BEINGENERGY

Integrated low temperature methanol steam reforming and high temperature polymer electrolyte membrane fuel cell

PANEL 4
Research activities for stationary applications

ACRONYM	BEINGENERGY
CALL TOPIC	SP1-JTI-FCH.2011.4.4: Research, development and demonstration of new portable Fuel Cell systems
START DATE	1/09/2012
END DATE	29/02/2016
PROJECT TOTAL COST	€4,2 million
FCH JU MAXIMUM CONTRIBUTION	€2,2 million
WEBSITE	http://www.beingenergy.eu/

PARTNERSHIP/CONSORTIUM LIST

UNIVERSIDADE DO PORTO, DEUTSCHES ZENTRUM FUER LUFT – UND RAUMFAHRT EV, Teknologian tutkimuskeskus VTT Oy, SerEnergy A/S, CONSIGLIO NAZIONALE DELLE RICERCHE, UNIVERSITAT POLITECNICA DE VALENCIA, INOVAMAIS – SERVICOS DE CONSULTADORIA EM INOVACAO TECNOLOGICA S.A., Rhodia Operations

MAIN OBJECTIVES OF THE PROJECT

- Synthesizing, characterizing, and optimizing catalysts for low temp. methanol steam reforming (LT-MSR, 180 °C) & developing strategies for industrial prep. of selected catalysts.
- Development, characterization & optimization of cell-reactor for LT-MSR.
- Integration, characterization & optimization of LT-MSR reactors with high temp. PEMFC (HT-PEMFC).
- Development, characterization and optimization of a LT-MSR/HT-PEMFC 500 W_e prototype.

PROGRESS/RESULTS TO-DATE

- The BeingEnergy catalyst (CuZnZrGa) is more efficient ca. 2 times higher activity) than G66-MR, from Süd Chemie, at 180 °C.
- Thermal coupling & operation of a HT-PEMFC with a LT-MSR was demonstrated experimentally, with efficiencies >35 %.
- A new bipolar plate material was tested & FC stack lifetime increased to >16000 h.
- 500 W_e cooled FC system with liquid heated reformer was built and operated for 852 h, with avg. electric efficiency of 38 %.

FUTURE STEPS

- Use of Beingenergy catalyst in the 500 We prototype.
- Optimization of startup procedure of the power supply to reach 15-20 minutes.

CONCLUSIONS, MAJOR FINDINGS AND PERSPECTIVES

- New catalyst, 2x more active and more selective.
- New bipolar plates / HT-PEMFC stack: much higher lifetime, better thermal energy integration & faster start up
- New reformer much smaller, with a far more efficient heat-exchange design.
- New and disruptive design associating reformer with fuel cells in a combined stack with a thin Pd-membrane divided the two reactors.

CONTRIBUTION TO THE PROGRAMME OBJECTIVES

PROJECT OBJECTIVES / TARGETS	CORRESPONDING PROGRAMME OBJECTIVE / QUANTITATIVE TARGET (SPECIFY TARGET YEAR)	CURRENT PROJECT STATUS	PROBABILITY OF REACHING INITIAL TARGET	STATE OF THE ART 2016 – VALUE AND REFERENCE	COMMENTS ON PROJECT PROGRESS / STATUS
(a) Project objectives relevant to multi-annual objectives (from MAIP/MAWP) – indicate relevant multi-annual plan:					MAIP 2008-2013
Electrical efficiencies >45 % for power only units	Program targets electrical efficiency for the combined power supply>30 % and the project aims>35 %	>35 %	100 %	Electrical efficiency for related power supplies: 27 % [Ballard, 5 kW system (1.1 LMeOH/kW)]	A new and far more active catalyst is now being up-scaled and will be soon tested
Lower emissions and use of multiple fuels	The project targets the use methanol as fuel. No objectives were defined concerning emissions.				
Cost of €1,500 – 2,500/kW for industrial/commercial units	€5,000/kW for the combined power supply unit at mass production	Mass production price of €5,656/kW	N/A		Research to continue after project for better/cheaper power supplies
(b) Project objectives relevant to annual objectives (from AIP/AWP) if different than above – indicate relevant annual plan:					AIP 2011
Proof of concept systems containing stacks	Project expects an integrated unit between methanol reformer FC stack	Prototype w/methanol reformer & FC stack working @ 180 °C built and tested.	100 %	Many labs working on synergetic integration of HT-PEMFC & LT-MSR, but still no commercial units	
Demonstrate electrical efficiency >30 %	Nominal electrical efficiency: >35 %	>35 %	100 %		
1,000 h lifetime incl. 100 start-stop cycles @ <35 kg/kW and 50 L/kW	Operation lifetime >1000 h; specific size/weight <35 kg/kW and 50 L/kW	Operation lifetime >1500 h; 82 kg/kW & 215 L/kW	N/A		For larger systems, the power and volume per power should decrease substantially
(c) Other project objectives					
Development of a highly performing and stable LT-MSR catalyst	N/A	Catalyst (CuZnZrGa) proved more efficient (activity x2) vs G66-MR (Süd Chemie)		Commercial SoA catalyst: BASF (RP 60). Best lab catalyst: Tsang [doi:10.1038/ncomms2242]	
Modeling of Membrane Reactors for LT-MSR reaction	Modeling+exp. demo that MSR reaction works in Pd-based MRs at >280 °C	Pure H_2 produced by self-supported Pd-based MR @ 280 °C	N/A		Silica & composite Pd-based MRs could be a serious alternative to expensive self-supported MRs for high grade H_2 by MSR

CISTEM

Construction of Improved HT-PEM MEAs and Stacks for long term stable modular CHP units

PANEL 4

Research activities for stationary applications

ACRONYM	CISTEM
CALL TOPIC	SP1-JTI-FCH.2012.3.1: Cell and stack degradation mechanisms and methods to achieve cost reduction and lifetime enhancements & SP1-JTI-FCH.2012.3.5: System level proof of concept for stationary power and CHP fuel cell systems at a representative scale
START DATE	1/06/2013
END DATE	30/09/2016
PROJECT TOTAL COST	€6,0 million
FCH JU MAXIMUM CONTRIBUTION	€3,9 million
WEBSITE	http://www.project-cistem.eu/

PARTNERSHIP/CONSORTIUM LIST

EWE-Forschungszentrum für Energietechnologie e. V., DANISH POWER SYSTEM APS, INHOUSE ENGINEERING GMBH, Eisenhuth GmbH & Co. KG, UNIVERSIDAD DE CASTILLA – LA MANCHA, VYSOKA SKOLA CHEMICKO-TECHNOLOGICKA V PRAZE, ICI CALDAIE SPA, OWI Oel-Waerme Institut GmbH

MAIN OBJECTIVES OF THE PROJECT

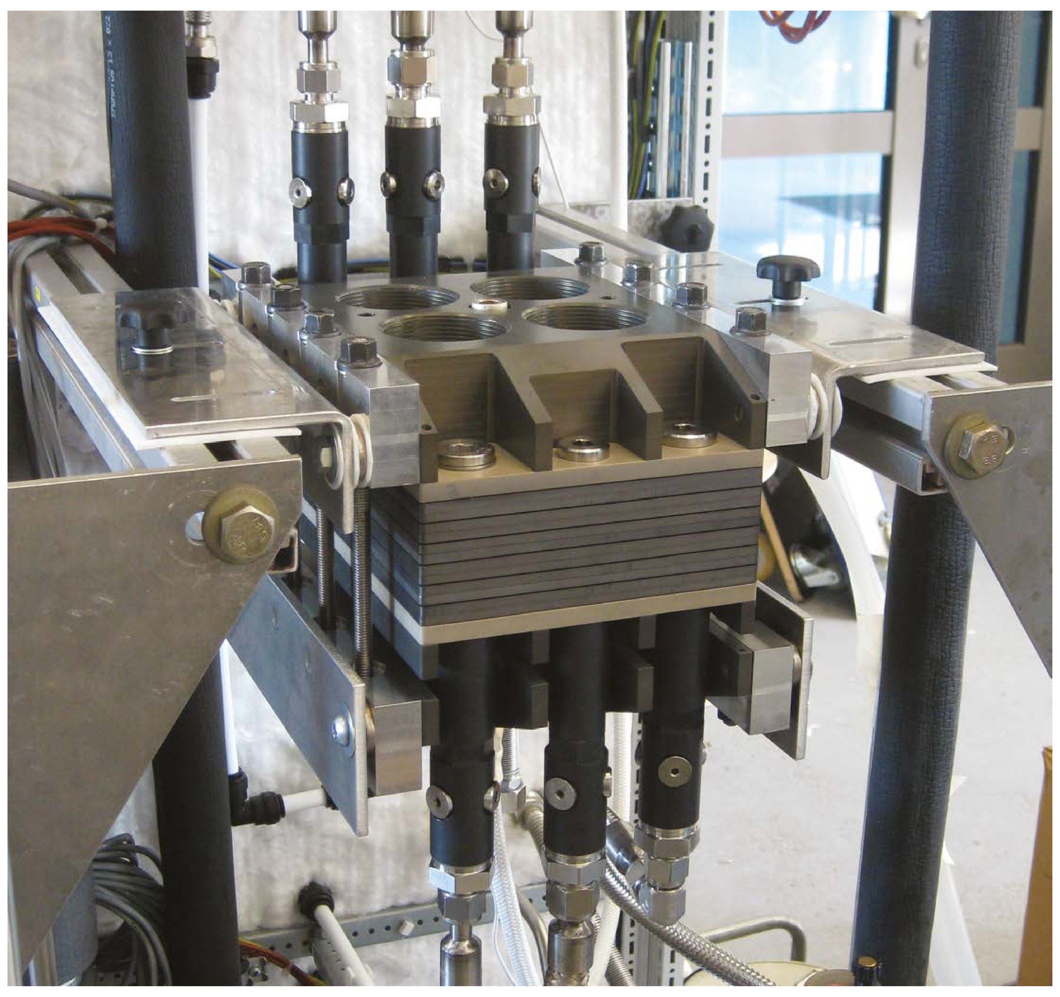
Key issue of CISTEM is the development of durable HT-PEM based 4 kW stack modules (including reformer) that are suitable for larger CHP systems up to 100 kW_e. The modular concept will be investigated in a Hardware-in-the-Loop (H-i-L) test bench with one module physically installed and 12 emulated by software. The development strategy starts on the single component level and rises up to the complete CHP system. Research and development includes the most important components like MEAs, bipolar plates (BPP), reformer system and the final CHP unit design with all necessary Balance-of-Plant (BoP) components.

PROGRESS/RESULTS TO-DATE

- 2,000 h long-term test of BoA-MEAs at 0.3 A/cm² with a degradation rate <-4 µV/h.
- SiC-TiC as catalyst support shows the best electrochemical behaviour and the lowest electrochemical surface area (ECSA) decrease and agglomeration (40 % Pt/SiCTiC).
- Bipolar plate material PPS (polyphenylene sulfide) shows highest stability and lowest acid uptake after operation.
- Completion of development of full-scale fuel processor and reformer.
- Extension of modeling to 3D stationary model of fuel cell stacks consisting of 100 cells.

FUTURE STEPS

- Testing of BoP components in H-i-L enviroment.
- Finalization of CHP system operational evaluation.
- Conversion of stationary to dynamic model and implementation of catalyst degradation.
- Finalization of Final Report.



CONCLUSIONS, MAJOR FINDINGS AND PERSPECTIVES

- FC electrical efficiency has been improved to more than 40 % by different measures.
- Significant improvement in reduction of degradation rates while using MEAs with thermally cured membranes.
- Short stack long term testing support improved durability of the FC stack.
- Final optimization made on the stamping tools and backing materials during hot-pressing procedure for manufacturing of commercial MEAs.

CONTRIBUTION TO THE PROGRAMME OBJECTIVES

PROJECT OBJECTIVES / TARGETS	CORRESPONDING PROGRAMME OBJECTIVE / QUANTITATIVE TARGET (SPECIFY TARGET YEAR)	CURRENT PROJECT STATUS	PROBABILITY OF REACHING INITIAL TARGET	STATE OF THE ART 2016 – VALUE AND REFERENCE	COMMENTS ON PROJECT PROGRESS / STATUS
(a) Project objectives relevant to multi-annual objectives (from MAIP/MAWP) – indicate relevant multi-annual plan:					MAIP 2008-2013
Application range: Up to 100 kW	Small scale commercial application range 5-50 kW and midscale industrial range	Modular set-up with 1 module (8 kWel) installed as hardware and 12 emulated modules (H-i-L)	100 %		
Electrical efficiency: Up to 45 %	Electrical efficiency: >40 %	42 % gross efficiency calculated (gain by oxygen enrichment not included)	95 %	Electrical efficiency of 40 %: Yuka Oona, PhD Thesis, 2013, Daido University, p. 16	100 % for targeting above 40 %, 75 % for targeting 45 % efficiency
Lifetime: Extended lifetime up to 40,000 hours	Lifetime: >20,000 hours	MEA degradation rate: <4 µV/h	100 %	Best degradation rate for HT-PEM MEA so far: -4.9 µV/h, S. Yu, *Fuel Cells*, 08, 3-4. 165-174 (2008)	
(b) Project objectives relevant to annual objectives (from AIP/AWP) if different than above – indicate relevant annual plan:					AIP 2012
MEA and bipolar plate (BPP) degradation, accelerated stress testing on MEAs to access lifetime predictions	Increased knowledge on degradation and failure mechanisms	ASTs predict improvement in lifetime. 10,000 h BPP material test. Degradation rate MEA <4µV/h	100 %	Best degradation rate for HT-PEM MEA so far: -4.9 µV/h, S. Yu, *Fuel Cells*, 08, 3-4. 165-174 (2008)	
One module, consisting of two 4 kW HT-PEM stacks and one reformer, in a H-i-L- environment	PoC prototype modular CHP system based on HT-PEM technology	Short stacks have been tested. Full stacks are currently under operation. BoP component finished	95 %		

DEMSTACK

Understanding the degradation mechanisms of a High Temperature PEMFCs Stack and optimization of the individual components

PANEL 4
Research activities for stationary applications

ACRONYM	DEMSTACK
CALL TOPIC	SP1-JTI-FCH.2012.3.1: Cell and stack degradation mechanisms and methods to achieve cost reduction and lifetime enhancements & SP1-JTI-FCH.2012.3.5: System level proof of concept for stationary power and CHP fuel cell systems at a representative scale
START DATE	1/05/2013
END DATE	31/10/2016
PROJECT TOTAL COST	€2,5 million
FCH JU MAXIMUM CONTRIBUTION	€1,4 million
WEBSITE	http://demstack.iceht.forth.gr/

PARTNERSHIP/CONSORTIUM LIST

FOUNDATION FOR RESEARCH AND TECHNOLOGY HELLAS, FUNDACION CIDETEC, VYSOKA SKOLA CHEMICKO-TECHNOLOGICKA V PRAZE, ADVANCED ENERGY TECHNOLOGIES AE EREUNAS & ANAPTYXIS YLIKON & PROIONTONANANEOSIMON PIGON ENERGEIAS & SYNAFON SYMVOULEFTIKON Y PIRESION*ADVEN, JRC -JOINT RESEARCH CENTRE-EUROPEAN COMMISSION, ELVIO ANONYMI ETAIREIA SYSTIMATON PARAGOGIS YDROGONOU KAI ENERGEIAS, Prototech AS

MAIN OBJECTIVES OF THE PROJECT

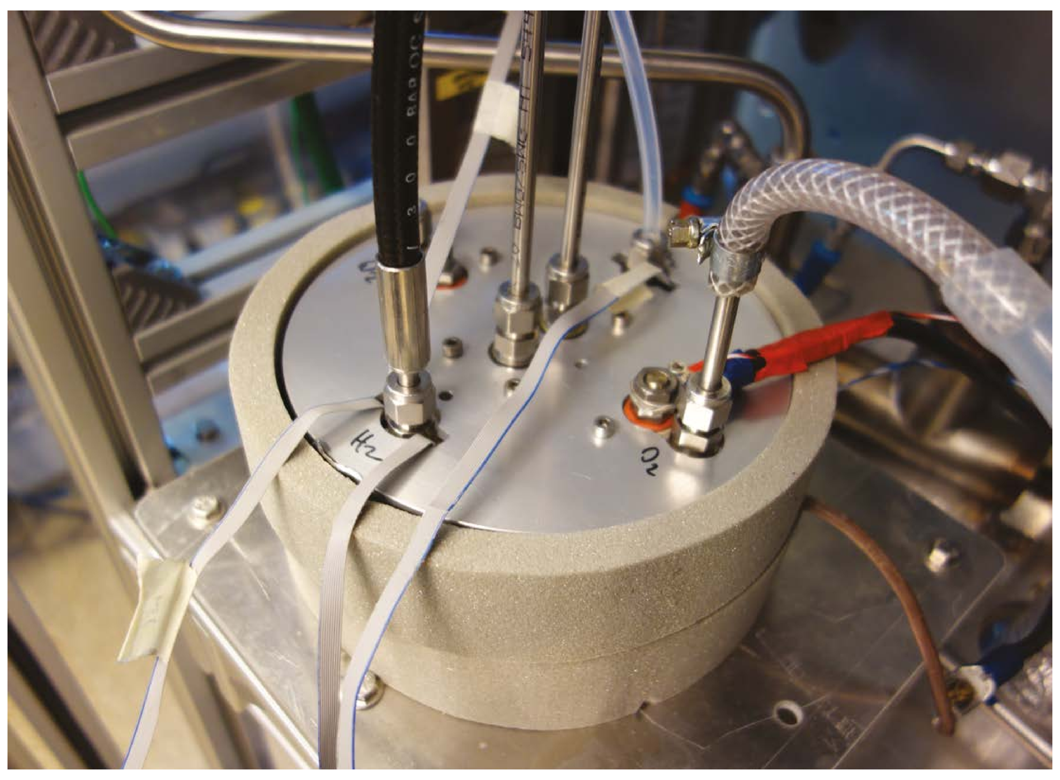
The activities of DeMStack are on the stack optimization and construction based on the high temperature MEA technology of Advent S.A.. The aim is to enhance the lifetime and reduce the cost of the HT PEMFC technology. The strategy involves improvements based on degradation studies and materials development. A fuel processor operating on natural gas will be integrated with the fuel cell stack. The robustness of the stack, the simplicity of BoP, the operational stability and the user friendly operation of the integrated system into a commercially reliable product, will be demonstrated.

PROGRESS/RESULTS TO-DATE

- Scaling up of the component materials of the MEAs (PEMs and electrocatalysts) has been performed.
- Best performing MEAs have been selected.
- The designs for the bipolar plates, fuel cell stack and fuel processor have been completed.
- Two 1 kW stacks have been constructed employing: (i) graphitic bipolar plates and external cooling (ii) metallic bipolar plates and internal cooling.
- The fuel processor has been constructed and integration with the stack is currently underway.

FUTURE STEPS

- Demonstration of the effective operation of the integrated system (reformer with graphitic stack).
- Testing of the 1kW metallic stack using synthetic reformate gas.



CONCLUSIONS, MAJOR FINDINGS AND PERSPECTIVES

- Optimized, efficient, robust materials and architectures for the components of the stack.
- Decreased cost compared to current high temperature PEMFC technology.
- Construction of a micro-CHP system comprising a 1kW high temperature PEM fuel cell and a reforming unit operating on natural gas or LPG.

CONTRIBUTION TO THE PROGRAMME OBJECTIVES

PROJECT OBJECTIVES / TARGETS	CORRESPONDING PROGRAMME OBJECTIVE / QUANTITATIVE TARGET (SPECIFY TARGET YEAR)	CURRENT PROJECT STATUS	PROBABILITY OF REACHING INITIAL TARGET
(a) Project objectives relevant to multi-annual objectives (from MAIP/MAWP) – indicate relevant multi-annual plan:			MAIP 2008-2013
Small Scale – Domestic 1 – 5 kW	1 kW HT PEMFC operating on reformates (operating at a current density of 0.2 A/cm^2 at 180oC)	Stacks from optimized components and fuel processor are constructed.	100 %
2015 target: Cost of €4,000/kW for industrial/ commercial units	<€3,000/kW	Cost analysis for mass production give close to €2500/kW	100 %
(b) Project objectives relevant to annual objectives (from AIP/AWP) if different than above – indicate relevant annual plan:			AIP 2012
Electrical efficiencies of 35-45 % for power units and 75-85 % for CHP units	Electrical efficiency of 45 % at 180oC	Already validated efficiency	100 %
Operational lifetime >20,000 h	5-6 month testing under reformate feed including measurements in an accelerated basis	Testing has not been completed	80 %
…improving stack & cell designs… components with improved performance, durability & cost…	Optimization of key MEA and stack components (lower cost, higher performance or stability)	This target has been achieved	100 %

DIAMOND

Diagnosis-aided control for SOFC power systems

PANEL 4
Research activities for stationary applications

ACRONYM	DIAMOND
CALL TOPIC	SP1-JTI-FCH.2013.3.3: Stationary Power and CHP Fuel Cell System Improvement Using Improved Balance of Plant Components/ Sub-Systems and/or Advanced Control and Diagnostics Systems
START DATE	1/04/2014
END DATE	31/03/2017
PROJECT TOTAL COST	€3,6 million
FCH JU MAXIMUM CONTRIBUTION	€2,1 million
WEBSITE	http://www.diamond-sofc-project.eu/about/

PARTNERSHIP/CONSORTIUM LIST

HyGear B.V., COMMISSARIAT À L'ÉNERGIE ATOMIQUE ET AUX ÉNERGIES ALTERNATIVES, Teknologian tutkimuskeskus VTT Oy, UNIVERSITA DEGLI STUDI DI SALERNO, HTceramix SA, INEA INFORMATIZACIJA ENERGETIKA AVTOMATIZACIJA DOO, INSTITUT JOZEF STEFAN

MAIN OBJECTIVES OF THE PROJECT

The DIAMOND project aims at improving the performance of solid oxide fuel cells (SOFCs) for CHP applications by implementing innovative strategies for on-board diagnosis and control. Advanced monitoring models will be developed to integrate diagnosis and control functions with the objective of having meaningful information on the actual state-of-the-health of the entire system. The new concepts will be validated using two different SOFC systems.

PROGRESS/RESULTS TO-DATE

- List of faults and failures of SOFC CHP systems.
- Fault signature matrices for FDI (fauld detection and isolation) developed; low level control schemes for both systems developed and analysed and soft sensors developed.
- System models for both systems developed.
- First sets of experimental data for both systems sent to partners for use of control, model, and diagnosis development.
- Applicability of THDA (total harmonic distrotion analysis) for SOFC systems shown.

FUTURE STEPS

- Implement improved low level conrol in both DIAMOND A and C system.
- Implement supervisory control.
- Implementation of signal- and model-based diagnosis schemes in the advanced system control.
- Experimentally validate control and diagnosis schemes.

CONCLUSIONS, MAJOR FINDINGS AND PERSPECTIVES

- Applicability of THDA for SOFC systems shown.
- Low-level control was designed and verified on a stack model. It provides better temperature control and system efficiency.
- A supervisory controller has been developed able to monitor and control the overall SOFC system performance.
- The system models have been verified using experimental data. The modelling appraoch is validated.

CONTRIBUTION TO THE PROGRAMME OBJECTIVES

PROJECT OBJECTIVES / TARGETS	CORRESPONDING PROGRAMME OBJECTIVE / QUANTITATIVE TARGET (SPECIFY TARGET YEAR)	CURRENT PROJECT STATUS	PROBABILITY OF REACHING INITIAL TARGET	COMMENTS ON PROJECT PROGRESS / STATUS
(a) Project objectives relevant to multi-annual objectives (from MAIP/MAWP) – indicate relevant multi-annual plan:				MAIP 2008-2013
Electric efficiency 50 %	2013	The systems are being tested using standard control. In the final stage of the project advanced control and diagnostic tools will be implemented. These will aid in achieving the target.	100 %	Developments are delayed due to experimental problems
Durability, 10 years, >85,000 hrs.	2013	The systems are being tested using standard control. In the final stage of the project advanced control and diagnostic tools will be implemented. These will aid in achieving the target.	100 %	Developments are delayed due to experimental problems
(b) Project objectives relevant to annual objectives (from AIP/AWP) if different than above – indicate relevant annual plan:				AIP 2013-1
To develop advanced diagnostic and innovative control strategies	SP!-JTI-FCH.2013.3.3; 2013	Dynamic models of both power systems have been developed and validated.		
To develop advanced diagnostic and innovative control strategies	SP!-JTI-FCH.2013.3.3; 2013	Control and diagnostic strategies are being designed using the models		
To develop advanced diagnostic and innovative control strategies	SP!-JTI-FCH.2013.3.3; 2013	Low-level controls were developed and tested using a stack model		
To develop advanced diagnostic and innovative control strategies	SP!-JTI-FCH.2013.3.3; 2013	Soft sensors have been designed and validated with the real SOFC system data		
System life 10 years for smaller-scale applications	SP!-JTI-FCH.2013.3.3; 2013	In the final stage of the project advanced control and diagnostic tools will be implemented.		

ENDURANCE

Enhanced durability materials for advanced stacks of new solid oxide fuel cells

PANEL 4

Research activities for stationary applications

ACRONYM	ENDURANCE
CALL TOPIC	SP1-JTI-FCH.2013.3.1: Improving understanding of cell & stack degradation mechanisms using advanced testing techniques, and developments to achieve cost reduction and lifetime enhancements for Stationary Fuel Cell power and CHP systems
START DATE	1/04/2014
END DATE	31/03/2017
PROJECT TOTAL COST	€4,4 million
FCH JU MAXIMUM CONTRIBUTION	€2,5 million
WEBSITE	http://www.durablepower.eu/index.php

PARTNERSHIP/CONSORTIUM LIST

UNIVERSITA DEGLI STUDI DI GENOVA, SOLIDPOWER SPA, MARION TECHNOLOGIES S.A., FUNDACIO INSTITUT DE RECERCA DE L'ENERGIA DE CATALUNYA, DEUTSCHES ZENTRUM FUER LUFT – UND RAUMFAHRT EV, INSTITUTE OF ELECTROCHEMISTRY AND ENERGY SYSTEMS, CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE, COMMISSARIAT À L'ÉNERGIE ATOMIQUE ET AUX ÉNERGIES ALTERNATIVES, SCHOTT AG, HTceramix SA, ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE, UNIVERSITA DI PISA

MAIN OBJECTIVES OF THE PROJECT

Improved and reliable predictive models to estimate long-term (i.e. >20 kh) performance, and real enhanced durability of SOFC stacks are the main goals of this project. To increase the knowledge of electrochemical and physicochemical phenomena occurring inside the stack during operation is considered the main tool to achieve such goals. To do so the strategy on two main axes was refined: design of micro-samples representative of meaningful zones of a real stack; selection of real-time and post operation investigation protocols suitable to enhance the models.

PROGRESS/RESULTS TO-DATE

- Electrochemical and thermomechanical models achieved higher resolution and a more accurate predictability of phenomena occurring at the stack level.
- Improved sealant better resisting to chemical stress and polarization.
- Enhanced diffusion barrier layer for a more reliable and durable cell.
- Tuned red-ox cycles to be applied to the anode for triple phase boundary (TPB) life extension with minor effects on Ni network.
- Microsamples simulating stack zones at operating conditions.

FUTURE STEPS

- Application of improved sealant in short stacks for statistical validation.
- Monitoring of the performances of a stack made with enhanced cells.
- Cycles (Idle to Load) applied 50 times to and improved short stack and evaluation of the degradation rate.
- Models further refined thanks to the operation of a segmented cells where each segment corresponds to specific operating conditions.

CONCLUSIONS, MAJOR FINDINGS AND PERSPECTIVES

- Degradation rate, modes and effects analyses is assessed and implemented with gathered results allowing an increased knowledge on phenomena.
- Improved and enhanced material more resilient degradation factors increase the reliability of the stacks making them more intersting for the market.
- Successful refinement of predictive and descriptive models allow to start the step forward of a more reliable predictability of the stack behaviour.
- The R&D strategy of this project was further optimized, a follow up to a more close to the market project is a realistic perspective.
- Dissemination and cross-cutting activities to increase public awareness and acceptation were successful.

CONTRIBUTION TO THE PROGRAMME OBJECTIVES

PROJECT OBJECTIVES / TARGETS	CORRESPONDING PROGRAMME OBJECTIVE / QUANTITATIVE TARGET (SPECIFY TARGET YEAR)	CURRENT PROJECT STATUS	PROBABILITY OF REACHING INITIAL TARGET	COMMENTS ON PROJECT PROGRESS / STATUS
(a) Project objectives relevant to multi-annual objectives (from MAIP/MAWP) – indicate relevant multi-annual plan:				MAIP 2008-2013
Improvement of durability & reliability (cost is not a target here)	2015: Cost of €1,500-2,500/kW for industrial/commercial units	First improvement carried on operated stacks, analysis of electrochem Performance	N/A	Stack costs €6-8k/kW depending on application (fuel type, lifetime specs etc.) which can impact current density & Capex/kW
(b) Project objectives relevant to annual objectives (from AIP/AWP) if different than above – indicate relevant annual plan:				AIP 2013-1
a) Failure modes and effects analysis (FMEA) b) Identification of sensitive zones and interfaces inside a stack C) Advanced predictive modelling	Identify, quantify and document relevant degradation and failure mechanisms over the long term	70% a) FMEA defined as Degradation Rate, Mode and Effect Analysis (DRMEA) b) Stack is divided in the min. nr of interfaces and materials interacting w/each other, leading to a list of "minima phenomena" needed to understand the origin and predict the consequences of materials/interfaces evolution c) Existing models refined using microstructural data & by testing specific microsamples. Sealant found to be critical	90 %	All results are from operated stacks (short and segmented type),& microsamples designed to represent the minima phenomena. They are analyzed in-experiment (electrochemical performances) & post- experiment (microstructural features). Technical risks & challenges are still ahead
Statistical validation loop on companies stacks (i.e. the core of the project)	Identify improvements, and verify these in existing cells and stack design	40 % Thermo-mechanical tests of materials are running. 50 thermal cycles succesfully achieved	90 %	Most planned targets achieved. Idle to load cycles (off-standard protocols) represent a minor issue
Statistically validated predictive modelling verified with segmented stacks and near-RealLife tests (@ fully operating & working conditions) on micro-samples replicating sensitive stack interfaces/interphases.	Development of accelerated testing strategies for specific failure modes, backed by modelling or specific experiments to verify the method(s) used and validate of claimed improvement(s)	80 % Improved cells checked in reversible mode to stress degradation without failure. New sealant composition tested under humid fuel & polarization without showing detrimental degradation after a few 100h. Improved cells stacked & tested using reformed fuel without visible degradation after a few 100 h	100 %	Results will be available only at end of the project

EURECA

Efficient use of resources in energy converting applications

PANEL 4

Research activities for stationary applications

ACRONYM	EURECA
CALL TOPIC	SP1-JTI-FCH.2011.3.1: Next generation stack and cell design
START DATE	1/07/2012
END DATE	31/08/2015
PROJECT TOTAL COST	€6,2 million
FCH JU MAXIMUM CONTRIBUTION	€3,5 million
WEBSITE	www.project-eureca.com

PARTNERSHIP/CONSORTIUM LIST

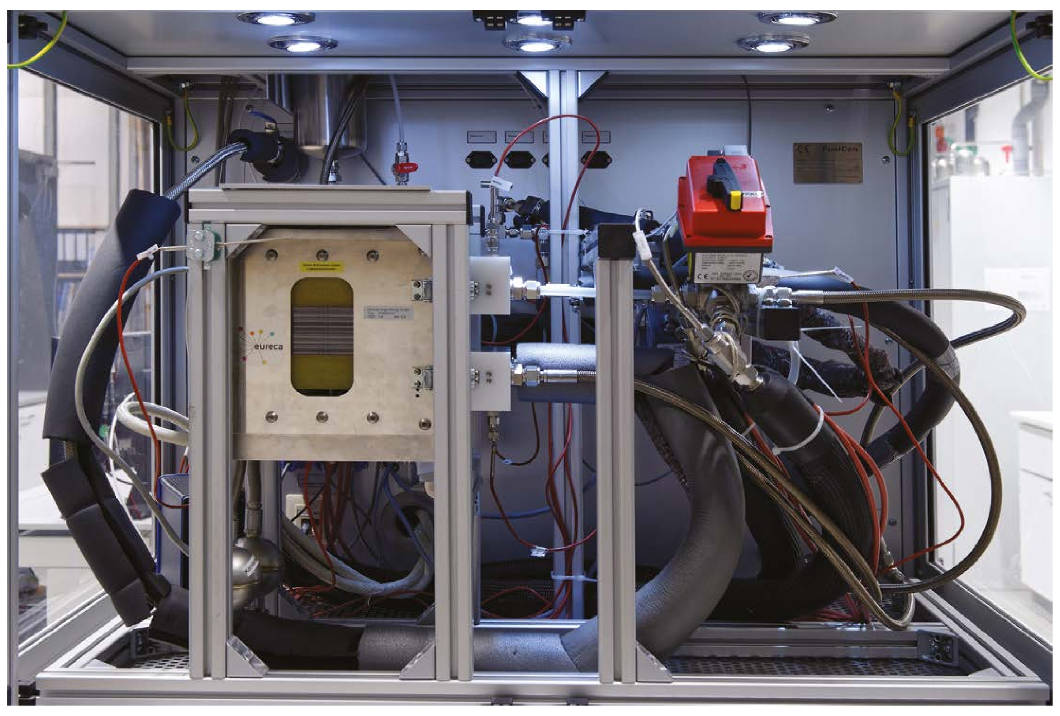
EWE-Forschungszentrum für Energietechnologie e. V., Eisenhuth GmbH & Co. KG, UNIVERZITET U BEOGRADU, COMMISSARIAT À L'ÉNERGIE ATOMIQUE ET AUX ÉNERGIES ALTERNATIVES, FOUNDATION FOR RESEARCH AND TECHNOLOGY HELLAS, INHOUSE ENGINEERING GMBH, CELAYA, EMPARANZA Y GALDOS INTERNACIONAL, S.A., FUNDACION CIDETEC, FRAUNHOFER-GESELLSCHAFT ZUR FOERDERUNG DER ANGEWANDTEN FORSCHUNG E.V, HYDROGENICS EUROPE NV, HYDROGEN EFFICIENCY TECHNOLOGIES (HYET) BV, WaterstofNet vzw, ETABLISSEMENTEN FRANZ COLRUYT NV, TUV Rheinland Industrie Service GmbH, JRC -JOINT RESEARCH CENTRE- EUROPEAN COMMISSION, THINKSTEP AG, ICELANDIC NEW ENERGY LTD, FAST – FEDERAZIONE DELLE ASSOCIAZIONI SCIENTIFICHE E TECNICHE, ITM POWER (TRADING) LIMITED, H2 Logic A/S, RAUFOSS FUEL SYSTEMS AS, DAIMLER AG, SHELL GLOBAL SOLUTIONS INTERNATIONAL B.V., BUNDESANSTALT FUER MATERIALFORSCHUNG UND -PRUEFUNG, ASSOCIATION POUR LA RECHERCHE ET LE DEVÉLOPPEMENT DES MÉTHODES ET PROCESSUS INDUSTRIELS – ARMINES, HOCHSCHULE ESSLINGEN, UNIRESEARCH BV, DEUTSCHES ZENTRUM FUER LUFT – UND RAUMFAHRT EV

MAIN OBJECTIVES OF THE PROJECT

The project aims at the development of Stationary Power Generation and Combined Heat and Power (SPG&CHP) systems based on PEMFC operating at 90 °C-120 °C. The main objective is to give a clear demonstration of the SPG&CHP systems, based on recent knowledge on the degradation mechanisms and innovative synthetic approaches. Main research tasks: (1) Develop long-life membranes, catalytic electrodes and MEAs; (2) Perform accelerated ageing tests (3) Develop a prototype of a modular SPG&CHP system.

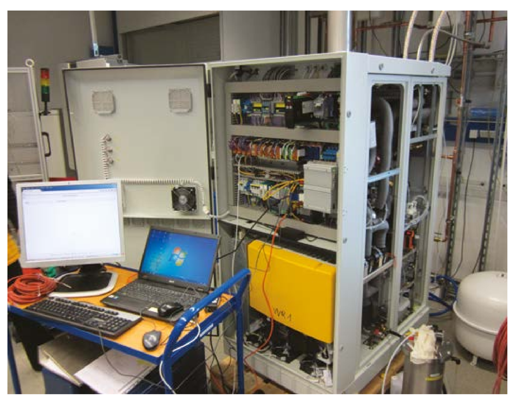
PROGRESS/RESULTS TO-DATE

- Membrane development.
- Catalyst development.
- Stack and System design development.
- System simplification.
- Design-to-cost approach.



CONCLUSIONS, MAJOR FINDINGS AND PERSPECTIVES

- Efficient energy supply.
- Middle temperature fuel cells are a resonable bridge between high and low temperature fuel cells.
- Influence of components to system costs and properties is sharpening the development strategy.



CONTRIBUTION TO THE PROGRAMME OBJECTIVES

PROJECT OBJECTIVES / TARGETS	CORRESPONDING PROGRAMME OBJECTIVE / QUANTITATIVE TARGET (SPECIFY TARGET YEAR)	CURRENT PROJECT STATUS	COMMENTS ON PROJECT PROGRESS / STATUS
(a) Project objectives relevant to multi-annual objectives (from MAIP/MAWP) – indicate relevant multi-annual plan:			MAIP 2008-2013
Cost of <€3k/kW	Cost of €4-5k/kW	<€5k/kW	MAIP aim is fulfilled, Project objective not reached
(b) Project objectives relevant to annual objectives (from AIP/AWP) if different than above – indicate relevant annual plan:			AIP 2011
Efficiency Improvement	35 % efficiency based on the the integrated reformer	Electrical effiency of 37 %	
Cost reduction	Lifetime improvement >10 kh (stack) and >12 kh (system)	stack >12 kh	

EVOLVE

Evolved materials and innovative design for high-performance, durable and reliable SOFC cell and stack

PANEL 4

Research activities for stationary applications

ACRONYM	EVOLVE
CALL TOPIC	SP1-JTI-FCH.2011.3.1: Next generation stack and cell design
START DATE	1/11/2012
END DATE	31/10/2016
PROJECT TOTAL COST	€5,7 million
FCH JU MAXIMUM CONTRIBUTION	€3,1 million
WEBSITE	http://www.evolve-fcell.eu/

PARTNERSHIP/CONSORTIUM LIST

DEUTSCHES ZENTRUM FUER LUFT – UND RAUMFAHRT EV, ALANTUM EUROPE GMBH, ASSOCIATION POUR LA RECHERCHE ET LE DEVÉLOPPEMENT DES MÉTHODES ET PROCESSUS INDUSTRIELS – ARMINES, Ceramic Powder Technology AS, CONSIGLIO NAZIONALE DELLE RICERCHE, INSTITUT POLYTECHNIQUE DE GRENOBLE, SAAN ENERGI AB, CERACO CERAMIC COATING GMBH

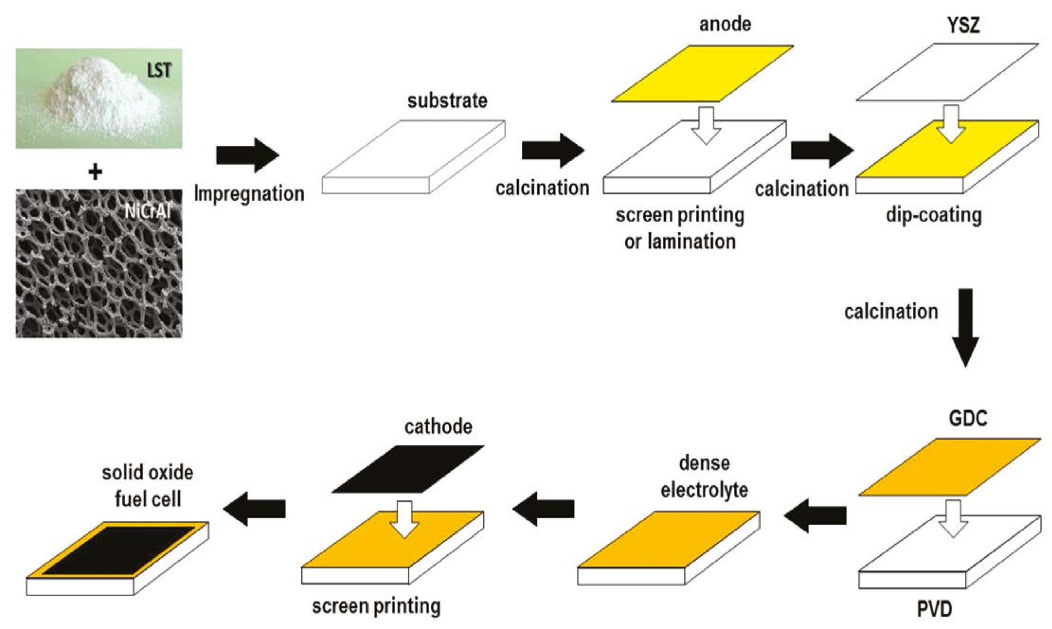
MAIN OBJECTIVES OF THE PROJECT

The project targets the demonstration at the stack level of a SOFC, implementing an innovative substrate resilient toward redox cycles with higher durability than mainstream Metal Supported Cells implementing porous ferritic stainless steel substrates and greater cyclability than mainstream anode-supported cells implementing the Ni-based cermet.

Focus: An innovative combination of advanced materials with reduced amount of nickel, showing improved tolerance against common fuel contaminants compared to mainstream nickel-based cermet Anode and higher resilience toward redox cycles.

PROGRESS/RESULTS TO-DATE

- A first prototype with La0,1Sr0,9TiO3-α (LST) based anode material and a thin film multi-layer electrolyte technology (less than 3µm).
- Power density above 350 mW.cm-2 at 750 °C and 0.7 V could be demonstrated with addition of nickel in the anode compartment.
- The EVOLVE cell can withstand at least 10 redox cycles without significant degradation.
- Cell architecture has been successfully up-scaled to a 90 mm x 100 mm footprint for stack integration.



FUTURE STEPS

- Performance shall be evaluated at stack level until the end of the project.
- Rationalization of the manufacturing route.
- Cost analysis.

CONCLUSIONS, MAJOR FINDINGS AND PERSPECTIVES

- Replacement of nickel based cermet anodes for high performance SOFC is still challenging.
- The architecture showed remarkable stability against redox cycles despite use of nickel.

CONTRIBUTION TO THE PROGRAMME OBJECTIVES

PROJECT OBJECTIVES / TARGETS	CORRESPONDING PROGRAMME OBJECTIVE / QUANTITATIVE TARGET (SPECIFY TARGET YEAR)	CURRENT PROJECT STATUS	PROBABILITY OF REACHING INITIAL TARGET	COMMENTS ON PROJECT PROGRESS / STATUS
(a) Project objectives relevant to multi-annual objectives (from MAIP/MAWP) – indicate relevant multi-annual plan:				MAIP 2008-2013
Cell survives at least 50 redox cycles	2020 target: must sustain repeated on/off cycling (CHP Unit)	Cell prototype has been demonstrated redox stable for at least 13 cycles without noticeable drop of Open Circuit Voltage	90 %	To be experimentally verified at cell level in October 2016
Degradation rate of cell voltage below 0.25 % per 1,000 hours with H_2 as fuel	2020 target: (CHP Unit) Life Time expected >20,000 hours	30 % of degradation of power density for 500 hours of operation in potentiostatic conditions. Origin of degradation is under investigation	<10 %	Unexpected high degradation rate measured on proof of concept cells. Degradation mechanisms not yet fully understood to propose adequate mitigation strategy
(b) Project objectives relevant to annual objectives (from AIP/AWP) if different than above – indicate relevant annual plan:				AIP 2011
Degradation rate of cell voltage below 1.5 % per 1,000 hours in Syngas (with H_2S)	Improved Tolerance to contaminants with respect to state of art FCs	Nickel amount reduced to 5wt% of the active anode material. Ni free catalysts under investigations	<10 %	
Heating rate of 25K/min for thermal cycles	Improved start-up time from room temperature to 30 % of power rating below 1 hour	Not yet evaluated	50 %	
Demonstrate up-scalability of cells & Use realistic model cost analysis, establish processing sequences and practices for the cell components to attain optimal cost-to-quality ratio	Decreased material consumption	Cell architecture up-scaled in size to industrially relevant dimensions	75 %	Reduction from 100µm to 3µm the thickness of the electrolyte required for comparable gas tightness at level 90 mm x 100mm. Manufacturing route still needs rationalization before being considered as competitive.

FERRET

A flexible natural gas membrane reformer for m-CHP applications

PANEL 4

Research activities for stationary applications

ACRONYM	FERRET
CALL TOPIC	SP1-JTI-FCH.2013.3.3: Stationary Power and CHP Fuel Cell System Improvement Using Improved Balance of Plant Components/ Sub-Systems and/or Advanced Control and Diagnostics Systems
START DATE	1/04/2014
END DATE	31/03/2017
PROJECT TOTAL COST	€3,2 million
FCH JU MAXIMUM CONTRIBUTION	€1,7 million
WEBSITE	http://www.ferret-h2.eu/

PARTNERSHIP/CONSORTIUM LIST

TECHNISCHE UNIVERSITEIT EINDHOVEN, FUNDACION TECNALIA RESEARCH & INNOVATION, POLITECNICO DI MILANO, ICI CALDAIE SPA, HyGear B.V., JOHNSON MATTHEY PLC

MAIN OBJECTIVES OF THE PROJECT

Within the FERRET project, the consortium will improve the technology based on membrane reactors and test a fully functional reactor for use in a current Hygear m-CHP unit.

FERRET project will:

– Design a flexible reformer: catalyst, membranes & control for different natural gas (NG) compositions.
– Use H_2 membranes to produce pure H_2.
– Scale-up the new H_2 selective membranes and catalyst production.
– Introduce ways to improve membrane recyclability.

PROGRESS/RESULTS TO-DATE

- NG reforming catalysts at 600 °C developed, stable with different NG compositions.
- Thin Pd-based membranes (<5 m) prepared & tested at lab scale + further scaled up.
- 1st experimental lab-scale tests concluded, phenomenological model validated.
- Pilot scale reformed assembled.
- BoP under construction for final testing.

FUTURE STEPS

- Prototype reactor testing and validation.
- Further validation at lab scale.
- Proof of concept of the novel micro-CHP system.
- Tech-economic assessment + optimization of reactors & complete system.

CONCLUSIONS, MAJOR FINDINGS AND PERSPECTIVES

- New catalysts been produced - can be scaled up.
- Fluidized Bed Membrane Reactor concept validated @ lab-scale.
- Membranes produced at larger scales for prototype unit.
- Pilot scale prototype built.

CONTRIBUTION TO THE PROGRAMME OBJECTIVES

PROJECT OBJECTIVES / TARGETS	CORRESPONDING PROGRAMME OBJECTIVE / QUANTITATIVE TARGET (SPECIFY TARGET YEAR)	CURRENT PROJECT STATUS	PROBABILITY OF REACHING INITIAL TARGET	STATE OF THE ART 2016 – VALUE AND REFERENCE	COMMENTS ON PROJECT PROGRESS / STATUS
(a) Project objectives relevant to multi-annual objectives (from MAIP/MAWP) – indicate relevant multi-annual plan:					MAIP 2008-2013
Overall efficiency CHP units	>80 %	>90 %	80 %		70% achievement. Simulation shows it is possible
Emissions and fuels	< Emissions, use of multiple fuels	Flexibility to use different NG qualities, reduced CO_2 emissions	100 %		75% achievement
Cost per system (1kW$_e$ + household heat).	Cost: €10k/system (2015), €5k/system (2020)	€5,000 (1 kW$_e$ + house heat)	100 %		Cost could be achieved @ mass prod. or slightly bigger m-CHP. Cost analysis to be carried out
(b) Project objectives relevant to annual objectives (from AIP/AWP) if different than above – indicate relevant annual plan:					AIP 2013-1
Cost: €10k/system (2015), €5k/system (2020)	Cost: €10k/system (2015), €5k/system (2020)	TRL 4 – technology validated in lab. Prototype built	100 %		The prototype is built and ready for FAT, afterwards proof-of-concept will start
Durability	Several 100h of continuous operating	1,000 h of operation	100 %		If factory acceptance testing is achieved, final durability test will be performed as planned
(c) Other project objectives					
Novel catalyst for NG reforming in fluidized beds	Not applicable	Novel catalyst for NG reforming in fluidized beds produced & upscaled	100 %	State of the art catalyst	
Development of >15 cm mechanicaly stronger H_2 selective membranes	Not applicable	40 membranes of >20 cm each have been produced for the prototype.	100 %	State-of art membranes	
Membrane reactor	Not applicable	Fluidized bed membrane reactor validated & scaled-up for prototype	100 %	State-of art reactors	

FLUIDCELL

Advanced m-CHP fuel cell system based on a novel bio-ethanol fluidized bed membrane reformer

PANEL 4

Research activities for stationary applications

ACRONYM	FLUIDCELL
CALL TOPIC	SP1-JTI-FCH.2013.3.4: Proof of concept and validation of whole fuel cell systems for stationary power and CHP applications at a representative scale & SP1-JTI-FCH.2013.3.3: Stationary Power and CHP Fuel Cell System Improvement Using Improved Balance of Plant Components/ Sub-Systems and/or Advanced Control and Diagnostics Systems
START DATE	1/04/2014
END DATE	30/11/2017
PROJECT TOTAL COST	€4,1 million
FCH JU MAXIMUM CONTRIBUTION	€2,4 million
WEBSITE	http://www.fluidcell.eu/

PARTNERSHIP/CONSORTIUM LIST

FUNDACION TECNALIA RESEARCH & INNOVATION, TECHNISCHE UNIVERSITEIT EINDHOVEN, COMMISSARIAT À L'ÉNERGIE ATOMIQUE ET AUX ÉNERGIES ALTERNATIVES, POLITECNICO DI MILANO, UNIVERSITA DEGLI STUDI DI SALERNO, UNIVERSIDADE DO PORTO, ICI CALDAIE SPA, Hy-Gear B.V., Quantis Sàrl

MAIN OBJECTIVES OF THE PROJECT

FluidCELL aims the Proof of Concept of an advanced high performance, cost effective bio-ethanol micro-CHP cogeneration FC system for decentralized off-grid applications. The system will be based on:

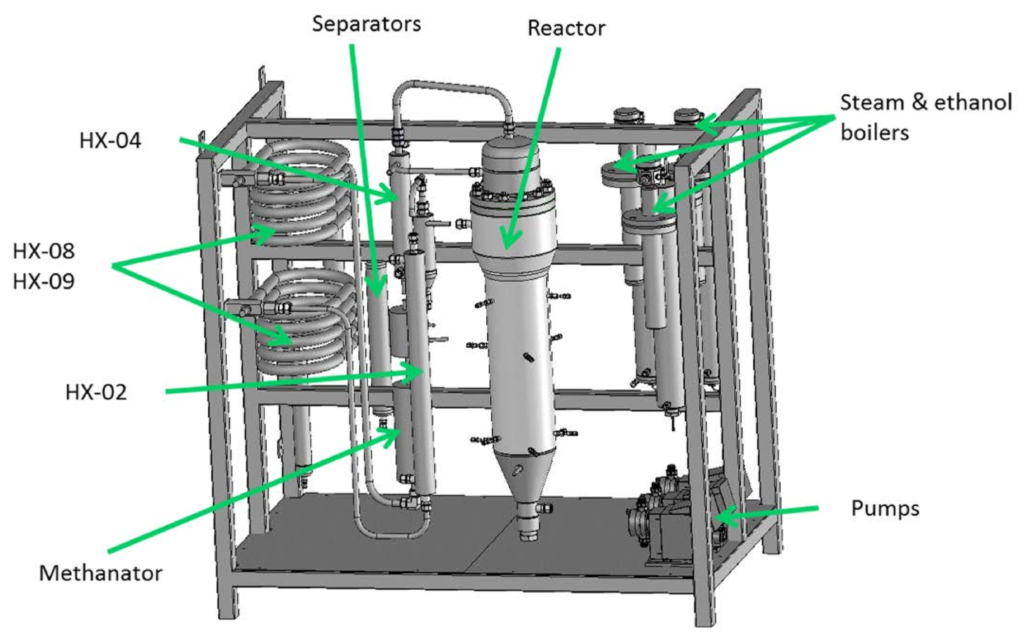
- Design, construction and testing of an advanced bio-ethanol reformer for pure H_2 production (3.5 Nm^3/h) based on Catalytic Membrane Reactor (CMR) &
- Design/ptimization of all subcomponents for the BoP with particular attention to the optimized thermal integration & connection of the membrane reformer to the FC stack.

PROGRESS/RESULTS TO-DATE

- Catalyst for bio-ethanol reforming under moderated (<500ºC) condition developed.
- New plating system for long (50 cm) Pd-based membranes developed. First batch prepared.
- First experimental lab-scale testing campaign of the CMR concluded. Phenomenological model validated.
- Pilot scale reformed designed. Assembling on going.
- Fuel Cell stack prototype layout defined.

FUTURE STEPS

- Development of the membranes for the prototype.
- Prototype reactor assembling, testing and validation.
- Proof of concept of the novel micro-CHP system, to integrate the new reactor prototype and FC stacks with an optimised BoP.
- Technical economic assessment and optimization of both reactors and complete system.
- Life Cycle Analysis and safety analysis.



CONCLUSIONS, MAJOR FINDINGS AND PERSPECTIVES

- Novel catalyst for bio-ethanol reforming under moderate conditions (<500ºC) and fluidization has been developed.
- The Fluidized Bed Membrane Reactor concept validated a lab-scale.
- Pilot scale prototype design concluded.
- Fuel Cell stack prototype defined.
- FluidCELL gives an answer to the many off-grid decentralized energy consumers dependant on expensive & polluting sources.

CONTRIBUTION TO THE PROGRAMME OBJECTIVES

PROJECT OBJECTIVES / TARGETS	CORRESPONDING PROGRAMME OBJECTIVE / QUANTITATIVE TARGET (SPECIFY TARGET YEAR)	CURRENT PROJECT STATUS	PROBABILITY OF REACHING INITIAL TARGET	STATE OF THE ART 2016 – VALUE AND REFERENCE	COMMENTS ON PROJECT PROGRESS / STATUS
(a) Project objectives relevant to multi-annual objectives (from MAIP/MAWP) – indicate relevant multi-annual plan:					MAIP 2008-2013
Overall efficiency CHP units	>80 %	>90 %	80 %		60% achievement, to be confirmed end of project.
Emissions and fuels	< emissions, use of multiple fuels	Bio-ethanol as fuel (instead of natural gas).	100 %		60 % achievement. To be confirmed end of the project. Reduced anthropogenic CO_2 emissions compared to conventional fossil fuels.
Cost per system (1 kW_e + household heat).	Cost: €10k/system (2015), €5k/system (2020)	€5,000 (1 kW_e + house heat)	70 %		Cost could be achieved @ mass prod. or slightly bigger m-CHP. Cost analysis to be carried out.
(b) Project objectives relevant to annual objectives (from AIP/AWP) if different than above – indicate relevant annual plan:					AIP 2013-1
Lab Proof-of-Concept of CHP	Lab Proof-of-Concept of CHP	N/A	80 %		Project extension needed
Durability	Several 100h of continuous operating	1,000 h of operation	80 %		Project extension needed
(c) Other project objectives					
Novel catalyst for bio-ethanol reforming	Not applicable	Novel catalyst for bio-ethanol reforming (<500ºC) & fluidization	100 %	State of the art catalyst	
Development of >15 cm mechanicaly stronger H_2 selective membranes	Not applicable	New plating system for long (50 cm) Pd based membranes. 1st batch.	100 %	State-of art membranes	Further developments are needed to ensure improved selectivity.
Membrane Scale-up, processing issues	Not applicable	Suitable 45 cm long ceramic supported membranes have been developed.	100 %	State-of art membranes	Further developments are needed to ensure improved selectivity.
Membrane reactor	Not applicable	FBMR concept validated at lab-scale (TRL 4) for bio-ethanol reforming	100 %	State of the art	Phenomenological model validated.

HEALTH-CODE

Real operation PEM fuel cells HEALTH-state monitoring and diagnosis based on dc-dc COnverter embeddeD Eis

PANEL 4

Research activities for stationary applications

ACRONYM	HEALTH-CODE
CALL TOPIC	FCH-02.3-2014: Stationary fuel cell system diagnostics: development of online monitoring and diagnostics systems for reliable and durable fuel cell system operation
START DATE	1/09/2015
END DATE	31/08/2018
PROJECT TOTAL COST	€2,3 million
FCH JU MAXIMUM CONTRIBUTION	€2,3 million
WEBSITE	http://pemfc.health-code.eu/

PARTNERSHIP/CONSORTIUM LIST

UNIVERSITA DEGLI STUDI DI SALERNO, AALBORG UNIVERSITET, DANTHERM POWER A/S, EIFER EUROPAISCHES INSTITUT FUR ENERGIEFORSCHUNG EDF KIT EWIV, ELECTRO POWER SYSTEMS MANUFACTURINGSRL, TORINO E-DISTRICT CONSORZIO, UNIVERSITE DE FRANCHE-COMTE, ABSISKEY CP

MAIN OBJECTIVES OF THE PROJECT

1) Implementation of monitoring & diagnostic tool based on Electrochemical Impedance Spectroscopy (EIS) for μ-CHP & O2-fed backup PEMFC.
2) Development of a tool for state-of-health assessment, fault detection & isolation as well as degradation level analysis for lifetime extrapolation. Determine the current status for the detection of 5 faults: i) change in fuel composition; ii) air and iii) fuel starvation; iv) sulphur poisoning; v) flooding and dehydration. Infer on the residual useful lifetime.
3) Reduce experiments, time & costs through scaling-up methodology.

PROGRESS/RESULTS TO-DATE

- Thorough state-of-art study on the most relevant PEMFC faults & on relevant diagnostic strategies.
- Test protocols developed for both μ-CHP and backup stacks, with respect to normal & faulty operation testing.
- All stacks have been installed on test benches at three laboratories.
- EIS board and power electronics under design process to meet measurements targets for monitoring & diagnostic purposes.
- Several diagnostic algorithms under development; preliminary analysis performed based on data from previous projects.

FUTURE STEPS

- Expecting a 1st set of EIS measurements for stacks characterization to be released in June 2016.
- Release of the 1st scaling-up algorithm to model stack behaviour from single cell EIS data.
- 2nd generation of the EIS board, improved with respet to the one developed in D-CODE project, will be released for first tests.
- Interfacing the EIS board and the converters to perform EIS during FC system operations.
- Integration of both hardware and algorithms for testing on FC systems.

CONCLUSIONS, MAJOR FINDINGS AND PERSPECTIVES

- Main activities are still ongoing and conclusions can't be drawn yet.
- Transfer EIS measurements from lab. to on-board applications to improve diagnostics + support advanced lifetime analysis.
- It is expected the implementation of a low cost board driving the DC/DC converter to perform the EIS, while the system is running on field.

CONTRIBUTION TO THE PROGRAMME OBJECTIVES

PROJECT OBJECTIVES / TARGETS	CORRESPONDING PROGRAMME OBJECTIVE / QUANTITATIVE TARGET (SPECIFY TARGET YEAR)	CURRENT PROJECT STATUS	PROBABILITY OF REACHING INITIAL TARGET	STATE OF THE ART 2016 – VALUE AND REFERENCE	COMMENTS ON PROJECT PROGRESS / STATUS
(a) Project objectives relevant to multi-annual objectives (from MAIP/MAWP) – indicate relevant multi-annual plan:					MAWP 2014-2020
Monitoring and diagnostic algorithm for improved PEMFC system efficiency, reliability & availability.	Increase electrical efficiency and durability of the different FCs used for power production	Several diagnostic algorithms (i.e. model- and signal-based) under design	100 %	From D-CODE project results, diagnostic algorithms have been successfully applied on PEMFC systems.	Activities are on time; preliminary results based on available data. Algorithms will tested on data acquired during project experiments.
EIS board cost <3% of the overall system manufacturing cost.	Reduce total cost ownership (TCO in €/kWh)	EIS board design based on components improvement for cost reduction.	100 %	From D-CODE project: overall cost of EIS board (with the provided accuracy) within 3% of the tested PEMFC system	EIS board cost under analysis vs the considered components for the the 2 systems (μ-CHP and backup).
Backup system designed to be coupled with electrolyser for an independent power production system	Improve grid stability through applications of stationary FCs + energy storage	Investigation of pure O2 feed instead of air considered for backup system	100 %	Negligible activity in literature on EIS applications & diagnostic analysis combined with O2-fed systems.	Test bench organized to perform tests on this system under normal & faulty conditions.
(b) Project objectives relevant to annual objectives (from AIP/AWP) if different than above – indicate relevant annual plan:					AWP 2014
Demo of fault diagnosis on 2 stacks for μ-CHP and Backup	Demo of detection of major stack/ system failure modes in lab tests with min. 2 different platforms	Stack installed on test benches and experimental activity at early stages	100 %	Not available for FC systems, few data available on stacks	Some delay due to change from air- to O2-fed system. However, overall progress is still on time, no further problem
5 faults considered: i) change in fuel composition; ii) air starvation; iii) fuel starvation; iv) sulphur poisoning; v) flooding and dehydration	5 failure modes detectable	Testing protocol defined; diagnostic algorithms under design	100 %	From D-CODE project, only 3 faults (flooding, dehydration & air starvation) were considered	Preliminary results obtained. Refinement on diagnostic algorithms with data from experimental activity to be done
Lab tests & field operation emulated on 2 PEMFC systems (μ-CHP and backup) to validate monitoring & diagnostic algorithms	Lab or field- demo of the monitoring/ diagnostics approach integrated into2 FC systems	Lab tests at early stages	100 %	From D-CODE: only lab tests on backup system	Field operation planned after the 1st mid-term
EIS to estimate electrochemical info at cell level to monitor/follow time evolution of several metrics	A methodology for state-of-health monitoring incl. degradation measurement & remaining lifetime prediction	Methodologies under investigation for lifetime evaluation from EIS data	100 %	Only few works available on this topic, mostly for lab application	No preliminary results yet; most work performed on literature data.

LIQUIDPOWER

Fuel cell systems and hydrogen supply for early markets

PANEL 4

Research activities for stationary applications

ACRONYM	LIQUIDPOWER
CALL TOPIC	SP1-JTI-FCH.2011.4.3: Research and development of 1-10kW fuel cell systems and hydrogen supply for early market applications
START DATE	1/10/2012
END DATE	31/05/2016
PROJECT TOTAL COST	€3,8 million
FCH JU MAXIMUM CONTRIBUTION	€1,9 million
WEBSITE	Not provided PRD 2016

PARTNERSHIP/CONSORTIUM LIST

DANTHERM POWER A.S, CATATOR AB, H_2 Logic A/S, ZENTRUM FUR BRENNSTOFFZELLEN-TECHNIK GMBH

MAIN OBJECTIVES OF THE PROJECT

R&D giving improved reliability and cost reductions for Backup Power systems (BP). R&D giving improved reliability and cost reductions for Material Handling Vehicles (MHV) and R&D of a methanol reformer for onsite hydrogen supply giving the markets BP and MHV access to cheap hydrogen.

PROGRESS/RESULTS TO-DATE

- Scalability of the fuel cell system developed and new DC/DC converter configuration introduced (BP).
- Efficiency targets reached and Simple Network Management Protocol (SMNP) included in system (BP).
- Several new parts have been changed in the system in order to decrease cost (MHV).
- A compact and highly integrated reformer system has been developed (methanol reformer).

FUTURE STEPS

- The project is finalized however we will keep on working with several issues such as:
- A new cost reduction project is likely to be initiated (new stack) BP.
- DTP will continue working on a number of issues ie cost of controller, DC/DC converter (MHV).

- For both subsystems (reformer and Pressure-Swing Absorption, PSA) the lifetime needs to be further evaluated (methanol reforming).
- Continued search for better and cheaper components (all segments).

CONCLUSIONS, MAJOR FINDINGS AND PERSPECTIVES

- The project is finalized however we will keep on working with several issues such as:
- BP several hot/humid and cold climate kits to our products in order for them to be able to operate in a larger temperature range.
- We will further test parts (and subsequently implement them) which can further decrease cost on the overall system (MHV).
- A cost reduction project will be initiated (mthanol reforming).

CONTRIBUTION TO THE PROGRAMME OBJECTIVES

PROJECT OBJECTIVES / TARGETS	CORRESPONDING PROGRAMME OBJECTIVE / QUANTITATIVE TARGET (SPECIFY TARGET YEAR)	CURRENT PROJECT STATUS	PROBABILITY OF REACHING INITIAL TARGET	STATE OF THE ART 2016 – VALUE AND REFERENCE	COMMENTS ON PROJECT PROGRESS / STATUS
(a) Project objectives relevant to multi-annual objectives (from MAIP/MAWP) – indicate relevant multi-annual plan:					MAIP 2008-2013
<€1.800/kW @ 5,000 unit production	Material handling fuel cell system cost of €1,500/kW in 2015	1700	100 %	On the material handling market we are competing with mainly North American (NA) based companies (Plug Power, Nuvera and Hydrogenics).They are state of the art 2016	DTP is working on a number of issues: Cost of controller, DC/DC converter, compressor etc. DTP will put an effort into finding better and cheaper components
(b) Project objectives relevant to annual objectives (from AIP/AWP) if different than above – indicate relevant annual plan:					AIP 2011
€1.300/kW @ 5,000 unit production	Back-up power fuel cell system cost of €1,500/kW in 2015	<€1.300/kW	100 percent	DTP is generally considered to be the State of the art company in the BP segment	It is possible to meet this target if the sale is above >5,000 units. For now, the sale is below <300 units and the price is €2400.
Back-up power fuel cell system efficiency 45 %	Back-up power fuel cell system efficiency of 30 % in 2015	52 %	100 %	DTP	Reached through improved power electronics, Software and purge intervals.
Hydrogen cost at point of consumption of <€7/kg PSA: target 2,000 €/m³/h (1-10 units) Hydrogen cost at point of consumption of <€7/kg PSA: target 2,000 €/m³/h (1-10 units)	Hydrogen price ≈10 €/kg PSA: status 3500 €/m³/h (1 – 10 units) à + 75 %	0 %			For both subsystems (reformer and PSA) the lifetime needs to be further evaluated. Both subsystems also need a cost reduction project in order to reach the cost targets.

MATISSE

Manufacturing improved stack with textured surface electrodes for stationary and CHP applications

PANEL 4

Research activities for stationary applications

ACRONYM	MATISSE
CALL TOPIC	SP1-JTI-FCH.2013.3.2: Improved cell and stack design and manufacturability for application-specific requirements for Stationary Fuel Cell power and CHP systems
START DATE	1/10/2014
END DATE	30/09/2017
PROJECT TOTAL COST	€3,1 million
FCH JU MAXIMUM CONTRIBUTION	€1,6 million
WEBSITE	http://matisse.zsw-bw.de/general-information.html

PARTNERSHIP/CONSORTIUM LIST

COMMISSARIAT À L'ÉNERGIE ATOMIQUE ET AUX ÉNERGIES ALTERNATIVES, ZENTRUM FUR SONNENENERGIE- UND WASSERSTOFF-FORSCHUNG BADEN-WURTTEMBERGSTIFTUNG, NEDSTACK FUEL CELL TECHNOLOGY BV, INHOUSE ENGINEERING GMBH, AREVA STOCKAGE D'ENERGIE SAS

MAIN OBJECTIVES OF THE PROJECT

Matisse aims at improving manufacturability thanks to the development of specific electrodes by screen printing; sealing solutions and automated assembly of MEAs and stacks for three stationary applications using: H_2/O2 (for Areva SE smart grid), H_2/Air (for Nedstack back-up or CHP in large power plant); or Reformate H_2/Air (for inhouse micro-CHP).
The final goal is to implement optimized MEAs improving performance and durability in the specific conditions of the partners' systems. Cost analysis is planned to check the impact of components and processes on the systems' cost.

PROGRESS/RESULTS TO-DATE

- Methodology and tools developed and set by all partners (manufacturing processes, in-situ tests including segmented cells and post-ageing).
- MEA components defined, manufactured and provided for the 3 stack designs considered (reference homogeneous electrodes and textured catalyst layers).
- Tests in specific conditions with Current Density Distribution Mapping; ageing in nominal or accelerated conditions. Post ageing analyses started.
- New gaskets, sub gasket, anti-wicking solutions identified, tested and proposed, with the aim to improve robustness for the different designs.
- Cost assessment done for the three stack designs and fuel cell technologies using the available reference data for each case.

FUTURE STEPS

- In-situ tests and post ageing characterizations to be analysed on first reference and textured electrodes for further improvements.
- Proposal of new designs and formulations for homogeneous or textured catalyst layers based on first results.
- Development, manufacturing and delivery of other reference MEAs for Areva SE design; of textured MEAs for Nedstack and Inhouse designs.
- Performance and durability testing with current density distribution mapping of new batches of MEAs and characterization of aged MEAs.
- Further developments for automated assembly of MEAs (including sealing solutions) and of stacks with adaptation of stacking machine to Areva SE design.

CONCLUSIONS, MAJOR FINDINGS AND PERSPECTIVES

- Validation of electrodes manufacturing process and assessment of improvements thanks to texturing for the 3 types of designs and applications.
- Validated transfer to a fully automated process (pilot line) of large size electrodes manufacturing.
- Validation of the automatic manufacturing of MEAs (reproducibility on one selected electrode design, with a representative number of MEA).
- Validation of the automatic assembly of stack (with selected reference MEAs for Areva SE design).
- Assessment of the impact of processes and components' modifications on stack and system costs for the final optimized MEAs.

CONTRIBUTION TO THE PROGRAMME OBJECTIVES

PROJECT OBJECTIVES / TARGETS	CORRESPONDING PROGRAMME OBJECTIVE / QUANTITATIVE TARGET (SPECIFY TARGET YEAR)	CURRENT PROJECT STATUS	PROBABILITY OF REACHING INITIAL TARGET	STATE OF THE ART 2016 – VALUE AND REFERENCE	COMMENTS ON PROJECT PROGRESS / STATUS
(a) Project objectives relevant to multi-annual objectives (from MAIP/MAWP) – indicate relevant multi-annual plan:					MAIP 2008-2013
mCHP: 43 % (H_2 reform./air) Large Power Plant: 50 % (H_2/air) Smart Grid: 47 % (H_2/O2)	Electrical efficiencies should be >45 % for power only units and >80 % for CHP units	Reference MEA tested In performance including current density distribution mapping	80 %	45 % 80 %	Performances at short stack level available for reference MEAs and gradient electrodes for H_2 and reformate/Air cases
mCHP: 40,000 h Large Power Plant: 20,000 h (without servicing the stack) Smart Grid: 40,000 h	lifetime requirements of 40,000 hours for cell and stack	Durability on reformate/Air on reference MEA (>3,000 h) Specific Accelerated Stress Test (AST) H_2/Air (600h) Post-ageing analyses	80 %	8,0000 hrs (Japanese systems)	Lifetime obtained at short stack level AST on H_2/Air (~300μV/h) Low degradation rate obtained in reformate /Air case (<20μV/h)
(b) Project objectives relevant to annual objectives (from AIP/AWP) if different than above – indicate relevant annual plan:					AIP 2013-1
Reduced stack components costs	Reduced system costs	Automation of electrodes manufacturing on-going First modifications of electrodes performed	80 %		First cost assessment available for reference components only

METSAPP

Metal supported SOFC technology for stationary and mobile applications

PANEL 4
Research activities for stationary applications

ACRONYM	METSAPP
CALL TOPIC	SP1-JTI-FCH.2010.3.1: Materials development for cells, stacks and balance of plant (BoP)
START DATE	1/11/2011
END DATE	31/12/2015
PROJECT TOTAL COST	€8 million
FCH JU MAXIMUM CONTRIBUTION	€3,3 million
WEBSITE	http://www.metsapp.eu/

PARTNERSHIP/CONSORTIUM LIST

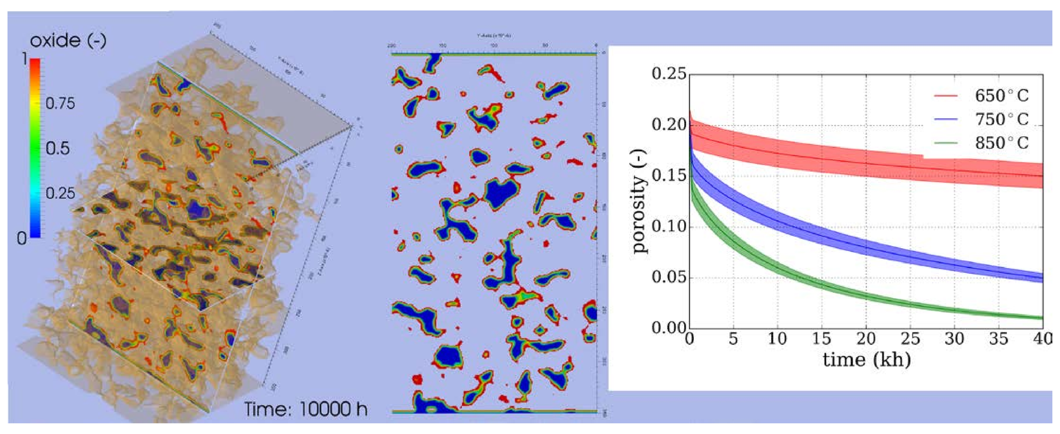
DANMARKS TEKNISKE UNIVERSITET, SANDVIK MATERIALS TECHNOLOGY AB, TOPSOE FUEL CELL A/S, AVL LIST GMBH, CHALMERS TEKNISKA HOEGSKOLA AB, Karlsruher Institut fuer Technologie, THE UNIVERSITY COURT OF THE UNIVERSITY OF ST ANDREWS, ICE STROMUNGSFORSCHUNG GMBH, JRC -JOINT RESEARCH CENTRE- EUROPEAN COMMISSION, ELRINGKLINGER AG

MAIN OBJECTIVES OF THE PROJECT

The aim of the METSAPP project is to develop novel cells and stacks based on a robust and reliable up-scale-able metal supported technology with the following primary objectives:
– Robust metal-supported cell design, with an area specific resistance (ASR) cell<0,5 Ωcm^2, 650 °C.
– Cell optimized and fabrication upscaled for various sizes
– Improved durability for stationary applications, degradation <0,25 %/kh.
– Modular, up-scaled stack design, stack ASRstack <0,6 Ωcm^2, 650 °C.
– Robustness of 1-3 kW stack verified. – Cost effectiveness, industrially relevance, up-scale-ability illustrated.

PROGRESS/RESULTS TO-DATE

- New LSFNT based anode backbone developed and integrated into the cell, demonstrating significant stability improvement.
- Up-scalability demonstrated on cell level. Cells fabricated in sizes up >300 cm^2. More than 200 cells of 12 x 12 cm^2 size produced.
- A corrosion model was implemented, which describes the oxide growth and pore volume change influencing the diffusion in the microstructure.
- New interconnect coatings established, with highly improved properties and a self-healing capability allowing mass production before deformation.
- Extensive electrochemical characterisation was carried out, facilitating the extraction of model parameters that are validated.



FUTURE STEPS

- Demonstration at the stack level .
- Further improvement of the LSFNT based anode backbone microstructure and electrocatalyst (towards lower degradation).
- Further improvement of the infiltration process.

CONCLUSIONS, MAJOR FINDINGS AND PERSPECTIVES

- If the achievements are verified on stacks, there is a high potential for special markets (mobile home, houseboat...), followed by APU.
- Increased effort and focus on computational modelling and simulation facilitates the development of concepts.

CONTRIBUTION TO THE PROGRAMME OBJECTIVES

PROJECT OBJECTIVES / TARGETS	CORRESPONDING PROGRAMME OBJECTIVE / QUANTITATIVE TARGET (SPECIFY TARGET YEAR)	CURRENT PROJECT STATUS	PROBABILITY OF REACHING INITIAL TARGET	STATE OF THE ART 2016 – VALUE AND REFERENCE	COMMENTS ON PROJECT PROGRESS / STATUS
(a) Project objectives relevant to multi-annual objectives (from MAIP/MAWP) – indicate relevant multi-annual plan:					MAIP 2008-2013
Improved durability for stationary applications, degradation	Degradation <0.25 %/kh	Degradation <1.5 %/kh	0 %	Degradation <1.5 %/kh	Further microstructure and material optimisation are expected to reduce degradation
Robustness of 1-3 kW stack verified	Not applicable	The stacks did not survive conditioning	0 %	Not available	Stack demonstration is possible with the current knowledge.
Cost effectiveness, industrially relevance, up-scale-ability illustrated	Ferritic stainless steel as alternative for Ni/YSZ	Successful demonstrated	100 %	Not available	
(b) Project objectives relevant to annual objectives (from AIP/AWP) if different than above – indicate relevant annual plan:					AIP 2011
Cell performance	ASRcell <0.5 Ωcm^2, 650°C	ASRcell <0.5 Wcm^2, 650°C	100 %	ASRcell <0.5 Ωcm^2, 650°C	ASRcell was reached down to 0,37 Ωcm^2, 650°C
Cell optimized and produced in various sizes	Production in various sizes	Cells produced in various sizes. Feasibility study for footprint >300 cm^2 successful	100 %	Not available	
Modular, up-scaled stack design	Stack ASRstack <0.6 Wcm^2, 650°C	The stacks did not survive conditioning	0 %	Not available	Stack demonstration is possible with the current knowledge.

NELLHI

New all-European high-performance stack: design for mass production

PANEL 4
Research activities for stationary applications

ACRONYM	NELLHI
CALL TOPIC	SP1-JTI-FCH.2013.3.2: Improved cell and stack design and manufacturability for application-specific requirements for Stationary Fuel Cell power and CHP systems
START DATE	1/05/2014
END DATE	30/04/2017
PROJECT TOTAL COST	€2,8 million
FCH JU MAXIMUM CONTRIBUTION	€1,6 million
WEBSITE	http://www.nellhi.eu/

PARTNERSHIP/CONSORTIUM LIST

AGENZIA NAZIONALE PER LE NUOVE TECNOLOGIE, L'ENERGIA E LO SVILUPPO ECONOMICO SOSTENIBILE, AKTSIASELTS ELCOGEN, Elcogen OY, Teknologian tutkimuskeskus VTT Oy, FLEXITALLIC LTD, BORIT NV, SANDVIK MATERIALS TECHNOLOGY AB, CLAUSTHALER UMWELTTECHNIK INSTITUT GMBH

MAIN OBJECTIVES OF THE PROJECT

NELLHI combines European know-how in single cells, coatings, sealing, and stack design for mass production to produce a 1 kW SOFC stack with high performance at reduced temperature. The stacks are developed over 3 generations according to system integrators' requirements. The target application of the development is stationary combined heat and power production based on natural gas, and will form the basis for Elcogen Oy's commercial SOFC stack technology as well as enforce market penetration for component manufacturers Elcogen AS, Sandvik, Borit and Flexitallic.

PROGRESS/RESULTS TO-DATE

- Validation of the cell production line, with demonstrated equivalent performance of the 12 x 12 cm cells as compared to the original 10 x 10 cm cells.
- A new sealing material was developed combining sealing and thermal resistance properties with compliance, relaxing thickness tolerances.
- The interconnects design streamlines manufacturing processes, and have been incorporated in the shaping tools used in the project.
- Continuous improvements are being assessed in terms of the coating-substrate materials for in-operando performance.

FUTURE STEPS

- In-depth cell validation tests to increase the understanding and control of cell reactions evolving along the surface.

- Adapting seal design to streamline stack assembly process.
- Multiple design improvements need to be assessed in combined operation with focused troubleshooting for gen. 3 design.
- Dual-atmosphere tests of interconnect samples in stack-representative conditions.

CONCLUSIONS, MAJOR FINDINGS AND PERSPECTIVES

- Elcogen AS cells prove high performance at low temperature and high yield on new production line.
- Flexitallic seals prove to be highly flexible and can be engineered to multiple designs and operating requirements.
- Interconnect manufacturing is already geared for mass-manufacture, optimization required for reliable performance in operando.
- Excellent collaboration in the project synergizes efforts and maximizes return without overlaps.

CONTRIBUTION TO THE PROGRAMME OBJECTIVES

PROJECT OBJECTIVES / TARGETS	CORRESPONDING PROGRAMME OBJECTIVE / QUANTITATIVE TARGET (SPECIFY TARGET YEAR)	CURRENT PROJECT STATUS	PROBABILITY OF REACHING INITIAL TARGET	STATE OF THE ART 2016 – VALUE AND REFERENCE	COMMENTS ON PROJECT PROGRESS / STATUS
(a) Project objectives relevant to multi-annual objectives (from MAIP/MAWP) – indicate relevant multi-annual plan:					MAIP 2008-2013
Stack's performance at 900 mV with 0.35 Acm-2 current density at 650 °C with increased cell footprint. The stack's fuel utilization capability should be at least 75 %. (Second year)	MAIP: Efficiency 35-45 % (elec) 75-85 % (tot) for mCHP system stacks	Stack voltage ~900 mV @ 0.35 Acm-2 at 650 °C Demonstrated stack fuel utilization capacity of 85 %	100 %	References unavailable due to confidentiality of information	60 % stack efficiency achievable
Less than 0.2 % voltage loss in 1,000 hours and 0.5 % after 10 thermal cycles (enables >25,000 hours life-time)	Increase the electrical efficiency and the durability for (CH)P, while reducing costs	Less than 5mΩ.cm²/kh (9,000 hours experiment) demonstrated with unit cells	82 %	References unavailable due to confidentiality of information	Ongoing validation at stack level
(b) Project objectives relevant to annual objectives (from AIP/AWP) if different than above – indicate relevant annual plan:					AIP 2013-1
920 mV @ 0.3 Acm-2 at 650 °C with new cells. Stack fuel utilization capability >75 %	AIP2013: increase performance, power density, and efficiency (not quantified)	Stack voltage ~910 mV @ 0.3 Acm-2 at 650 °C Demonstrated stack fuel utilization capacity of 85 %	100 %	References unavailable due to confidentiality of information	Optimization of multiple design improvements for design freeze and final generation in 2017
Stack production yield over 95 %	AIP2013: reduce materials and manufacturing cost (not quantified)	Stack production yield for the project use has been 100 %	100 %	References unavailable due to confidentiality of information	More stacks have to be built in order to gain exact production yield figure.
(c) Other project objectives					
Improvement in seal material and designs for slender low cost manufacturing	not applicable	10-fold increase in seal compliance with unaltered sealing and thermal resistance properties	100 %	Company internal references	Optimization of multiple design improvements for design freeze and final generation in 2018
Optimization of material-coating combinations for robustness in performance and in manufacturing	not applicable	2-fold increase in durability for ex-situ tested material-coating combinations	100 %	Company internal references	Optimization of multiple material improvements for design freeze and final generation in 2017

PROSOFC

Production and reliability oriented SOFC cell and stack design

PANEL 4
Research activities for stationary applications

ACRONYM	PROSOFC
CALL TOPIC	SP1-JTI-FCH.2012.3.2: Improved cell and stack design and manufacturability for application specific requirements
START DATE	1/05/2013
END DATE	31/10/2017
PROJECT TOTAL COST	€7,3 million
FCH JU MAXIMUM CONTRIBUTION	€3 million
WEBSITE	http://prosofc-project.eu/

PARTNERSHIP/CONSORTIUM LIST

AVL LIST GMBH, HTceramix SA, DYNARDO AUSTRIA GMBH, DANMARKS TEKNISKE UNIVERSITET, FORSCHUNGSZENTRUM JULICH GMBH, Karlsruher Institut fuer Technologie, IMPERIAL COLLEGE OF SCIENCE, TECHNOLOGY AND MEDICINE, JRC -JOINT RESEARCH CENTRE- EUROPEAN COMMISSION, ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE, TOPSOE FUEL CELL A/S

MAIN OBJECTIVES OF THE PROJECT

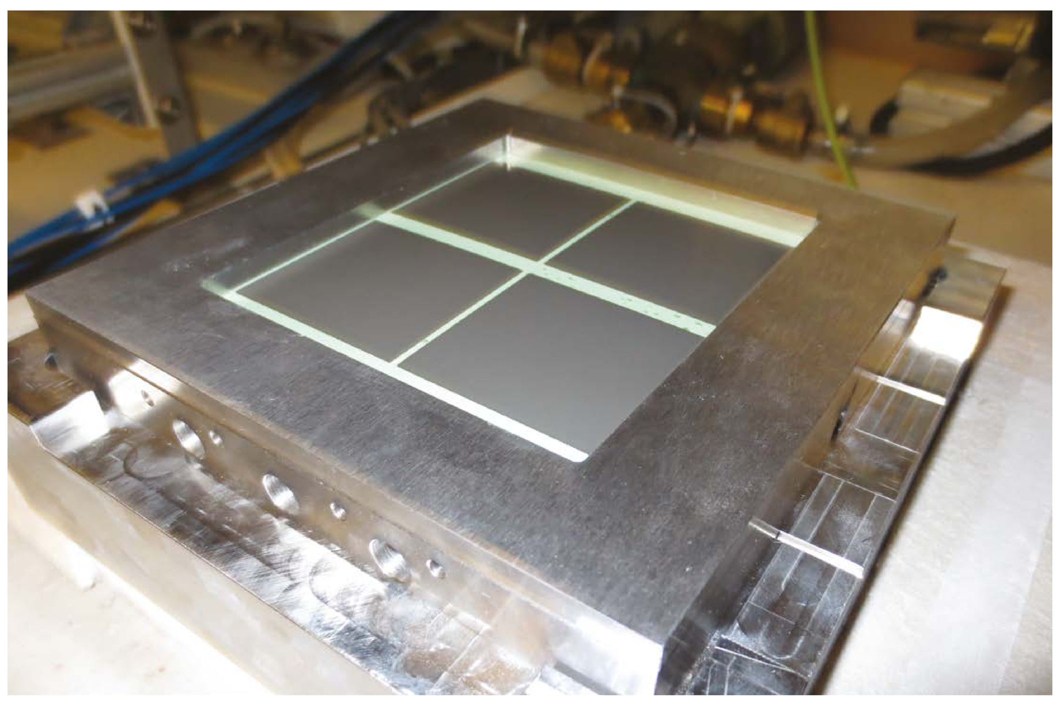
The PROSOFC project aims at improving the robustness, manufacturability, efficiency and cost of Topsoe Fuel Cell's state-of-the-art SOFC stacks so as to reach market entry requirements. The key issues are the mechanical robustness of solid oxide fuel cells (SOFCs), and the delicate interplay between cell properties, stack design, and operating conditions of the SOFC stack. The novelty of the project lies in combining state of the art methodologies for cost-optimal reliability-based design (COPRD) with actual production optimization.

PROGRESS/RESULTS TO-DATE

- First reliable multi-physics stack cell simulation models dedicated to subsequent statistical analysis successfully built.
- Mechanical characterization of SoA cells ongoing.
- Test of close-to-reality cell test equipment successfully carried out and validated by means of computational fluid dynamics (CFD).
- CFD simulation for full stack assembly established.
- 2nd workshop on mechanical investigations on SOFCs held.

FUTURE STEPS

- Further development of stack simulation model towards 3D temperature and stress distribution.
- Testing of mechanical material behaviour in relation to production and microstructure.



- Long term stack testing for reliability validation.
- Further test of close-to-reality segmented cell test equipment for methane operation.
- Implementation of failure modes which have been experimentally determined into the meta-model.

CONCLUSIONS, MAJOR FINDINGS AND PERSPECTIVES

- SOFC exhibits complex multi-physics compared to other areas where COPRD has been applied; failure mode description is not trivial.
- Close-to-reality segmented cell test equipment well suitable for CFD model calibration.
- Discovery of a new phenomenon "accelerated creep".

CONTRIBUTION TO THE PROGRAMME OBJECTIVES

PROJECT OBJECTIVES / TARGETS	CORRESPONDING PROGRAMME OBJECTIVE / QUANTITATIVE TARGET (SPECIFY TARGET YEAR)	CURRENT PROJECT STATUS	PROBABILITY OF REACHING INITIAL TARGET	COMMENTS ON PROJECT PROGRESS / STATUS
(a) Project objectives relevant to multi-annual objectives (from MAIP/MAWP) – indicate relevant multi-annual plan:				MAIP 2008-2013
Electrical efficiency (SOFC system) / 55 %+	ASR=600mOhm*cm^2	ASR=650mOhm*cm^2	75 %	Promising leads identified, but not yet realised
Lifetime/Durability (SOFC System)	Indirectly targeted by improving stack robustness			
Cost (SOFC system)	Indirectly targeted by cost reduction of stack			
(b) Project objectives relevant to annual objectives (from AIP/AWP) if different than above – indicate relevant annual plan:				AIP 2012
Improved electrical efficiency	ASR=600mOhm*cm^2	ASR=650mOhm*cm2	75 %	Promising leads identified, but not yet realised
Better robustness, better lifetime, improved manufacturing methods	Identify major failure modes and link them to stack design and production using an statistical simulation approach Operation in real life environment >4,000 h	Major failure modes identified Statistical simulation model linked with stack model On-going stack tests	Failure mode: 90 % Statistical approach: 50 % 4,000 h test time reached: 90 %	Risk of discovering a new major failure modes based on on-going investigations cannot be avoided Reliability optimization: Development of stack model capable of addressing major failure modes as well as the application of the statistical approach progresses slower than anticipated Aggressive testing might provoke early failure
Cost reduction	Index 75 (M36)	Index 33	100 %	
Improved manufacturing methods / Stack scrap rate: 5 % by 2017	Yield rate: 95 %	Yield rate: 85 %	50 %	Reliability optimization needed to reach 95 % stack yield rate, but development of stack model capable of addressing major failure modes as well as the application of the statistical approach progresses slower than anticipated
Higher power density	Indirectly targeted by improved stack robustness			

REFORCELL

Advanced multi-fuel reformer for fuel cell CHP systems

PANEL 4
Research activities for stationary applications

ACRONYM	REFORCELL
CALL TOPIC	SP1-JTI-FCH.2010.3.3: Component improvement for stationary power applications
START DATE	1/02/2012
END DATE	31/12/2015
PROJECT TOTAL COST	€5,4 million
FCH JU MAXIMUM CONTRIBUTION	€2,8 million
WEBSITE	http://www.reforcell.eu/

PARTNERSHIP/CONSORTIUM LIST

FUNDACION TECNALIA RESEARCH & INNOVATION, TECHNISCHE UNIVERSITEIT EINDHOVEN, COMMISSARIAT À L'ÉNERGIE ATOMIQUE ET AUX ÉNERGIES ALTERNATIVES, POLITECNICO DI MILANO, STIFTELSEN SINTEF, ICI CALDAIE SPA, HyGear B.V., SOPRANO INDUSTRY, HYBRID CATALYSIS BV, Quantis Sàrl, JRC -JOINT RESEARCH CENTRE- EUROPEAN COMMISSION

MAIN OBJECTIVES OF THE PROJECT

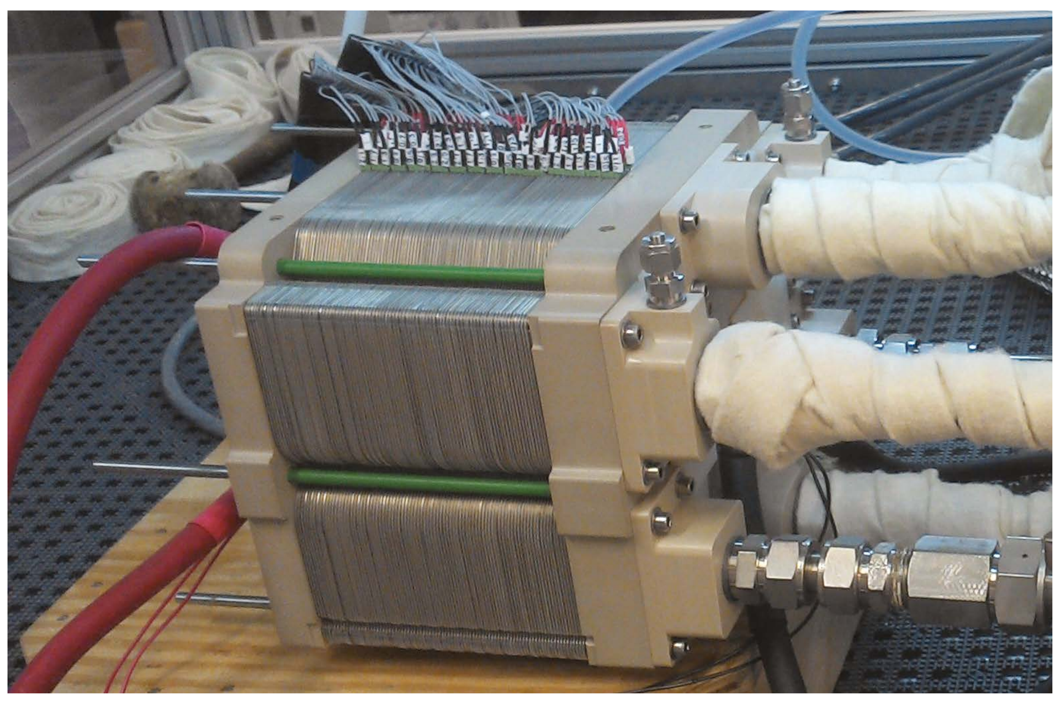
ReforCELL aims at developing a high efficiency PEM fuel cell micro Combined Heat and Power system (net energy efficiency >42 % and overall efficiency >90 %) based on a novel, more efficient and cheaper pure hydrogen production unit (5 Nm3/h), together with optimized design of the subcomponent for the Balance of Plant (BoP). The target will be pursued with the integration of the reforming and purification in one single unit using Catalytic Membrane Reactors (CMR).

PROGRESS/RESULTS TO-DATE

- Fluidized bed membrane reactor (FBMR) concept validated at lab-scale (TRL 4) for Steam Methane Reforming (SMR) and Autothermal Reforming .
- Pilot reactor prototype including all BoP components assembled and tested.
- Models for the FBMR and complete Fuel Processor developed.
- Fuel cell stack prototype manufactured and validated.
- Design and selection of the components for the m-CHP system. Size scale-up, market, cost analysis and technological feasibility for sizes up to 50 kW_e.
- Life-Cicle Analysis and safety analysis of the novel m-CHP.

FUTURE STEPS

- N/A. Project has finished end 2015.



CONCLUSIONS, MAJOR FINDINGS AND PERSPECTIVES

- Novel catalyst, membranes and membrane reactors for autothermal reforming (ATR)/SMR has been developed and validated at lab-scale (TRL 4).
- Further developments are needed on the membranes to ensure the long-term durability over 550 -600 °C.
- CMR PEM m-CHP systems could improve the efficiency while reducing the cost due to the integration of the reforming and purification in one single unit.
- The new CMR PEM m-CHP system should be tested to achieved TRL6 as a first step before any testing in operational environment.
- Large scale production and/or intermediated size of the m-CHP system is needed to achieve the target of €5,000 1 kW_e + household heat.

CONTRIBUTION TO THE PROGRAMME OBJECTIVES

PROJECT OBJECTIVES / TARGETS	CORRESPONDING PROGRAMME OBJECTIVE / QUANTITATIVE TARGET (SPECIFY TARGET YEAR)	CURRENT PROJECT STATUS	PROBABILITY OF REACHING INITIAL TARGET	STATE OF THE ART 2016 – VALUE AND REFERENCE	COMMENTS ON PROJECT PROGRESS / STATUS
(a) Project objectives relevant to multi-annual objectives (from MAIP/MAWP) – indicate relevant multi-annual plan:					MAIP 2008-2013
Overall efficiency CHP units	>80 %	>90 %	0 %, project finished	93 Panosonic Household fuel cell	µ-CHP system not tested (partner in charge liquidated). 90 % feasible with appropriate heat exchanger sizing & insulation
Cost/system (NG-based µ-CHP, 1 kW_e + household heat).	Cost €10k/system (2015), €5k/system (2020)	€5,000 (1 kW_e + house heat)	100 %	This project is setting the actual state-of-art	Cost could be achieved for mass production or slightly higher m-CHP system sizes
(b) Project objectives relevant to annual objectives (from AIP/AWP) if different than above – indicate relevant annual plan:					AIP 2010
Viable mass production	Mass prod. Technol. are considered	Mass production technologies are considered in the development	100 %		
Recyclability	LCA and safety study	LCA and safety study	100 %		LCA performed
(c) Other project objectives					
Novel catalyst synthesis	Not applicable	Catalyst developed, active @ lower temp. than foreseen (<600 °C).	100 %	State of the art catalyst	
Development of H_2 selective membranes	Not applicable	Metallic-supported ceramic membranes working at <550 °C	100 % (<550 °C)	State-of art membranes	Further developments needed for improved mech. properties + long term durability over 550-600 °C
Membrane Scale-up, processing issues	Not applicable	23 cm ceramic-supported membranes developed.	100 %	State-of art membranes	Further developments are needed develop longer membranes (i.e. >40 cm)
Membrane reactor	Not applicable	FBMR concept validated at lab scale (TRL 4) for SMR & ATR	100 %	State of the art	New CMR reactor to be tested for TRL6 as 1st step before testing in operational environment
Micro-channel membrane module	Not applicable	Concept validated @ lab scale (TRL4) for SMR. Tests w/integrated catalysts	100 %	State of the art	Further developments needed for up-scaled modules & better temp. stability (curr. ~500 °C)

SAPPHIRE

System automation of PEMFCs with prognostics and health management for improved reliability and economy

PANEL 4

Research activities for stationary applications

ACRONYM	SAPPHIRE
CALL TOPIC	SP1-JTI-FCH.2012.3.3: Robust, reliable and cost effective diagnostic and control systems design for stationary power and CHP fuel cell systems
START DATE	1/05/2013
END DATE	30/04/2016
PROJECT TOTAL COST	€3,2 million
FCH JU MAXIMUM CONTRIBUTION	€1,7 million
WEBSITE	https://sapphire-project.eifer.kit.edu/index.php/about

PARTNERSHIP/CONSORTIUM LIST

STIFTELSEN SINTEF, EIFER EUROPAISCHES INSTITUT FUR ENERGIEFORSCHUNG EDF-KIT EWIV, ECOLE NATIONALE SUPERIEURE DE MECANIQUE ET DES MICROTECHNIQUES, University of Split, Faculty of Electrical Engineering, Mechanical Engineering and Naval Architecture, ZENTRUM FUER SONNENENERGIE- UND WASSERSTOFF-FORSCHUNG, BADEN-WUERTEMBERG, DANTHERM POWER A.S, Ludwig-Boelkow-Systemtechnik GmbH

MAIN OBJECTIVES OF THE PROJECT

The Sapphire project aimed to develop a new type of controller for µCHP generators providing power and hot water for domestic use and run on natural gas. With fuel cells producing power, energy from natural gas is converted into electricity, more valuable than natural gas on an energy basis.

PROGRESS/RESULTS TO-DATE

- Demonstrated two systems for 6,000 h with minimal or no degradation.
- Achieved rejuvenation rates of up to 4 µV/h.
- Identified prognostic variables in equivalent-circuit model .
- Developed model-based and data-driven prognostics.
- Controllers to counteract dry-out, flooding, CO poisoning and hydrogen starvation.

FUTURE STEPS

- Roll-out of new controllers in new generation of µCHP units.
- Licensing of patents for control system.
- Follow-up project on automotive systems (Giantleap).
- Further research on stack rejuvenation.
- Improvement of stack designs for reduced degradation.

CONCLUSIONS, MAJOR FINDINGS AND PERSPECTIVES

- A lot of voltage degradation is reversible by catalyst regeneration.
- Need more research on rejuvenation mechanisms, including side effects.
- Targets set by MAIP and AIP were attained.
- Electrochemical Impdenace Spectroscopy (EIS) can identify reliable prognostic variables.
- Air bleed in µCHP systems can be significantly reduced.

CONTRIBUTION TO THE PROGRAMME OBJECTIVES

PROJECT OBJECTIVES / TARGETS	CORRESPONDING PROGRAMME OBJECTIVE / QUANTITATIVE TARGET (SPECIFY TARGET YEAR)	CURRENT PROJECT STATUS	PROBABILITY OF REACHING INITIAL TARGET	STATE OF THE ART 2016 – VALUE AND REFERENCE	COMMENTS ON PROJECT PROGRESS / STATUS
(a) Project objectives relevant to multi-annual objectives (from MAIP/MAWP) – indicate relevant multi-annual plan:					MAIP 2008-2013
Stack lifetime	3,0000 hours	>5,0000 hours	100 %	8,0000 hours (Dodds et al.: Hydrogen and fuel cell technologies for heating: A review, Int. J. Hydr. En., 40 (2015), 2065-2083)	Degradation halted and even reversed for over 6,000 h in demonstration.
(b) Project objectives relevant to annual objectives (from AIP/AWP) if different than above – indicate relevant annual plan:					AIP 2012
Stack lifetime	2,0000 hours	>5,0000 hours	100 %	8,0000 hours (Dodds et al.: Hydrogen and fuel cell technologies for heating: A review, Int. J. Hydr. En., 40 (2015), 2065-2083)	Degradation halted and even reversed for over 6,000 h in demonstration.
Additional cost of control system	€100/kW	€75/kW	100 %	N/A	No comparable values in literature

SCORED 2:0

Steel coatings for reducing degradation in SOFC

PANEL 4 Research activities for stationary applications	
ACRONYM	SCORED 2:0
CALL TOPIC	SP1-JTI-FCH.2012.3.4: Component and sub-system cost and reliability improvement for critical path items in stationary power and CHP fuel cell systems
START DATE	1/07/2013
END DATE	30/06/2017
PROJECT TOTAL COST	€3,7 million
FCH JU MAXIMUM CONTRIBUTION	€2,1 million
WEBSITE	http://www.birmingham.ac.uk/research/activity/scored/index.aspx

PARTNERSHIP/CONSORTIUM LIST

THE UNIVERSITY OF BIRMINGHAM, Teknologian tutkimuskeskus VTT Oy, ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE, AGENZIA NAZIONALE PER LE NUOVE TECNOLOGIE, L'ENERGIA E LO SVILUPPO ECONOMICO SOSTENIBILE, Teer Coatings Limited, Turbocoating s.p.a., SOLIDPOWER SPA

MAIN OBJECTIVES OF THE PROJECT

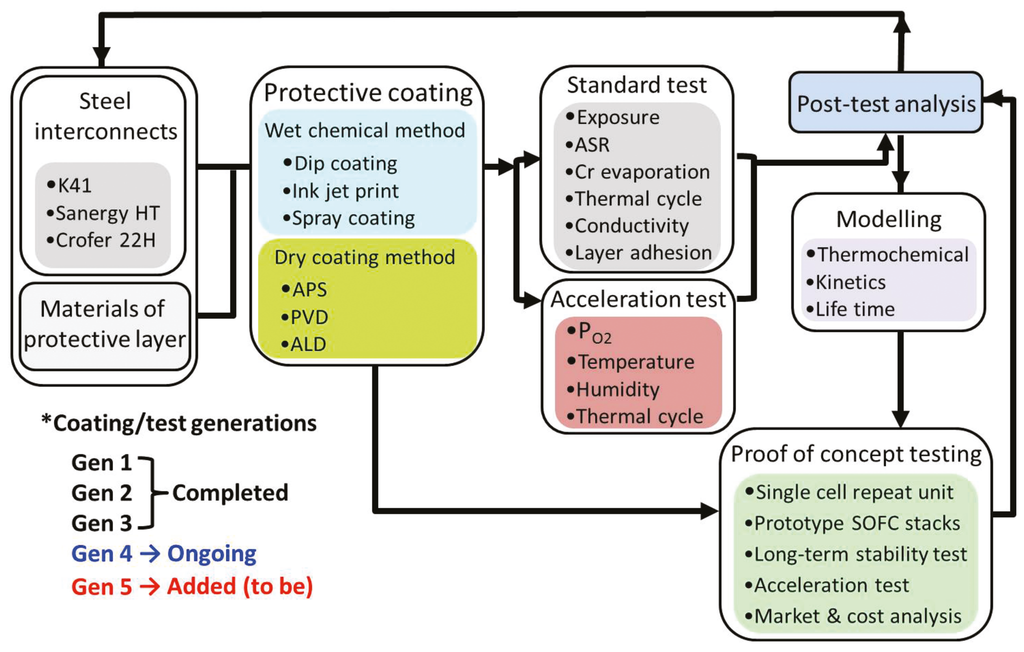
The SCoReD 2:0 will provide coated steel interconnects with improved properties with regard to oxide scale growth, chromium evaporation, and contact resistance by optimising combinations of different steel qualities, including low-cost options, protective layer materials, and various coating methods. The main objective is to demonstrate stack lifetime of ca. 10,000 hours with coated interconnects. Influence of coating method, practicality, and cost of different coating techniques will be analysed to bridge the gap to industrialisation.

PROGRESS/RESULTS TO-DATE

- Sample choice and preparation, Test matrix established.
- First to fourth generation coatings tested.
- Systematic testing, analysis, and post-mortem analysis ongoing.
- Stack demonstration testing (proof-of-concept) ongoing.
- Fifth generation of coating in preparation.

FUTURE STEPS

- Continuation of stack testing and systematic analysis.
- Establishment of lifetime prediction model.
- Accelerated testing.
- Validation of lifetime prediction model with data obtained with accelerating tests.



CONCLUSIONS, MAJOR FINDINGS AND PERSPECTIVES

- Area Specofoc Resistance (ASR) values that are similar or lower than SoA were achieved.
- New types of surface treatment with protective coatings were evaluated – this might constitute a new approach at corrosion protection.
- New protective layer coating material with high electrical conductivity and sinterability is being evaluated.

CONTRIBUTION TO THE PROGRAMME OBJECTIVES

PROJECT OBJECTIVES / TARGETS	CORRESPONDING PROGRAMME OBJECTIVE / QUANTITATIVE TARGET (SPECIFY TARGET YEAR)	CURRENT PROJECT STATUS	PROBABILITY OF REACHING INITIAL TARGET	STATE OF THE ART 2016 – VALUE AND REFERENCE	COMMENTS ON PROJECT PROGRESS / STATUS
(a) Project objectives relevant to multi-annual objectives (from MAIP/MAWP) – indicate relevant multi-annual plan:					MAIP 2008-2013
SOFC system life time (h)	30,000 (2020)	>3,000	100 %	>30,000	>10,000 will be proven within project
System cost (€/kW)	<2,000 (2020)	N/A	N/A	>6500 [1]	Interconnects are only one cost element of many, though, therefore no further statements can be made on stack cost
(b) Project objectives relevant to annual objectives (from AIP/AWP) if different than above – indicate relevant annual plan:					AIP 2011
Manufacturing processes and quality control techniques for high performance and cost effective components	N/A	Six different coating methods applied including cost-effective and/or high quality techniques	100 %	N/A	Six different coating methods have been applied to optimise best combination(s) of interconnect steels and protective layer materials
Validation of lifetime, durability/ robustness, corrosion rate in application specific environments	N/A	Accelerated tests under development	100 %	N/A	Acceleration testing methods need to evaluate component lifetime within the project's nominal termination date

FUEL CELLS AND HYDROGEN JOINT UNDERTAKING

SECOND ACT

Simulation, statistics and experiments coupled to develop optimized and durable µCHP systems using accelerated tests.

PANEL 4
Research activities for stationary applications

ACRONYM	SECOND ACT
CALL TOPIC	SP1-JTI-FCH.2013.3.1: Improving understanding of cell & stack degradation mechanisms using advanced testing techniques, and developments to achieve cost reduction and lifetime enhancements for Stationary Fuel Cell power and CHP systems
START DATE	1/05/2014
END DATE	30/04/2017
PROJECT TOTAL COST	€4,6 million
FCH JU MAXIMUM CONTRIBUTION	€2,5 million
WEBSITE	http://second-act.eu/

PARTNERSHIP/CONSORTIUM LIST

COMMISSARIAT À L'ÉNERGIE ATOMIQUE ET AUX ÉNERGIES ALTERNATIVES, IRD FUEL CELLS A/S (INDUSTRIAL RESEARCH & DEVELOPMENT A/S), NEDSTACK FUEL CELL TECHNOLOGY BV, ICI CALDAIE SPA, POLITECNICO DI MILANO, DEUTSCHES ZENTRUM FUER LUFT – UND RAUMFAHRT EV, JRC -JOINT RESEARCH CENTRE- EUROPEAN COMMISSION, STIFTELSEN SINTEF, TECHNISCHE UNIVERSITAET GRAZ

MAIN OBJECTIVES OF THE PROJECT

To improve understanding of stack degradation and propose durability improvements for µCHP systems using H_2 or Reformate PEMFC or DMFC.
Analysing systems lifetime data to identify main causes for failure; Investigating degradation in cells and stacks; Developing and validating accelerated stress test (AST) and specific harsh tests; Developing in- and ex-situ analyses for identification and local resolution of mechanisms; Developing statistical approach and models, including reversible degradation and heterogeneities; Demonstrating improvements on tolerance to applications' relevant modes with modified components.

PROGRESS/RESULTS TO-DATE

- Manufacturing and delivery among partners of reference MEAs (from 25 to 220 cm²) for single cells and stack (8 to 75 cells).
- Ageing tests conducted in nominal or accelerated conditions on test stations or systems. >1,000 hrs or >6,000 hrs for stacks tested on the power plant.
- Local in-situ data (segmented cells in cells or stacks) and post ageing ex-situ analyses. Evolution of heterogeneities and ageing of MEA components.
- Development of degradation models about reversible mechanisms (PtOx formation, CO poisoning). Validation versus specific experiment or diagnostics.
- Identification of ideas for possible improvement at components level (new A or C catalysts, heterogeneous electrodes, modified gas diffusion layers – GDL).

FUTURE STEPS

- Delivery of new MEAs with modified catalysts or GDL. Definition and manufacturing of heterogeneous electrodes regarding local degradation.
- Implementation of new components and validation in cells or stacks following selected tests for H_2 or Reformate PEMFC or DMFC.
- Further implementation in cell models, consolidation and validation of degradation models describing reversible mechanisms and heterogeneities.

CONCLUSIONS, MAJOR FINDINGS AND PERSPECTIVES

- Clarification of reversible mechanisms. Simulation of PtOx formation/reduction or of CO poisoning, from inlet to outlet, depending on local conditions.
- Validation for DMFC and PEMFC of operation strategies against reversible losses (proposal of refresh procedures including stops or air starvation).
- Identification of differences in local degradation of catalysts due to heterogeneous operation (basis for design of new electrodes)
- Plan of the components modifications for the 3 types of FC and selection of the validation tests to complete the iterative process of improvement.
- Final demonstration of durability improvement at stack level (evidence of less performance losses during selected AST) with the last improved MEA .

CONTRIBUTION TO THE PROGRAMME OBJECTIVES

PROJECT OBJECTIVES / TARGETS	CORRESPONDING PROGRAMME OBJECTIVE / QUANTITATIVE TARGET (SPECIFY TARGET YEAR)	CURRENT PROJECT STATUS	PROBABILITY OF REACHING INITIAL TARGET	STATE OF THE ART 2016 – VALUE AND REFERENCE	COMMENTS ON PROJECT PROGRESS / STATUS
(a) Project objectives relevant to multi-annual objectives (from MAIP/MAWP) – indicate relevant multi-annual plan:					MAIP 2008-2013
Understanding of cell/stack degradation for H2 or Reformate PEMFC and DMFC	Degradation and lifetime fundamentals and typical operation environments	Experimental and modelling studies	90%	Mainly non reversible mechanisms already described in literature	Identification/mitigation of reversible degradation of PtOx formation. Identification/modelling of CO poisoning
>20,000 h for H_2 case thanks to core components modifications	Proposal of new/improved materials, aim of 40,000 h	Different catalysts proposed. Non homogeneous design identfied	80%	NA	Proposal of more CO tolerant catalyst and stable ORR catalyst layers.
(b) Project objectives relevant to annual objectives (from AIP/AWP) if different than above – indicate relevant annual plan:					AIP 2013-1
Collection, production and statistical analysis of ageing data	Identify/quantify degradation and long-term failure mechanisms	Data available from ageing tests on DMFC and PEMFCs	90%	Mainly non reversible mechanisms already described in littérature	Many representative or AST tests (>1000 hours) on DMFC and PEMFC cells or stacks. Long term tests (>6000 hrs) on H2 full stack
Integration of improved core components for demonstrating lifetime improvement	Identify lifetime improvements, and verify these in existing cell and stack design	Tests of different anode or cathode catalysts on-going	80%	NA	Proposal of more CO tolerant catalyst and qualification of more stable ORR catalyst layers
Quantification by iterative loops. Verification of losses by AST	Quantification of mechanisms and verification of improvements	Definition of specifc ageing tests or AST.	100%	Generic AST already available for materials like cathode catalyst	Load cycles, start-up/shut-down, test of contaminants, potential cycles applied for quantification of degradation. Test of mitigation strategies against PtOx reversible mechanism

T-CELL

Innovative SOFC architecture based on triode operation

PANEL 4
Research activities for stationary applications

ACRONYM	T-CELL
CALL TOPIC	SP1-JTI-FCH.2011.3.1: Next generation stack and cell design
START DATE	1/09/2012
END DATE	29/02/2016
PROJECT TOTAL COST	€3,4 million
FCH JU MAXIMUM CONTRIBUTION	€1,7 million
WEBSITE	www.tcellproject.eu

PARTNERSHIP/CONSORTIUM LIST

CENTRE FOR RESEARCH AND TECHNOLOGY HELLAS, FOUNDATION FOR RESEARCH AND TECHNOLOGY HELLAS, CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE, ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE, AGENCIA ESTATAL CONSEJO SUPERIOR DE INVESTIGACIONES CIENTIFICAS, MANTIS DEPOSITION LIMITED, Prototech AS, SOFCPOWER SPA

MAIN OBJECTIVES OF THE PROJECT

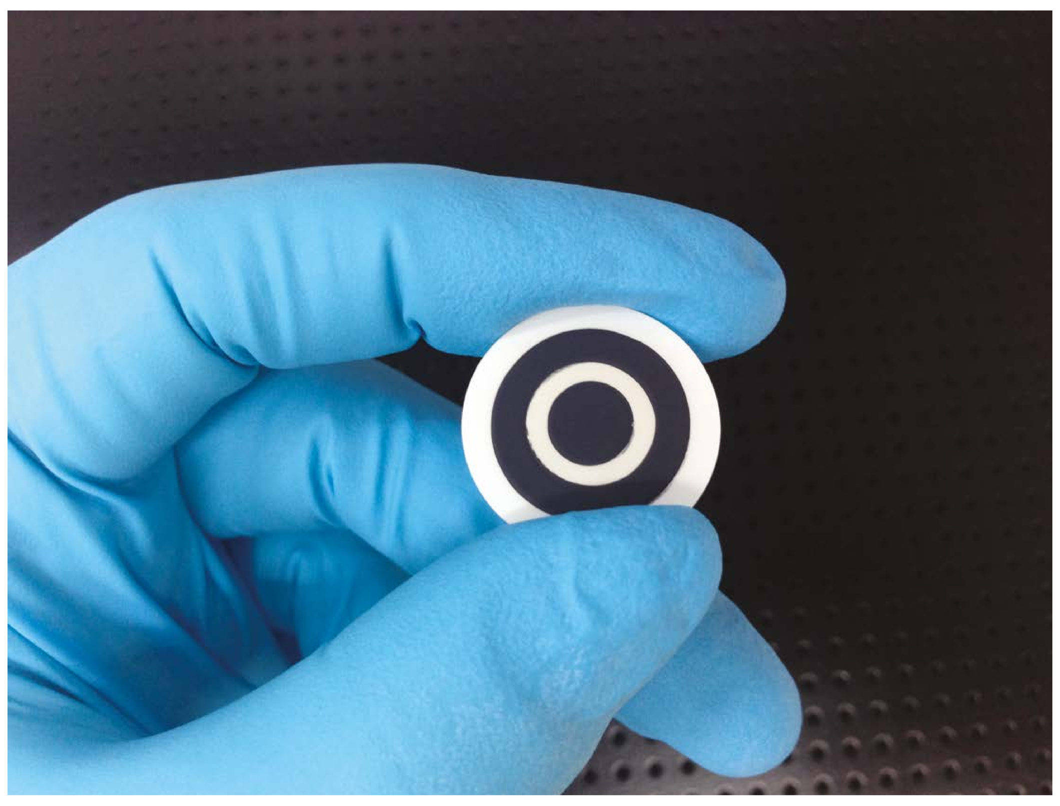
The project objective was the investigation of the synergetic effect of advanced Ni-based cermet anodes modified via doping with a 2nd or a 3rd metal in conjunction with triode operation, in order to control the rate of C deposition and S poisoning. A detailed mathematical model was developed to describe the triode mechanism thus enabling prediction of the behaviour of triode SOFCs as a function of cell design and operational parameters. Proof of the triode concept was provided through the development and performance evaluation of a prototype triode stack, consisting of 5 repeating units.

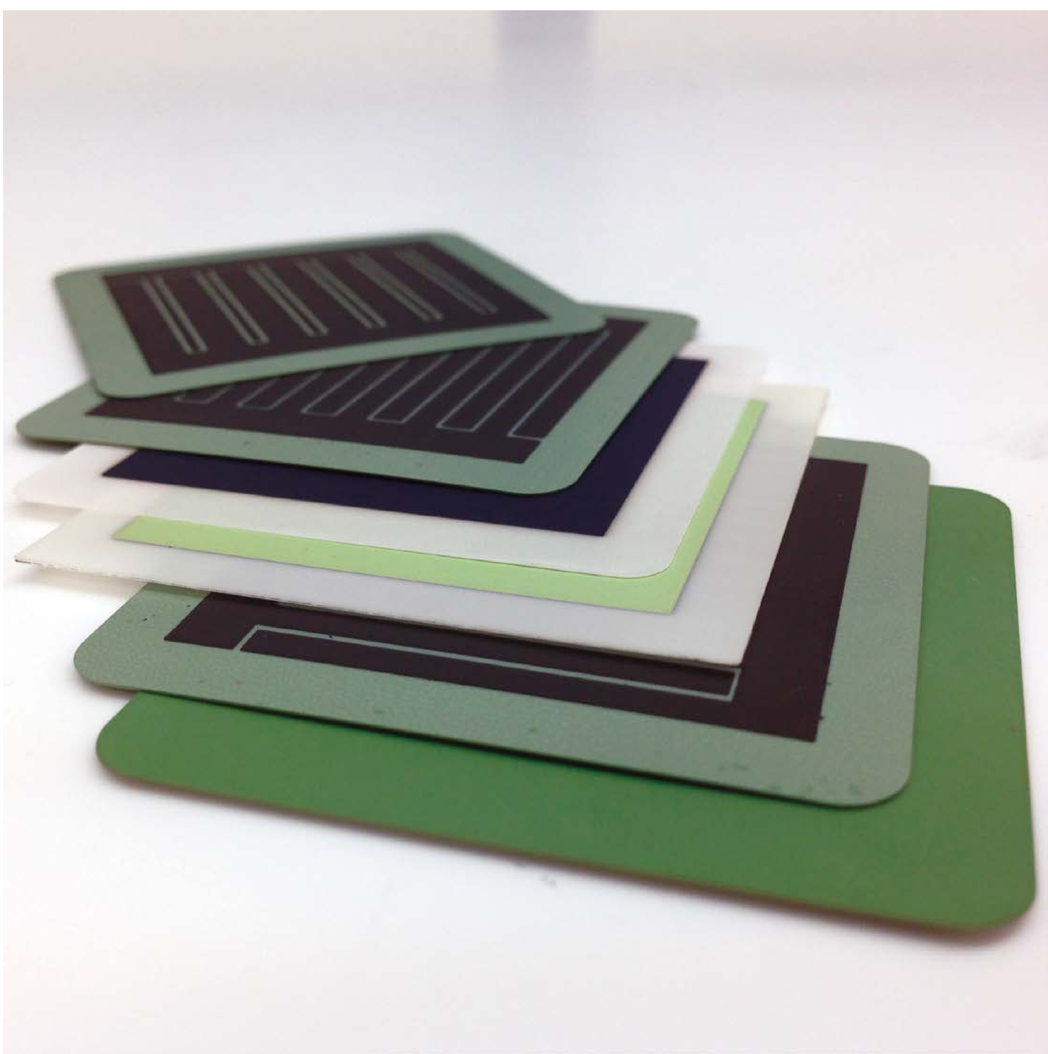
PROGRESS/RESULTS TO-DATE

- Preparation of complete triode cells utilizing standard and (Au, Mo nanoparticles) modified anodes using standard and magnetron sputtering methods.
- Complete physicochemical characterization of modified powder and electrodes.
- Assessment of the effect of triode operation on cell performance and carbon deposition rate.
- Development and verification of a simple model describing the dependence of fuel cell and auxiliary circuit potential.
- Design, construction and operation of a 5-cell triode stack.

CONCLUSIONS, MAJOR FINDINGS AND PERSPECTIVES

- The synergy between Au-Mo-Ni regarding electrocatalytic stability under methane steam reforming has been proven (MSR).
- The magnetron sputtered Ni-YSZ films exhibit good electrical conductivity and can serve as buffer layer between anode and the electrolyte.
- Triode operation results in 40-50 % lower carbon deposition rate on commercial anodes.
- The minimization of the resistance between the cathode and auxiliary electrode is crucial for triode performance.
- Proof of the triode stackability through the development and evaluation of a prototype triode 5-cell SOFC stack operating in MSR.





CONTRIBUTION TO THE PROGRAMME OBJECTIVES

PROJECT OBJECTIVES / TARGETS	CORRESPONDING PROGRAMME OBJECTIVE / QUANTITATIVE TARGET (SPECIFY TARGET YEAR)	CURRENT PROJECT STATUS	PROBABILITY OF REACHING INITIAL TARGET	COMMENTS ON PROJECT PROGRESS / STATUS
(a) Project objectives relevant to multi-annual objectives (from MAIP/MAWP) – indicate relevant multi-annual plan:				MAIP 2008-2013
Electrical efficiency / >55 % (natural gas fueled in presence of ~30ppm sulphur)	Electrical efficiency (natural gas and biogas fuels) / 55 %	Finished	100 %	The tests in button cells revealed electrical efficiency exceeding 55 %; remarkable performance enhancement (~20 % increase in power output) has been realized by triode operation
Stack lifetime / 40,000 hrs	Durability/Reliability (stack lifetime) / 20,000 hrs	Finished	100 %	Triode operation results in 40-50 % lower carbon deposition rate
(b) Project objectives relevant to annual objectives (from AIP/AWP) if different than above – indicate relevant annual plan:				AIP 2011
Development of cells with novel, triode architecture	New architectures, adaptation of cell and/or stack designs to specific applications	Finished	100 %	Delivery of triode cells and short stack with standard and (Au, Mo nanoparticles) modified anodes using standard and magnetron sputtering methods
Development of modified Ni-based materials with enhanced carbon and sulphur tolerance	New materials and/or strategies to improve tolerance to contaminants	Finished	100 %	Development of advanced, carbon and sulfur tolerant Au and Mo modified Ni-based cermet anodes
Development of modified Ni-based materials with enhanced carbon and sulphur tolerance	Improved tolerance to contaminants with respect to state of art FCs	Finished	100 %	Triode operation results in 40-50 % lower carbon deposition rate
Electrical efficiency / >55 %	Improved electrical efficiency over the state of the art / >50 %	Finished	100 %	The tests in button cells revealed electrical efficiency exceeding 55 %; remarkable performance enhancement (~20 % increase in power output) has been realized by triode operation