stacks for use in large systems for the conversion of electricity from renewable sources and from nuclear power, i.e. large-area cells	Manufacture of dedicated HTE cell	HELMETH will deliver a proof of concept towards this direction. Large systems are the development focus of the involved industrial partners and especially of SUNFIRE. Concerning large area cells a modular approach with more cell elements on a common interconnector frame is followed.	For non-pressurized operation, sunfire has already produced a system in the 100 kW range; scalability can be reached effectively with the common sunfire cell size, which is applied within the HELMETH project also for pressurized conditions. The durability for pressurized conditions has to be proven by the ongoing pressurized tests.
AIP 2013	Demonstration of a HTE system of kW size under realistic conditions	Demonstration of a HTE system of kW size under realistic conditions with degradation rates around 1 %/1000 h (0,5 %/1000 h for short stack tests)	HELMETH will demonstrate the feasibility of a 10-15 kW class system with degradation rates around 1 %/1000 h (0,5 %/1000 h for short stack tests)	First pressurized test is ongoing @ 10 bar (g) and 700°C with stack in 5 kW power range; current density target and fluctuating production not evaluated yet; degradation prediction not yet possible in this state of preliminary testing
AIP 2013	Proof-of-concept for co-electrolysis, syngas production and final chemical product, and validation of efficiency figures. Total efficiencies are expected in the 85-95% range	Total efficiencies are expected in the 85-95% range	Conversion efficiencies > 85 % from electricity to methane	Detailed process simulations including all BoP components for the chosen reactor concept predict a total conversion efficiency of 86%. (Efficiency of prototype plant will be lower due to heat losses, which are dependent on size of plant; the difference is predictable)

FUEL CELLS AND HYDROGEN JOINT UNDERTAKING

HYDROSOL-PLANT

Thermochemical Hydrogen Production in Solar Monolithic Reactor: Construction and Operation of a 750 kWth Plant

AIP / APPLICATION AREA	AIP 2012 / AA 2: Hydrogen Production and Distribution
CALL TOPIC	SP1-JTI-FCH.2012.2.5: Thermo-electrical-chemical processes with solar heat sources
START & END DATE	01 Jan. 2014 - 31 Dec. 2016
TOTAL BUDGET	€ 3,480,806
FCH JU CONTRIBUTION	€ 2,265,385
PANEL	Panel 5 - Hydrogen Production, Distribution and Storage

PARTNERSHIP/CONSORTIUM LIST

Coordinator: APTL/CPERI/CERTH

Partners: DLR, CIEMAT, HYGEAR, HELPE

PROJECT WEBSITE/URL

http://hydrosol-plant.certh.gr

PROJECT CONTACT INFORMATION

souzana@cperi.certh.gr

MAIN OBJECTIVES OF THE PROJECT

The HYDROSOL-PLANT project comes as the natural continuation of the successful HYDROSOL and is expected to develop and operate all of the tools required to scale up solar H_2O splitting to the 750 kWth scale.

Main objectives:

• Define all key components and aspects

• Develop tailored heliostat field technology that enables accurate temperature control of the solar reactors.

• Construct a 750 kWth solar hydrogen production demonstration plant to verify the developed technologies for solar H_2O-splitting.

• Operate the plant and demonstrate hydrogen production and storage on site.

• Techno-economic study for the commercial exploitation of the solar process.

PROGRESS/RESULTS TO-DATE

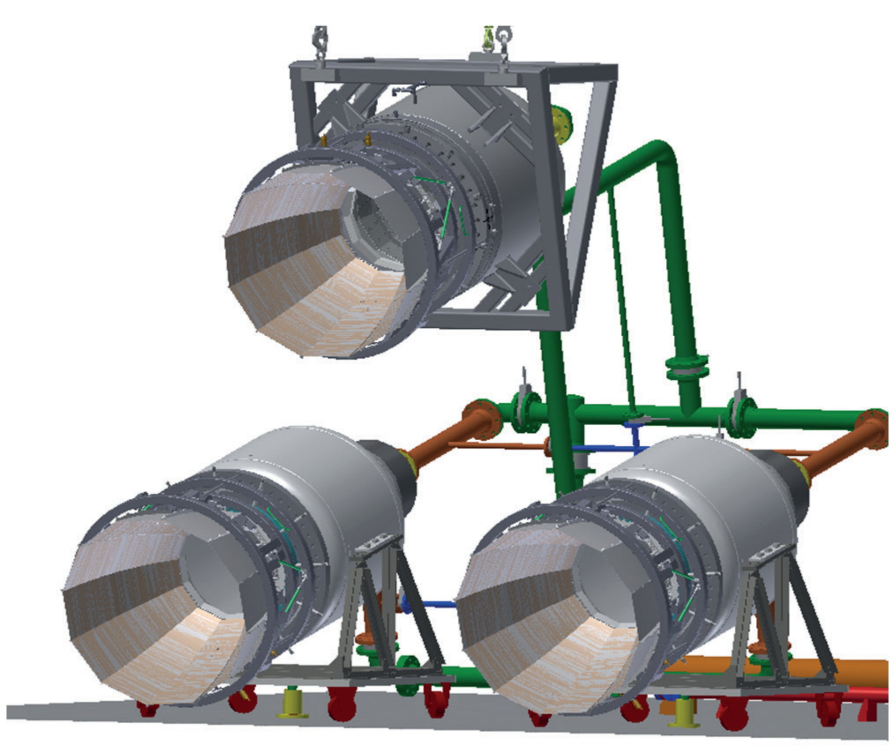
- Definition of key components
- Completion of process flowsheet layout and piping/ instrumentation diagram

FUTURE STEPS

- Construction of H_2 production reactor
- Completion of BoP and subBoP units
- Completion of adaptation of solar tower platform including reactor, peripherals and components integration
- Thermal-only and solar hydrogen production campaigns of prototype plant

CONCLUSIONS, MAJOR FINDINGS AND PERSPECTIVES

- A flow sheet of the H_2 production plant was elaborated involving all necessary components for the operation of the plant by taking into account also existing facilities on the PSA in Almeria.
- A P&ID diagram was elaborated in order to define the control strategy of the plant. Within the current period changes were implemented in the process layout, mainly related to the addition of one more reactor (a total of 3 parallel reactors), as well as to the feeding of nitrogen in the process.
- The design of the reactor was revisited to cover certain specifications (such as platform space and weight limitations, reactor volume, scalability of the redox porous structures, and also budget limitations). The final reactor design involves a set-up of 3 reactors put in a triangular arrangement.
- Honeycomb as well as foam monolithic structures consisting entirely of the redox material were considered as possible structures for the building of the reactor body and were developed and evaluated. Within the current project period a redox monolithic structure was subjected to more than 450h of consecutive splitting and regeneration cycles in the laboratory with no significant degradation in each redox activity being observed.
- The main process BoP and sub-BoP components were described while the solar platform is prepared to host the HYDROSOL-plant (structural improvements at the 27m height platform, renovation of the heliostat facets, new control program etc.).



CONTRIBUTION TO THE PROGRAMME OBJECTIVES

SOURCE OF OBJECTIVE/ TARGET (MAIP, AIP)	ASPECT ADDRESSED	PROGRAMME OBJECTIVE/ QUANTITATIVE TARGET	PROJECT OBJECTIVES/ QUANTITATIVE TARGETS	CURRENT STATUS/ ACHIEVEMENTS TO-DATE
AIP 2012	Materials with performances suitable for economic operation, i.e. life times in the range of more than 1000 operational hours	1000 h	1000 h	450 h
AIP 2012	Solar hydrogen generator in a demonstration range @ 0.5-2 MW scale for high temperature water splitting	0.5-2MW	0.75 MW	construction in preparation
AIP 2012	Demonstration of hydrogen production and storage on site (>3kg/week)	3 kg H_2/week	3 kg H_2/week	3.3 (average-based on lab scale experiments)

HyTIME

Low Temperature Hydrogen Production from Second Generation Biomass

AIP / APPLICATION AREA	AIP 2010 / AA 2: Hydrogen Production and Distribution
CALL TOPIC	SP1-JTI-FCH.2010.2.4: Low temperature H2 production processes.
START & END DATE	01 Jan. 2012 - 30 Jun. 2015
TOTAL BUDGET	€ 3,057,249
FCH JU CONTRIBUTION	€ 1,606,900
PANEL	Panel 5 - Hydrogen Production, Distribution and Storage

PARTNERSHIP/CONSORTIUM LIST

Coordinator: DLO-FBR

Partners: Awite, ENVIPARK, Heijmans, RWTH, TUW, HyGear, Veolia Water (Wiedemann-Polska left in Month 27)

PROJECT WEBSITE/URL

www.hy-time.eu

PROJECT CONTACT INFORMATION

Pieternel Claassen
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MAIN OBJECTIVES OF THE PROJECT

The target of HyTIME is to construct a prototype process for the production of 1-10 kg H_2/day from second generation biomass. The strategy is to employ thermophilic bacteria, growing at 70 °C, which have superior yields in H_2 production from grass and straw hydrolysates, or molasses. Dedicated bioreactors and gas upgrading devices will be constructed with the aim to increase productivity. The effluent of the H_2 reactor will be used for biogas production to cover the energy demand of the system.

PROGRESS/RESULTS TO-DATE

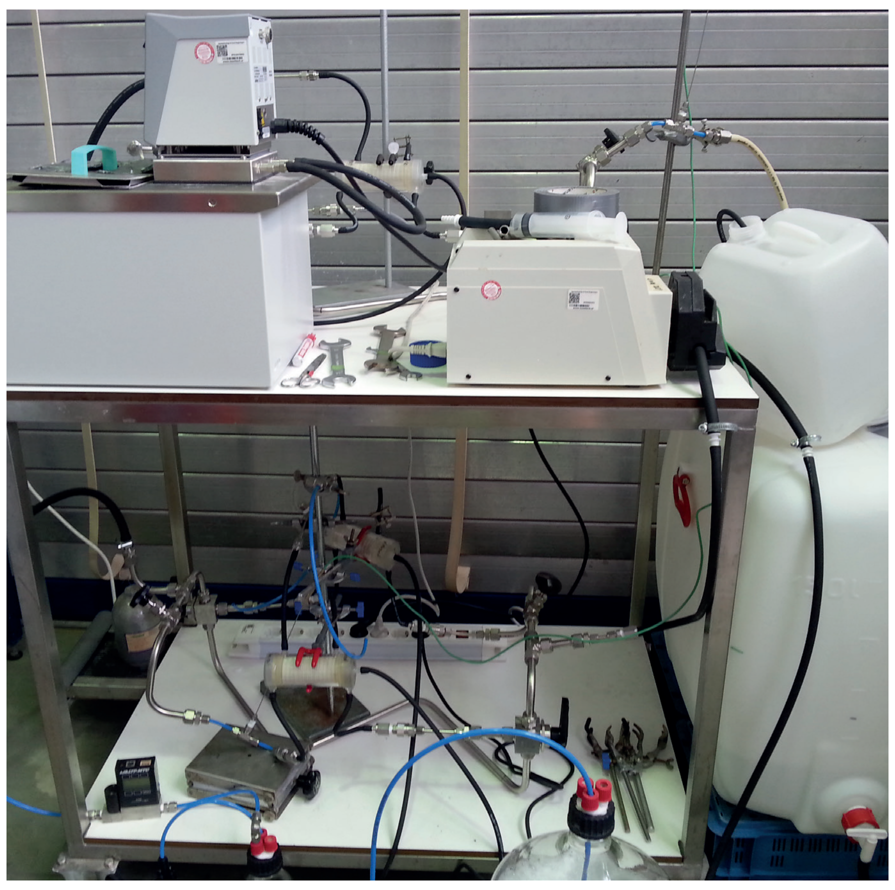
1. Productivity increase was proportional to decrease of hydraulic retention time during stable fermentation for > 37 days
2. On pure sugar max productivity was 66 mg H_2/L.h with 26 % H_2 in off gas at 53% yield
3. On steam exploded and enzymatically hydrolysed straw hydrolysate max productivity was 3.6 mg H_2/L.h with 44% H_2 in off gas
4. Subsequent anaerobic digestion was 6.3 CH_4/L.h with 47% CH_4 in off gas
5. In a 255 L packed bed reactor 110 g H_2/day was achieved using pure sugars at 25% yield

FUTURE STEPS

1. Further fundamental R&D aimed at management of bacterial population dynamics
2. Selection of robust hydrogen producers
3. Verification of new strategies with mixed product portfolios

CONCLUSIONS, MAJOR FINDINGS AND PERSPECTIVES

1. Biomass is a potential source for hydrogen production
2. Combination of hydrogen fermentation with anaerobic digestion is successful starting from straw
3. Selection pressure in hydrogen fermentation by applying thermophilic conditions seems insufficient



CONTRIBUTION TO THE PROGRAMME OBJECTIVES

SOURCE OF OBJECTIVE/ TARGET (MAIP, AIP)	ASPECT ADDRESSED	PROGRAMME OBJECTIVE/ QUANTITATIVE TARGET	PROJECT OBJECTIVES/ QUANTITATIVE TARGETS	CURRENT STATUS/ ACHIEVEMENTS TO-DATE
AIP 2010	Biomass availability and mobilization of sugars with dedicated fractionation processes	Efficient, easy to handle biological systems shall be developed with digestion systems based on 2nd generation biomass feedstock	75% mobilization of sugars from biomass	71% from straw 36% from verge grass <10% from kitchen waste
AIP 2010	Increase of hydrogen productivity	Low temperature H_2 production process	0.08 g H_2/L.h with high H_2 yield (75%)	On glucose: 0.034 g H_2/L.h with H_2 yield of 80%; On grass hydrolysate 0.04 g H_2/L.h with H_2 yield of 90%.
AIP 2010	Upscaling hydrogen production	Stable continuous hydrogen production in large scale reactor	1-10 kg H_2/day at 75% efficiency in large scale bioreactor on molasses	In the 5L reactor: 9 g H_2/day on glucose at 68 % efficiency; 6 g H_2/day on grass hydrolysate at 90% efficiency In the 50L reactor: 23.4 g H_2/day at 88% efficiency on sucrose and 18,3 at 20% on molasses, respectively In the 225L reactor: 108 g H_2/day at circa 25% efficiency
AIP 2010	System integration to produce hydrogen and methane	Development of bio H_2 production systems	n.a.	No data yet available

FUEL CELLS AND HYDROGEN JOINT UNDERTAKING

HyTransfer

Pre-Normative Research for Thermodynamic Optimization of Fast Hydrogen Transfer

AIP / APPLICATION AREA	AIP 2012 / AA 2: Hydrogen Production and Distribution
CALL TOPIC	SP1-JTI-FCH.2012.2.6: Pre-normative research on gaseous hydrogen transfer
START & END DATE	01 Jun. 2013 - 31 Jul. 2016
TOTAL BUDGET	€ 3,095,956
FCH JU CONTRIBUTION	€ 1,608,684
PANEL	Panel 5 - Hydrogen Production, Distribution and Storage

PARTNERSHIP/CONSORTIUM LIST

Coordinator: Ludwig-Bölkow-Systemtechnik GmbH

Partners: Ludwig-Bölkow-Systemtechnik GmbH, Air Liquide S.A., The CCS Global Group Limited, Hexagon Raufoss AS, Honda R&D Europe (Deutschland) GmbH, JRC – Joint Research Centre – European Commission, Centre National de la recherche scientifique, Testnet Engineering GmbH

PROJECT WEBSITE/URL

www.hytransfer.eu

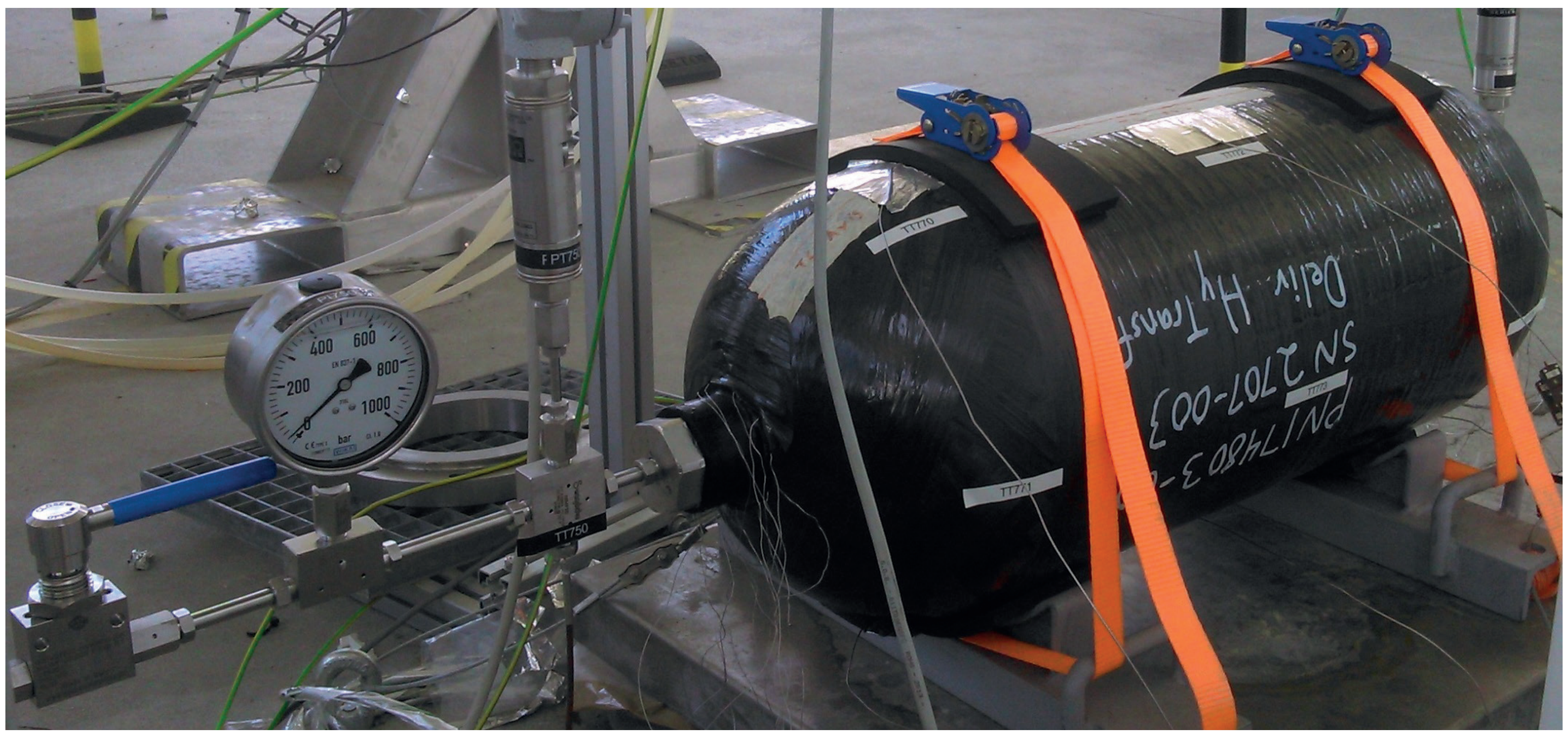
PROJECT CONTACT INFORMATION

Sofia Capito, Coordinator
info@HyTransfer.eu

MAIN OBJECTIVES OF THE PROJECT

HyTransfer aims to develop and experimentally validate a more practical approach for optimized fast filling of compressed hydrogen, meeting the material temperature limits of the tanks taking into account the container and system's thermal behaviour.

This project aims to create conditions for an uptake of the approach by international standards, for wide-scale implementation into refuelling protocols. The new approach will be thus evaluated and its benefits quantified with regards to performance, costs, and safety. Finally, recommendations for implementation into international standards will be proposed.



PROGRESS/RESULTS TO-DATE

- Tanks with temperature measuring devices (thermocouples) in the tank walls were manufactured by two different tank manufacturers. Thermocouples were strategically placed according to Computational Fluid Dynamics (CFD) calculations.
- 65 filling and emptying experiments on two different kinds of small tanks have been performed at three different labs in Europe. Temperature was measured inside the tank in the gas, inside the tank wall between liner and composite wrapping and on the outside of the tank wall.
- Results show a significant temperature difference between hydrogen gas and tank wall at the end of fast-fills
- A simple model predicting all temperatures is in very good agreement with the experiments. The error is in the magnitude of 3°C.
- Existing RCS and opportunities for improvements by the project are continuously monitored.

FUTURE STEPS

- Experiments on tank systems with up to 5 tanks of different sizes will be performed in autumn and winter 2015/2016
- Further optimization of CFD and simple model to match experiments even better
- Development and validation of simple model sustaining energy based fuelling process control criteria
- Techno-economical evaluation of results
- Prepare recommendations for RCS

CONCLUSIONS, MAJOR FINDINGS AND PERSPECTIVES

Perspectives:

- Optimized and more efficient refuelling protocol
- Guidance and simple model for optimized temperature control during hydrogen transfer
- Reduction of HRS operational expenditures (OPEX) and capital expenditures (CAPEX)
- Increased reliability and life time of technical HRS components
- Recommendations for international RCS

CONTRIBUTION TO THE PROGRAMME OBJECTIVES

SOURCE OF OBJECTIVE/ TARGET (MAIP, AIP)	ASPECT ADDRESSED	PROGRAMME OBJECTIVE/ QUANTITATIVE TARGET	PROJECT OBJECTIVES/ QUANTITATIVE TARGETS	CURRENT STATUS/ ACHIEVEMENTS TO-DATE
AIP 2012	Identification of opportunities for optimization	Not specified	Not specified	Optimization by focussing on heat transfer
AIP 2012	Identification of existing RCS and opportunities for improvement	Not specified	Not specified	Work in progress
AIP 2012	Improved approaches for carrying out the transfer with less pre-cooling	Not specified	Not specified	Work in progress
AIP 2012	Recommendations for implementation in international standards	Not specified	Not specified	This will be the final result of HyTransfer
AIP 2012	Evaluate the influence of tank construction on the maximum allowable filling speed	Not specified	Not specified	Tanks of three different sizes from two different manufacturers with two different liner materials were purchased and will be evaluated in three different labs concerning their thermal behaviour under a variety of filling conditions.

MEGASTACK

Stack Design for a Megawatt Scale PEM Electrolyser

AIP / APPLICATION AREA	AIP 2013 / AA 2: Hydrogen Production and Distribution
CALL TOPIC	SP1-JTI-FCH.2013.2.3: Large capacity PEM electrolyser stack design
START & END DATE	01 Oct. 2014 - 30 Sep. 2017
TOTAL BUDGET	€ 3,912,286
FCH JU CONTRIBUTION	€ 2,168,543
PANEL	Panel 5 - Hydrogen Production, Distribution and Storage

PARTNERSHIP/CONSORTIUM LIST

Coordinator: Stiftelsen SINTEF

Partners: Fraunhofer Gesellschaft zur Förderung der angewandten Forschung e.V., ITM Power Trading Limited, Commissariat A L'Energie Atomique et Aux Energies Alternatives

PROJECT WEBSITE/URL

www.megastack.eu

PROJECT CONTACT INFORMATION

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MAIN OBJECTIVES OF THE PROJECT

The main objective of MEGASTACK is to develop a cost efficient stack design for MW sized PEM electrolysers and to construct and demonstrate a prototype of this stack. The prototype will demonstrate a capability to produce hydrogen with an efficiency of at least 75% (LHV) at a current density of 1.2 Acm-2 with a stack cost below €2,500/Nm3h-1 and a target lifetime in excess of 40,000 hours (< 15 µVh-1 voltage increase at constant load).

PROGRESS/RESULTS TO-DATE

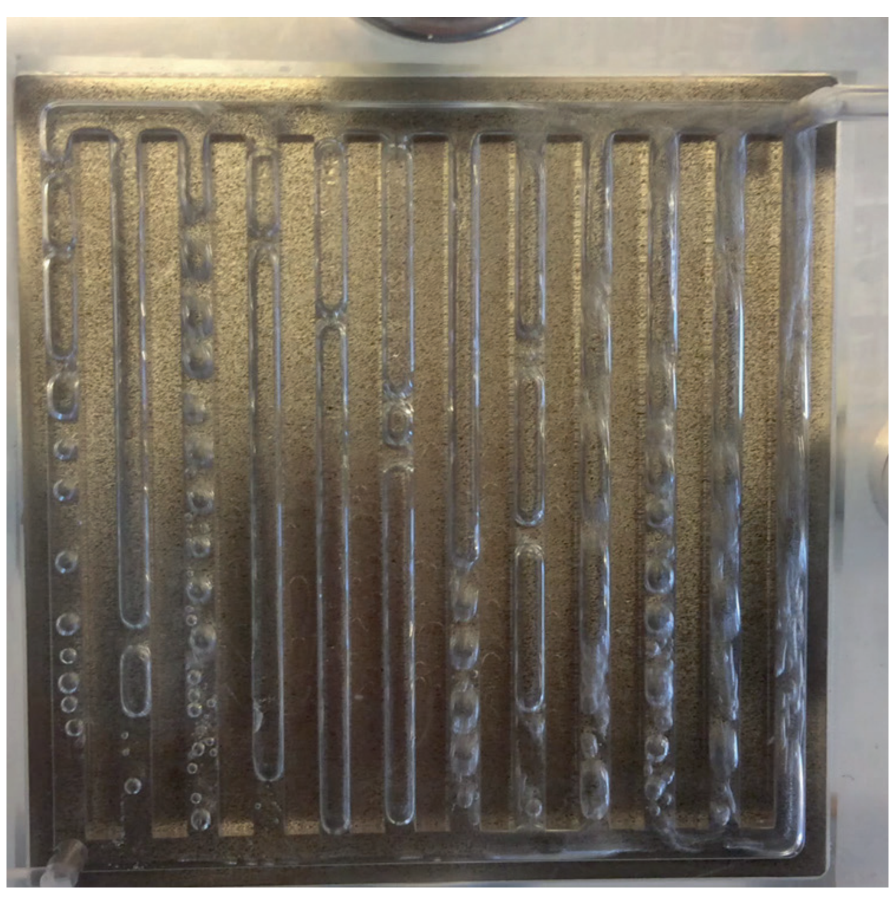
- Organised PEM electrolyser cost workshop
- Selection of supplier of MEA for MW stack concluded
- Multiphase flow model established
- 1st generation stack model completed
- 1st generation stack design completed

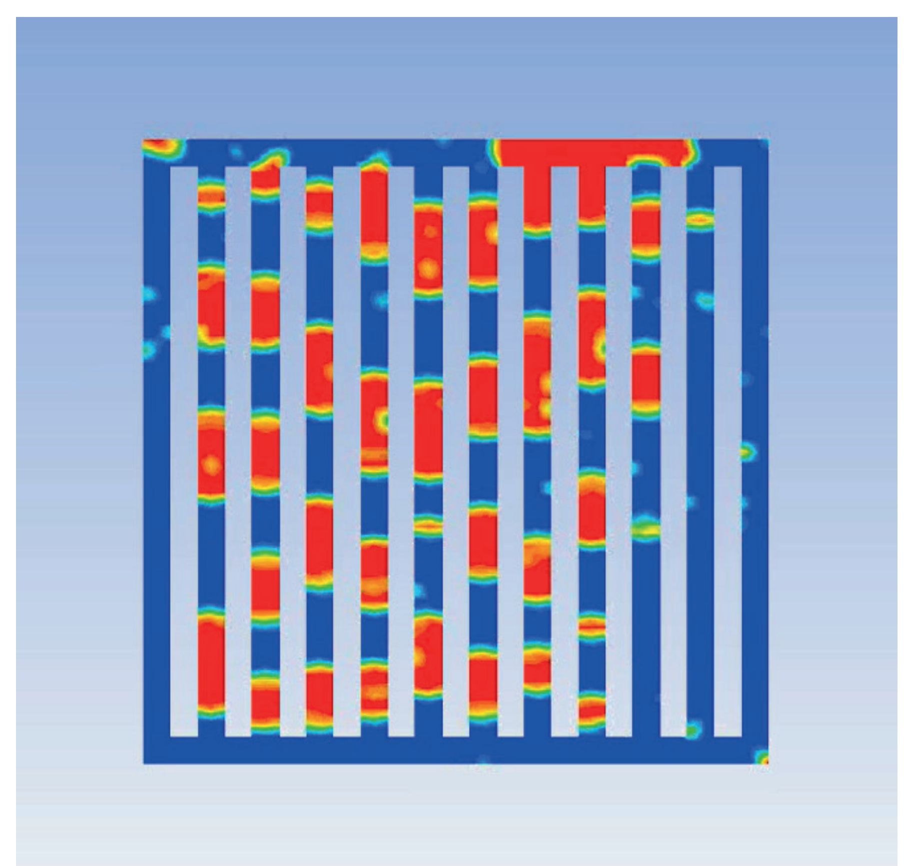
FUTURE STEPS

- Considerations of stack costs vs. markets
- Validation of multiphase flow model by bubble flow imaging
- Evaluation of stack design by mathematical models
- Component level testing on single cell and short stack level

CONCLUSIONS, MAJOR FINDINGS AND PERSPECTIVES

- MW scale PEM electrolyser design launched by ITM Power
- Further cost reductions possible through manufacturing and supply chain improvements





CONTRIBUTION TO THE PROGRAMME OBJECTIVES

SOURCE OF OBJECTIVE/ TARGET (MAIP, AIP)	ASPECT ADDRESSED	PROGRAMME OBJECTIVE/ QUANTITATIVE TARGET	PROJECT OBJECTIVES/ QUANTITATIVE TARGETS	CURRENT STATUS/ ACHIEVEMENTS TO-DATE
AIP 2013	Hydrogen production capacity of single stack	> 100 Nm3/h	60 Nm3/h	60 Nm3/h
AIP 2013	Stack efficiency	Current density @ 1.2 A/cm^2 with η > 80% on LHV basis up to @ 2.4 A/cm^2 with η > 70% on LHV basis	Current density @ 1.2 A/cm^2 with η > 75% on LHV basis	No stack tests or single cell tests (in stack size) performed yet
AIP 2013	Modular stack cost	< € 2 500/Nm3/h capacity	€ 2 500/Nm3/h capacity	Not available, no cost estimation performed to date.
AIP 2013	Stack availability	> 99%	> 99%	Not available, no stack constructed for testing.
AIP 2013	Lifetime	> 40 000h	> 40 000h	Not available, no stack constructed for testing.

NEMESIS2+

New Method for Superior Integrated Hydrogen Generation System 2+

AIP / APPLICATION AREA	AIP 2010 / AA 2: Hydrogen Production and Distribution
CALL TOPIC	SP1-JTI-FCH.2010.2.2: Development of fuel processing catalysts, modules and systems
START & END DATE	01 Jan. 2012 - 30 Jun. 2015
TOTAL BUDGET	€ 3,393,341
FCH JU CONTRIBUTION	€ 1,614,944
PANEL	Panel 5 - Hydrogen Production, Distribution and Storage

PARTNERSHIP/CONSORTIUM LIST

Coordinator: Deutsches Zentrum für Luft- und Raumfahrt e.V.

Partners: HyGear B.V., Johnson Matthey PLC., Abengoa Hidrógeno, S.A., Abengoa Bioenergía San Roque, S.A., Centre for Research and Technology Hellas, Instituto Superior Técnico

PROJECT WEBSITE/URL

www.nemesis-project.eu

PROJECT CONTACT INFORMATION

Stefan Martin
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MAIN OBJECTIVES OF THE PROJECT

Within the 3.5-year project NEMESIS2+ a small-scale hydrogen generator capable of producing 50 $m^3 h^{-1}$ hydrogen (purity: 5.0) from biodiesel and diesel has been developed.

With the envisaged process concept, a system efficiency (based on the lower heating value of hydrogen related to the lower heating value of liquid fuel) > 65 % was targeted. Hydrogen production costs of 4 €/kg were targeted.

PROGRESS/RESULTS TO-DATE

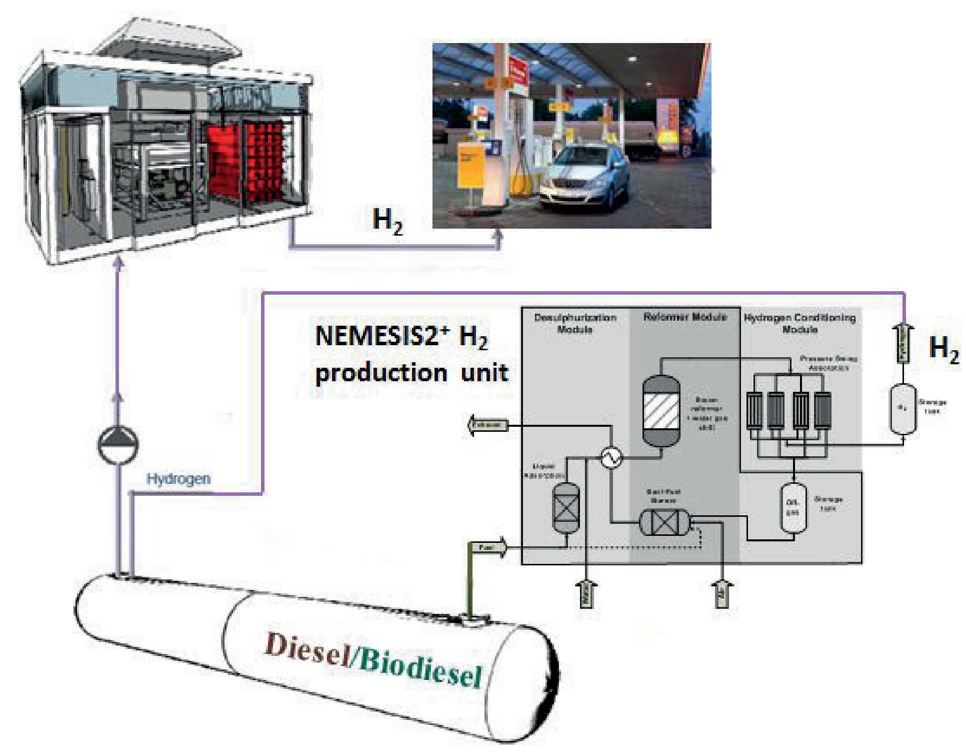
- Stable steam reforming of diesel and biodiesel shown on laboratory scale (100 hours) + Successful development pre-commercial prototype H2 generator
- Stable water gas shift performance in the presence of 1 ppm H2S and 100 ppm hydrocarbons (100 hours)
- Liquid desulphurization (< 2 ppm S) achieved in an adsorption bed of activated carbon
- Improved catalyst formulations (reformer, water gas shift) developed

FUTURE STEPS

- Project has been finalized

CONCLUSIONS, MAJOR FINDINGS AND PERSPECTIVES

- Stable operation of pre-commercial hydrogen generator based on feedstock diesel and biodiesel has been shown
- Hydrogen production cost of the envisaged 50 Nm^3/h system (5.8 Euro/kg H_2 for biodiesel) is competitive with renewable hydrogen production in Europe
- Stable steam reforming of diesel and biodiesel is possible! We were the first to publish respective results for feedstock biodiesel.



CONTRIBUTION TO THE PROGRAMME OBJECTIVES

SOURCE OF OBJECTIVE/ TARGET (MAIP, AIP)	ASPECT ADDRESSED	PROGRAMME OBJECTIVE/ QUANTITATIVE TARGET	PROJECT OBJECTIVES/ QUANTITATIVE TARGETS	CURRENT STATUS/ ACHIEVEMENTS TO-DATE
MAIP 2008-2013	Supply of 50 % of the anticipated hydrogen energy demand (expected to come mainly from transport and early market applications) from renewable energy sources by 2020	NEMESIS2+ will contribute to reach this target by using biodiesel as an environmentally friendly resource with high energy density.	Stable and cheap hydrogen production from biodiesel	Successful and stable steam reforming of biodiesel and diesel shown on lab scale and prototype level
AIP 2010	System efficiency (Higher Heating Value H2/Higher Heating Value Fuel)	80	70	This target was not met
AIP 2010	Catalyst durability	stable long-term operation	1000 hours	1000 hours
AIP 2010	Scalability	Scalable from 2 to 750 Nm3/h	Scalable from 2 to 750 Nm3/h	Scalable beyond 1000 Nm3/h (due to modular set-up)
AIP 2010	Catalyst efficiency	reforming catalyst system should exhibit enough shift activity to reduce CO concentration below 10vol% (dry basis) to reduce shift catalyst quantity	CO-conc. < 10 vol.-%	achieved
MAIP 2008-2013	H2 production costs (€/kg)	<5	<4	~5.8
AIP 2010	Material costs (after 6 years)	< 5000 Euro/Nm^3 for a capacity of 50 Nm^3/H > plant costs should not exceed 250 000 Euro	Plant costs < 250 000 Euro (assuming 2 5 units/year)	227 000 Euro per plant

NOVEL

Novel Materials and System Designs for Low Cost, Efficient and Durable PEM Electrolysers

AIP / APPLICATION AREA	AIP 2011 / AA 2: Hydrogen Production and Distribution
CALL TOPIC	SP1-JTI-FCH.2011.2.7: Innovative Materials and Components for PEM electrolysers
START & END DATE	01 Sep. 2012 - 31 Aug. 2016
TOTAL BUDGET	€5,743,445
FCH JU CONTRIBUTION	€2,663,357
PANEL	Panel 5 - Hydrogen Production, Distribution and Storage

PARTNERSHIP/CONSORTIUM LIST

Coordinator: Stiftelsen SINTEF

Partners: Fraunhofer Gesellschaft zur Förderung der angewandten Forschung e.V., Commissariat A L'Energie Atomique Et Aux Energies Alternatives, AREVA H2 Gen, Johnson Matthey Fuel Cells Limited, Teer Coatings Limited, Paul Scherrer Institute

PROJECT WEBSITE/URL

www.novelhydrogen.eu

PROJECT CONTACT INFORMATION

Magnus Thomassen
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MAIN OBJECTIVES OF THE PROJECT

The main objective of NOVEL is 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 will demonstrate a capability to produce hydrogen with an efficiency of at least 75% (LHV) at rated capacity with a stack cost below €2,500/Nm^{3}h^{-1} and a target lifetime in excess of 40,000 hours (< 15 μVh^{-1} voltage increase at constant load)

PROGRESS/RESULTS TO-DATE

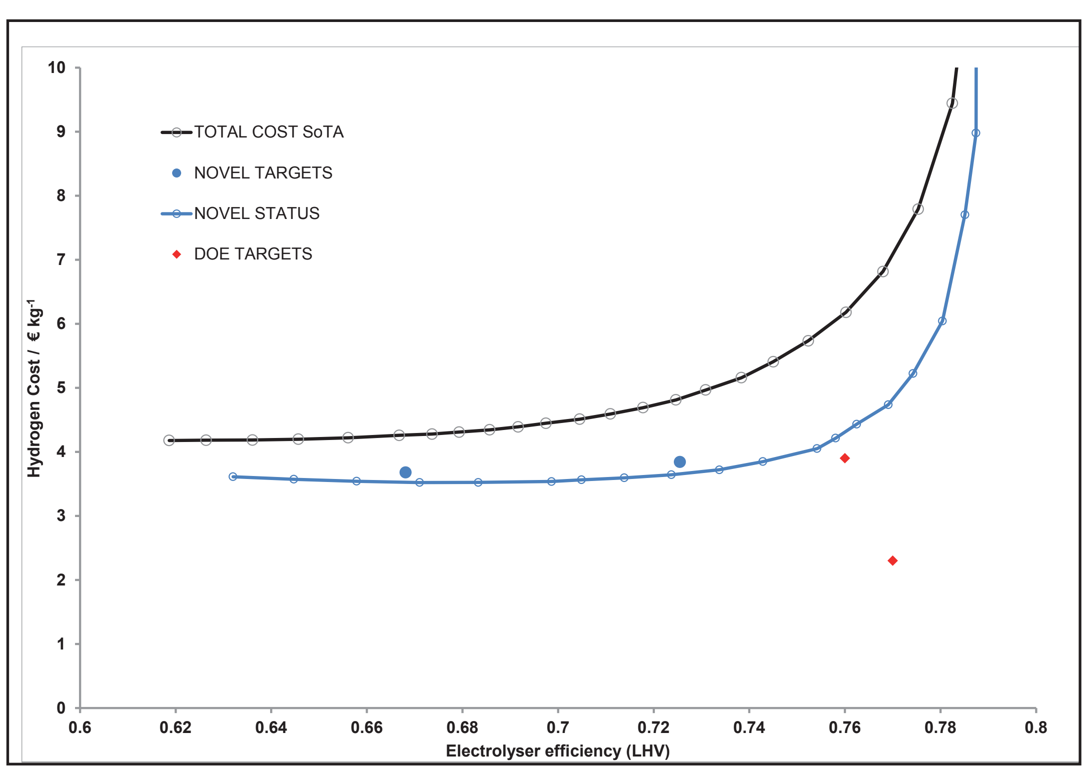
- Identified degradation mechanisms in PEM electrolysers
- Developed membranes with lower H_2 crossover and lower costs
- Supported electrocatalysts with higher activity developed
- Oxide coatings for Ti bipolar plates developed
- AREVA electrolyser stack tested more than 6000h

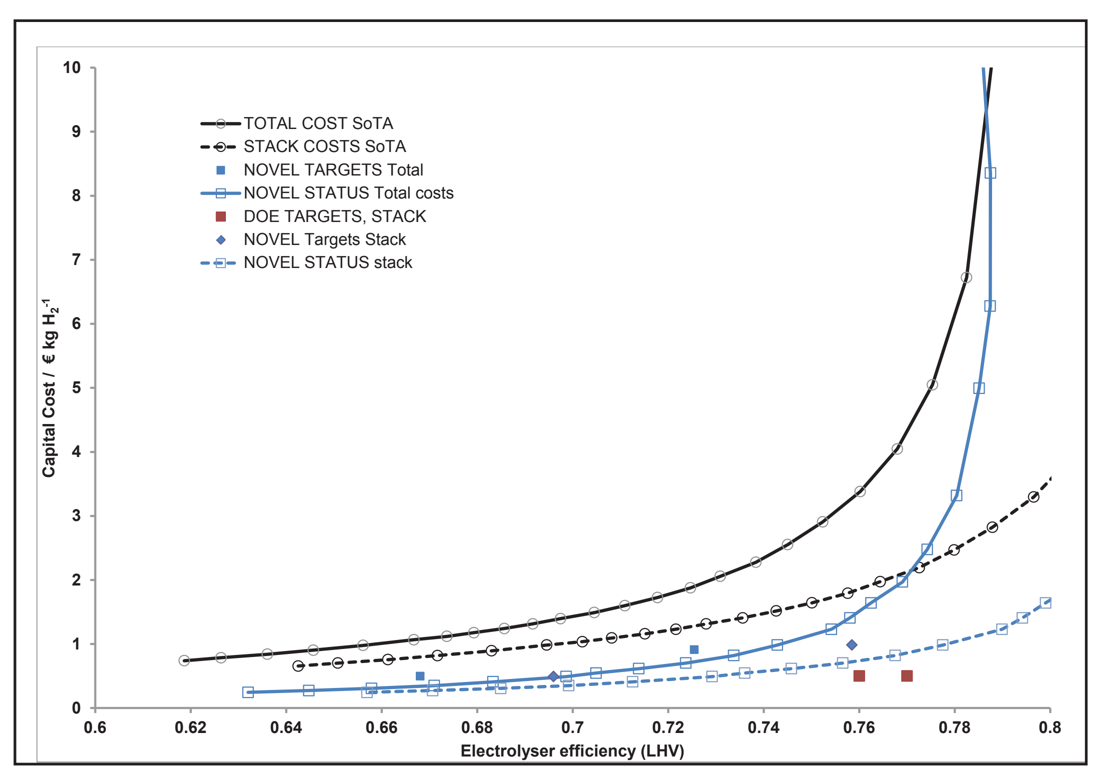
FUTURE STEPS

- Integration of catalysts and membranes to new MEAs
- Upscaling of process optimisation of bipolar plate coating process
- Lifetime evaluation of PEM electrolysers

CONCLUSIONS, MAJOR FINDINGS AND PERSPECTIVES

- A new generation polyaromatic membranes for PEM electrolysers with significant potential for cost reduction
- New oxygen evolution catalysts with improvement in catalytic activity and potential for noble metal thrifting.
- Increased understanding of degradation issues in PEM electrolysers and parameters affecting overall lifetime which can contribute to increasing the lifetime of these units.
- Novel stack design, reducing construction material costs and easing assembly.





CONTRIBUTION TO THE PROGRAMME OBJECTIVES

SOURCE OF OBJECTIVE/ TARGET (MAIP, AIP)	ASPECT ADDRESSED	PROGRAMME OBJECTIVE/ QUANTITATIVE TARGET	PROJECT OBJECTIVES/ QUANTITATIVE TARGETS	CURRENT STATUS/ ACHIEVEMENTS TO-DATE
AIP 2011	More efficient catalysts for the oxygen evolution reaction presenting lower activation overpotential as well as new catalyst structures or metal alloys resulting in lower noble metal loadings	N/A	Improved catalysts with 200% mass activity vs. state of the art demonstrated. Fibrous catalyst supports and the use of alternatives to Pt for hydrogen evolution is being evaluated	Catalysts with 300% mass activity vs. state of the art demonstrated ex situ. Fibrous catalyst supports and the use of alternatives to Pt for hydrogen evolution has been evaluated
AIP 2011	Polymer membranes with improved conductivity, low gas crossover and high mechanical stability at operating conditions such as hydrocarbon membranes or other novel membrane concepts, including composite structures	N/A	• Thinner, more conductive and reinforced PFSA membranes • Radiation grafted membranes • More advanced concepts, such as structured radiation grafted membranes and hybrid membranes	Membranes with a higher ratio of conductivity vs hydrogen crossover has been developed and tested for hydrogen crossover and conductivity ex situ. First tests of electrolyser MEAs are ongoing
AIP 2011	Alternative materials for bipolar plates and current collectors, replacing the use of titanium as construction material, e.g. novel coatings for stainless steel capable of withstanding potentials up to 2 V and pressurised oxygen	N/A	Development of coatings using several coating processes. The goals of the coatings are either to reduce the contact resistance of Titanium or, preferably to coat lower costs materials such as stainless steel.	N/A

PECDEMO

Photoelectrochemical Demonstrator Device for Solar Hydrogen Generation

AIP / APPLICATION AREA	AIP 2013 / AA 2: Hydrogen Production and Distribution
CALL TOPIC	SP1-JTI-FCH.2013.2.5: Validation of photoelectrochemical hydrogen production
START & END DATE	01 Apr. 2014 – 31 Mar. 2017
TOTAL BUDGET	€ 3,394,010.00
FCH JU CONTRIBUTION	€ 1,830,644.00
PANEL	Panel 5 - Hydrogen Production, Distribution and Storage

PARTNERSHIP/CONSORTIUM LIST

Coordinator: Helmholtz-Zentrum Berlin für Materialien und Energie (HZB)

Partners: Ecole Polytechnique Federale de Lausanne (EPFL), Technion – Israel Institute of Technology (IIT), Deutsches Zentrum für Luft- und Raumfahrt (DLR), Universidade do Porto, Evonik Industries AG, Solaronix SA

PROJECT WEBSITE/URL

www.pecdemo.eu

PROJECT CONTACT INFORMATION

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Daniela Kaden daniela.kaden@helmholtz-berlin.de

MAIN OBJECTIVES OF THE PROJECT

To address the challenges of solar energy capture and storage in the form of a chemical fuel, we will develop a hybrid photoelectrochemical-photovoltaic tandem device for light-driven water splitting with an active area of ≤50 cm^2 and a solar-to-hydrogen (STH) efficiency of 8-10% that is stable for more than 1000 h. In parallel, our partners from industry and research institutions will work together on an extensive techno-economic and life-cycle analysis based on actual performance characteristics. This will give a reliable evaluation of the application potential of photoelectrochemical hydrogen production, and further strengthen Europe's leading position in this growing field.

PROGRESS/RESULTS TO-DATE

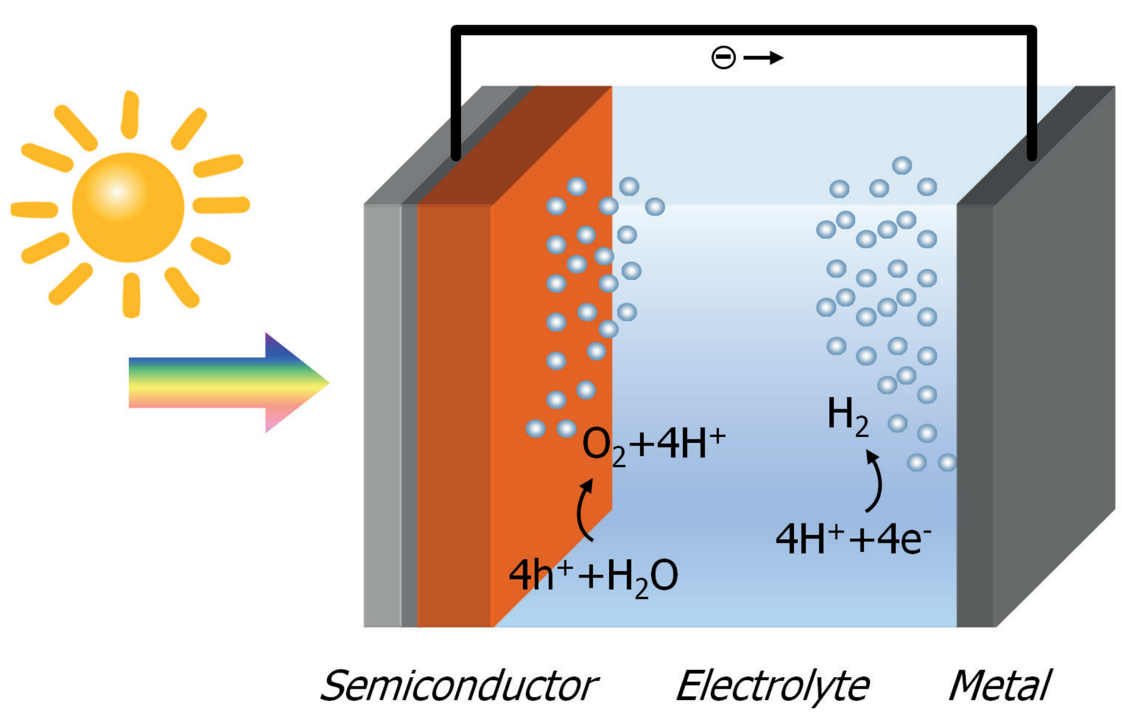
- Photoactive $BiVO^4$ films made with reactive magnetron sputtering
- ALD protection layers significantly reduce photocorrosion
- First stand-alone water splitting device with Cu2O/perovskite cell shows STH efficiency of 2.1%
- Process flow sheets worked out for three H_2 production scenarios, first simulations on energy flows completed.
- First CFD simulations on temperature profiles in angled PEC cell design completed

FUTURE STEPS

- Further optimization of magnetron sputtering process
- Development of nanostructured composite photoanodes
- Experimental studies on optimal PEC/PV combinations
- Experimental validation of CFD simulations

CONCLUSIONS, MAJOR FINDINGS AND PERSPECTIVES

- Stability and efficiency of individual components continue to be improved
- Initial results on innovative cell architectures look promising
- The consortium is on track to reach overall goals.



CONTRIBUTION TO THE PROGRAMME OBJECTIVES

SOURCE OF OBJECTIVE/ TARGET (MAIP, AIP)	ASPECT ADDRESSED	PROGRAMME OBJECTIVE/ QUANTITATIVE TARGET	PROJECT OBJECTIVES/ QUANTITATIVE TARGETS	CURRENT STATUS/ ACHIEVEMENTS TO-DATE
MAIP 2008-2013	New hydrogen production pathway	Development and testing of new hydrogen production pathways (the MAIP does not specify quantitative targets for these pathways).	Development of a hybrid photoelectrochemical-photovoltaic tandem device for light-driven water splitting with an active area of at least 50 cm2 and a solar-to-hydrogen efficiency of 8% that is stable for more than 1000 h.	Concept has been demonstrated by applicants, the best efficiency achieved so far is 6.5% (HHV) for a <1 cm2 device.
AIP 2013	Hydrogen cost	Estimate feasibility to meet EU target cost of 5 €/kg H_2.	Cost estimation for photoelectrochemically produced hydrogen through economic analysis (Task 5.4).	Process flow sheets worked out for three H_2 production scenarios, first simulations on energy flows completed.
AIP 2013	Development and integration of prototypes	Demonstrate prototypes that allow easy integration in small to medium scale applications ranging from 100 W to 100 kW.	Demonstration of a prototype module of 4 devices, each larger than 50 cm^2 having an efficiency of 8%.	Construction of prototype module is scheduled to start in M28.
AIP 2013	Development of new architectures	To design innovative device architectures that combine efficient sunlight harvesting.	Development of effective light management strategies for tandem devices based on wavelength-selective mirrors and filters.	First dichroic mirrors fabricated, simulations show positive impact on overall cell performance. Film transfer method developed for making Fe_2O_3 photoanodes with reflecting back-contact.
AIP 2013	Development of diagnostic methods	To develop diagnostic methods to identify the energy loss and material degradation mechanisms limiting performance.	Modeling of optical and electrical coupling of PEC-PV tandem devices and development of diagnostic methods to identify and quantify losses.	Intensity-modulated photocurrent spectroscopy has revealed that surface recombination is an important loss mechanism in $BiVO_4$.
AIP 2013	Development of new technology with a higher large area	To develop technologies that enable controlled, reproducible and potentially large-scale production of large-area (>50 cm^2) stable solar hydrogen production devices.	To evaluate and develop the deposition technology that is needed for fabricating large-area hybrid PEC-PV devices.	Photocurrents of 2.9 mA/cm2 achieved for BiVO4 photoanodes made with reactive magnetron sputtering.
AIP 2013	Durability	Laboratory and field tests of ≥1000 h duration.	Performance and stability test ≥1000 h.	Tests will start in M28.

FUEL CELLS AND HYDROGEN JOINT UNDERTAKING

RESelyser

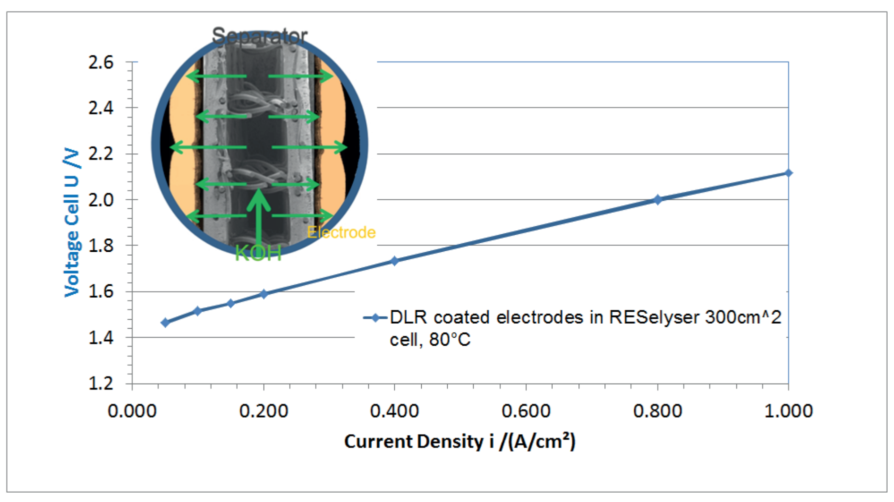
Hydrogen from RES: Pressurised Alkaline Electrolyser with High Efficiency and Wide Operating Range

AIP / APPLICATION AREA	AIP 2010 / AA 2: Hydrogen Production and Distribution
CALL TOPIC	SP1-JTI-FCH.2010.2.1: Efficient alkaline electrolysers
START & END DATE	01 Nov. 2011 - 30 Apr. 2015
TOTAL BUDGET	€ 2,888,957.40
FCH JU CONTRIBUTION	€ 1,484,358
PANEL	Panel 5 - Hydrogen Production, Distribution and Storage

PARTNERSHIP/CONSORTIUM LIST

Coordinator: Deutsches Zentrum fuer Luft- und Raumfahrt eV. (DLR)

Partners: Vlaamse Instelling voor Technologisch Onderzoek N.V. (VITO), Hydrogenics Europe N.V., Danmarks Tekniske Universitet (DTU)



PROJECT WEBSITE/URL

www.reselyser.eu

PROJECT CONTACT INFORMATION

Regine Reissner
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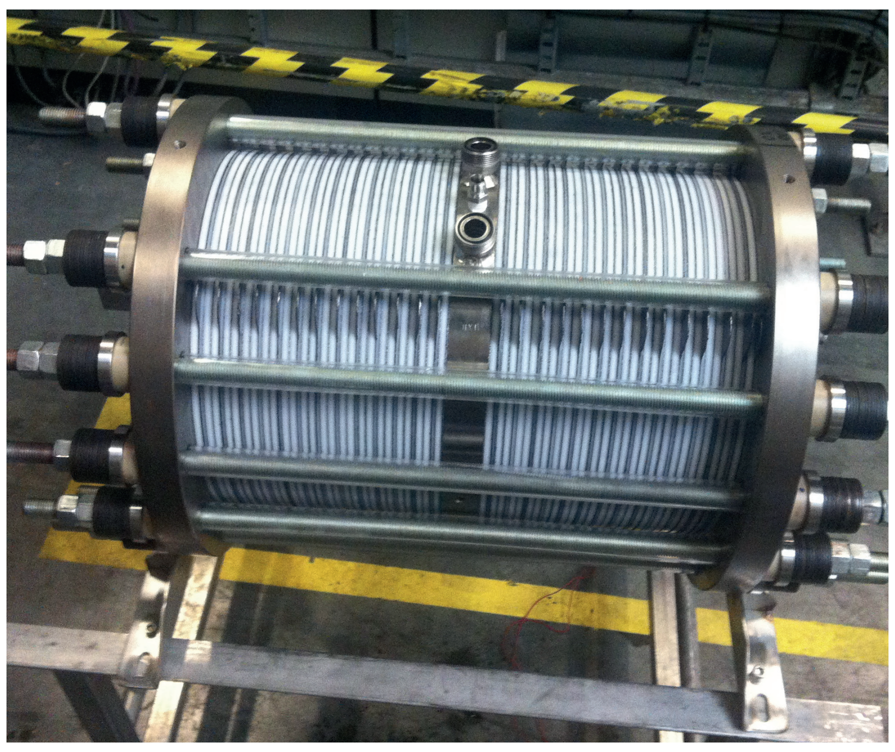
MAIN OBJECTIVES OF THE PROJECT

The project RESelyser develops high pressure, highly efficient, low cost alkaline electrolysers that can be integrated with renewable energy power sources (RES) using an advanced membrane concept, highly efficient electrodes and a new cell concept. Quantitative objectives: efficiency >80%, 1,000 on/off switching cycles; 3,000 €/(Nm^3/h) plant capacity.



PROGRESS/RESULTS TO-DATE

- Novel diaphragms with internal electrolyte bypass and properties for maximum benefit of the cell developed and produced in technical size
- 300 cm^2 cell and 10 kW stack up to 30 bar used for tests
- Electrode coatings with low-cost material developed with 411 mV overpotential reduction versus uncoated electrodes retaining 98% of their initial efficiency in 1100 on-off cycles
- Electrode coating porosity and degradation investigated with two and three dimensional electron microscopy
- Gas impurity at low current density very low: 48 ppm O_2 in H_2 and 247 ppm H_2 in O_2 at 5 bar

FUTURE STEPS

The project is terminated.

- Promising electrode coating needs further development and transfer to commercialisation.
- Double layer separator is ready for commercial licensing.
- High pressure stack technique will be used in future electrolyser development.

CONCLUSIONS, MAJOR FINDINGS AND PERSPECTIVES

- Key steps towards a next generation alkaline water electrolyser for higher pressure and highly fluctuating power supply were achieved: separators, electrodes, stack construction, and BoP construction

CONTRIBUTION TO THE PROGRAMME OBJECTIVES

SOURCE OF OBJECTIVE/ TARGET (MAIP, AIP)	ASPECT ADDRESSED	PROGRAMME OBJECTIVE/ QUANTITATIVE TARGET	PROJECT OBJECTIVES/ QUANTITATIVE TARGETS	CURRENT STATUS/ ACHIEVEMENTS TO-DATE
AIP 2010	Power level stack	Exceeding 5kW	10 kW	10 kW stack 30 bar
AIP 2010	Efficiency @current density 0.75 A/cm^2	>80% on HHV basis	η >80% on HHV basis 300 cm^2 electrodes, low-cost materials	Total efficiency η=76% on HHV basis at a current density of 0.75 A/cm^2 in a 300 cm^2 cell, 82% for smaller cell
AIP 2010	Electrolyser system operation at high pressure	15MPa=150 bar with compression or 3 MPa=30 bar without compression	100-150 bar concept, 25 bar realisation without compression	Tests up to 30 bar, stack ready for 50 bar
AIP 2010	Retention of ...% of initial efficiency over at least 1000 on/off switching cycles	>90%	>90% demonstrated with 10 kW electrolyser	Electrode potential 98% of initial efficiency over 1100 on/off switching cycles; higher degradation in stack
AIP 2010	Modular system cost	€1,000 per Nm^3/h plant capacity for the stack and €3,000 per Nm^3/h plant for a complete system	System costs €3,000 per Nm^3/h plant capacity for the complete system	Estimate 2,300 €/(Nm^3/h) plant capacity stack costs S2500 running at 65 bar, 7K€/(Nm^3/h) for a 6-stack-arrangement (1000 cm^2) 65barg reselyser system. Costs of electrolyser system for some application cases lower than state of the art

SOL2HY2

Solar To Hydrogen Hybrid Cycles

AIP / APPLICATION AREA	AIP 2012 / AA 2: Hydrogen Production and Distribution
CALL TOPIC	SP1-JTI-FCH.2012.2.5: Thermo-electrical-chemical processes with solar heat sources
START & END DATE	01 Jun. 2013 - 31 May 2016
TOTAL BUDGET	€ 3,701,300
FCH JU CONTRIBUTION	€ 1,991,115
PANEL	Panel 5 - Hydrogen Production, Distribution and Storage

PARTNERSHIP/CONSORTIUM LIST

Coordinator: EnginSoft S.p.A.

Partners: Aalto-korkeakoulusäätiö, Deutsches Zentrum fuer Luft- und Raumfahrt e.V., Agenzia per le Nuove Tecnologie l'Energia e lo Sviluppo Economico Sostenibile, Outotec (Finland) Oy, Erbicol S.A., Oy Woikoski AB.

PROJECT WEBSITE/URL

sol2hy2.eucoord.com

PROJECT CONTACT INFORMATION

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Michael Gasik
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MAIN OBJECTIVES OF THE PROJECT

1. Development of the key hybrid plant components (SO_2-depolarized electrolyzer (SDE), solar-powered H_2SO_4 cracker and heat storage)
2. Multi-objective design and optimisation and testing of improved critical materials solutions and processes
3. Designing and running field tests of key blocks of the hybrid cycles their performance analysis
4. Technical-economic evaluation of the new process concept
5. Development of the flexible centralised H_2 production plant options using interfaces to running industrial process as the starting point for renewable H2 by-production

PROGRESS/RESULTS TO-DATE

- A multi-cell SDE stack was constructed and tested in the lab for hydrogen and sulphuric acid co-production.
- An acid decomposition chamber, acid evaporator and gas handling were designed for field demo tests using solar tower
- Hybrid solar plant flowsheets were analysed and optimized.
- Multi-objective design and optimization were performed on key units such as SDE and their optimal processing parameters were identified
- Balance of plant has been selected and prepared for the virtual plant model for specific locations

FUTURE STEPS

- Finalising tests of SDE in different conditions
- Field tests of efficient catalysts for sulphuric acid cracking
- Final multi-objective optimization of the plant
- Running demo activities in 2015 at the solar tower in Jülich
- Analysing feedback and update of the final steps of the project

CONCLUSIONS, MAJOR FINDINGS AND PERSPECTIVES

- The hybrid plant design was demonstrated flexibility for selected locations and input parameters, able to adjust with solar input
- SO_2-depolarized electrolyzer was successfully designed and tested
- Molten salt technology is feasible to ensure continuous operation for hydrogen and acid production, where high-temperature solar power is only used for acid cracking and recycling
- Virtual plant model linked with multi-objective design and optimization provides opportunity for user-tailored solutions.
- Combination of closed (hybrid sulphur) and Outotec open cycles allows greater cost-efficiency at high power utilization.

CONTRIBUTION TO THE PROGRAMME OBJECTIVES

SOURCE OF OBJECTIVE/ TARGET (MAIP, AIP)	ASPECT ADDRESSED	PROGRAMME OBJECTIVE/ QUANTITATIVE TARGET	PROJECT OBJECTIVES/ QUANTITATIVE TARGETS	CURRENT STATUS/ ACHIEVEMENTS TO-DATE
AIP 2012	Catalysts with activities	+30% vs. state of the art	>100% vs. known Pt/Pd loads	Good electrolyzer performance achieved with only 1-3 µg/cm^2 loads vs. known 100-1000 µg/cm^2
AIP 2012	Redox materials with conversion rate	+100% vs. state of the art	Redox materials not used	Use of redox materials eliminated
AIP 2012	Development of key components with enhanced efficiency in relevant scale	0.5-2.0 MW	>0.5 MW at daily input 20 MWh	Design according to the program objective

SOPHIA

Solar Integrated Pressurized High Temperature Electrolysis

AIP / APPLICATION AREA	AIP 2013 / AA 2: Hydrogen Production and Distribution
CALL TOPIC	SP1-JTI-FCH.2013.2.4: New generation of high temperature electrolyser
START & END DATE	01 Aprl 2014 - 31 Mar. 2017
TOTAL BUDGET	€6,080,105
FCH JU CONTRIBUTION	€3,325,751
PANEL	Panel 5 - Hydrogen Production, Distribution and Storage

PARTNERSHIP/CONSORTIUM LIST

Coordinator: HyGear BV

Partners: HTceramix SA, Commissariat à l'énergie atomique et aux énergies alternatives, Deutsches Zentrum fuer Luft- und Raumfahrt ev, Ecole polytechnique federale de Lausanne, Teknologian Tutkimuskeskus VTT, GdF Suez, SOFCpower Spa

PROJECT WEBSITE/URL

http://www.sophia-project.eu/

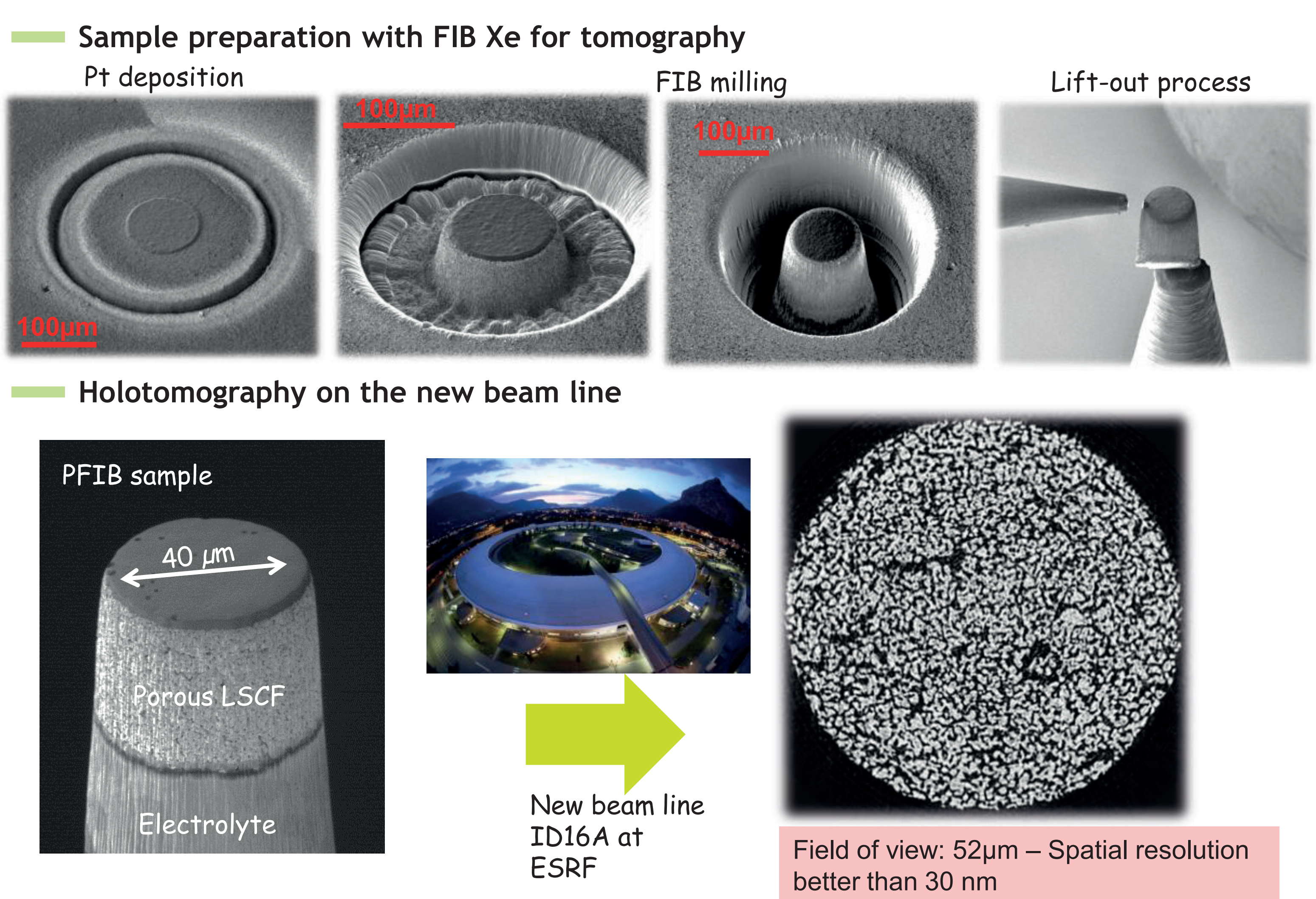
PROJECT CONTACT INFORMATION

Dr. Ellart de Wit
Ellart.de.wit@hygear.nl

MAIN OBJECTIVES OF THE PROJECT

Design, fabrication, and operation on-sun of a 3 kWe-size pressurized High Temperature Electrolysis (HTE) system, coupled to a concentrated solar energy source as proof of principle. Proof of concept of co-electrolysis at the stack level, and pressurized.

Development and manufacturing of optimized large area cells for HTE operation targeting at high performance, and improved durability. Degradation analysis. Design of a stack for pressurized operation.



Development of a methodology for relevant 3D reconstruction for SOC electrodes with a high field of view and high spatial resolution

PROGRESS/RESULTS TO-DATE

- PFD of system ready
- Concept P&ID of SOE sub-system ready
- Solar receivers build and tested, optimisation on going
- 1st Market analysis is done, case studies are defined (varying country, hydrogen or syngas pathway, definition of end use), the simulation model is in progress.
- Short stack experiments at 1 bar done

FUTURE STEPS

- Design of components and construction of BoP
- Stack design validation (self-clamping system validation) – Integration of SP cells; build of 3 kW SOE stack,
- Finalize design and build of Solar receiver/steam generator
- Continue cell and short stack tests according to the plan
- Electrode microstructure optimization and degradation analysis ongoing (H2 electrode form SP to be well-characterized, electrode model calibration to be performed, co-electrolysis model validation to be continued)

CONCLUSIONS, MAJOR FINDINGS AND PERSPECTIVES

- Tailor made test station validated for reversible operation of a SOE stack
- Current H2 for industrial : huge market in EU, very high prices; mobility market by 2020 : might be huge for renewable in EU depending on regulation
- A complete numerical model considering two phase flow, radiative heat transfer, and natural convection is developed for evaluation and optimization of the solar receiver for cogeneration of high temperature steam and CO2. Based on the model, parametric studies show that the current receiver prototype design has potential to be improved by changing the tube diameter, orientation and position of tubes and aperture, and operation strategies.
- First performance tests performed with SP button cells under pressurized conditions in electrolysis and co-electrolysis modes – At the thermoneutral voltage: positive impact of the pressure. The electrochemical model at P≥1 bar validated at the Single Repeat Unit. Simulations performed to identify the best operating conditions of this cell in pressurized electrolysis mode.

Model calibrated for the O2 electrode thanks to polarization curve obtain in symmetrical configuration and microstructure data input- > First recommendations/conclusions for microstructure optimization :) Because of a non-symmetrical behavior in both polarization, a specific microstructural optimization is required in electrolysis mode. A LSCF-CGO composite with fine and percolated phases has been recommended for electrolysis operation. ..)A sensitivity analysis on microstructural properties has shown that electrode performances could be improved in both polarization (i.e. fuel and electrolysis)

- More accurate characterization of the electrode of the electrolyzer and its transport properties is achieved by tomography-based direct numerical simulations, which increase the accuracy of the overall cell and stack models. Using the tomography-based direct numerical simulations, no significant difference in transport properties of the electrode is quantifiable for an electrode exposed to air for 3000 hours at 800°C

CONTRIBUTION TO THE PROGRAMME OBJECTIVES

SOURCE OF OBJECTIVE/ TARGET (MAIP, AIP)	ASPECT ADDRESSED	PROGRAMME OBJECTIVE/ QUANTITATIVE TARGET	PROJECT OBJECTIVES/ QUANTITATIVE TARGETS	CURRENT STATUS/ ACHIEVEMENTS TO-DATE
MAIP 2008-2013	Carbon free/carbon lean H_2 production	10 – 20%	HT SOE system at kW size	System design is ready; cell and short stack stack experiments have been done.
AIP 2013	Low degradation rate	<0.5% per 1000 h		First degradation rate at the single cell level: 50 mV/kh during the first 500h and then 5 mV/kh between t=500 and t=2000h (850°C, i=-0.5 A/cm^2, SC=60%)
AIP 2013	Pressurized electrolysis	>1	15	At the thermoneutral voltage: positive impact of the pressure Electrochemical model validated. Identification of the best operating conditions under pressure

UNIfHY

UNIQUE Gasifier for Hydrogen Production

AIP / APPLICATION AREA	AIP 2011 / AA 2: Hydrogen Production and Distribution
CALL TOPIC	SP1-JTI-FCH.2011.2.3 - BTH - Biomass-to-hydrogen (thermal conversion process)
START & END DATE	01 Sep. 2012 - 31 Dec. 2015
TOTAL BUDGET	€ 3,438,061.36
FCH JU CONTRIBUTION	€ 2,203,599.00
PANEL	Panel 5 - Hydrogen Production, Distribution and Storage

PARTNERSHIP/CONSORTIUM LIST

Coordinator: Università degli Studi Guglielmo Marconi (USGM) - Italy

Partners: Università Degli Studi Di Roma La Sapienza (DIMA) - Italy, Università degli Studi Dell'aquila (UNIVAQ) - Italy, HyGear B.V (HyGear) - Netherland, Agenzia Nazionale per le Nuove Tecnologie, l'Energia e lo Sviluppo Economico Sostenibile (ENEA) - Italy, Universite de Strasbourg (UNISTRA) - France, Engineering, Procurement & Construction (EPC) - Germany, Pall Filtersystems Gmbh (PALL) - Germany, Air Liquide Hydrogen Energy (ALAB) - France

Third Parties: HyGear Fuel Cell Systems B.V. (HyGear FCS)- Netherland, Hygear Technology and Services (BV - HyGear TS) - Netherland

PROJECT WEBSITE/URL

www.unifhy.eu

PROJECT CONTACT INFORMATION

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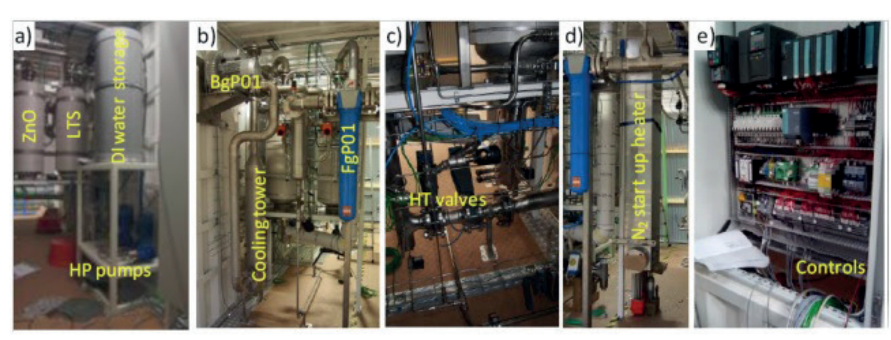
MAIN OBJECTIVES OF THE PROJECT

By exploitation of the results obtained in past R&D EU projects on hot gas catalytic conditioning, UNIfHY aims to develop a continuous process for pure hydrogen production from biomass, for fuelling vehicles in a low-cost and effective way, by the integration of: (i) biomass gasification with catalytic hot syngas cleaning and conditioning integrated in the gasifier vessel (UNIQUE gasification concept); (ii) Water-Gas Shift (WGS) performed with catalysts impregnated on ceramic foams; (iii) Pressure Swing Adsorption (PSA) for hydrogen separation from syngas; (iv) High thermal integration and efficiency, by means of utilization of the H2- depleted syngas within the conversion process.

PROGRESS/RESULTS TO-DATE

- Iron and copper WGS catalysts supported on ceramic alumina foams have been developed and characterized, showing good lifetime, low pressure drop and resistance to sintering
- Gasification bench scale tests allowed to evaluate the performance of new types of catalytic candle filters
- Extensive gasification test campaigns have been started and are due to be completed shortly in order to evaluate the performance of the two prototype gasifiers, without and with the candle filters, utilizing nut shells as biomass feedstock
- Portable Purification System (PPS) has been realized and is ready to be connected to the 1000 kWth gasifier for the final test of the entire system
- An analysis of the economical requirements and the hydrogen target cost (5€/kg) for UNIfHY-based-hydrogen production has been done



FUTURE STEPS

- Achievement of new results on the modelling at different scales
- Final testing on the 1000 kWth system to demonstrate that pure hydrogen (PEM grade) can be produced by thermo-chemical way starting from biomass wastes
- Long term testing with the prototype reactor
- Finalization of Life Cycle Assessment (LCA) and business exploitation

CONCLUSIONS, MAJOR FINDINGS AND PERSPECTIVES

- The tests of fluidized bed steam biomass gasifiers integrating the hot gas cleaning system in the freeboard have verified the realization of compact, high efficiency and cost-effective gasification systems.
- New materials, as Fe-Cu/Foams, have permitted to obtain high efficient WGS also at atmospheric pressure that is a constraint for more sustainable small plant sizes, and modified PSA permits to obtain continuous hydrogen production at PEMFC grade even with reduced (> 34%) hydrogen content in the feed flow.
- By the analysis of economical requirements and the operative plant scenarios, according to preliminary evaluations UNIfHY is a profitable solution to match the hydrogen target cost of 5€/Kg.
- The integrated system is able to produce hydrogen from various biomass feedstocks in the forecourt size range for a hydrogen filling station (from 100 to 500 kg/day) with: (i) Energy and cost savings; (ii) reduction of space and components up to 50% ; (iii) overall hydrogen efficiency greater than 50% in comparison to standard systems (70% vs 45%).
- Due to the variety and complexity of problems, expertise and know-how, either scientific or technological, which are necessary for implementation of the UNIFHY technology, the project combines the efforts and capabilities available in Europe in order to maintain competitiveness on the global market.

CONTRIBUTION TO THE PROGRAMME OBJECTIVES

SOURCE OF OBJECTIVE/ TARGET (MAIP, AIP)	ASPECT ADDRESSED	PROGRAMME OBJECTIVE/ QUANTITATIVE TARGET	PROJECT OBJECTIVES/ QUANTITATIVE TARGETS	CURRENT STATUS/ ACHIEVEMENTS TO-DATE
MAIP 2008-2013	H2 price at pump (€/kg)	Cost of H2 delivered at refueling station = €5/kg (€ 0.15/kWh)	Cost of H2 delivered at refueling station < €5/kg (€ 0.15/kWh)	Hydrogen cost <5 €/kg is obtainable if: 1) CAPEX: ~3000 €/kW, efficiency ~66% (steam to biomass 1-2, gasification temperature 850 °C, all PSA off gas used for the plant energy requirement), plant utilization index ≥ 6000 h/year 2) OPEX: automatic control to avoid on site daily operation necessary at small size (<MW), reduction of energy plant requirements, low cost biomass waste (<100 €/t)
AIP 2011	Demonstration of the technical and economic viability of hydrogen production from biomass	Development and scale-up activities on materials and reactor design to demonstrate the technical and economic viability of the global process: Technology Readiness Level (TRL): TRL 3 to TRL 6)	100 and 1000 kWth biomass gasifiers integrating filter candles. New materials to realize WGS also at atmospheric pressure. PSA integrated. All to increase efficiency and reduce cost and plant complexity allowing the technical feasibility and reliability.	Catalytic filter tested (TRL 4) showing tar <0.3 g/Nm3. Foam tested (CO conversion up to 43%) and integrated in a WGS reactor (TRL 5). Gasifiers in operation (gas yield up to 2 Nm3/kg of dry biomass, Hydrogen content up to 40% vol dry, tars ~10 g/Nm3, 0 particulate; others 50 ppmv) with filter candle inserted in (TRL 5). PSA tested (performs well down to H2 concentrations of 34% at purity 5.0 with about 65% H2 yield). 1MWth plus PPS connected (TRL 6).
AIP 2011	Global efficiency	Efficiency > 66% (gas/feedstock heating value)	Efficiency = 67% (gas/feedstock heating value)	At steam to biomass 2, gasification temperature 850 °C, all PSA off gas used for the plant energy requirement seems achievable 67% efficiency.
AIP 2011	Evaluation of the scalability	Scalability minimum to 500 kg/day	UNIFHY 100 (kWth input) can produce 50 kg/day. UNIFHY 1000 about 500 kg/day.	The scalability, owing to the fluidized bed gasifier technology and the two prototypes developed is achievable (up to now the only limit is the PPS designed to a flow corresponding to about 200 kWth input)
AIP 2011	Durability and availability	Durability > 10 years (80,000 h) with availability > 95%	Durability = 15 years. Availability = 80% (7000 hours)	The stability of the reactors, filter candles, catalyst seems to confirm the durability. 7000 annual operative hours seems achievable.
AIP 2011	LCA analysis	LCA/LCI analysis (ILCD compliant) compatible with green-H2 fuel-cell requirements	LCA analysis (ILCD compliant) compatible with green-H2 fuel-cell requirements	The preliminary results on the prototypes are negative but the full use of the PSA off gas and other improvements should obtain a positive LCA