Cell3Ditor
Cost-effective and flexible 3D printed SOFC stacks for commercial applications

Panel 4 — Research activities for stationary applications

Acronym:	**Cell3Ditor**
Project ID:	700266
Title:	Cost-effective and flexible 3D printed SOFC stacks for commercial applications
Call Topic:	FCH-02.6-2015
Project total costs (€):	€ 2,2 million
FCH JU maximum contribution (€):	€ 2,2 million
Project start/end:	01 Jul 2016 - 31 Dec 2019
Coordinator:	Fundacio Inst. De Recerca de L'Energia De Catalunya, Spain
Beneficiaries:	3Dceram, Saan Energi, Promethean Particles Ltd, Hygear Fuel Cell Systems, Francisco Albero, Uni. La Laguna, Danmarks Tek. Uni.
Website:	www.cell3ditor.eu
Linkedin:	Cell3Ditor
Twitter:	@cell3ditor

Project and objectives

The main goal of the Cell3Ditor project is to develop a 3D printing technology for the industrial production of SOFC stacks by covering research and innovation in all the stages of the industrial value chain (inks formulation, 3D printer development, ceramics consolidation and system integration). All-ceramic joint-free SOFC stacks with embedded fluidics and current collection will be fabricated in a two-step process (single-step printing and sintering) to reduce in energy, materials and assembly costs. A novel multi-material hybrid printing technology has been developed in the first year.

Major project achievements

- Development of a hybrid 3D printer able to print multi-material ceramic devices
- Development of printable slurries of YSZ for being used with the SLA technology
- Design of a printable SOFC joint-less stack with embedded fluidics

Future steps

- Hybrid SLA inkjet printing machine ready for multi-material fabrication of 3D pieces
- Printable slurries for SLA and inkjet ready
- Multi-material 3D printing machine validated
- SOFC parts printed by inkjet or SLA
- Printable design of the SOFC stack ready

Non-quantitative objectives and status

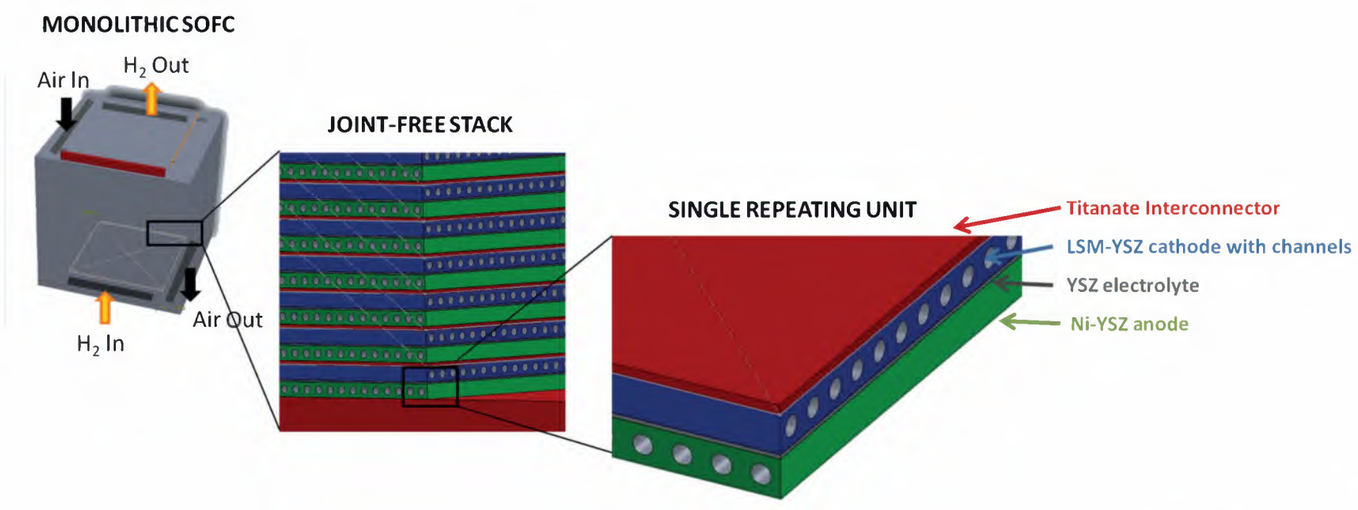
- Hybridisation of SLA and inkjet printer for fabrication of 30x30x10 cm
  To be achieved in June 2017
- Fabrication of SOFC parts by 3D printing
  To be achieved in June 2019
- Fabrication of joint-less SOFC stacks
  To be achieved in December 2019

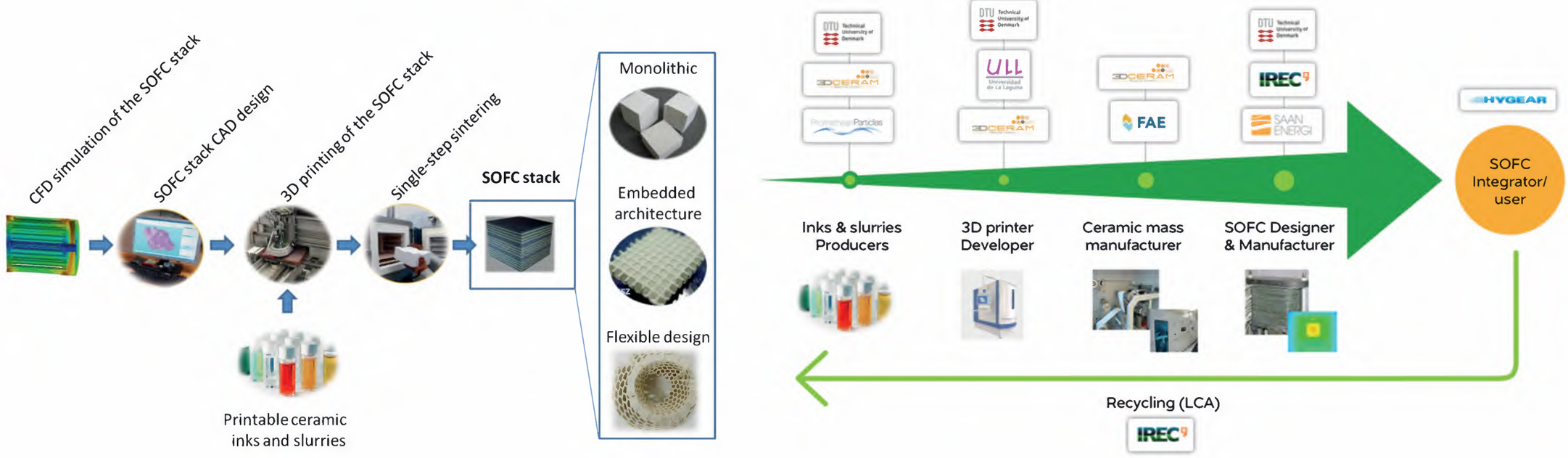
Relevant to FCH JU overarching objectives

- Increase the electrical efficiency and the durability of the different fuel cells used for power production to levels which can compete with conventional technologies, while reducing costs
- Reduce the use of the EU defined 'Critical raw materials', for instance through low-platinum or platinum-free resources and through recycling or reducing or avoiding the use of rare earth elements

Quantitative targets and status

Target Source	Parameter	Unit	Starting point	Target for project	Achieved to date in project	Best est. of final project result	Target: status on May 1st 2017	Description
AIP 2015	Cost	€/W	0.33	0.12		0.12	Due later	Target is cost reduction of min. 50% vs SoA
AIP 2015	Time to market	years	1	0.1		0.5	Due later	Shape customization is inherent to the technology
AIP 2015	Nr fabrication steps		60	2		2	Due later	Two steps: printing and sintering
MAWP 2014-2020	Reduce the use of "critical raw materials"	% reduction	100	80		60	Due later	Thickness reduction of interconnect and anode





FUEL CELLS AND HYDROGEN JOINT UNDERTAKING

EG-04-17-700-EN-P

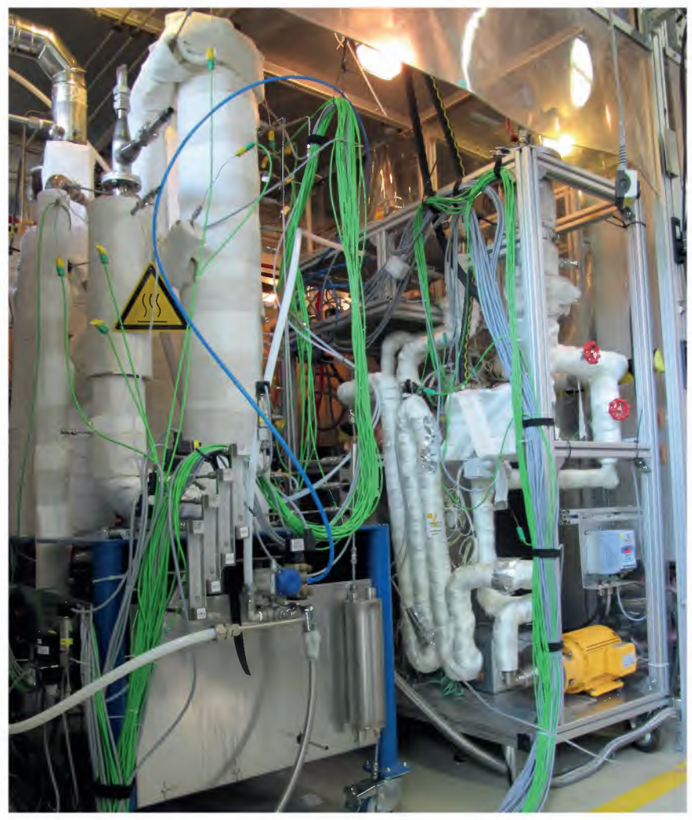
CISTEM
Construction of Improved HT-PEM MEAs and Stacks for long term stable modular CHP units

Panel 4 — Research activities for stationary applications

Acronym:	**CISTEM**
Project ID:	325262
Title:	Construction of Improved HT-PEM MEAs and Stacks for long term stable modular CHP units
Call Topic:	SP1-JTI-FCH.2012.3.1 &SP1-JTI-FCH.2012.3.5
Project total costs (€):	€ 6,1 million
FCH JU maximum contribution (€):	€ 4,0 million
Project start/end:	01 Jun 2013 - 30 Sep 2016
Coordinator:	Ewe-Forschungszentrum für EnergieTechnol., Germany
Beneficiaries:	Eisenhuth, Ici Caldaie, Inhouse Engineering, Owi Oel-Waerme Institut, Uni. Castilla - La Mancha, Danish Power System, Vysoka Skola Chemicko-Technologicka V Praze
Website:	http://www.project-cistem.eu/

Project and objectives

Key issue of CISTEM is the development of HT-PEM based 4 kW stack modules (including reformer) that are suitable for larger CHP systems up to 100 kWel. The modular concept will be investigated in a Hardware-in-the-Loop (HiL) test bench with one module physically installed and the others emulated by software. The development strategy starts on the single component level and rises up to the complete CHP system. So, R&D includes the most important components like Membrane-Electrode Assemblies (MEAs), bipolar plates, reformer system and the final CHP unit design with all necessary Balance-of-Plant (BoP) components. Project is finished.



Major project achievements

- Electrical efficiency of 46% under operation with hydrogen and 0.3 A/cm²
- Degradation rate of 3 µV/h at 0.3 A/cm² und hydrogen/air operation, extended long term test with runtime over 16000 hours
- Extended long-term test with runtime over 16000 hours

Future steps

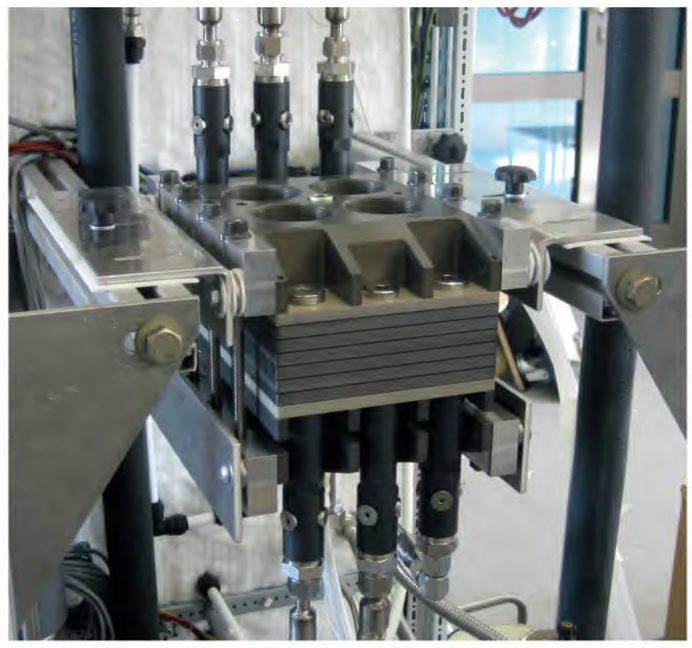
- Project finished

Quantitative targets and status

Target Source	Parameter	Unit	Starting point	Target for project	Achieved to date in project	Best est. of final project result	Target: status on May 1st 2017	Description
MAIP 2008-2013	Commercial application range 5-50 kW	kW	0.00	104.00	100.00		Achieved	HiL operation of complete CHP unit
MAIP 2008-2013	electrical efficiency	%	36	45	46		Achieved	
AIP 2012	degradation rate	µV/hr	6	4	3		Achieved	BoA MEAs with high durability
AIP 2012	lifetime	hr	10,000	20,000	40,000		Achieved	less than 3 µV/hr degradation rate

Relevant to FCH JU overarching objectives

- Reduce the production cost of fuel cell systems to be used in transport applications, while increasing their lifetime to levels which can compete with conventional technologies
- Increase the electrical efficiency and the durability of the different fuel cells used for power production to levels which can compete with conventional technologies, while reducing costs



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**
Project ID:	325368
Title:	Understanding the degradation mechanisms of a High Temperature PEMFCs Stack and optimization of the individual components
Call Topic:	SP1-JTI-FCH.2012.3.1 &SP1-JTI-FCH.2012.3.5
Project total costs (€):	€ 2,5 million
FCH JU maximum contribution (€):	€ 1,5 million
Project start/end:	01 May 2013 - 31 Oct 2016
Coordinator:	Foundation for Research and Technol. Hellas, Greece
Beneficiaries:	Advanced Energy Technol. Ae Ereunas & Anaptyxis Ylikon & Proiontonananeosimon Pigon Energeias & Synafon Symvouleftikon Y Piresion*Adven, Prototech, Elvio Anonymi Etaireia Systimaton Paragogis Ydrogonou Kai Energeias, Fundacion Cidetec, JRC -Joint Research Centre, European Commission, Vysoka Skola Chemicko-Technologicka V Praze
Website:	http://demstack.iceht.forth.gr/

Project and objectives

The activities of the DeMStack project were on the stack optimisation and construction based on the high temperature MEA technology of ADVENT S.A. and its long term stability testing.

The product of DeMStack is a 1kW HT PEMFC prototype stack integrated with a fuel processor. DeMStack aim was to enhance the lifetime and reduce the cost of the overall HT PEMFC technology by introducing improvements based on degradation studies and materials development that led to a reliable cost-effective product that fulfils all prerequisites for relevant field uses.

Major project achievements

- Robust MEAs with low Pt loading and excellent stability under harsh reformate feed
- Mathematical modelling assisted the efficient design of the bipolar plates and stack and can be used for the understanding of the MEA processes
- Design & manufacturing of HT PEMFC stack integrated with a fuel processor. Operation with natural gas with no degradation after >40 start-stop cycles

Future steps

- Project finished

Non-quantitative objectives and status

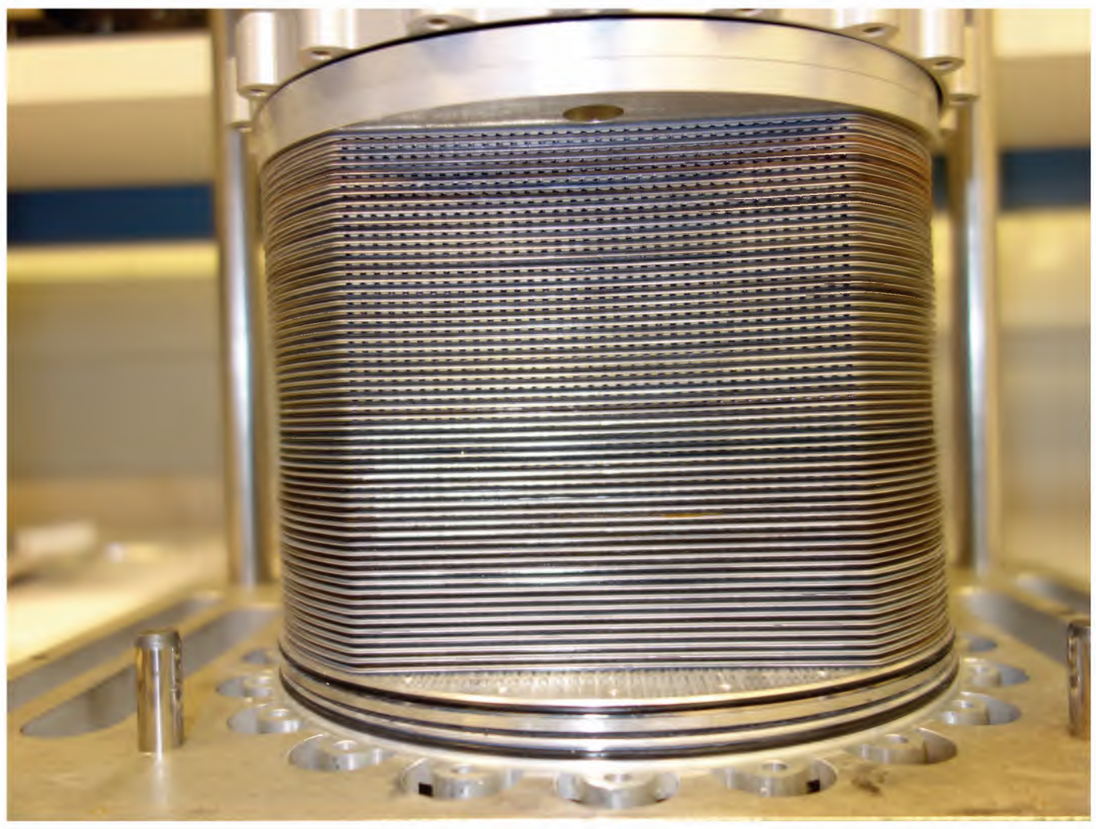
- Improving stack & cell designs.. components with improved performance
  Optimization of key MEA and stack components took place resulting in lower cost, ability to operate under reformate, higher performance and stability
- Construction of a fuel processor and fuel cell stack system prototype
  A unit (reformer-HT PEMFC) is constructed and operated with natural gas showing excellent stability; > 40 start-stop cycles with no degradation

Relevant to FCH JU overarching objectives

- Increase the electrical efficiency and the durability of the different fuel cells used for power production to levels which can compete with conventional technologies, while reducing costs

Quantitative targets and status

Target Source	Parameter	Unit	Starting point	Target for project	Achieved to date in project	Best est. of final project result	Target: status on May 1st 2017	Description
MAIP 2008-2013	Power output, small scale domestic 1 - 5 kW	kW		1	1	1	Achieved	Construction of 1 kW HT PEMFC, stacks from optimized components
Project's own	Nr units			1	1	1	Achieved	HT PEMFC operating on reformates at 180 °C
MAIP 2008-2013	Cost	€/kW		3,000	2,000	2,000	Achieved	Estimate for industrial/commercial units @ mass production
AIP 2012	Electrical efficiency	%		35-45	45	45	Achieved	Electrical efficiency at 180 degC under reformates: stack 47% LHV, system 45% LHV
AIP 2012	Operational lifetime	months		30	4	4	Achieved	Target 20000 h- 30 months; 4-5 month testing in an accelerated basis (start-stop cycles) under reformate feed



FUEL CELLS AND HYDROGEN JOINT UNDERTAKING

EG-04-17-700-EN-P

DIAMOND
Diagnosis-aided control for S systems

Panel 4 — Research activities for stationary applications

Acronym:	**DIAMOND**
Project ID:	621208
Title:	Diagnosis-aided control for SOFC power systems
Call Topic:	SP1-JTI-FCH.2013.3.3
Project total costs (€):	€ 3,6 million
FCH JU maximum contribution (€):	€ 2,1 million
Project start/end:	01 Apr 2014 - 30 Sep 2017
Coordinator:	Hygear, The Netherlands
Beneficiaries:	Htceramix, VTT, VTT, Uni. Salerno, Commissariat à l'Energie Atomique et aux Energies Alternatives CEA, Inea Informatizacija Energetika Avtomatizacija Doo, Inst. Jozef Stefan
Website:	www.diamond-sofc-project.eu/about/

Project and objectives

The objective of the project is to contribute to SOFC systems reliability and durability through design and implementation of a hierarchical control system supported by fault diagnostic system on two different SOFC CHP systems, one conventional (DIAMOND C) and the other advanced (DIAMOND A). A thorough inventory of faults and failures, which might occur in SOFC CHP systems, has been made. Fault detection and isolation algorithms and advanced and supervisory control algorithms have been developed and implemented on both systems for validation.

Major project achievements

- Development and validation of soft sensors to determine the minimum and maximum stack temperature in the DIAMOND C system
- Development and validation of models for the DIAMOND A and DIAMOND C system
- Operation of the DIAMOND A system for over 2000 hours using standard control

Future steps

- Testing DIAMOND C system with advanced control
- Test DIAMOND A system using the advanced control, supervisory control and FDI algorithms

Non-quantitative objectives and status

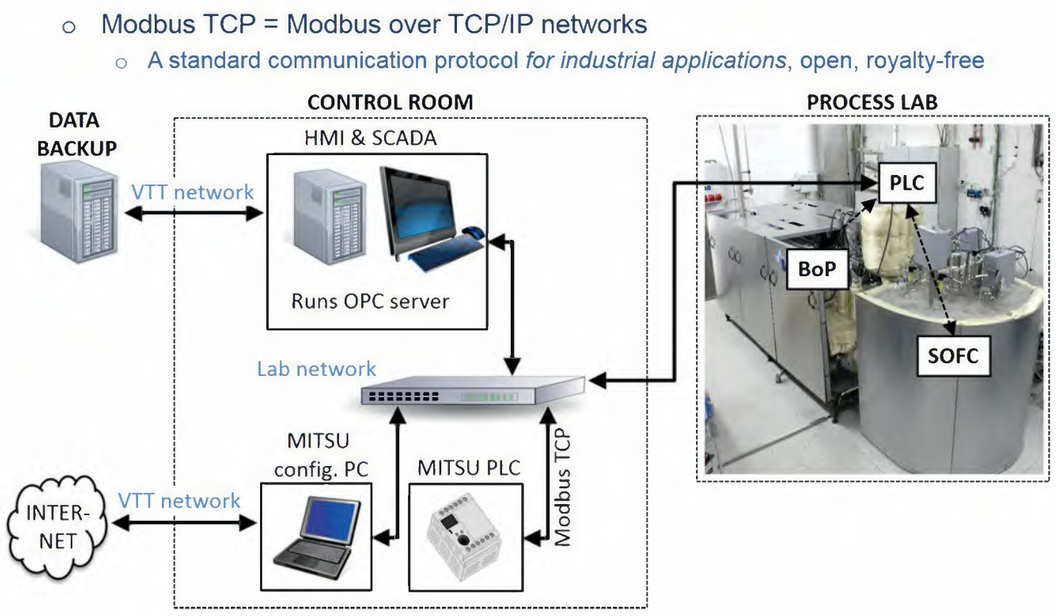
- Advanced diagnostics
  Dynamic system models have been developed in combination with the Fault Tree Analysis a FDI algorithms have been developed, and implemented
- Advanced diagnostics
  Soft sensors were developed and validated. THDA (Total Harmonic Distortion Analysis) has been validated for use with SOFC stacks
- Innovative control strategies
  Low-level feedforward-feedback control was designed and verified, and is implemented for system control;
- Supervisory control was designed and verified

Relevant to FCH JU overarching objectives

- Increase the electrical efficiency and the durability of the different fuel cells used for power production to levels which can compete with conventional technologies, while reducing costs

Quantitative targets and status

Target Source	Parameter	Unit	Starting point	Target for project	Achieved to date in project	Best est. of final project result	Target: status on May 1st 2017	Description
MAIP 2008-2013	lifetime	hrs		85,000		-	Due later	The advanced control is able to determine the system remaining useful life (RUL)
MAIP 2008-2013	Electrical efficiency	%		50		50	Due later	Efficiency not yet determined, will be determined using the Optimizer control



FUEL CELLS AND HYDROGEN JOINT UNDERTAKING

EG-04-17-700-EN-P

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

Panel 4 — Research activities for stationary applications

Acronym:	**ENDURANCE**
Project ID:	621207
Title:	Enhanced durability materials for advanced stacks of new solid oxide fuel cells
Call Topic:	SP1-JTI-FCH.2013.3.1
Project total costs (€):	€ 4,4 million
FCH JU maximum contribution (€):	€ 2,5 million
Project start/end:	01 Apr 2014 - 31 May 2017
Coordinator:	Uni. Genova, Italy
Beneficiaries:	Schott, Htceramix, Marion Technol., Solidpower, Uni. Di Pisa, Centre National de la Recherche Scientifique CNRS, Commissariat à l'Energie Atomique et aux Energies Alternatives CEA, Helmholtz-Zentrum Berlin fur Materialien und Energie, Ecole Polytechnique Federale de Lausanne, Fundacio Inst. De Recerca de L'Energia De Catalunya, Inst. of Electrochemistry and Energy Systems
Website:	http://www.durablepower.eu/index.php

Project and objectives

The focus of the project was to contribute to SOFC breakthrough marketing process by increasing the stack longevity without losing efficiency. To start from the state-of-art achievements with the purpose of reinvest the knowledge for the sake of technology, the consortium has a strong industrial core balanced by the scientific partners with the common goal to solve the most urgent issues and then to increase the life span of the SOFC stacks. The main strategy:

1) to improve the knowledge on degradation mechanisms
2) to refine the predictive models
3) to introduce interactive counteractions

Major project achievements

- Improved descriptive and predictive models: electrochemical behaviour, mechanical behaviour, degradation rate according to specific failures
- Positive effect of improved diffusion barrier in cells; introduction of improved glass-ceramic sealant in real stacks
- Realisation of the Serious Game "The Lost Colony: an Energy game" as a dissemination tool for schools about hydrogen and renewable energy

Future steps

- Project finished

Non-quantitative objectives and status

- Improved glass-ceramic as sealing material
  Completed. Two new formulations were selected out of 20 and applied to final short stacks for statistical validation
- Knowledge on electrodes and electrolytes evolution in operating cells
  Advances in the study of evolution of single elements and of interfaces between elements of a cell
- Introduction of advanced virtual research communication tools (VRIMS)
  Development and use of VRIMS products: Book of Samples; Knowledge Pool and Handbook of Experiments
- Advanced Testing Method: Intensive Active Tests and Analyses (IATA)
  Development and Application of IATA - successfully approbated on cells, stacks, modelling data; demonstrates increased sensibility towards degradation

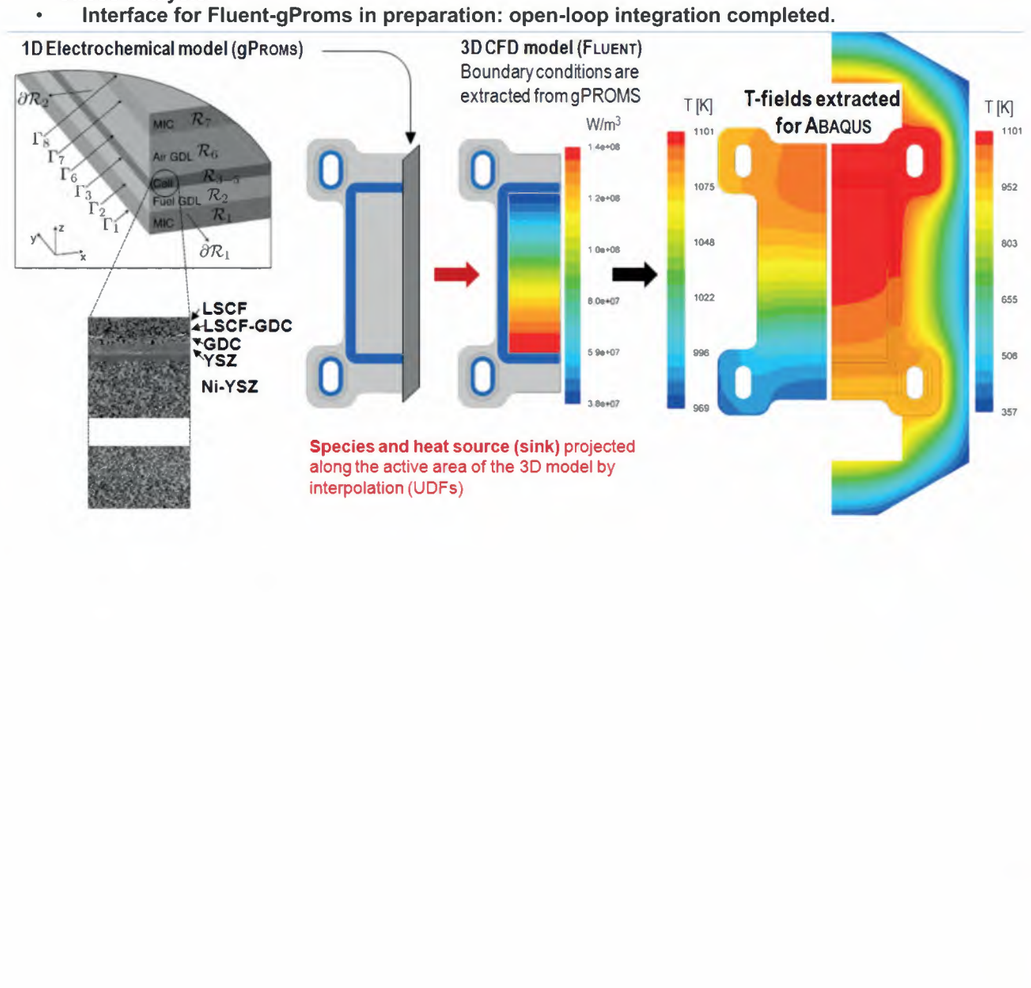
Relevant to FCH JU overarching objectives

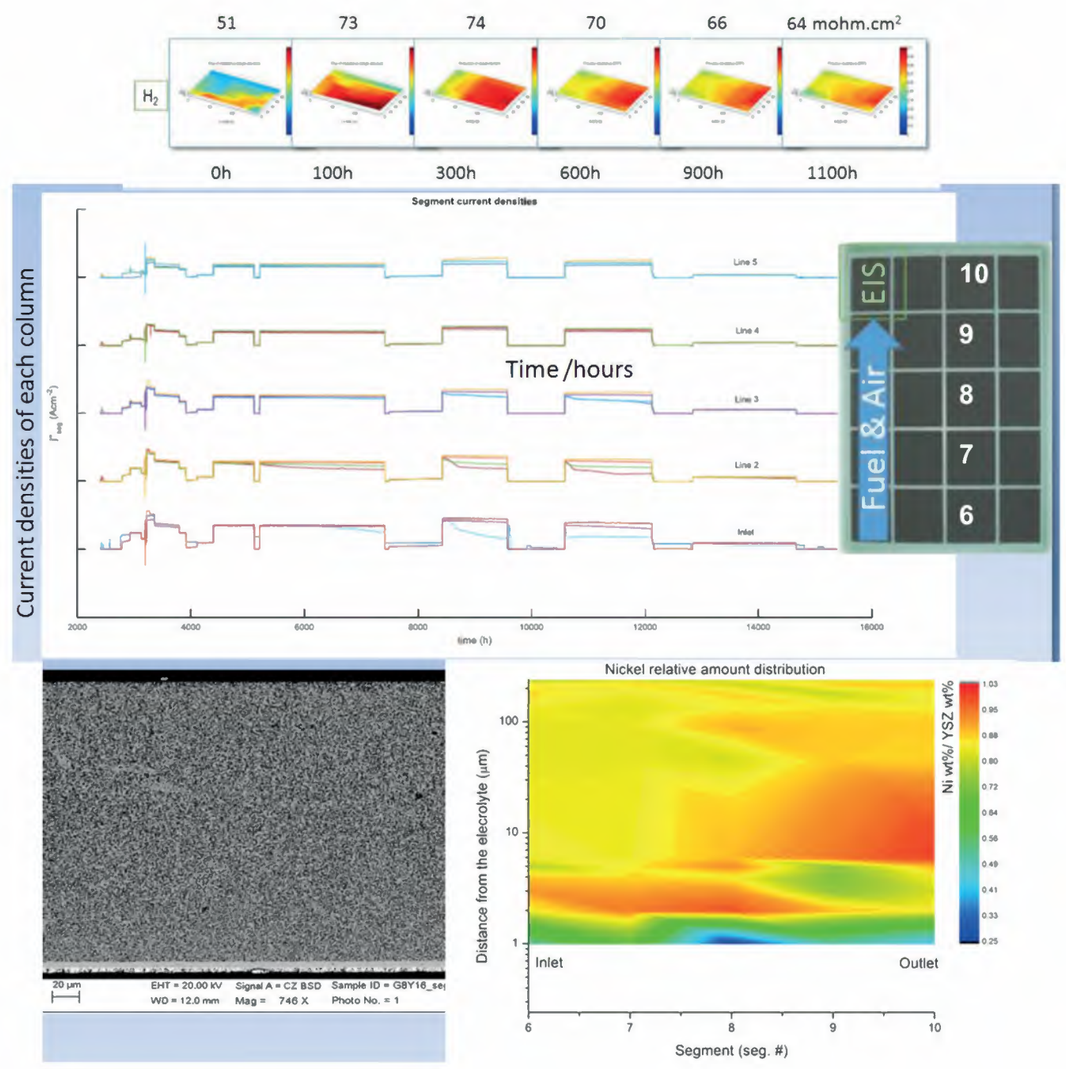
- Increase the electrical efficiency and the durability of the different fuel cells used for power production to levels which can compete with conventional technologies, while reducing costs
- Demonstrate on a large scale the feasibility of using hydrogen to support integration of renewable energy sources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

Quantitative targets and status

Target Source	Parameter	Target for project	Achieved to date in project	Best est. of final project result	Target: status on May 1st 2017	Description
AIP 2013	Failure Mode and Effects Analysis				Achieved	The FMEA was turned into Degradation Rate & Mode and Effects analysis. Literature and research data collected to reach an higher degree of awareness
AIP 2013	Nr thermal cycles	50	50	50	Achieved	Complete short stacks tested from room to operating temperature
AIP 2013	Nr of idle to load cycles	100	100	100	Achieved	Complete short stacks at operating temperature

- **Thermo-electrochemical stack simulations:**
  - **Rationale: computation of temperature profile with detailed geometry, e.g. the sealing region, for stress analysis.**
  - **Interface for Fluent-gProms in preparation: open-loop integration completed.**





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**
Project ID:	303429
Title:	Evolved materials and innovative design for high-performance, durable and reliable SOFC cell and stack
Call Topic:	SP1-JTI-FCH.2011.3.1
Project total costs (€):	€ 5,7 million
FCH JU maximum contribution (€):	€ 3,1 million
Project start/end:	01 Nov 2012 - 31 Jan 2017
Coordinator:	DLR, Deutsches Zentrum fuer Luft und Raumfahrt, Germany
Beneficiaries:	Alantum Europe, Ceraco Ceramic Coating, Ceramic Powder Technology, Saan Energi, Ass. pour la Recherche et le Developpement des Methodes et Processus Industriels - Armines, Consiglio Nazionale delle Ricerche CNR, Inst. Polytechn. Grenoble
Website:	http://www.evolve-fcell.eu/

Project and objectives

Beyond the state of the art, the EVOLVE cell concept aims at combining the beneficial characteristics of the previous cell generations, the so called ASC and MSC (anode-supported or metal-supported cells) while tackling key challenges like sulphur poisoning and redox stability. The innovation of the EVOLVE cell concept remains in its anode compartment avoiding the use of pure nickel as structural component. The substrate, providing mechanical strength to the fuel cell, is based on a robust metal alloy 3D porous backbone enhancing stability during re-oxidation cycles and an electronic conducting material based on perovskite oxides

Major project achievements

- Cell Architecture with processing route demonstrating significant power density demonstrated at Stack level
- Superior redox tolerance against state of the art anode supported cells demonstrated
- Technology at competitive cost compared to other High Temperature Fuel Cell technologies

Future steps

- Project finished

Non-quantitative objectives and status

- Next generation cell and stack
  Achieved: Novel architecture with breakthrough manufacturing route demonstrated

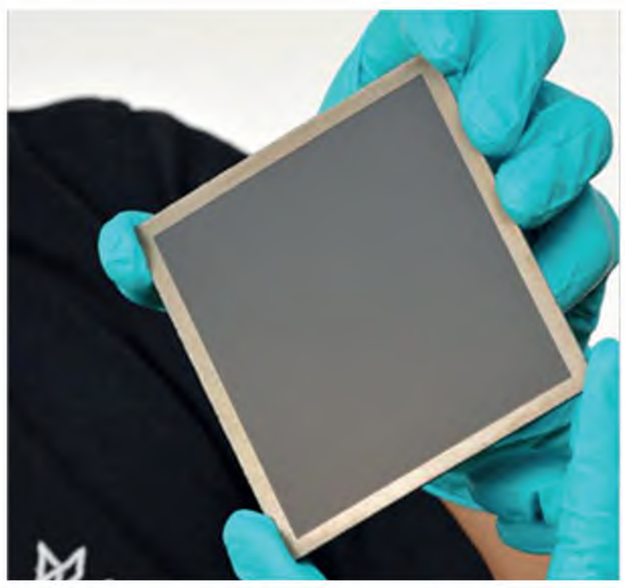
Relevant to FCH JU overarching objectives

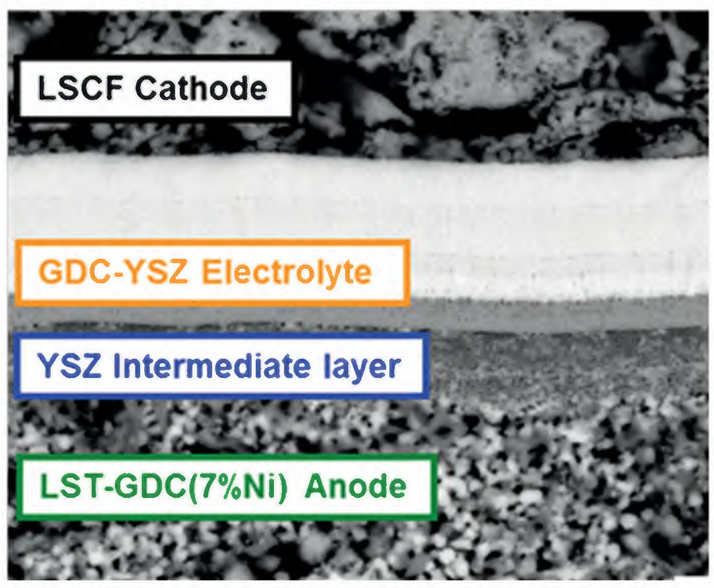
- Increase the electrical efficiency and the durability of the different fuel cells used for power production to levels which can compete with conventional technologies, while reducing costs

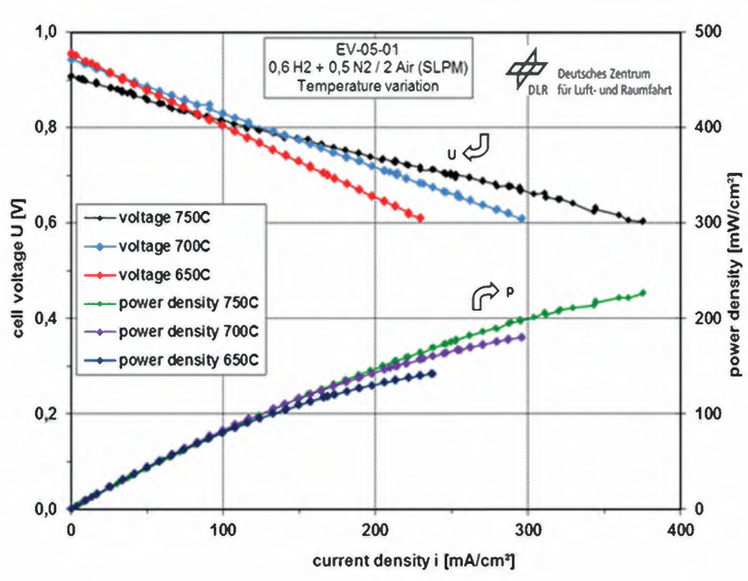
EG-04-17-700-EN-P

Quantitative targets and status

Target Source	Parameter	Unit	Starting point	Target for project	Achieved to date in project	Best est. of final project result	Target: status on May 1st 2017	Description
Project's own	Lifetime in terms of red-ox cycles	cycles	1	50	54	54	Achieved	Isothermal redox cycles (750°C) Cell voltage variation < 2%. Power Density at 0,7 V varied by 30% max.
AIP 2011	Materials consumption for the electrolyte	mg/cm²	20	5	3	3	Achieved	1.2mg/cm² of yttria stabilised zirconia + 1.5mg/cm² of gadolina doped ceria
MAIP 2008-2013	Degradation rate of cell voltage s	% / 1000 h	1	0.25	30	30	Not achieved	Need to mature the architecture and understand the degradation processes. Not achievable in the frame of the project







FERRET
A flexible natural gas membrane reformer for m-CHP applications

Panel 4 — Research activities for stationary applications

Acronym:	**FERRET**
Project ID:	621181
Title:	A flexible natural gas membrane reformer for m-CHP applications
Call Topic:	SP1-JTI-FCH.2013.3.3
Project total costs (€):	€ 3,2 million
FCH JU maximum contribution (€):	€ 1,7 million
Project start/end:	01 Apr 2014 - 31 Mar 2017
Coordinator:	Tech. Uni. Eindhoven, The Netherlands
Beneficiaries:	Hygear, ICI Caldaie, Johnson Matthey., Politec. Milano, Fundacion Tecnalia Research & Innovation
Website:	http://www.ferret-h2.eu/
Linkedin:	Membrane Reactors

Project and objectives

The FERRET project aimed at improving the technology based on membrane reactors and test a fully functional reactor for use in a μ-CHP unit suitable for different qualities of natural gas found across Europe.

FERRET objectives

- Design a flexible reformer in terms of catalyst, membranes and control for different natural gas compositions
- Use hydrogen membranes to produce pure hydrogen and help with shifting all the possible H_2 production reactions towards the desired products.
- Scale up the new H_2 selective membranes and catalyst production
- Introduce ways to improve the recyclability of the membrane

Major project achievements

- Novel catalyst produced for fluidised beds
- A new type of membrane has been produced and patented
- The fluidized bed membrane reactor system has been proven at TRL 5

Future steps

- Project finished

EG-04-17-700-EN-P

Quantitative targets and status

Target Source	Parameter	Unit	Starting point	Target for project	Achieved to date in project	Best est. of final project result	Target: status on May 1st 2017	Description
MAIP 2008-2013	Lower emissions and use of multiple fuels	%			100		Achieved	System flexible for different NG qualities
MAIP 2008-2013	Overall efficiency CHP units	%	80	90	80	80	Not achieved	Only reformer was functional
MAWP 2014-2020	Cost per system (1kWe + household heat).	€	20,000	5,000	5,500	5,500	Achieved	Cost could be achieved for mass production or slightly higher μ-CHP system sizes. With ceramic-supported membranes the cost is < the target
AIP 2013	Proof-of-Concept of CHP applications within laboratory.	TRL	3	5	5	5	Achieved	Prototype built and tested
AIP 2013	Durability	h	0	1000	300	300	Not achieved	
select	Length	cm	15	20	20	20	Achieved	

Non-quantitative objectives and status

- Novel catalyst for NG reforming in fluidized beds
- New types of membranes
  We have developed a new kind of membrane that is more resistant than the standard one. We have patented the new double skin membrane

Relevant to FCH JU overarching objectives

- Increase the electrical efficiency and the durability of the different fuel cells used for power production to levels which can compete with conventional technologies, while reducing costs

FUEL CELLS AND HYDROGEN JOINT UNDERTAKING

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**
Project ID:	621196
Title:	Advanced m-CHP fuel cell system based on a novel bio-ethanol fluidized bed membrane reformer
Call Topic:	SP1-JTI-FCH.2013.3.4 &SP1-JTI-FCH.2013.3.3
Project total costs (€):	€ 4,2 million
FCH JU maximum contribution (€):	€ 2,5 million
Project start/end:	01 Apr 2014 - 30 Apr 2017
Coordinator:	Fundacion Tecnalia Research & Innovation, Spain
Beneficiaries:	Hygear, ICI Caldaie, Politec. Milano, Tech. Uni. Eindhoven, Uni. Porto, Uni. Salerno, Commissariat à l'Energie Atomique et aux Energies Alternatives CEA, Quantis Sàrl
Website:	http://www.fluidcell.eu/

Project and objectives

The FluidCELL project aims at developing an advanced μ-CHP fuel cell system for decentralized off-grid applications. The new μ-CHP will be based on a novel bio-ethanol fluidised bed catalytic membrane reformer working at low temperature (≤ 500ºC) and the most advance technology at the fuel cell level.

Main progresses up to date:

- Catalyst & membranes for bio-ethanol reforming prototype developed
- Bioethanol steam reforming in a CMR under fluidisation validated at lab-scale and model validated
- Pilot scale reformer built (membranes should be integrated)
- Fuel cell stack prototype manufactured

Major project achievements

- Fluidised Bed Membrane Reactor concept validated at lab-scale (TRL 4). Phenomenological model validated.
- Prototype membrane reactor system built (membranes should be integrated in). Catalyst and membranes for prototype manufactured.
- Fuel cell stack manufactured

Future steps

- Prototype reactor final assembling, testing and validation
- Manufacturing the FC stack
- Proof of Concept of the novel μ-CHP system, integrating the new reactor prototype and FC stack with optimised BoP (at least 1000 h testing)
- Technical economic assessment and optimization of both reactors and complete system
- Life Cycle Analysis and safety analysis

Quantitative targets and status

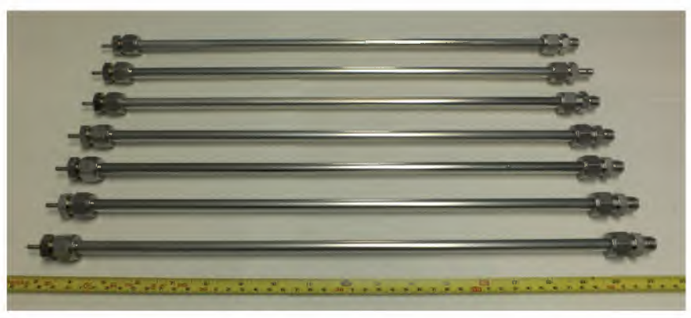
Target Source	Parameter	Unit	Starting point	Target for project	Achieved to date in project	Best est. of final project result	Target: status on May 1st 2017	Description
MAIP 2008-2013	Overall efficiency mCHP unit	%	80	90	NA	90	Due later	To be confirmed end of the project; simulations show it is possible to achieve this
MAIP 2008-2013	Cost per system (1kWe + household heat)	€	20,000	5,000			Due later	Cost could be achieved for mass production or slightly higher μ-CHP system sizes
AIP 2013	Durability in continuous operating	h	0	1000	0	1000	Due later	70,000 h operation on other μ-CHP. None of them have a CMR as reformer

Non-quantitative objectives and status

- Lower emissions and use of multiple fuels
  Bio-ethanol as fuel (instead of LPG or Diesel). Production of H_2 validated at lab-scale
- Novel catalyst for bio-ethanol reforming
  Catalyst for the prototype developed. Novel catalyst for bio-ethanol reforming under moderate conditions (<500ºC) and fluidisation has been developed
- Development of long (>15 cm) and mechanically stronger H_2-selective membrane
  Pd-based membranes developed onto 50 cm long thicker ceramic porous supports
- Membrane scale-up, processing issues
  40 membranes around 40 cm long 10/4 mm Out and Inner diameter have been manufactured
- Membrane reactor
  FBMR concept validated at lab-scale (TRL 4). Phenomenological model validated

Relevant to FCH JU overarching objectives

- Increase the electrical efficiency and the durability of the different fuel cells used for power production to levels which can compete with conventional technologies, while reducing costs
- Increase the energy efficiency of production of hydrogen mainly from water electrolysis and renewable sources while reducing operating and capital costs, so that the combined system of the hydrogen production and the conversion using the fuel cell system can compete with the alternatives for electricity production available on the market



FUEL CELLS AND HYDROGEN JOINT UNDERTAKING

EG-04-17-700-EN-P

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**
Project ID:	671486
Title:	Real operation PEM fuel cells HEALTH-state monitoring and diagnosis based on dc-dc COnverter embeddeD Eis
Call Topic:	FCH-02.3-2014
Project total costs (€):	€ 2,3 million
FCH JU maximum contribution (€):	€ 2,3 million
Project start/end:	01 Sep 2015 - 31 Dec 2018
Coordinator:	Uni. Salerno, Italy
Beneficiaries:	Bitron, Ballard Power Systems Europe, Electro Power Systems Manufacturing, Uni. Technol. Belfort Montbeliard, Uni. Franche-Comte, Aalborg Uni., Torino E-District Consorzio, Eifer Europaisches Inst. fur Energieforschung, Absiskey
Website:	http://pemfc.health-code.eu/

Project and objectives

HEALTH-CODE aims at improving and validating in emulated real operations an advanced monitoring and diagnostic tool capable of evaluating the state-of-health and extrapolating lifetime of Polymer Electrolyte Membrane Fuel Cell systems (PEMFCs). The focus of the project is related to µ-Combined Heat and Power and backup applications. The tool is based on the use of suitable data derived from Electrochemical Impedance Spectroscopy (EIS) measurements performed during systems operation. HEALTH-CODE also aims at reducing experimental campaign time and costs by means of innovative scaling-up methodology.

Major project achievements

- Completion of the first experimental campaign on both stack technologies with the measurements of about 1200 EIS spectra in normal and faulty states
- Design and preliminary testing of the Second Generation of the EIS board and the Low Voltage DC/DC converter
- Design and preliminary testing on project data of the different algorithms accounted for the Monitoring and Diagnostic Tool

Future steps

- Completion of the Second Experimental Campaign on both stack technologies and with respect to the remaining faults to be tested
- Delivery of High Voltage DC/DC converter and testing its functionalities as well as communication and performance with EIS board
- Improvement of diagnostic algorithms on new data from the project and thorough assessment of performances
- Testing of Scaling-up algorithm on whole project data for final performance assessment and validation
- Integration of designed power electronics, EIS board and diagnostic algorithm on systems and validation tests

Non-quantitative objectives and status

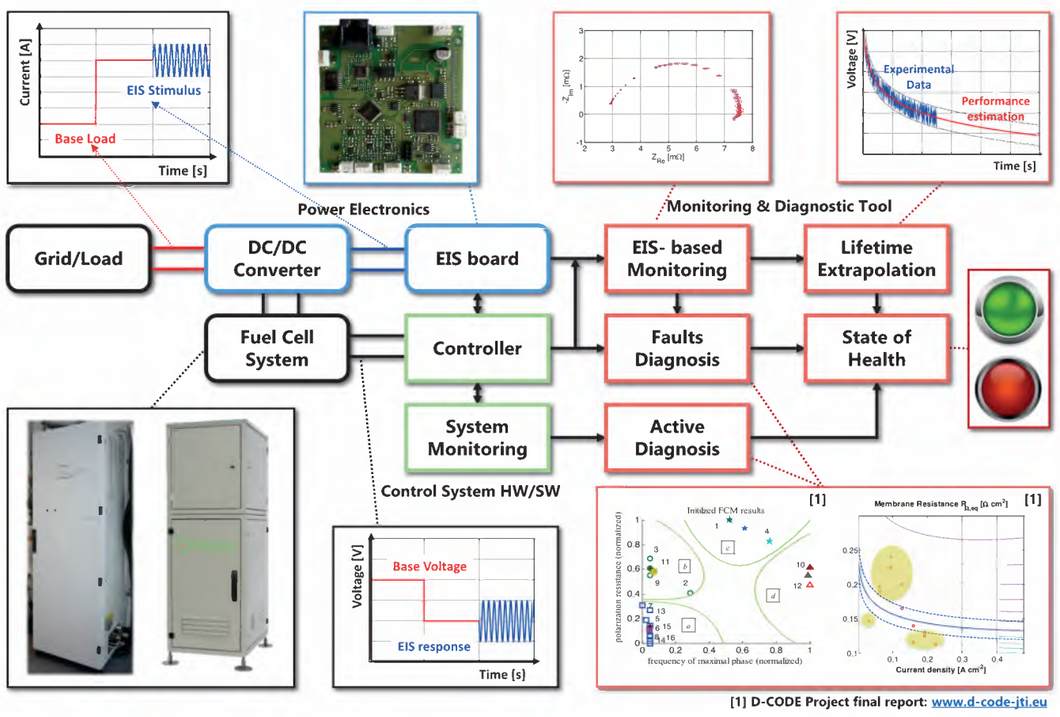
- Enhanced Monitoring and Diagnostic Tool for PEMFC systems
  Activities on time; first results achieved on data acquired in the project; further tests are ongoing upon availability of new data from the project
- EIS board cost <3% of the overall system manufacturing cost
  The final design of the EIS board fulfilled the requirement of cost being under the 3% of the overall cost of both residential and backup systems
- Backup system designed to be coupled with electrolyser
  The tests on O_2-fed backup system has been performed with respect to all the faults accounted in the project
- EIS to estimate features at cell level to monitor their time evolution
  Methodologies for State-of-Health and lifetime assessment have been designed and preliminary tested upon available project data

Relevant to FCH JU overarching objectives

- Increase the electrical efficiency and the durability of the different fuel cells used for power production to levels which can compete with conventional technologies, while reducing costs

Quantitative targets and status

Target Source	Parameter	Unit	Starting point	Target for project	Achieved to date in project	Best est. of final project result	Target: status on May 1st 2017	Description
MAWP 2014-2020	Efficiency	%	32	36	32	36	Due later	Proper fault diagnosis will reduce voltage decay over the working time.
MAWP 2014-2020	Durability	years	1.71	2.28	1.71	2.28	Due later	Proper fault diagnosis will reduce voltage decay over the working time.
MAWP 2014-2020	Availability	%	98	99	98	99	Due later	Increase in the mean time between failures



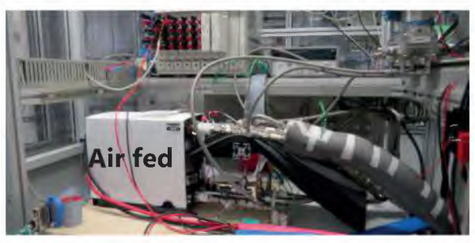
[1] D-CODE Project final report: www.d-code-jti.eu

EPS short stack @ UFC

EIS spectra acquired so far:
Around **1200**
of which **25% in nominal conditions** and **75% in faulty operations**

BPSE stack @ AAU

BPSE stack @ EIFER



FUEL CELLS AND HYDROGEN JOINT UNDERTAKING

EG-04-17-700-EN-P

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

Panel 4 — Research activities for stationary applications

Acronym:	**MATISSE**
Project ID:	621195
Title:	Manufacturing improved stack with textured surface electrodes for stationary and CHP applications
Call Topic:	SP1-JTI-FCH.2013.3.2
Project total costs (€):	€ 3,2 million
FCH JU maximum contribution (€):	€ 1,7 million
Project start/end:	01 Oct 2014 - 30 Sep 2017
Coordinator:	Commissariat à l'Energie Atomique et aux Energies Alternatives CEA, France
Beneficiaries:	Areva Stockage D'Energie, Inhouse Engineering, Nedstack Fuel Cell Technology, Zentrum fuer Sonnenenergie und Wasserstoff-Forschung, Baden-Wuertemberg
Website:	http://matisse.zsw-bw.de/general-information.html

Project and objectives

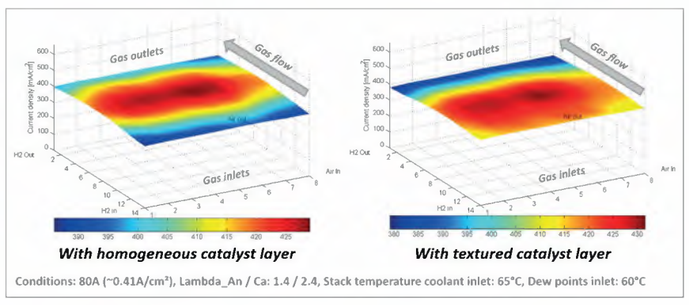
MATISSE is targeting the delivery of PEMFC advanced cells and stacks for stationary applications. Three fuel cell designs are addressed for specific operation i.e. H_2/O_2, H_2/Air and reformate H_2/Air. The methodology is based on the assessment of stacks with improved MEAs, including new compositions and processes developed to validate automated manufacturing. Performance, durability and heterogeneities of reference MEAs with homogeneous electrodes have been analysed before implementing MEAs with textured electrodes, allowing to modify the local operation of the cells and stacks behaviour.

Major project achievements

- Analysis of current distribution and improvement of cells performance by texturing the catalyst layers for 3 conditions (H_2 or Reformate/Air, H_2/O_2)
- Validated transfer to a fully automated process (screen-printing pilot line) for manufacturing large size electrodes of 3 different PEMFC designs
- Successful implementation of reference and textured MEAs showing targeted performance in all cases and expected durability under Reformate or H_2/Air

Future steps

- Complete performance and durability tests in short stacks with textured electrodes
- Validation of automated manufacturing of textured electrodes to be implemented in short or full stacks
- Validation of automated assembling with the MEAs for the full stacks and final tests
- Cost assessment for the different stacks with last selected type of electrodes and MEAs
- Description of automated stacking machine with analysis and feasibility of adaptation to different design



Quantitative targets and status

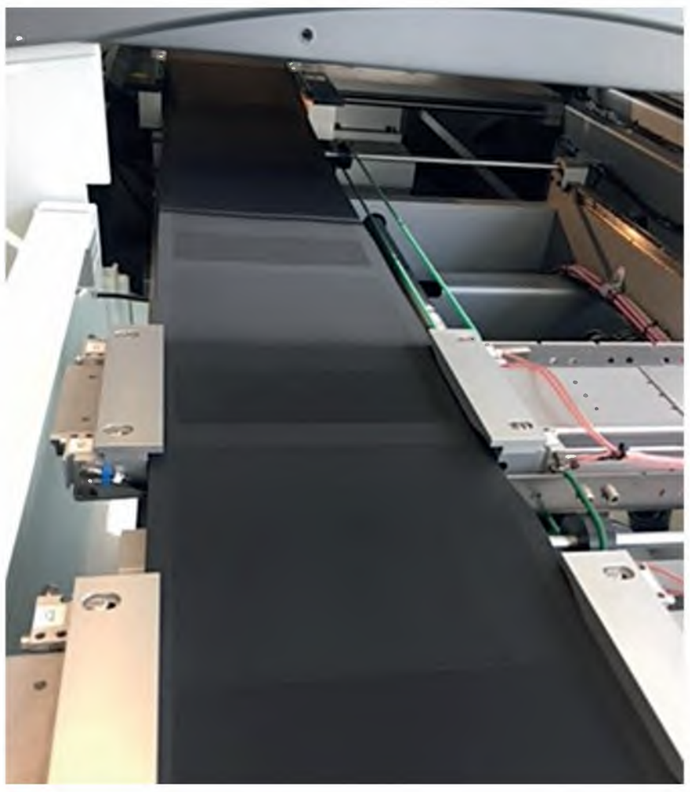
Target Source	Parameter	Unit	Starting point	Target for project	Achieved to date in project	Best est. of final project result	Target: status on May 1st 2017	Description
MAIP 2008-2013	Electrical efficiencies for power unit (μ-CHP reformate H_2/Air)	%	34	43			Not yet addressed	Improved performance at short stack level with reference MEAs and textured electrodes
MAIP 2008-2013	Electrical efficiencies for power unit (power plant H_2/air)	%	45	50			Not yet addressed	Improved performance at short stack level with reference MEAs and textured electrodes
MAIP 2008-2013	Electrical efficiencies for power unit (smart grid H_2/O_2)	%	45	47			Not yet addressed	Improved performance at short stack level with reference MEAs and textured electrodes
MAIP 2008-2013	lifetime for cells and stack (mCHP reformate/air)	hrs		40,000	10,000		Due later	Lower degradation rate in reformate /air case. Achieved: ≤10.000 h (based on decay rate of 15microV/h and power loss of 20%)
MAIP 2008-2013	lifetime for cells and stack (power plant H_2/air)	hrs		20,000			Due later	Lower degradation rate with improved electrodes under specific AST cycles H_2/Air ~ 350hrs and ~90μV/h
MAIP 2008-2013	lifetime for cells and stack (smart grid H_2/O_2)	hrs		40,000			Due later	durability of new MEAs to be tested
AIP 2013	Reduced stack components costs						Due later	Cost assessment to be done for final MEAs developed with textured electrodes and automated processes

Non-quantitative objectives and status

- Validate automated manufacturing of MEAs for cost reduction Electrodes by screen-printing pilot line successfully implemented in 3 stack designs for industrial applications (reformate or pure H_2/Air and H_2/O_2)
- Analysis of local operation for understanding and cells improvement In-situ analysis of current density distribution using segmented plates in specific performance and ageing conditions for 3 PEMFC technologies
- Develop textured electrodes to improve MEA performance and robustness Modified current distribution and improved cells behaviour demonstrated with non-homogeneous active layers in 3 types of short stacks
- Validation of new electrodes under specific ageing conditions MEAs tested on the long term (>4000hrs) under Reformate/Air or with AST cycles under H_2/Air reached expected degradation rates (15 or 90μV/h)

Relevant to FCH JU overarching objectives

- Increase the electrical efficiency and the durability of the different fuel cells used for power production to levels which can compete with conventional technologies, while reducing costs



EG-04-17-700-EN-P

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

Panel 4 — Research activities for stationary applications

Acronym:	**NELLHI**
Project ID:	621227
Title:	New all-European high-performance stack: design for mass production
Call Topic:	SP1-JTI-FCH.2013.3.2
Project total costs (€):	€ 2,8 million
FCH JU maximum contribution (€):	€ 1,6 million
Project start/end:	01 May 2014 - 30 Apr 2017
Coordinator:	ENEA, Agenzia Nazionale per le Nuove Tecnologie, l'Energia e lo Sviluppo Economico Sostenibile, Italy
Beneficiaries:	Borit, Clausthaler Umwelttechnik Inst., Aktsiaselts Elcogen, Sandvik Materials Technology, VTT, VTT, Elcogen, Flexitallic Ltd
Website:	http://www.nellhi.eu/

Project and objectives

NELLHI combines European know-how in single cells, coatings, sealing, and stack design to produce a novel modular 1 kW SOFC stack at reduced temperature, of unprecedented performance. The stack has been developed over 3 successive generations according to system integrators' requirements guided by an industrial advisory group. The target application of the development is stationary and residential 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.

Major project achievements

- Highest efficiencies achieved for SOFC operated below 700°C
- Cost reductions achieved by designing for mass manufacture and low-cost materials
- Advanced knowledge gained on cell processes, sealing materials and interconnect oxidation behaviour

Future steps

- Project finished

Non-quantitative objectives and status

- Improve capacity and maturity of all-European SOFC stack supply chain Industrial partners specializing in specific stack components have increased reliability, capacity and know-how

Relevant to FCH JU overarching objectives

- Increase the electrical efficiency and the durability of the different fuel cells used for power production to levels which can compete with conventional technologies, while reducing costs

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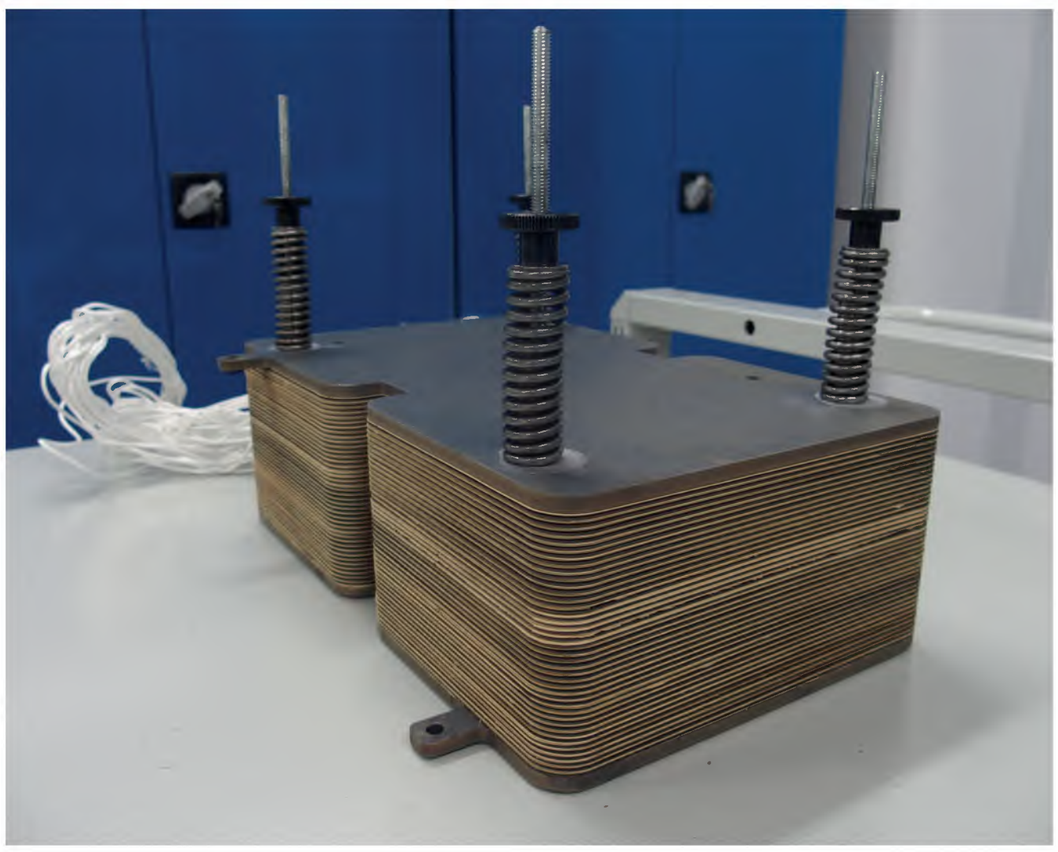
Quantitative targets and status

Target Source	Parameter	Unit	Starting point	Target for project	Achieved to date in project	Best est. of final project result	Target: status on May 1st 2017	Description
MAIP 2008-2013	Electrical efficiency	%	50	60	74	74	Achieved	Measured with natural gas for Elcogen 1 kW stack; Achieved thanks to: innovative stack design, high manufacturing quality and optimized operation
MAIP 2008-2013	Stack cost	€/kW	10000	1000	1000	1000	Achieved	At >50MW/year stack production volume
Project's own	Durability	h	2000	10000	10000	30000	Not achieved	projected through current measurement with natural gas for Elcogen 1 kW stack
Project's own	Leak rate	%	1.00	0.50	0.30	0.30	Achieved	After 10 thermal cycles
Project's own	fuel utilization capability	%	70	85	91	91	Achieved	Measured with H_2 Achieved thanks to innovative stack design
Project's own	manufacturing yield	%	90	95	97	97	Achieved	For stacks. Achieved thanks to innovative design allowing component imperfections
Project's own	voltage loss	%	1	0.50	0.60	0.60	Not achieved	After 10 thermal cycles.
Project's own	Cell cost	€/kW		300	280	280	Achieved	For cells these results were obtained after a series of experiments optimising all manufacturing process steps.
Project's own	interconnect cost	€/kW		200	290	290	Not achieved	At 100k pieces per year.
Project's own	manufacturing yield	%	90	95	95	96	Achieved	Achieved thanks to simplified design, optimized material, volume



PROGRAMME REVIEW DAYS 2017

FUEL CELLS AND HYDROGEN JOINT UNDERTAKING

PROSOFC
Production and reliability oriented SOFC cell and stack design

Panel 4 — Research activities for stationary applications

Acronym:	**PROSOFC**
Project ID:	621216
Title:	Production and reliability oriented SOFC cell and stack design
Call Topic:	SP1-JTI-FCH.2012.3.2
Project total costs (€):	€ 7,3 million
FCH JU maximum contribution (€):	€ 3,0 million
Project start/end:	01 May 2013 - 31 Oct 2017
Coordinator:	AVL List, Austria
Beneficiaries:	Danmarks Tek. Uni., Dynardo Austria, Forschungszentrum Julich, Htceramix, Imperial College Science Technol. and Medicine, Ecole Polytechnique Federale de Lausanne, Karlsruher Inst. Technol., JRC -Joint Research Centre, European Commission, Topsoe Fuel Cell
Website:	http://prosofc-project.eu/

Project and objectives

PROSOFC directly contributes to the FCH JU objectives "Improved cell and stack design and manufacturability for application specific requirements", with the following targets for stationary SOFC systems:

- lifetime > 40.000h
- electrical efficiency 55%+, total efficiency 85%+
- commercial cost target of 4000 EUR/kW

The aim of the project is to significantly improve the stack robustness and decrease costs.

Major project achievements

- Identification of most critical failure modes for the considered baseline SOFC stack design
- Evaluation and implementation of design enhancement to improve reliability and durability
- Creation of a methodological and tooling framework to be used in future projects

Future steps

- Long term stack testing
- Demonstration of the methodology by applying the sensitivity analysis (based on optSlang) on the stack models (e.g. of EPFL or AVL)
- Finalization of reliability calculation
- Material and cell tests

Non-quantitative objectives and status

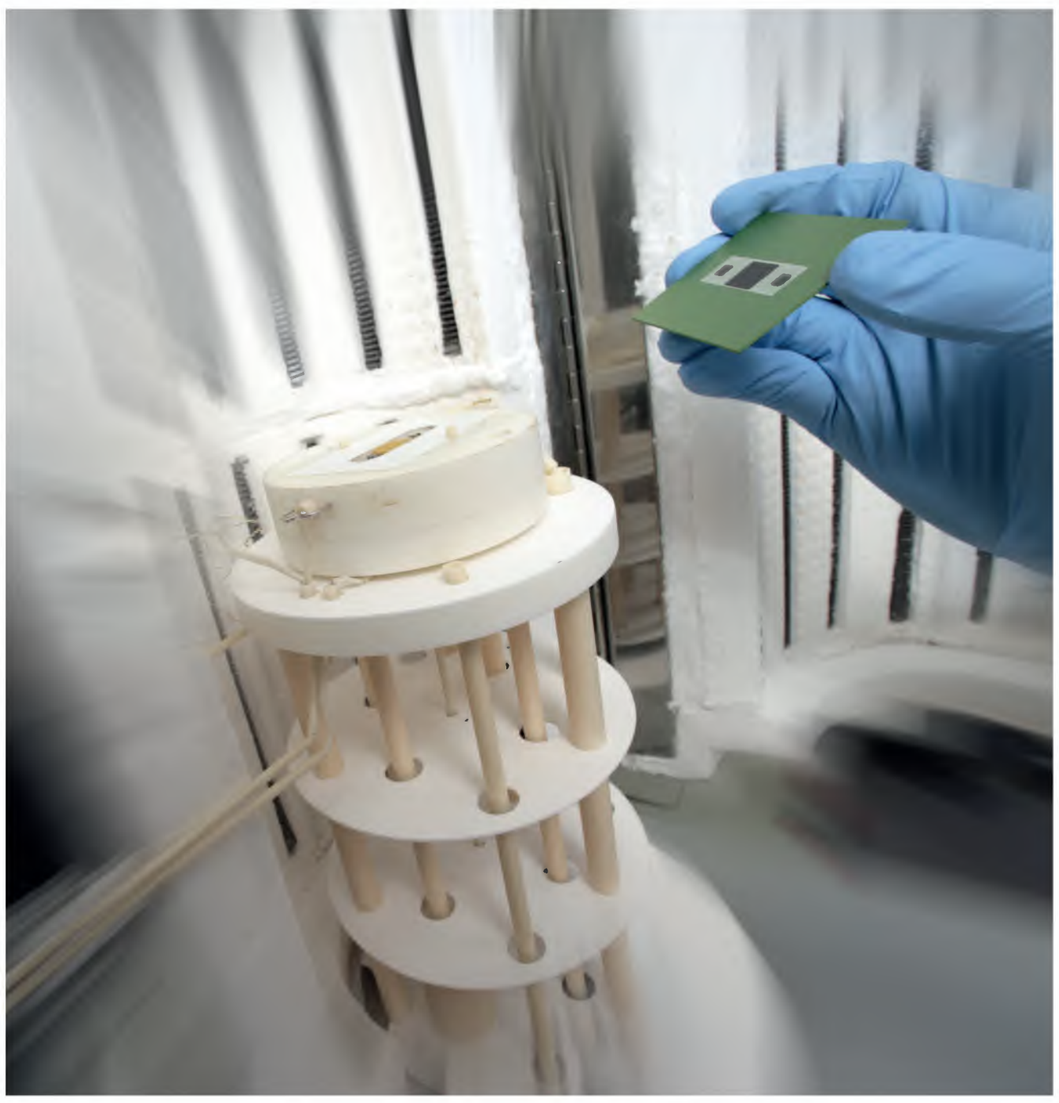
- Better robustness, better lifetime, improved manufacturing methods Major failure modes and sources identified (glass seal breakage/ delamination, loss of contact). Design alternatives proposed and implemented

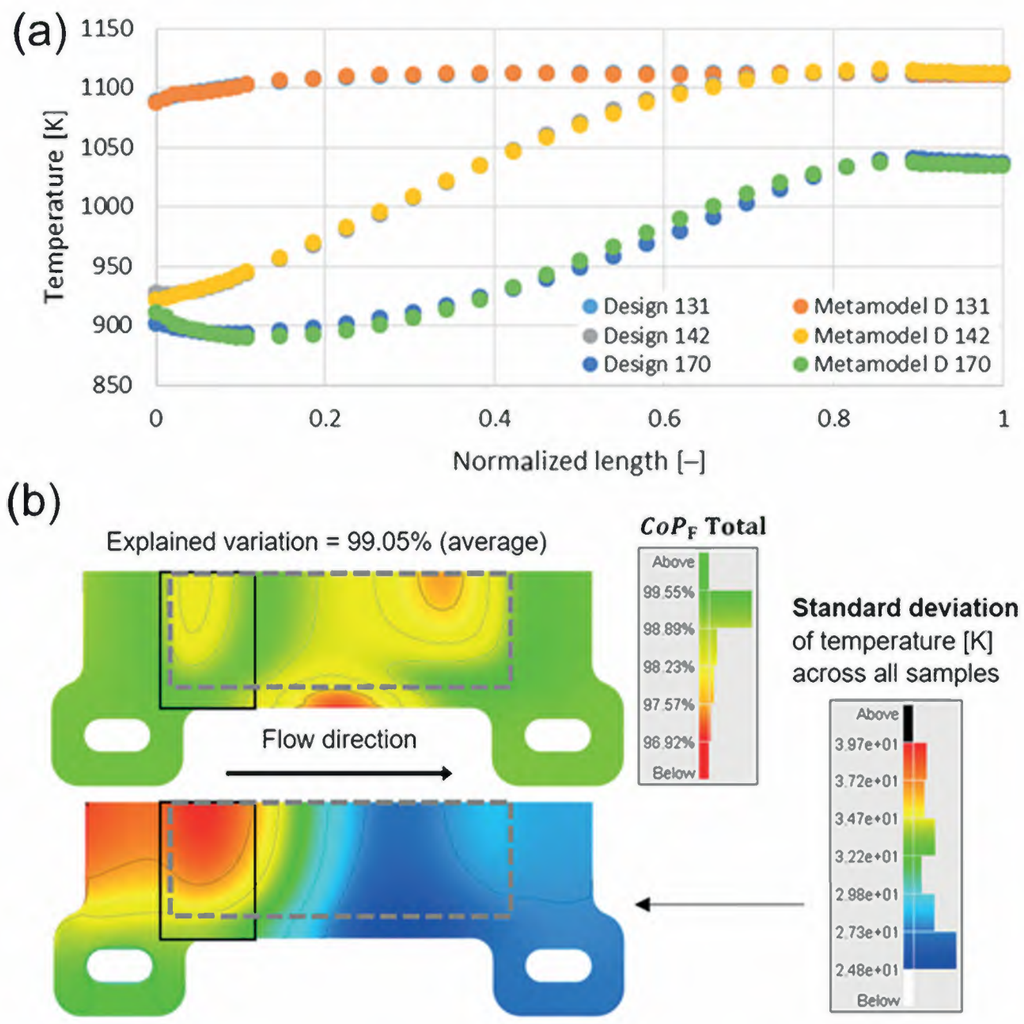
Relevant to FCH JU overarching objectives

- Increase the electrical efficiency and the durability of the different fuel cells used for power production to levels which can compete with conventional technologies, while reducing costs

Quantitative targets and status

Target Source	Parameter	Unit	Starting point	Target for project	Achieved to date in project	Best est. of final project result	Target: status on May 1st 2017	Description
MAIP 2008-2013	Electrical efficiency (SOFC system)	%	45	55	55	56	Achieved	Objective attained on the system, achieving 55% electrical efficiency net AC at 1.5kW
MAIP 2008-2013	Lifetime/Durability (SOFC System)	h	0	40,000	13,000	17,500	Due later	Durability mostly impacted by external factors (infrastructure and system). Robustness clearly improved thanks current project.
MAIP 2008-2013	Cost vs starting value (SOFC system)	%	100	50	50	40	Achieved	Cost reduction @ stack and system level.
MAIP 2008-2013	Improved manufacturing methods / Stack scrap rate: 5% by 2017	%	NA	95	88	92	Due later	Increasing quality requirements limit yield. Cost reduction efforts limit yield additionally on certain components (e.g. cells)
MAIP 2008-2013	Higher power density	W/cm²	0.32	0.30	0.32	0.32	Achieved	





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PROGRAMME REVIEW DAYS 2017

FUEL CELLS AND HYDROGEN JOINT UNDERTAKING

SCORED 2:0
Steel coatings for reducing degradation in SOFC

Panel 4 — Research activities for stationary applications

Acronym:	**SCORED 2:0**
Project ID:	325331
Title:	Steel coatings for reducing degradation in SOFC
Call Topic:	SP1-JTI-FCH.2012.3.4
Project total costs (€):	€ 3,8 million
FCH JU maximum contribution (€):	€ 2,2 million
Project start/end:	01 Jul 2013 - 30 Jun 2017
Coordinator:	Uni. Birmingham, United Kingdom
Beneficiaries:	ENEA, Agenzia Nazionale per le Nuove Tecnologie, l'Energia e lo Sviluppo Economico Sostenibile, Solidpower, Ecole Polytechnique Federale de Lausanne, VTT, VTT, Turbocoating, Teer Coatings Ltd
Website:	http://www.birmingham.ac.uk/research/activity/scored/index.aspx

Project and objectives

High temperature corrosion is a crucial problem in operating solid oxide fuel cell (SOFC) systems. In particular, the chromium poisoning of the air electrode (cathode) is recognised as one of more serious contributions to the performance degradation of SOFC devices. The project aimed at testing different coating materials and processes to apply protective coatings to stainless steel SOFC interconnects to reduce chromium release on cathode side interconnect surfaces. A succession of 5 generations of different coating materials were tested. The project ends in June 2017.

Major project achievements

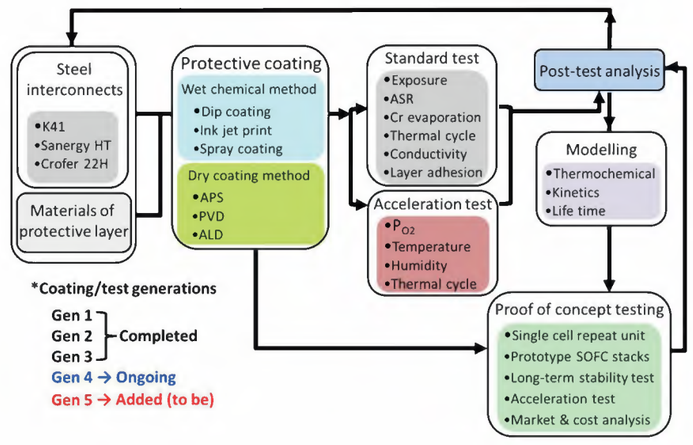
- Proof-of-concept stacks have been operated, one >11,000 hours, the second still ongoing to prove the effectiveness of coating and coating processes
- Degradation of G3 and G5 coatings lead to degradation rates <0.3%/kh
- Proof that several coating techniques will lead to satisfactory solutions

Future steps

- Project finished

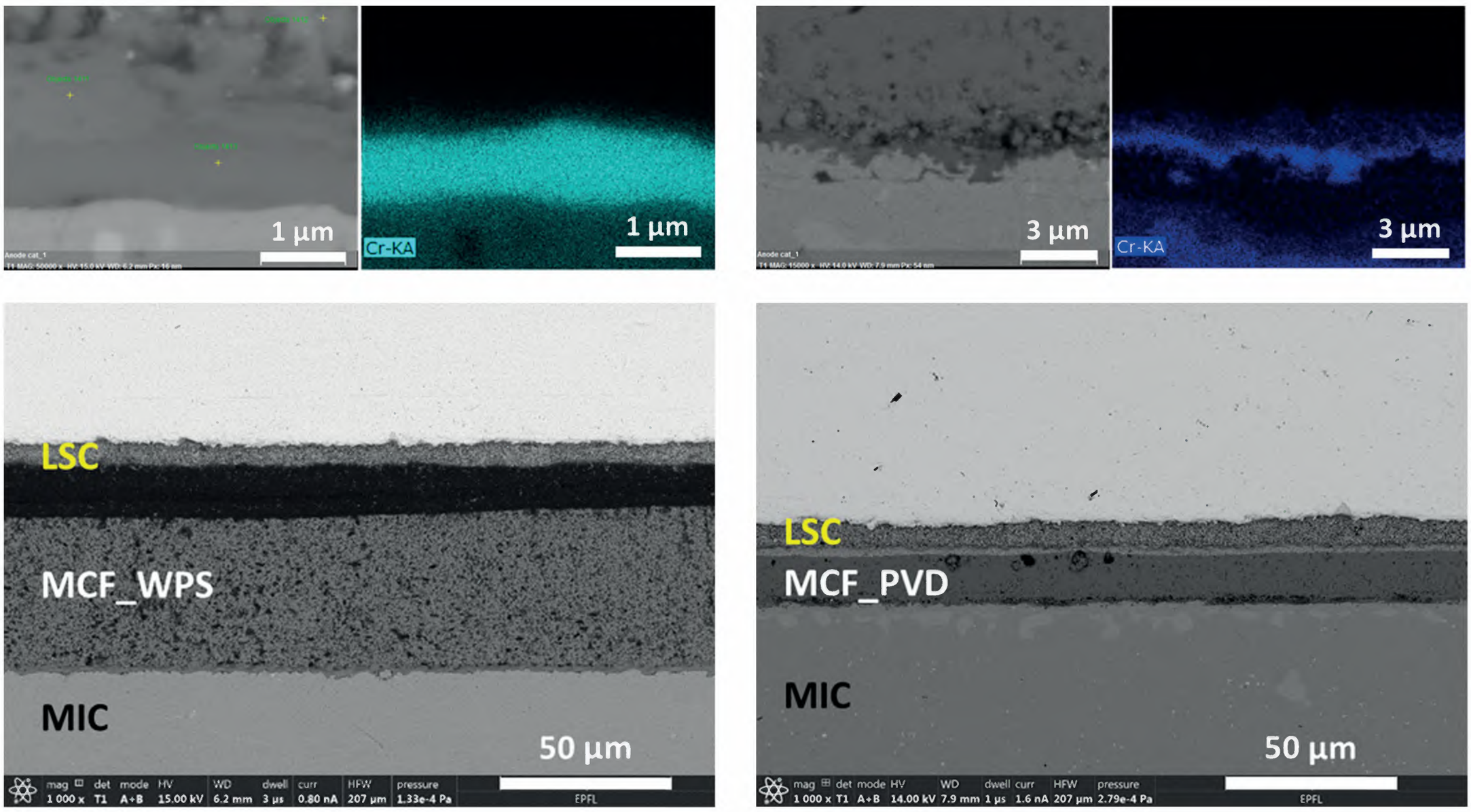
Relevant to FCH JU overarching objectives

- Reduce the production cost of fuel cell systems to be used in transport applications, while increasing their lifetime to levels which can compete with conventional technologies
- Increase the electrical efficiency and the durability of the different fuel cells used for power production to levels which can compete with conventional technologies, while reducing costs



Quantitative targets and status

Target Source	Parameter	Unit	Starting point	Target for project	Achieved to date in project	Best est. of final project result	Target: status on May 1st 2017	Description
Project's own	testing duration	hours	3,000	10,000	11,000	>11,000	Achieved	testing proof-of-concept stack
Project's own	ASR of protective layer	mΩ cm^2	40	40	40	40	Achieved	ASR better than pre-coated Sandvik steel



FUEL CELLS AND HYDROGEN JOINT UNDERTAKING

EG-04-17-700-EN-P

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**
Project ID:	325331
Title:	Simulation, statistics and experiments coupled to develop optimized and durable µCHP systems using accelerated tests
Call Topic:	SP1-JTI-FCH.2013.3.1
Project total costs (€):	€ 4,6 million
FCH JU maximum contribution (€):	€ 2,5 million
Project start/end:	01 May 2014 - 31 Oct 2017
Coordinator:	Commissariat à l'Energie Atomique et aux Energies Alternatives CEA, France
Beneficiaries:	DLR, Deutsches Zentrum fuer Luft und Raumfahrt, Ici Caldaie, EWII Fuel Cells, Nedstack Fuel Cell Technology, Politec. Milano, JRC -Joint Research Centre, European Commission, Tech. Uni. Graz, Stiftelsen Sintef
Website:	http://second-act.eu/

Project and objectives

Second Act is focused on degradation understanding and proposal of modified stack components for improved durability of PEM fuel cell systems operating under Hydrogen, Reformate, or Direct Methanol. Modelling and experimental characterisations during or post-ageing allowed to identify mechanisms and causes for reversible or non-reversible losses mainly related to the catalysts. New cathode catalyst and catalyst layers made with various local compositions along the cells surface were implemented in cells or stacks and showed improved stability during long term or accelerated ageing tests.

Major project achievements

- Integration of a new cathode catalyst leading to reduced degradation rates for cells and stacks aged in the different conditions of the project
- Local data analyses and modelling allowed to define non-homogeneous active layers mitigating localized degradations & improving performance stability
- Successful modelling of non-reversible or reversible mechanisms allowing to simulate local operation within catalyst layers during ageing

Future steps

- Complete ageing tests on the long term with modified electrodes implemented in H_2 and reformate PEMFC stacks
- Finalize demonstration of improved stability for gradient DMFC MEAs at larger scale in real size cell
- Complete analyses of long term ageing data
- Complete validation of degradation models and related simulation of performance losses
- Complete post-ageing analyses on modified electrodes for further interpretation

Relevant to FCH JU overarching objectives

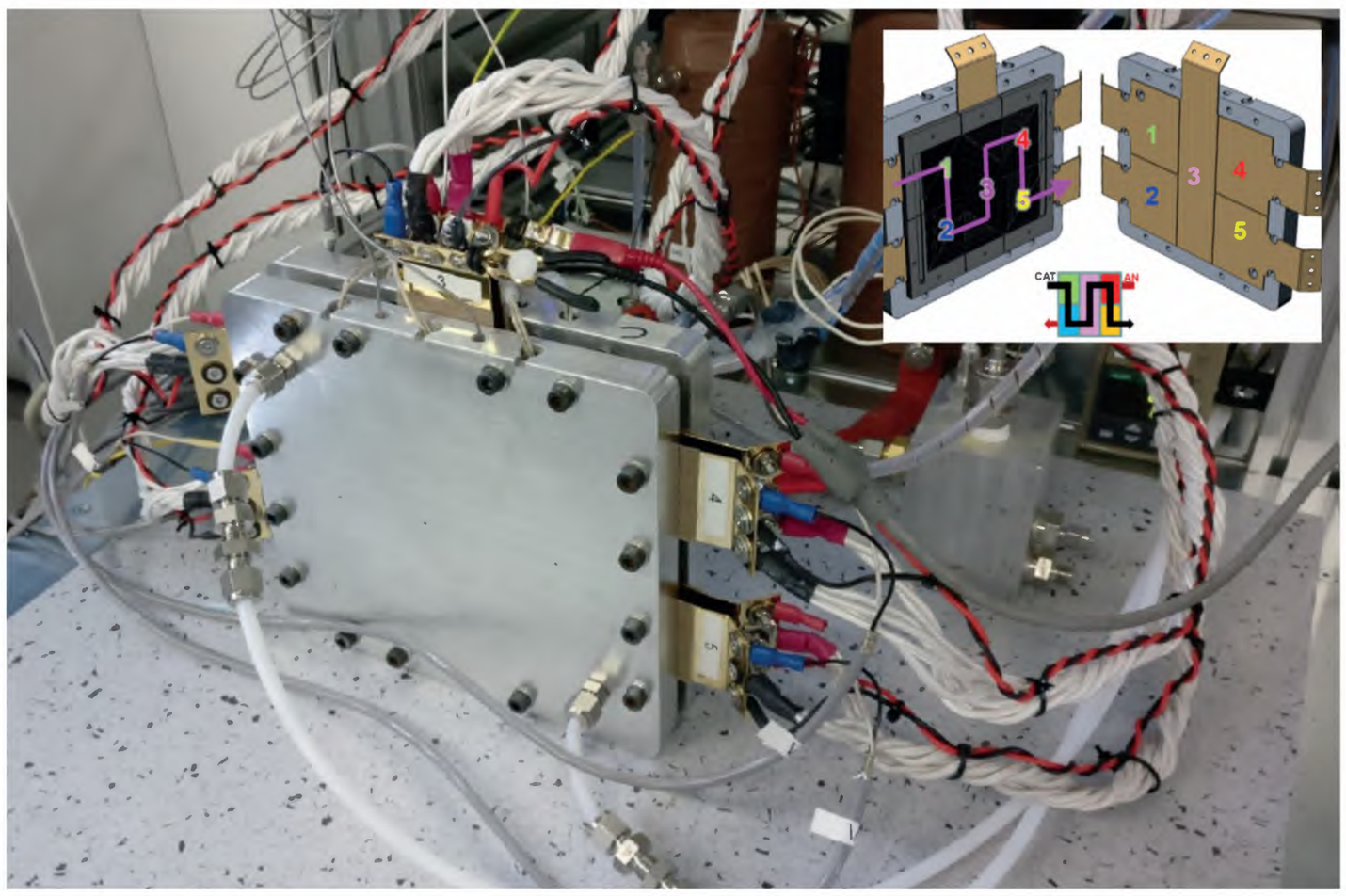
- Increase the electrical efficiency and the durability of the different fuel cells used for power production to levels which can compete with conventional technologies, while reducing costs
- Demonstrate on a large scale the feasibility of using hydrogen to support integration of renewable energy sources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

Quantitative targets and status

Target Source	Parameter	Unit	Starting point	Target for project	Achieved to date in project	Best est. of final project result	Target: status on May 1st 2017	Description
MAIP 2008-2013	~ 100 MW installed electric capacity	kW					Not yet addressed	outcomes are related to the operation and data exploitation of different stacks (more than 80kW total) + installation of one new system of 2-3kW
MAIP 2008-2013	Cost for micro CHP	€/kW		4000-5000			Not yet addressed	Cost reduction considered through improved durability with better stability and robustness of the fuel cells
MAIP 2008-2013	Cost for industrial / commercial units	€/kW		1500-2500			Not yet addressed	Cost reduction considered through improved durability with better stability and robustness of the fuel cells
AIP 2013	Long-term degradation observations	hrs	20,000	20,000	12,300	15,000	Due later	Focus was on the investigation of ref and modified MEAs aged on the long term, with specific or accelerated tests and comparing the degradation rates

Non-quantitative objectives and status

- Understanding of cell/stack degradation for H_2 & Reformate PEMFC; DMFC
  In-situ and post-ageing analyses on reference and modified components. Integration of mechanisms in cell models and validation of their impact
- Demonstrating improvements thanks to core components modifications
  Demonstration of less performance losses with new cathode catalyst and modified catalyst layers with non-homogeneous compositions along the surface
- Collection, production and analysis of ageing data (3 FC types)
  Ageing tests performed on several cells and stacks including continuous data collection and analysis of reversible and permanent losses vs conditions
- Quantification of mechanisms (experimental and models) & verification of improvement
  Application of selected accelerated or specific tests and mitigation strategies, for the assessment of mechanisms' impact and of modified electrodes



EG-04-17-700-EN-P

SOSLeM
Solid Oxide Stack Lean Manufacturing

Panel 4 — Research activities for stationary applications

Acronym:	**SOSLeM**
Project ID:	700667
Title:	Solid Oxide Stack Lean Manufacturing
Call Topic:	FCH-02.6-2015
Project total costs (€):	€ 2,9 million
FCH JU maximum contribution (€):	€ 2 million
Project start/end:	01 Apr 2016 - 31 Mar 2019
Coordinator:	Solidpower, Italy
Beneficiaries:	Greenlight Innovation, Htceramix, AVL List, Athena, Ecole Polytechnique Federale de Lausanne
Website:	www.soslem.eu

Project and objectives

SOSLeM aims at reducing manufacturing costs for SOFC stacks by about 70%, while at the same time making production more resource efficient and realising environmental benefits by:

- Optimising the production of SOFC cassettes by lean manufacturing processes, improved sealing adhesion and using automated anode contact layer laser welding
- Improving stack preparation by advanced glass curing, stack conditioning and improved gas stations
- Enabling environmental benefits by on-site nickel removal from wastewater
- Implementing a large furnace arrangement and a multi-stack production station

Major project achievements

- Reduction of manufacturing costs for stack production
- Enable of environmental benefits through removal of Co-based powder from the stack manufacturing process

Future steps

- Implementation of cassettes produced with new welding process
- SOFC stack conditioning with new stack qualification test station in SOLIDpower's production line

Quantitative targets and status

Target Source	Parameter	Unit	Starting point	Target for project	Achieved to date in project	Best est. of final project result	Target: status on May 1st 2017	Description
MAWP 2014-2020	Manufacturing costs for stack production	€/kW	4,500	981	3,108	1,500	Due later	This parameter summarises most of the activities of the SOSLeM project

Non-quantitative objectives and status

- Enable environmental benefits:
  - Replacement of Co-based powder
  - Evaluation of On-site Nickel removal from wastewater

Relevant to FCH JU overarching objectives

- Increase the electrical efficiency and the durability of the different fuel cells used for power production to levels which can compete with conventional technologies, while reducing costs