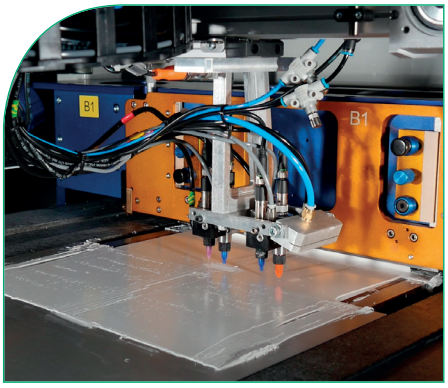
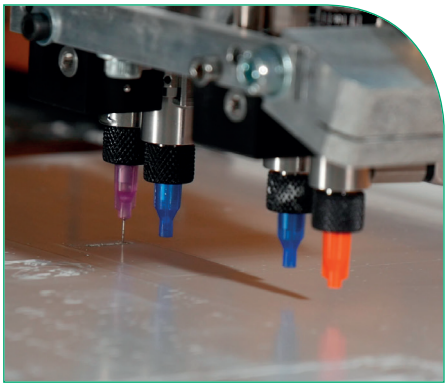
Cell3Ditor

COST-EFFECTIVE AND FLEXIBLE 3D PRINTED SOFC STACKS FOR COMMERCIAL APPLICATIONS

Project ID:	**700266**
Call topic:	**FCH-02.6-2015** - Development of cost effective manufacturing technologies for key components or fuel cell systems
Project total costs:	**€ 2,191,133.75**
FCH JU max. Contribution:	**€ 2,180,662.5**
Project start - end:	01/07/2016- 31/12/2019
Coordinator:	**FUNDACIO INSTITUT DE RECERCA DE L'ENERGIA DE CATALUNYA, ES**
Website:	**www.cell3ditor.eu**





BENEFICIARIES: 3DCERAM, DANMARKS TEKNISKE UNIVERSITET, FRANCISCO ALBERO SA, HyGear Fuel Cell Systems B.V., PROMETHEAN PARTICLES LTD, SAAN ENERGI AB, UNIVERSIDAD DE LA LAGUNA

PROJECT AND OBJECTIVES

The main goal of Cell3Ditor project is the development of a 3D printing technology for the industrial production of SOFC stacks. To achieve this, several intermediate steps have to be accomplished, including: formulation of printable inks and slurries of SOFC materials, development of a 3D printer for multi-material ceramics, fabrication of SOFC cell parts by 3D printing and two–step fabrication of joint-free 3D printed SOFC stack ready for integration in systems. Up to now, the project is matching the objectives with minor deviations due to the incorporation of a new fabrication technology.

NON QUANTITATIVE OBJECTIVES

- EHS issues due to utilization of nanometric raw materials
- Business plans looking for the commercialization of two outcomes of the project
- Dissemination in scientific, industrial and public forums
- Creation of an Industry Advisory Board focused on deployment and scalability of technology
- Evaluation of the investment and running costs of the technologies developed

PROGRESS & MAIN ACHIEVEMENTS

- Development of a multi-material ceramic 3D printing machine
- Formulation of printable inks and slurries of technical ceramic materials
- Fabrication of SOFC parts by 3D printing

FUTURE STEPS & PLANS

- Fabrication of complex design multi-material parts
- Fabrication of multi-material SOFC components
- Fabrication of SOFC stacks

RELEVANCE TO FCH JU OVERARCHING OBJECTIVES

Reduce the production cost of fuel cell systems to be used in transport applications

Although mainly thought for stationary applications, SOFC technology can be applied in transport sector as well. Actually, SOFC systems are the preferred solution for APUs in trucks and ships while Nissan has implemented a SOFC running on bioethanol. The technology developed in Cell3Ditor project presents a significant decrease of the CAPEX due to the elimination of fabrication stages and an increasing of the durability based on the removal of sealing.

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

The technology developed within Cell3Ditor project allow the fabrication of SOFC stacks without seals among the cells, decreasing one of the weakest points of such systems and increasing their durability.

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

SOFC systems fabricated by Cell3Ditor technology could be used in electrolysis mode. Therefore, reduction of CAPEX expected due to the original manufacturing process can be easily extended.

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

Cell3Ditor project is based on the manufacturing of SOFC stacks by additive manufacturing which implies a more efficient utilization of materials.

QUANTITATIVE TARGETS AND STATUS

State of the Art (SoA)*

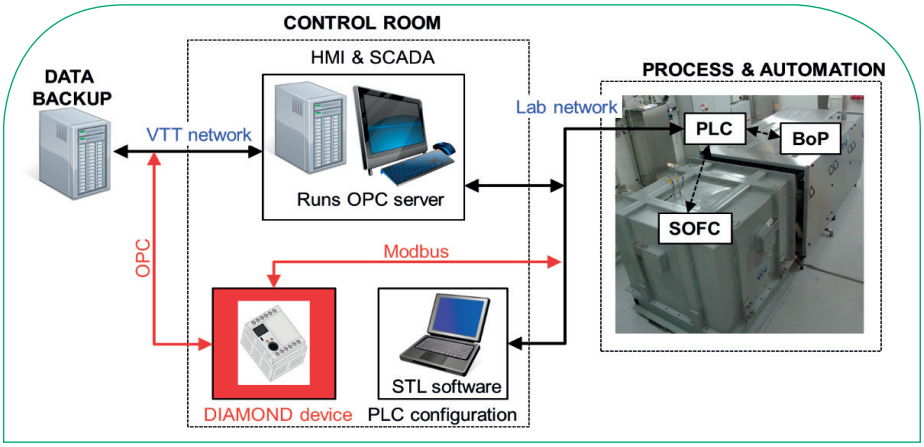
PARAMETER	UNIT	RESULT ACHIEVED TO DATE	SoA result achieved to date by other group/project (SoA Year)	SoA YEAR	SoA Source
Stack weight	kg	6.7	3.5	2017	From experience in reference commercial stack: (SOFCMAN-ASC 60-cell Stack Module)
Stack volume	litters	1.8	1	2017	
Stack nominal capacity	kW	5	5	2014	Manufacturing cost analysis of 1 kW and 5 kW Solid Oxide Fuel Cell (SOFC) for auxiliary power applications, Battelle for the US Department of Energy (DOE Contract No. DE-EE0005250), February 2014
Active area per cell	cm2	100	200	2014	

*** Available data provided by the Project**

DIAMOND

DIAGNOSIS-AIDED CONTROL FOR SOFC POWER SYSTEMS

Project ID:	621208
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
Project total costs:	€ 3,613,489.6
FCH JU max. Contribution:	€ 2,101,808
Project start - end:	01/04/2014 - 30/09/2017
Coordinator:	HYGEAR B.V., NL
Website:	www.diamond-sofc-project.eu/about



BENEFICIARIES: COMMISSARIAT A L ENERGIE ATOMIQUE ET AUX ENERGIES ALTERNATIVES, HTceramix SA, INEA INFORMATIZACIJA ENERGETIKA AVTOMATIZACIJA DOO, INSTITUT JOZEF STEFAN, TEKNOLOGIAN TUTKIMUSKESKUS VTT, Teknologian tutkimuskeskus VTT Oy, UNIVERSITA DEGLI STUDI DI SALERNO

PROJECT AND OBJECTIVES

The DIAMOND project aimed 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 have been developed integrating 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 have been validated using two different SOFC systems.

NON QUANTITATIVE OBJECTIVES

- Monitoring and diagnosis support the advanced control strategies to find the optimal values of the controller to be actuated on the system
- Diagnosis and control algorithms will be released for implementation into conventional hardware
- New diagnosis concepts will be introduced (e.g. backward residuals via inverse model)
- Improvement of the fault signature matrix will be achieved starting from the outcomes of the FCH-JU funded GENIUS and DESIGN projects
- Monitoring and diagnosis will support the control algorithms in adapting its parameters according to the actual system status reducing the risk of faults

PROGRESS & MAIN ACHIEVEMENTS

- Advanced control strategies to find the optimal operating point implemented and validated
- A procedure to estimate the remaining useful life has been developed and validated
- System models have been developed and validated

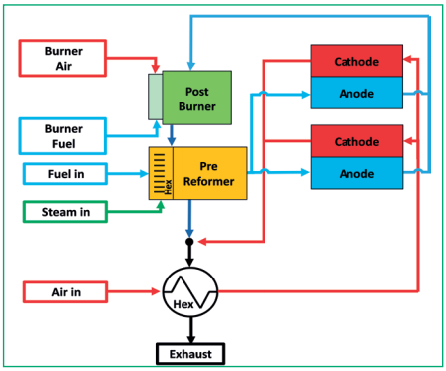
FUTURE STEPS & PLANS

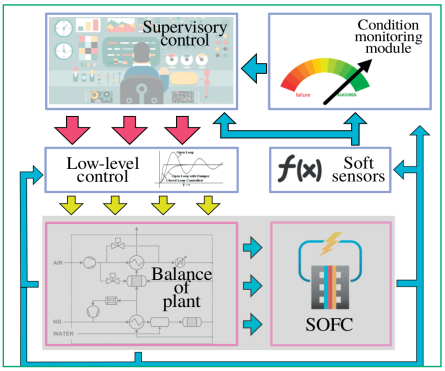
Project is finished

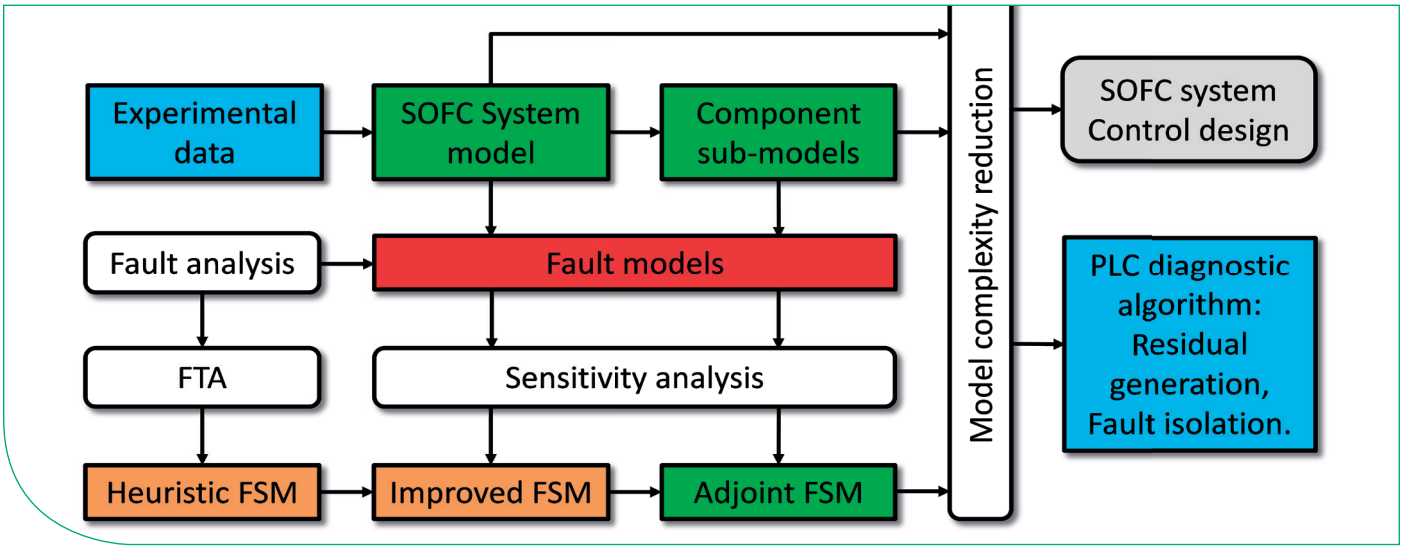
RELEVANCE TO FCH JU OVERARCHING OBJECTIVES

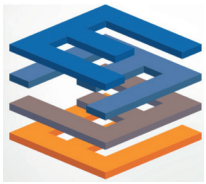
Increase the electrical efficiency and the durability of the different fuel cells

Diagnostics and monitoring of systems will improve durability.





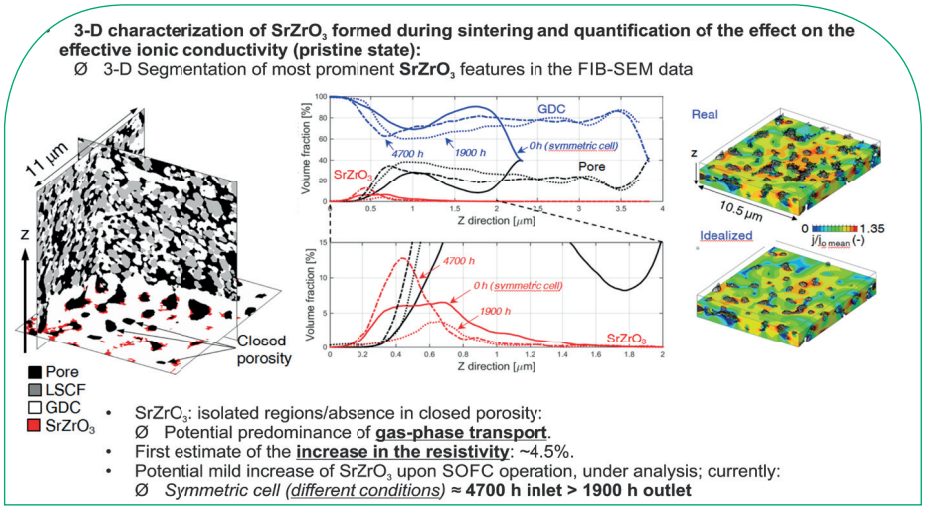




Endurance

ENHANCED DURABILITY MATERIALS FOR ADVANCED STACKS OF NEW SOLID OXIDE FUEL CELLS

Project ID:	**621207**
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
Project total costs:	**€ 4,256,293.61**
FCH JU max. Contribution:	**€ 2,556,232**
Project start - end:	01/04/2014 - 31/05/2017
Coordinator:	**UNIVERSITA DEGLI STUDI DI GENOVA, IT**
Website:	**www.durablepower.eu/index.php**



BENEFICIARIES: CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE, COMMISSARIAT A L ENERGIE ATOMIQUE ET AUX ENERGIES ALTERNATIVES, DEUTSCHES ZENTRUM FUER LUFT - UND RAUMFAHRT EV, ECOLE POLYTECHNIQUE FEDERALE DE LAUSANNE, FUNDACIO INSTITUT DE RECERCA DE L'ENERGIA DE CATALUNYA, HTceramix SA, INSTITUTE OF ELECTROCHEMISTRY AND ENERGY SYSTEMS, MARION TECHNOLOGIES S.A., SCHOTT AG, SOLIDPOWER SPA, UNIVERSITA DI PISA

PROJECT AND OBJECTIVES

The project ended up on May 2017. The main objectives of the project were:

- to contribute to the understanding of the degradation phenomena of the cells (SOFC) and of the stacking materials under operation in relationship with the steady state, the thermal cycles (up to 50), the idle to load cycles (up to 100)
- to refine the descriptive and predictive models at micro and macro level
- to introduce improvements at cella and stacking level in order to decrease the degradation rate

NON QUANTITATIVE OBJECTIVES

- D4.1: Handbook of testing procedures and protocols
- D8.1: Proceedings of the workshop « Degradation Mechanisms in Solid Oxide Cell and Systems »
- Serious Game « The lost colony »
- Public website

PROGRESS & MAIN ACHIEVEMENTS

- Degradation rate In Steam reforming Methane lower than 0.1% each 1000h (0.03%/1kh), achieved 100%
- Fully operating Joined thermomechanical and Electrochemical for micro and macro behaviours of SOFC stacks. Achievement 100%
- Idle to Load 100 cycles with contained losses (<4 mW/Icycle). Achievement 100%

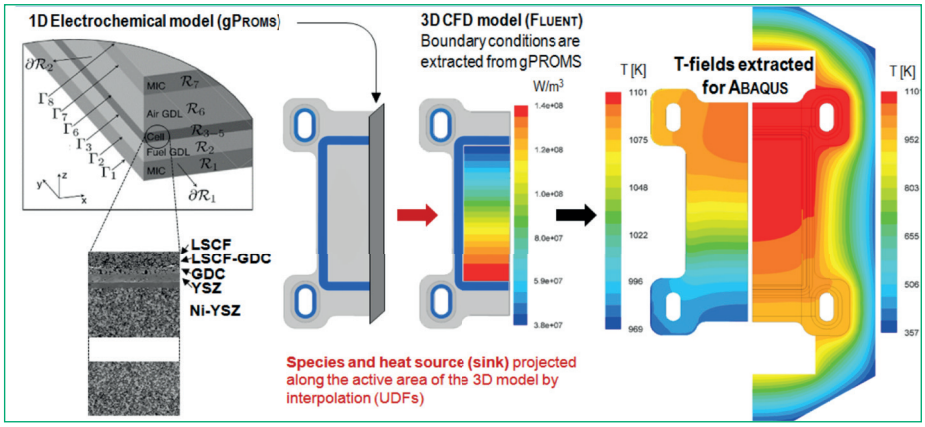
FUTURE STEPS & PLANS

Project is finished

RELEVANCE TO FCH JU OVERARCHING OBJECTIVES

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

The project contributed to lower the degradation rate in steady state and cycling conditions.



QUANTITATIVE TARGETS AND STATUS

FCH JU Programme Targets *

PARAMETER	UNIT	RESULT ACHIEVED TO DATE	TARGET	TARGET ACHIEVED?
Stack durability	hours	50,000	50,000	✓
Stack availability	%	100	97	✓
Stack electrical efficiency (LHV) - observed	%	50	42-60	✓
Degradation rate	%/kh	0.2	<0.2	✓

*** As identified in MAWP Addendum 2018-2020 and AWP 2017, Target year 2020**

FluidCELL

ADVANCED M-CHP FUEL CELL SYSTEM BASED ON A NOVEL BIO-ETHANOL FLUIDIZED BED MEMBRANE REFORMER

Project ID:	621196
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
Project total costs:	**€ 4,193,548.92**
FCH JU max. Contribution:	**€ 2,492,341**
Project start - end:	01/04/2014 - 31/07/2018
Coordinator:	**FUNDACION TECNALIA RESEARCH & INNOVATION, ES**
Website:	**www.fluidcell.eu**

BENEFICIARIES: COMMISSARIAT A L ENERGIE ATOMIQUE ET AUX ENERGIES ALTERNATIVES, HyGear B.V., ICI CALDAIE SPA, POLITECNICO DI MILANO, Quantis Sàrl, TECHNISCHE UNIVERSITEIT EINDHOVEN, UNIVERSIDADE DO PORTO, UNIVERSITA DEGLI STUDI DI SALERNO

PROJECT AND OBJECTIVES

FluidCELL aims at developing an advanced m-CHP fuel cell system for decentralized off-grid applications. The new m-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 fluidised bed membrane reformer validated at lab-scale & model validated
- Pilot scale reformer & fuel cell stack built & Factory Acceptance tests completed
- m-CHP system integrated

NON QUANTITATIVE OBJECTIVES

- Traineeships of UNISA students at TUE
- Catalysts characterization (UNISA and TUE)
- PEM manufacturing and characterization (CEA and POLIMI at CEA)

PROGRESS & MAIN ACHIEVEMENTS

- Bioethanol steam reforming in a membrane reactor under fluidization validated at lab-scale both experimentally and model
- Pilot scale ATR membrane reactor & fuel cell stack built and Factory Acceptance tests completed
- m-CHP system integrated

FUTURE STEPS & PLANS

- Modifying the pilot reactor working conditions to deliver a higher amount of H2 and purity (after the methanator)
- Proof of concept of the novel m-CHP system
- Technical economic assessment and optimization of both reactors and complete system
- Life Cycle Analysis and safety Analysis

RELEVANCE TO FCH JU OVERARCHING OBJECTIVES

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

FluidCELL is developing an advanced m-CHP fuel cell system for decentralized off-grid applications. The new m-CHP is based on a novel bio-ethanol fluidised bed catalytic membrane reformer working at low temperature (≤ 500ºC) for the production of H2 and the most advance technology at the fuel cell level.

QUANTITATIVE TARGETS AND STATUS

State of the Art (SoA)*

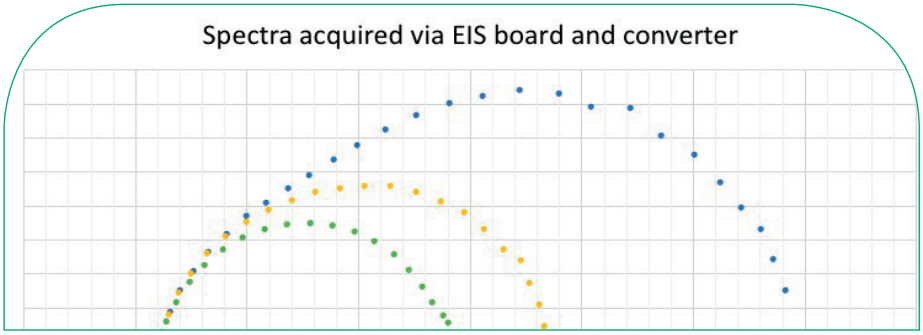
PARAMETER	UNIT	RESULT ACHIEVED TO DATE	SoA result achieved to date by other group/project	SoA YEAR	SoA Source
Overall efficiency m-CHP unit	%	90 (Rated system total efficiency (LHV)	80	N.A.	Sidera30 by ICI Caldaie (http://www.icicaldaie.com/sidera-30.asp) Ethanol reformer and fuel cell by ZSW (https://www.zsw-bw.de/fileadmin/user_upload/PDFs/Aktuelles/2013/PDFs_Presseinformationen_Deutsch/ZSW_EtOHSystem_01.pdf).
Novel catalyst for bio-ethanol reforming with high durability	Highly-stable catalysts	Carbon formation rate (CFR) among the lowest found in the recent literature. Stable behaviour after 400 h of test with no further activity loss	Other studies were rarely focused on stability tests higher than 100 h. conversion until total deactivation of the catalyst	2015,2017 (long term stability)	C. Montero, A. Ochoa, P. Castaño, J. Bilbao, A.G. Gayubo, Monitoring NiO and coke evolution during the deactivation of a Ni/La2O3–ĐAl2O3 catalyst in ethanol steam reforming in a fluidized bed, Journal of Catalysis, 331 (2015) 181–192. V. Palma, C. Ruocco, E. Meloni, A. Ricca, Oxidative steam reforming of ethanol on mesoporous silica supported Pt-Ni/CeO2 catalysts, International Journal of Hydrogen Energy, 42 (2017) 1598-1608.
Development of long (>15 cm) and mechanically stronger H2 selective membranes & membrane production scale-up	cm	45 cm long membranes. 1 membrane per batch. But process optimized for having 4 membranes coated per day.	1 m long membranes (3 per batch)	-	ECN: http://www.hysep.com/ TECNALIA membranes have better properties than ECN membranes. ECN module is used for H2 separation, not for/as membrane reactor. J.L Viviente et al, Int. J. Hydrogen Energy 2017, 42, 13970-13987

* Available data provided by the Project

HEALTH-CODE

REAL OPERATION PEM FUEL CELLS HEALTH-STATE MONITORING AND DIAGNOSIS BASED ON DC-DC CONVERTER EMBEDDED EIS

Project ID:	**671486**
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
Project total costs:	**€ 2358736.25**
FCH JU max. Contribution:	**€ 2358736.25**
Project start - end:	01/09/2015 - 31/12/2018
Coordinator:	**UNIVERSITA DEGLI STUDI DI SALERNO, IT**
Website:	**www.pemfc.health-code.eu**



BENEFICIARIES: AALBORG UNIVERSITET, ABSISKEY, ABSISKEY CP, BALLARD POWER SYSTEMS EUROPE AS, BITRON SPA ,EIFER EUROPAISCHES INSTITUT FUR ENERGIEFORSCHUNG EDF KIT EWIV, ELECTRO POWER SYSTEMS MANUFACTURINGSRL, EPS ELVI ENERGY S.R.L., TORINO E-DISTRICT CONSORZIO, UNIVERSITE DE FRANCHE-COMTE, UNIVERSITE DE TECHNOLOGIE DE BELFORT - MONTBELIARD

PROJECT AND OBJECTIVES

HEALTH-CODE aims at implementing an advanced monitoring and diagnostic tool for μ-CHP and backup PEMFC systems, to determine FC status (condition monitoring) and infer on residual useful lifetime. Five failure modes are detected: change in fuel composition; air and fuel starvation; sulphur poisoning; flooding and drying. The main objectives are: enhancement of EIS based diagnosis; development of monitoring and diagnostic tool for state-of-health assessment, fault detection and isolation and degradation level analysis; reduction of experimental campaign time and costs.

PROGRESS & MAIN ACHIEVEMENTS

- More than 2000 EIS spectra acquired on two different PEMFC technologies for either single cells or short/full stacks, in nominal and faulty states
- EIS board correctly engineered & interfaced with LV & HV DC/DC converters. Converters suitably modified and adapted for EIS board interfacing and use
- Three diagnostic algorithms designed, tested offline and under implementation for validation. One active diagnosis approach tested as well

FUTURE STEPS & PLANS

- Integration of EIS board and DC/DC converter on PEMFC systems, for system testing in normal and faulty conditions
- Diagnostic methods benchmarking and overall evaluation assessment
- Diagnostic algorithms implementation on EIS board and online testing
- Completion of experimental activities still ongoing for lifetime extrapolation

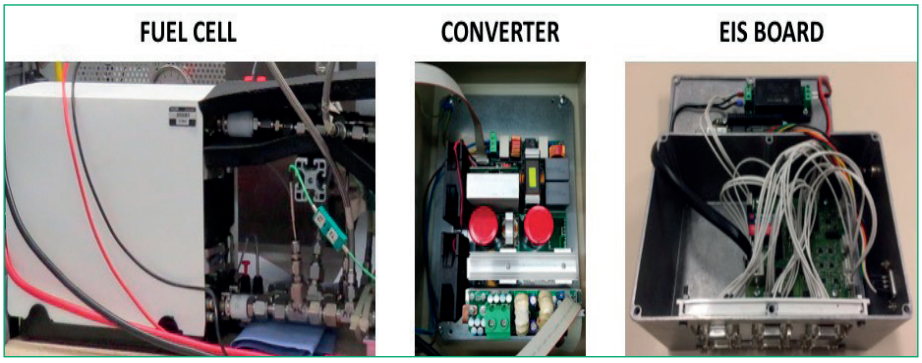
RELEVANCE TO FCH JU OVERARCHING OBJECTIVES

Reduce the production cost of fuel cell systems to be used in transport applications

The diagnostic algorithms can improve system ... of health and lifetime, with a consequent reduction in maintenance costs. Moreover, the implementation of scaling-up approach can reduce testing time and costs.

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

The amount of detectable faulty states, coupled with the different types of diagnostic algorithms, can improve system efficiency, reliability and availability through advanced control techniques (not considered in HEALTHCODE).



QUANTITATIVE TARGETS AND STATUS

FCH JU Programme Targets *

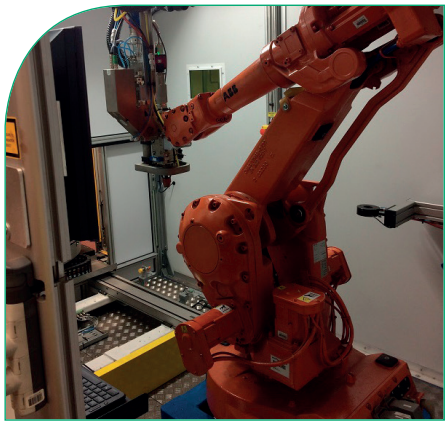
PARAMETER	UNIT	RESULT ACHIEVED TO DATE	TARGET	TARGET ACHIEVED?	DESCRIPTION
System electrical efficiency at start	%	50	36	✓	In nominal condition.
System electrical efficiency at end	%	40	36	✓	In nominal condition.
Diagnosis/monitoring tool availability	%	N/A	99	✗	Not yet available / to verify with tests scheduled in 2018.
Predicted System durability	hours	15,000	20,000	✗	5 years or 15000 hours or 1000 cycles.
System electrical efficiency at start	%	33.60	36	✗	Value measured by notified body DGC.
Predicted System durability	hours	13,610	20,000	✗	13610 MIN /40000 MAX. Highest number of operating hours on one system with same fuel processor and stack.

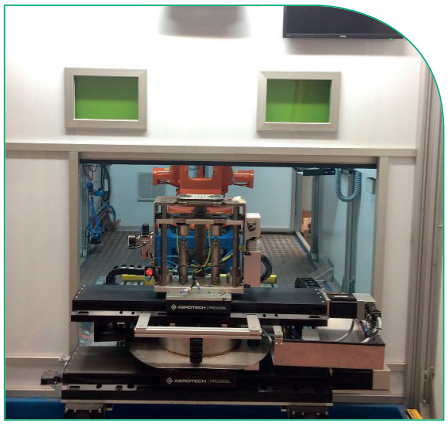
* As identified in MAWP 2014-2020

HEATSTACK

PRODUCTION READY HEAT EXCHANGERS AND FUEL CELL STACKS FOR FUEL CELL M-CHP

Project ID:	**700564**
Call topic:	**FCH-02.6-2015** - Development of cost effective manufacturing technologies for key components or fuel cell systems
Project total costs:	**€ 2,899,760**
FCH JU max. Contribution:	**€ 2,899,760**
Project start - end:	01/04/2016 - 30/06/2019
Coordinator:	**SENIOR UK LTD, UK**
Website:	**www.heatstack.eu/news-and-events/heatstack-production-ready-heat-exchangers-fuel-cell-stacks-fuel-cell-mchp**





BENEFICIARIES: I.C.I CALDAIE SPA, PNO CONSULTANTS LIMITED, SENIOR FLEXONICS CZECH S.R.O., SUNFIRE GMBH, THE UNIVERSITY OF BIRMINGHAM, VAILLANT GMBH

PROJECT AND OBJECTIVES

The project focuses on the industrialisation of manufacturing the Cathode Air Preheater and Full Cell stack two realise a 50% cost saving once in volume production of these two most expensive components of micro-CHP systems. Currently system cost is the biggest hurdle to wide scale adoption of this technology in the domestic market. Research is also being undertaken into the benefits of using AluChrom in the CAPH to extend the longevity of the CAPH, further enhancing the overall lifetime cost of micro-CHP. Project currently at the start of the second half of a 37 month duration.

NON QUANTITATIVE OBJECTIVES

Change to MicroTIG welding from laser to reduce operator Health and Safety risk- but to overcome the material cracking and reduced precision.

PROGRESS & MAIN ACHIEVEMENTS

- Research results showing ax10 reduction of Cr evaporation using AluChrom318 in CAPH compared to the current standard of Inconel 625, SS309, Al SS309
- Redesigned CAPH which has proven to resist deformation when subjected to rigorous system level tests, suggesting component will last as long as stack
- Equipment in place and process validated for the automated welding of the cells and side plates off the CAPH, exceeding targeted process time reduction

FUTURE STEPS & PLANS

Transfer of CAPH automated production equipment to either new Welsh premises of Senior Olomouc facility.

- Completion of the stack glass sealing optimisation process by Sunfire, and implementation into their production line
- Sunfire to develop their first prototype system level units, first 5 then another 20. Over Q4 2019 Q1 & Q2 2020 they will manufacture 500 systems
- Integration of the Senior CAPH into ICICaldaie systems and testing to validate the cross system scale viability of the single design CAPH
- Delivery of techno-economic assessment of the improved processes compared to the pre-project approaches, and LCA analysis

RELEVANCE TO FCH JU OVERARCHING OBJECTIVES

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

Although the project does not focus on efficiency or target durability, the focus on cost reduction of the two most expensive components will contribute to adoption of the technology in domestic homes.

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

Whilst not targeting efficiency of hydrogen production, the project does aim to half the production costs of microchip systems, so that if widely adopted these can contribute to electricity production at the point of use, reducing transmission losses, and create heat at the same time without the usual associated CO2 waste products, thus contributing to more efficient power generation and reduced environmental impact.

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

The project is focussed on the fuel source being natural gas. However this is used to produce hydrogen for the fuel cell by reducing the system cost and therefore facilitating mass market adoption, this can demonstrate large scale renewable sourced electricity production- for example if biogas is used in the network, and also enables domestic use of hydrogen as a heat and power source if hydrogen is successfully adopted into the grid.

QUANTITATIVE TARGETS AND STATUS

FCH JU Programme Targets *

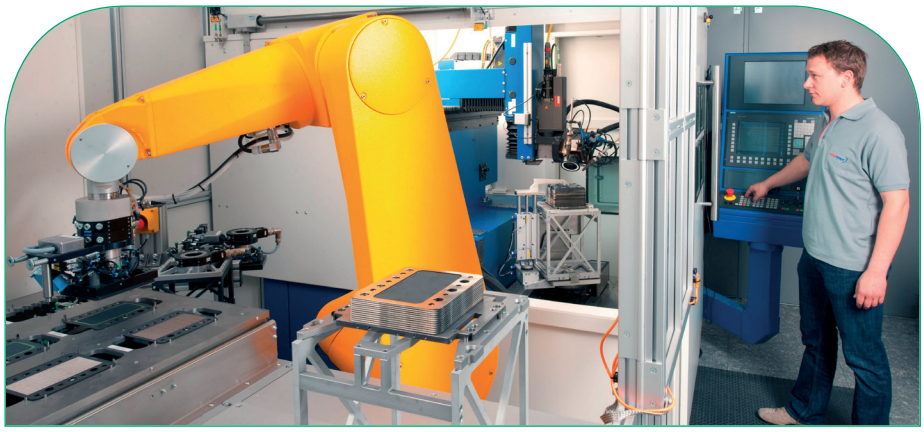
PARAMETER	UNIT	RESULT ACHIEVED TO DATE	TARGET	TARGET ACHIEVED?
CAPH cost (sale) from 2000	%	Not able to confirm until high volume production of 10000pa has been realised	60	
CAPH manufacture time reduction from 8.83 hours	hours	The automated process and robotic laser welders are no in place- full cycle time yet to be tested but expected to be close to target	1.35	
Reduction of glass needed for Stack	%	Process still in development, but expected to realise this target	50	
Reduction of process time for glass sealant from 200 minutes	minutes	Process still in development, but expected to realise this target	100	
Electrical efficiency	%	34	55-60	
Durability	%	40,000	50,000	

* As identified in MAWP Addendum 2018-2020 and project's own objectives, Target years 2019- 2020

INNO-SOFC

DEVELOPMENT OF INNOVATIVE 50 KW SOFC SYSTEM AND RELATED VALUE CHAIN

Project ID:	**671403**
Call topic:	**FCH-02.5-2014** - Innovative fuel cell systems at intermediate power range for distributed combined heat and power generation
Project total costs:	**€ 3,998,081.25**
FCH JU max. Contribution:	**€ 3,998,081.25**
Project start - end:	01/09/2015 - 30/04/2019
Coordinator:	**TEKNOLOGIAN TUTKIMUSKESKUS VTT OY, FI**
Website:	**www.innosofc.eu**



BENEFICIARIES: AGENZIA NAZIONALE PER LE NUOVE TECNOLOGIE, L'ENERGIA E LO SVILUPPO ECONOMICO SOSTENIBILE, CONVION OY, Elcogen OY, ELRINGKLINGER AG, ENERGY MATTERS BV, FORSCHUNGSZENTRUM JULICH GMBH

PROJECT AND OBJECTIVES

INNO-SOFC project combines leading European SOFC technology companies and research centres to collaborate and form required phases in the SOFC value chain. Within this project a next generation 50 kW SOFC system together with its key components will be developed, manufactured, and validated. This system includes many significant improvements compared to current State of the Art, leading to 30,000 hours operating time, 4000 €/kW system costs, 60% electrical efficiency, and 85% total efficiency, which are required for large-scale commercialization of stationary fuel cells.

PROGRESS & MAIN ACHIEVEMENTS

- Conceptual design of the system finished
- Stack delivery for the system started
- Most promising end-users and applications identified and analysed.

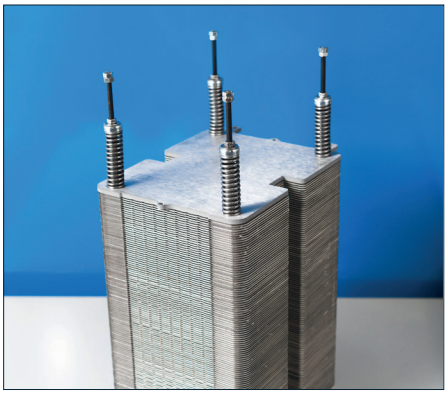
FUTURE STEPS & PLANS

- Finish system detail design
- Manufacture stacks for the system
- System manufacturing and start-up

RELEVANCE TO FCH JU OVERARCHING OBJECTIVES

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

60% electrical efficiency and 85% total efficiency will be reached within this project in 50 kW power level which is a clear improvement over the SoA.



QUANTITATIVE TARGETS AND STATUS

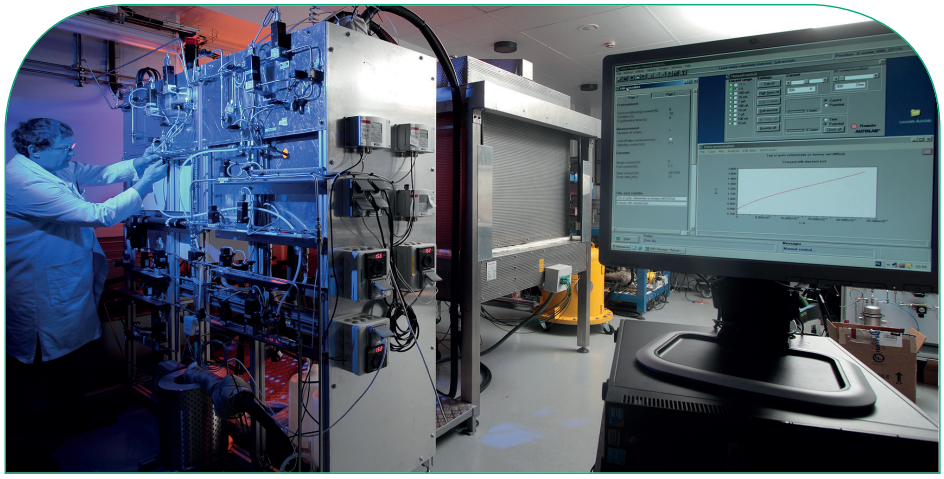
FCH JU Programme Targets *

PARAMETER	UNIT	RESULT ACHIEVED TO DATE	TARGET	TARGET ACHIEVED?	SoA result achieved to date by other group/project (SoA year)	DESCRIPTION
Rated system electrical efficiency (LHV)	%	60	42-60	✓	60% -a small demo system (2009)	Stationary demo unit - LHV
Rated system thermal efficiency (LHV)	%	25	24-42	✓	N/A	Stationary demo unit - LHV
Lifetime of the fuel cell system	years	11.41	6 - 20	✓	N/A	Stationary demo unit
Stack durability	hours	30,000	50,000	Achieved SoA 2017	N/A	Stationary demo unit
Land use / footprint	m2/kW	0.1	0.08	Achieved SoA 2017	N/A	Stationary demo unit
Est. FC system CAPEX @ mass production	EUR/kW	4000	4,500 - 7,500	✓ projection has achieved	14,000 - real costs no mass production	FC system
BoP CAPEX @ mass production	EUR/kW	2000		✓ projection has achieved		FC system

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

INSIGHT

IMPLEMENTATION IN REAL SOFC SYSTEMS OF MONITORING AND DIAGNOSTIC TOOLS USING SIGNAL ANALYSIS TO INCREASE THEIR LIFETIME



Project ID:	**735918**
Call topic:	**FCH-02-5-2016** - Advanced monitoring, diagnostics and lifetime estimation for stationary SOFC stacks and modules
Project total costs:	**€ 3,146,056.25**
FCH JU max. Contribution:	**€ 2,498,948.75**
Project start - end:	01/01/2017- 31/12/2019
Coordinator:	**COMMISSARIAT A L ENERGIE ATOMIQUE ET AUX ENERGIES ALTERNATIVES, FR**
Website:	**www.insight-project.eu**

BENEFICIARIES: ABSISKEY, ABSISKEY CP, AVL LIST GMBH, BITRON SPA, DANMARKS TEKNISKE UNIVERSITET, ECOLE POLYTECHNIQUE FEDERALE DE LAUSANNE, HTceramix SA, INSTITUT JOZEF STEFAN, SOLIDPOWER SPA, Teknologian tutkimuskeskus VTT Oy, UNIVERSITA DEGLI STUDI DI SALERNO

PROJECT AND OBJECTIVES

The project aims at developing a Monitoring, Diagnostic and Lifetime Tool for SOFC stacks. Monitoring is based on 2 advanced techniques (EIS and THD) in addition to conventional stack signal. Durability tests with faults added on purpose generate the data required to develop and validate the algorithms. Fault mitigation logics will be developed to avoid stack failures and slow down their degradation. A specific low-cost hardware, consisting in a single board able to embed the tool will be developed and integrated into a commercial m-CHP, which will be tested on-field.

NON QUANTITATIVE OBJECTIVES

- Perform test with faults added on purpose
- Development of a monitoring, diagnostic and lifetime tool (MDLT)
- Implement the MDLT on a board

PROGRESS & MAIN ACHIEVEMENTS

- Definition and test of 3 faults considered as major for the SOFC stacks (high fuel utilisation, leakage and carbon deposition)
- Implementation of pseudo-random binary signal (PRBS) technique on short stack during testing
- First release of the board, so called "Bitron box"

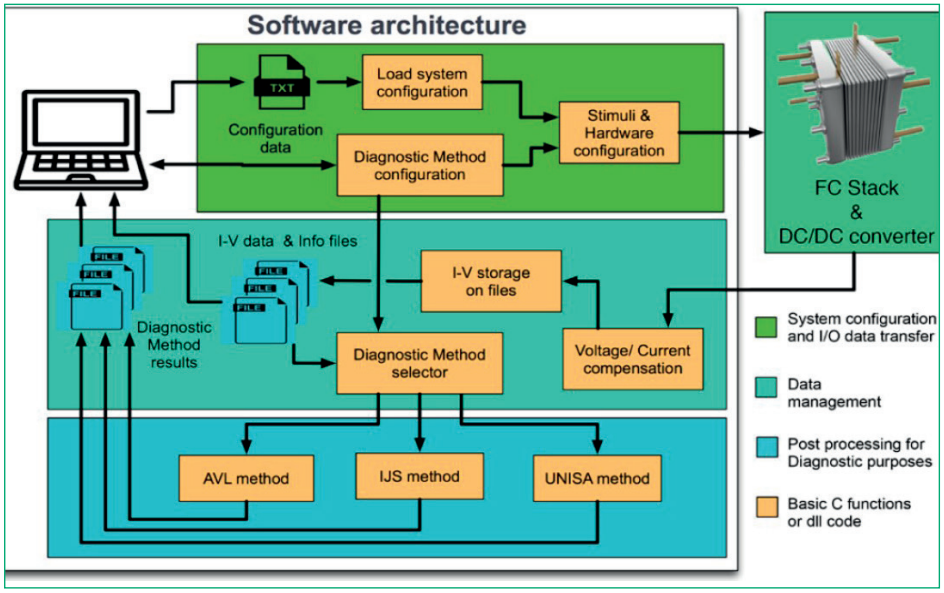
FUTURE STEPS & PLANS

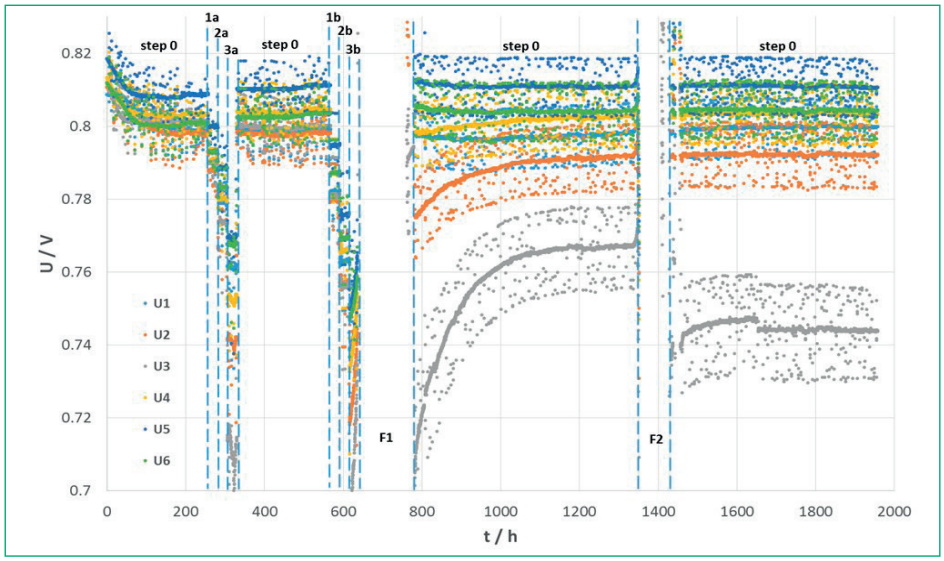
- Continuous interaction between WP2 testing and WP4/5 MDLT to provide data for the algorithms developments
- Completion of the testing campaign
- Completion of the board embedding the algorithms
- System integration of the board, lab test and subsequently on-field test on a m-CHP system

RELEVANCE TO FCH JU OVERARCHING OBJECTIVES

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

Project targets a lifetime prolongation by 5% thanks to the MDLT tool embedding on the board included in the SOFC system Indeed, the combination of diagnostic algorithms and mitigations strategies will reduce the impact of faults and improve system reliability and availability.



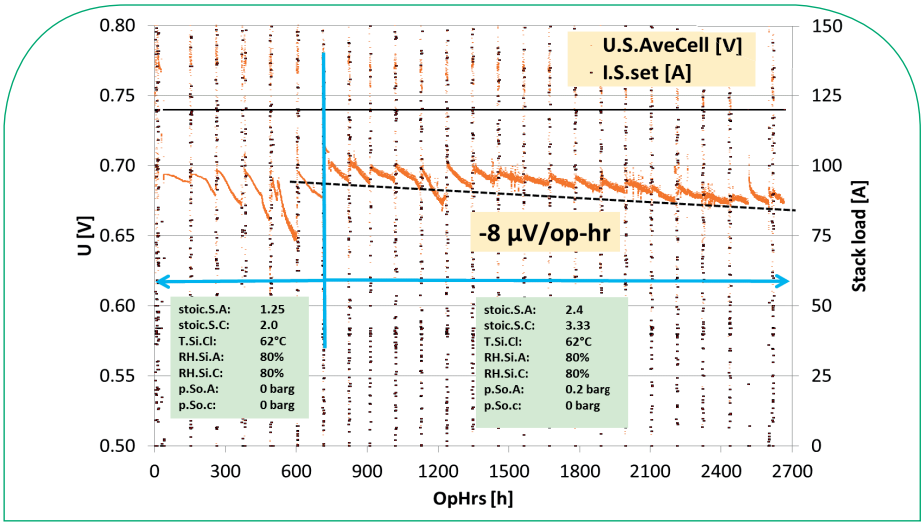


PRD 2018 PANEL
NEXT GENERATION OF PRODUCTS - ENERGY

MATISSE

MANUFACTURING IMPROVED STACK WITH TEXTURED SURFACE ELECTRODES FOR STATIONARY AND CHP APPLICATIONS

Project ID:	**621195**
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
Project total costs:	**€ 3,192,819.8**
FCH JU max. Contribution:	**€ 1,684,717**
Project start - end:	01/10/2014 - 31/12/2017
Coordinator:	**COMMISSARIAT A L ENERGIE ATOMIQUE ET AUX ENERGIES ALTERNATIVES, FR**
Website:	**www.matisse.zsw-bw.de/general-information.html**



BENEFICIARIES: AREVA STOCKAGE D'ENERGIE SAS, INHOUSE ENGINEERING GMBH, NEDSTACK FUEL CELL TECHNOLOGY BV, ZENTRUM FUR SONNENENERGIE- UND WASSERSTOFF-FORSCHUNG BADEN-WURTTEMBERGSTIFTUNG

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. H2/O2, H2/Air and reformate H2/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 and improve stacks behaviour.

NON QUANTITATIVE OBJECTIVES

- Validate automated manufacturing of MEAs for cost reduction
- Analysis of local operation for understanding and cells improvement
- Develop textured electrodes to improve MEA performance and robustness
- Validation of new electrodes under specific ageing conditions

PROGRESS & MAIN ACHIEVEMENTS

- Analysis of current distribution and improvement of cells performance by texturing the catalyst layers for 3 conditions (H2 or Reformate/Air, H2/O2)
- 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 H2/Air

FUTURE STEPS & PLANS

Project is finished

RELEVANCE TO FCH JU OVERARCHING OBJECTIVES

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

Development of electrodes improving stack operation for H2/O2, H2/Air, and Reformate/air.

QUANTITATIVE TARGETS AND STATUS

FCH JU Programme Targets *

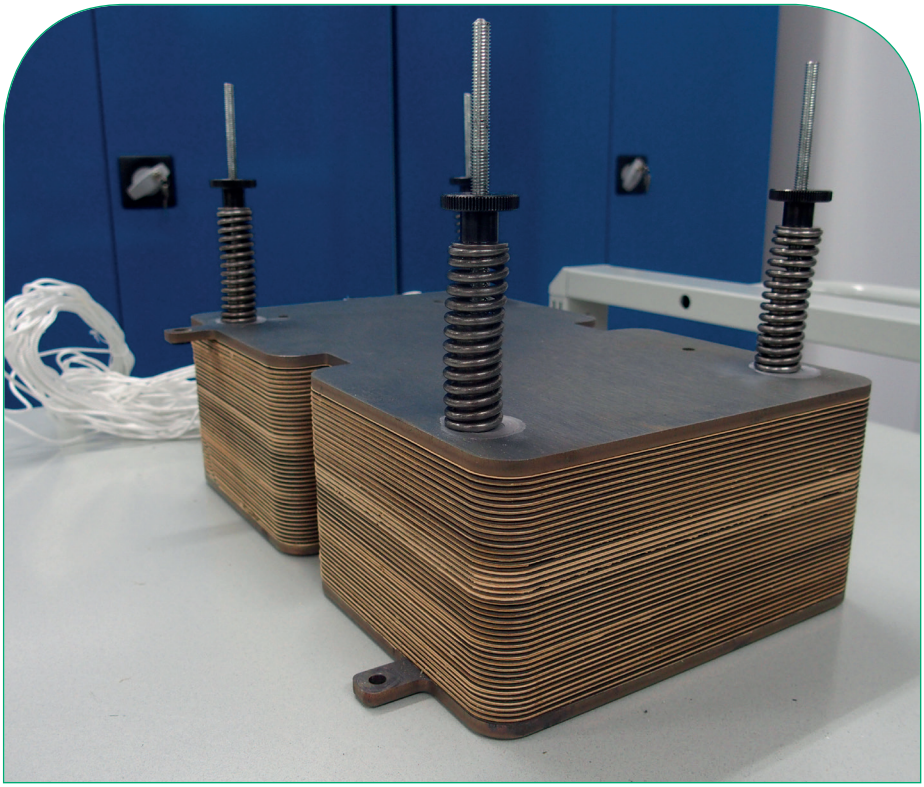
PARAMETER	UNIT	RESULT ACHIEVED TO DATE	TARGET	TARGET ACHIEVED?	SoA result achieved to date by other group/project
Stack electrical efficiency (LHV) - observed	%	50	43-55	✓	N/A
Degradation rate	%/kh	0.7	< 0.25	✗	N/A
Stack durability	hours	14,000	20,000	✗	80,000
Stack availability	%	100	97	✓	N/A
Areal power density	%/kh	0.7	0.67	✓	N/A

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

NELLHI

NEW ALL-EUROPEAN HIGH-PERFORMANCE STACK: DESIGN FOR MASS PRODUCTION

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



Project ID:	**621227**
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
Project total costs:	**€ 2,858,447.2**
FCH JU max. Contribution:	**€ 1,633,895**
Project start - end:	01/05/2014 - 30/04/2017
Coordinator:	**AGENZIA NAZIONALE PER LE NUOVE TECNOLOGIE, L'ENERGIA E LO SVILUPPO ECONOMICO SOSTENIBILE, IT**
Website:	**www.nellhi.eu**

BENEFICIARIES: AKTSIASELTS ELCOGEN, BORIT NV, CLAUSTHALER UMWELTTECHNIK INSTITUT GMBH, Elcogen OY, FLEXITALLIC LTD, SANDVIK MATERIALS TECHNOLOGY AB, TEKNOLOGIAN TUTKIMUSKESKUS VTT, Teknologian tutkimuskeskus VTT Oy

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, achieving all objectives. The target application is stationary and residential combined heat and power production based on natural gas, and will form the basis for Elcogen's commercial stack technology as well as enforce market penetration for component manufacturers.

NON QUANTITATIVE OBJECTIVES

Improve capacity and maturity of all-European SOFC stack supply chain.

PROGRESS & MAIN ACHIEVEMENTS

- Record stack efficiency obtained: 74% electrical
- Very high single-pass fuel utilization achieved: 91% with hydrogen feed
- Very high yield rate of manufacturing process: 96% for cells, 97% for stacks

FUTURE STEPS & PLANS

Project finished. Outstanding objectives being dealt with in INNOSOFC and qSOFC projects.

RELEVANCE TO FCH JU OVERARCHING OBJECTIVES

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

Record single-pass stack efficiency was achieved and production costs were reduced. Durability was consolidated but can be further improved.

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

The SOFC production process in NELLHI minimizes the use of critical raw materials.

QUANTITATIVE TARGETS AND STATUS

FCH JU Programme Targets *

PARAMETER	UNIT	RESULT ACHIEVED TO DATE	TARGET	TARGET ACHIEVED?	SoA result achieved to date by other group/project (SoA year)	DESCRIPTION
Project process: Electrical efficiency	%	70	55-60	✓	60 (2013)	NELLHI - first generation FC stack
Project process: Electrical efficiency	%	74	55-60	✓		NELLHI - second generation FC stack
Durability	hours	20,000	50,000	✗	40,000 (2016)	N/A

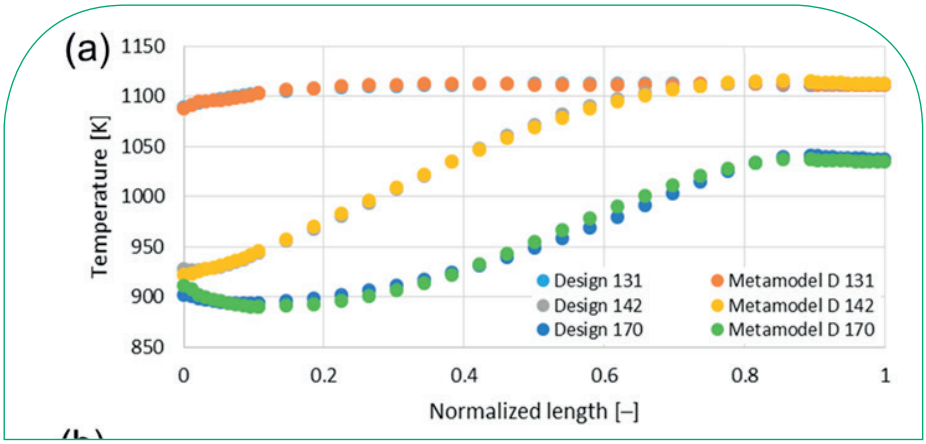
*As Identified in MAWP Addendum 2018-2020 and AWP 2017, Target year 2020

PROSOFC

PRODUCTION AND RELIABILITY ORIENTED SOFC CELL AND STACK DESIGN

PROSOFC

Project ID:	**325278**
Call topic:	**SP1-JTI-FCH.2012.3.2** - Improved cell and stack design and manufacturability for application specific requirements
Project total costs:	**€ 7,331,214.71**
FCH JU max. Contribution:	**€ 3,011,000**
Project start - end:	01/05/2013 - 31/10/2017
Coordinator:	**AVL LIST GMBH, AT**
Website:	**www.prosofc-project.eu**



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

PROJECT AND OBJECTIVES

The PROSOFC project aims at improving the robustness, manufacturability, efficiency and cost of SOLIDpowers 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 project was finished in October 2017.

PROGRESS & MAIN ACHIEVEMENTS

- Material and electrochemical characterization to develop homogenized models to describe the properties used in multi physics modelling accomplished
- Multi-physics meta-models of stack to be utilized for automatic design variation and cost-based design optimization established
- Automated sensitivity analysis with the software tool optiSlang in combination with the design software tools (e.g. AVL FIRE, gProms) carried out

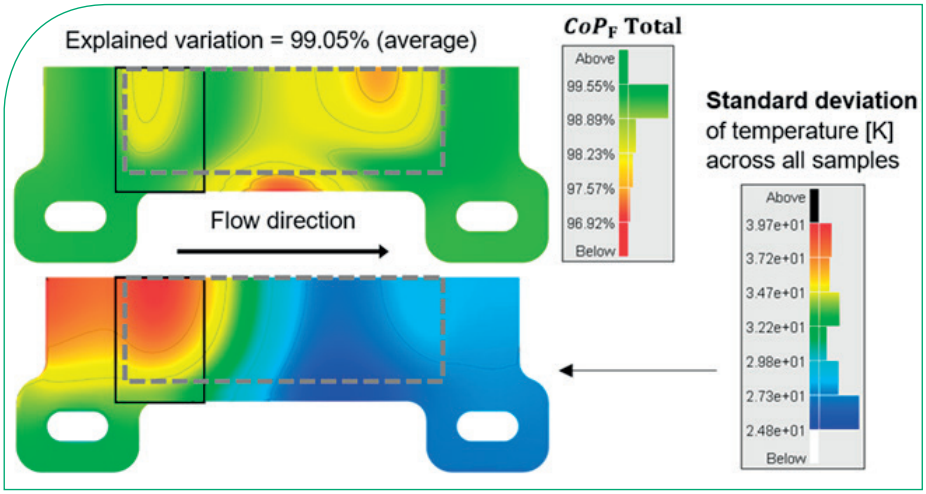
FUTURE STEPS & PLANS

Project is finished

RELEVANCE TO FCH JU OVERARCHING OBJECTIVES

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

Robustness of stack could be improved by improved stack design



QUANTITATIVE TARGETS AND STATUS

FCH JU Programme Targets *

PARAMETER	UNIT	RESULT ACHIEVED TO DATE	TARGET	TARGET ACHIEVED?	SoA result achieved to date by other group/project (SoA year)
Stack electrical efficiency (LHV) - observed	%	62	55-60	✓	N/A
Electrical efficiency (SOFC system)	%	55	35-60	✓	52-60 (2017-2018)
Power density	W/cm2	0.3	N/A	✗	0.22 (2017)

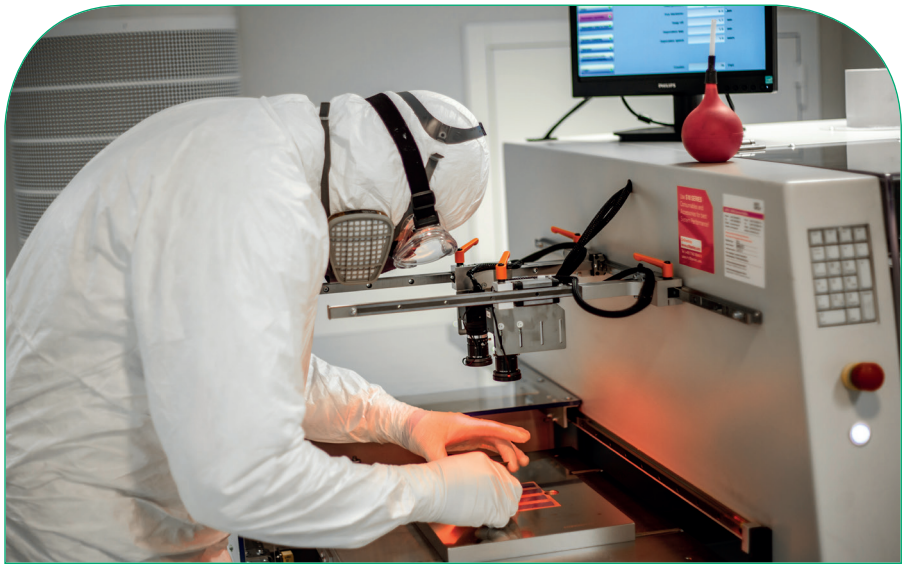
*** As Identified in AWP 2017, Target year 2020**

qSOFC

AUTOMATED MASS-MANUFACTURING AND QUALITY ASSURANCE OF SOLID OXIDE FUEL CELL STACKS

Project ID:	**735160**
Call topic:	**FCH-02-6-2016** -Development of cost effective manufacturing technologies for key components or fuel cell systems
Project total costs:	**€ 2,110,015**
FCH JU max. Contribution:	**€ 2,110,015**
Project start - end:	01/02/2017 - 31/01/2020
Coordinator:	**TEKNOLOGIAN TUTKIMUSKESKUS VTT OY, FI**
Website:	**www.qsofc.eu**

BENEFICIARIES: AGENZIA NAZIONALE PER LE NUOVE TECNOLOGIE, L'ENERGIA E LO SVILUPPO ECONOMICO SOSTENIBILE, AKTSIASELTS ELCOGEN, Elcogen OY, ELRINGKLINGER AG, HAIKU TECH EUROPE BV, MUKO MASCHINENBAU GMBH, SANDVIK MATERIALS TECHNOLOGY AB



PROJECT AND OBJECTIVES

qSOFC project focuses on SOFC stack cost reduction and quality improvement by replacing manual labour in all key parts of the stack manufacturing process with automated manufacturing and quality control. This will lead to stack cost of 1000 €/kW and create a further cost reduction potential down to 500 €/kW at mass production (2000 MW/year).

PROGRESS & MAIN ACHIEVEMENTS

- First tests to detect defects in cell manufacturing using automated 3D machine vision inspection system have been successfully completed
- First results to streamline stack production show promising results
- Good results from cell manufacturing optimization for mass-production
- Optimization of interconnect manufacturing using coated steel substrate
- Validation of the performance and durability of a stack manufactured using the developed mass-manufacturing methodology

FUTURE STEPS & PLANS

- Stack manufacturing (conditioning process) streamlined to reduce CAPEX and OPEX
- Cell manufacturing pastes and slurries modified to enable mass-manufacturing
- Validation of automated 3D machine vision inspection in cell production line

RELEVANCE TO FCH JU OVERARCHING OBJECTIVES

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

qSOFC project introduces efficient quality assurance methods for the entire stack manufacturing value-chain thus reducing costs.

QUANTITATIVE TARGETS AND STATUS

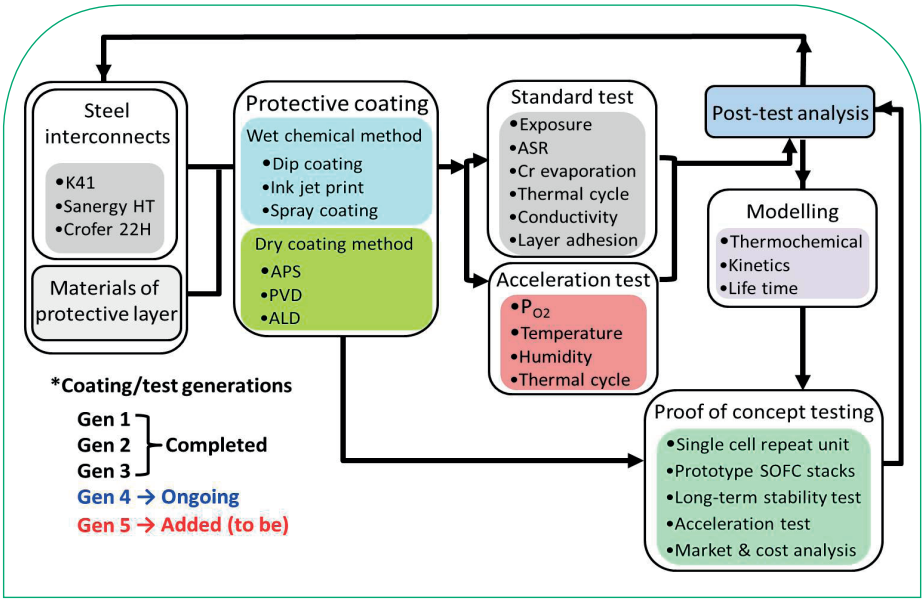
FCH JU Programme Targets *

PARAMETER	UNIT	RESULT ACHIEVED TO DATE	TARGET	TARGET ACHIEVED?	SoA result achieved to date by other group/project (SoA year)
Reference & Project process: Electrical efficiency	%	74	55-60	✓	N/A
Reference process: Durability	hours	20,000	50,000	✗	N/A
Reference process: Degradation rate	%/kh	1	<0.2	✗	N/A
Stack manufacturing cost at 20 MW/a volume	€/kW	2000	<3000	✓	3000 (2017)

* As Identified in MAWP Addendum 2018-2020 and AWP 2017, Target year 2020

SCoReD 2:0

STEEL COATINGS FOR REDUCING DEGRADATION IN SOFC



Project ID:	325331
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
Project total costs:	€ 3,792,559.2
FCH JU max. Contribution:	€ 2,183,023
Project start - end:	01/07/2013 - 30/06/2017
Coordinator:	THE UNIVERSITY OF BIRMINGHAM, UK
Website:	www.birmingham.ac.uk/research/activity/scored/index.aspx

BENEFICIARIES: AGENZIA NAZIONALE PER LE NUOVE TECNOLOGIE, L'ENERGIA E LO SVILUPPO ECONOMICO SOSTENIBILE, ECOLE POLYTECHNIQUE FEDERALE DE LAUSANNE, SOLIDPOWER SPA, Teer Coatings Limited, TEKNOLOGIAN TUTKIMUSKESKUS VTT, Teknologian tutkimuskeskus VTT Oy, Turbocoating s.p.a.

PROJECT AND OBJECTIVES

Stainless steel interconnects in SOFC require protective coatings to subdue the formation of chromium hydroxide. The benchmark for such coatings is Sandvik Ce-Co PVD pre-coated steel sheet with an ASR of 5 mOhm cm2. SCORED 2:0 successfully attempted to find other coating materials and procedures that might be cheaper and just as effective as the Sandvik development. Two proof-of-concept stacks were tested for 10,000 hours to prove the effectiveness of the processes developed.

NON QUANTITATIVE OBJECTIVES

Cost reduction

PROGRESS & MAIN ACHIEVEMENTS

- The project delivered several materials/process combinations that deliver an ASR of 5 mOhm cm2 with low and very low chromium release rates
- The project developed a novel and to-date uncommon method of improving ASR and Cr release
- The project tested two stacks for 10,000+ hours to prove the effectiveness of the coatings developed

FUTURE STEPS & PLANS

Project is finished.

RELEVANCE TO FCH JU OVERARCHING OBJECTIVES

Reduce the production cost of fuel cell systems to be used in transport applications

Low-cost applications of protective layers will contribute to reducing cost; likewise longer lifetime will reduce TCO

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

Longer lifetime will reduce TCO

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

Use of materials with no or less critical materials and lower cost

QUANTITATIVE TARGETS AND STATUS

FCH JU Programme Targets *

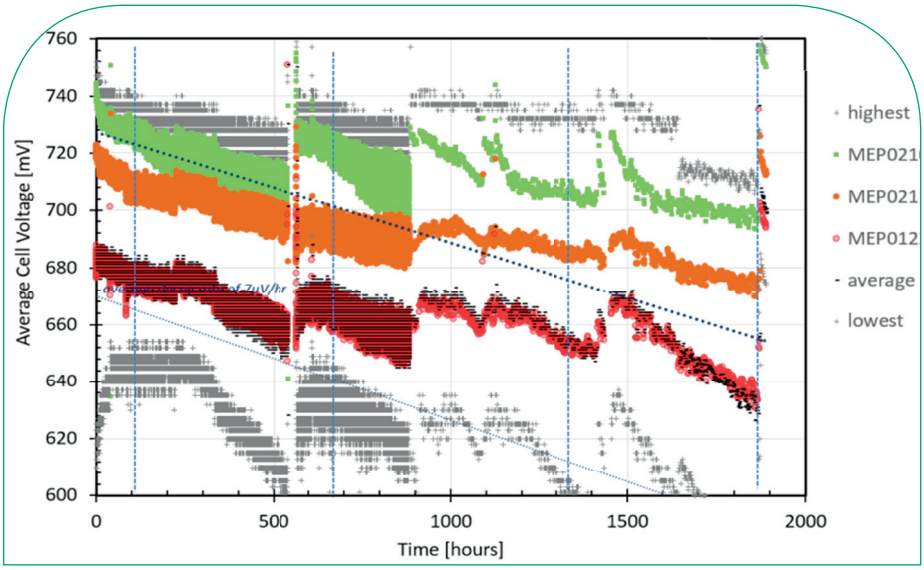
PARAMETER	UNIT	RESULT ACHIEVED TO DATE	TARGET	TARGET ACHIEVED?
Stack durability rated	hours	80,000	50,000	✓
Stack availability	%	100	97	✓
Degradation rate	%/kh	0.25	<0.2	✗
Stack Durability	hours	80,000	50,000	✓

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

SECOND ACT

SIMULATION, STATISTICS AND EXPERIMENTS COUPLED TO DEVELOP OPTIMIZED AND DURABLE ĐCHP SYSTEMS USING ACCELERATED TESTS

Project ID:	**621216**
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
Project total costs:	**€ 4,700,436.57**
FCH JU max. Contribution:	**€ 2,523,254**
Project start - end:	01/05/2014 - 31/10/2017
Coordinator:	**COMMISSARIAT A L ENERGIE ATOMIQUE ET AUX ENERGIES ALTERNATIVES, FR**
Website:	**www.second-act.eu**



BENEFICIARIES: AGENZIA NAZIONALE PER LE NUOVE TECNOLOGIE, L'ENERGIA E LO SVILUPPO ECONOMICO SOSTENIBILE, ECOLE POLYTECHNIQUE FEDERALE DE LAUSANNE, SOLIDPOWER SPA, Teer Coatings Limited, TEKNOLOGIAN TUTKIMUSKESKUS VTT, Teknologian tutkimuskeskus VTT Oy, Turbocoating s.p.a.

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 characterizations 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

NON QUANTITATIVE OBJECTIVES

- Understanding of cell/stack degradation for H2 & Reformate PEMFC; DMFC
- Demonstrating improvements thanks to core components modifications
- Collection, production and analysis of ageing data (3 FC types)
- Quantification of mechanisms (exp and models) & verify of improvement)

PROGRESS & MAIN ACHIEVEMENTS

- Integration of a new cathode catalyst leading to reduced degradation rates for cells and stacks aged in the different conditions of the project
- Successful local data analyses and modelling of reversible and non-reversible degradation mechanisms allowing to define relevant mitigations methods
- Validation of non-homogeneous active layers mitigating local losses and improving DMFC or PEMFC stack performance stability in different conditions

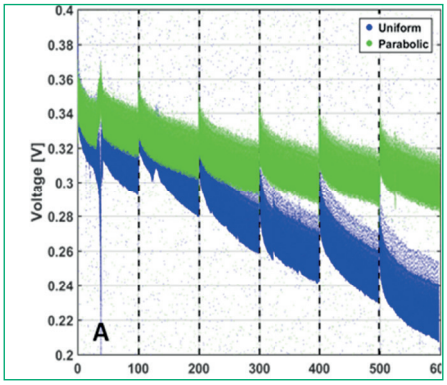
FUTURE STEPS & PLANS

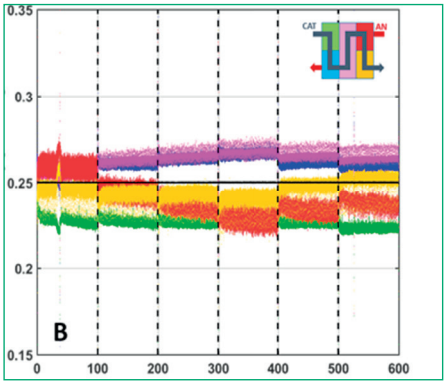
Project is finished.

RELEVANCE TO FCH JU OVERARCHING OBJECTIVES

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

Increased of stack durability thanks to improved electrodes





QUANTITATIVE TARGETS AND STATUS

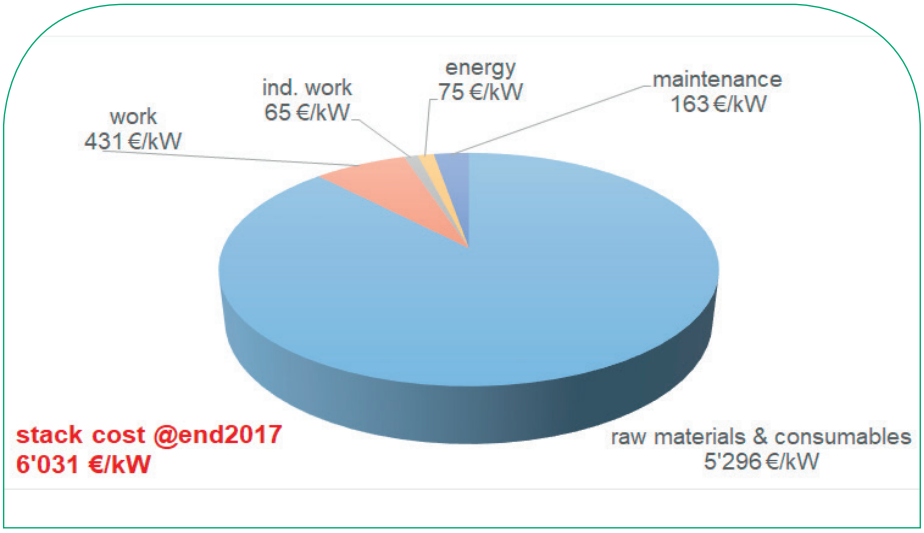
FCH JU Programme Targets *

PARAMETER	UNIT	RESULT ACHIEVED TO DATE	TARGET	TARGET ACHIEVED?
Rated stack electrical efficiency (LHV)	%	50	42- 55	✓
Stack availability	%	100	97	✓
Degradation rate	%/kh	2	< 0.25	✗

*** As identified in MAWP 2014-2020, AWP 2016, 2017, Target years 2017-2020**

SOSLeM
SOLID OXIDE STACK LEAN MANUFACTURING

Project ID:	**700667**
Call topic:	**FCH-02.6-2015** -Development of cost effective manufacturing technologies for key components or fuel cell systems
Project total costs:	**€ 2,944,176.25**
FCH JU max. Contribution:	**€ 1,994,301.25**
Project start - end:	01/04/2016 - 31/03/2019
Coordinator:	**SOLIDPOWER SPA, IT**
Website:	**www.soslem.eu**



BENEFICIARIES: Athena S.p.a, AVL LIST GMBH, ECOLE POLYTECHNIQUE FEDERALE DE LAUSANNE, GREENLIGHT INNOVATION GMBH, HTceramix SA

PROJECT AND OBJECTIVES

Project aims at reducing manufacturing costs for SOFC stacks while making production more resource efficient and realizing environmental benefits. Significant results achieved are:

- Improvement of the manufacturing process of cassettes
- Definition of the implementation of optimized stack test system that will help stack preparation by advanced stack curing and conditioning
- Evaluation of alternative solutions for nickel removal from waste water
- Generation of environmental benefit and improved stack durability performances through alternative protective coating of cassettes

NON QUANTITATIVE OBJECTIVES

Enable environmental benefits.

PROGRESS & MAIN ACHIEVEMENTS

- Reduction of manufacturing costs for stack production
- Enable environmental benefits through removal of Co-based powder from cassettes manufacturing process
- Improvement of stack electrochemical performances

FUTURE STEPS & PLANS

- Implementation of new cassette design that will lead to a further decrease of capital costs
- Implementation of new stack design that will lead to a further decrease of capital costs
- Increase of productivity will lead to a better use of production resources

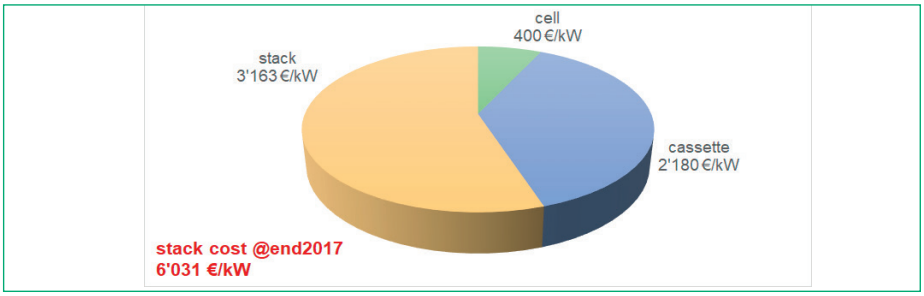
RELEVANCE TO FCH JU OVERARCHING OBJECTIVES

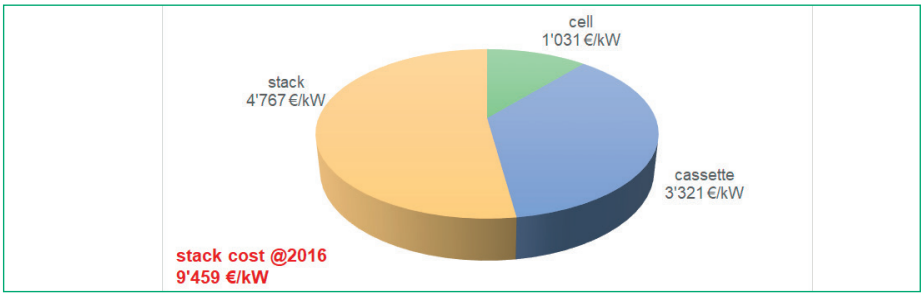
Reduce the production cost of fuel cell systems to be used in transport applications

Not to system to be used in transport applications, but stationary. Reduction of production cost of fuel cell system is the main purpose of project.

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

Removal of Co-based powder from manufacturing process of cassettes and evaluation of on-site nickel removal system from waste water were done in the project.





QUANTITATIVE TARGETS AND STATUS

FCH JU Programme Targets *

PARAMETER	UNIT	RESULT ACHIEVED TO DATE	TARGET	TARGET ACHIEVED?
Stack cost decrease	€/kW	3,428	≈ 3,500	✓

*Project's own objective