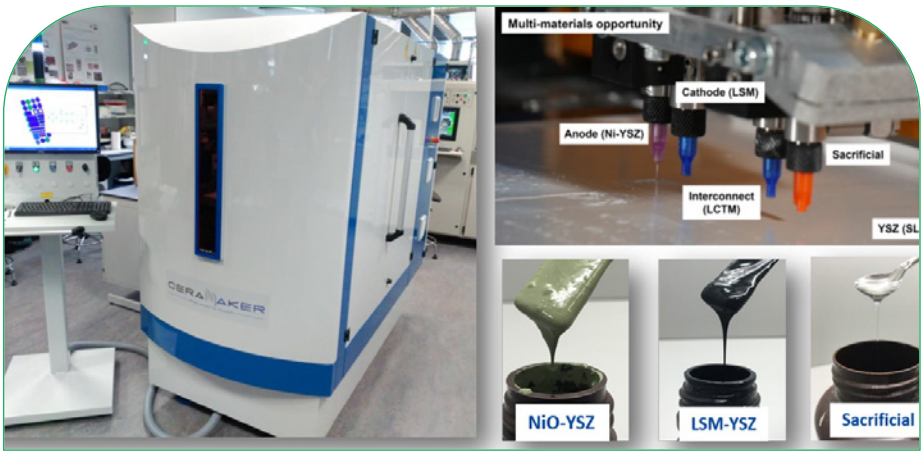
Cell3Ditor

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- 30/04/2020
Coordinator:	**FUNDACIO INSTITUT DE RECERCA DE L'ENERGIA DE CATALUNYA, ES**
Website:	**www.cell3ditor.eu/**



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

PROJECT AND OBJECTIVES

The main goal of the Cell3Ditor project was the development of a 3D printing technology for the industrial production of SOFC components by covering research and innovation in all the stages of the industrial value chain. Cell3Ditor technology was demonstrated by the end of the project, with the release of printable feedstock (electrolyte, electrodes and interconnects), a hybrid printing machine (now commercialised) and enhanced corrugated SOFC cells with 60 % increase in performance (using conventional materials).

NON-QUANTITATIVE OBJECTIVES

- Development of new materials for the 3D printing of ceramics. The project has delivered new ceramic slurries, adding to the list of materials available for 3D printing: 8YSZ, LSM, Ni-YSZ, LCTM (interconnector)
- Development of 3D printing processes for SOFC stacks manufacturing. The proof of concept of the 3D printing process for SOFCs has been provided and new processes have been created.

PROGRESS AND MAIN ACHIEVEMENTS

- Printable feedstock for electrolyte (YSZ), electrodes (Ni-YSZ, LSM-YSZ) and interconnects (LTO)
- Hybrid printing machine able to print complete cells and stacks released
- New families of 3D-printed SOFC cells with enhanced performance and long durability.

FUTURE STEPS AND PLANS

The project has finished. While the final goal of producing a 3D printed stack has not been attained, printing and co-sintering processes have been developed. Button cells have been printed and tested successfully.

QUANTITATIVE TARGETS AND STATUS

TARGET SOURCE	PARAMETER	UNIT	TARGET	ACHIEVED TO DATE BY THE PROJECT	TARGET ACHIEVED?	SOA RESULT ACHIEVED TO DATE (BY OTHERS)	YEAR FOR SOA TARGET
Project's own objectives	Power density Increment of specific power of cells	mW/cm	260	410	✓	0.2	2004
	Global Warming Potential (GWP)	kg CO_2/kW	1 230	93	✓	1 230	2015
	Material use	kg/kW	25.84	7.6	✓	25.84	2015

EMPOWER

EUROPEAN METHANOL POWERED FUEL CELL CHP

Project ID:	**875081**
Call topic:	**FCH-02-7-2019:** Development of highly efficient and flexible mini CHP fuel cell system based on HTPEMFCs
Project total costs:	**€1 499 876.25**
FCH JU max. Contribution:	**€1 499 876.25**
Project start - end:	01/01/2020 - 31/12/2022
Coordinator:	**TEKNOLOGIAN TUTKIMUSKESKUS VTT OY, FI**
Website:	**www.empower-euproject.eu/**

BENEFICIARIES: BLUE WORLD TECHNOLOGIES APS, THT CONTROL OY, CATATOR AB, UNIVERSIDADE DO PORTO

PROJECT AND OBJECTIVES

The project will develop, manufacture and validate a methanol-fuelled 5 kWe combined heat and power (CHP) system based on high-temperature PEM fuel cell technology. The project will enhance the system efficiency to target the mini-CHP market and provide a cost-competitive and low-carbon option. The CHP unit developed will be capable of fast start-up and fast dynamic response to help integration of intermittent power production from renewable energy sources. Currently, the subsystems of the CHP are being built and tested by project partners.

NON-QUANTITATIVE OBJECTIVES

- Increase visibility and awareness of the potential of renewable methanol. Open communication and dissemination of project results will lead to increased visibility and awareness of the potential of renewable methanol
- Develop a business plan for the use of renewable methanol in CHP as well as other applications. A preliminary market potential study will be done in spring 2021and updated by the end of the project
- Support knowledge exchange and production ramp-up through identification of stakeholders, information and linkage. An industrial webinar was arranged in January 2021 and there will be an industrial workshop by the end of 2021
- The main goal is the production of affordable and secure electricity with a low-carbon footprint.

PROGRESS AND MAIN ACHIEVEMENTS

- A new, compact concept for HTPEM fuel cell stack compression with bands instead of rods has been tested
- An MCU was planned and built for the 5-kW power unit, including controls for safety, fuel supply system, cooling and power electronics
- A complete gas-phase reformer was designed and constructed. Commissioning and evaluation are under way. The work is progressing over time.

FUTURE STEPS AND PLANS

- Develop, manufacture and characterise a highly efficient methanol reformer in spring 2021
- Develop, manufacture and characterise a highly efficient HTPEM fuel cell in summer 2021
- Characterise and integrate reformer with the HTPEM fuel cell in autumn 2021
- Integrate, commission and demonstrate the system in a laboratory environment in winter 2021
- Integrate, commission and demonstrate the system in a relevant end-user environment in spring/summer 2022
- Conduct a system scale-up study (50 kW), environmental analysis and business analysis in 2022.

QUANTITATIVE TARGETS AND STATUS

TARGET SOURCE	PARAMETER	UNIT	TARGET	TARGET ACHIEVED?
Project's own objectives	Rated stack electrical efficiency (LHV reformate gas)	%	55	
	Fuel processing efficiency	%	85	
MAWP Addendum (2018-2020)	CHP electrical efficiency (LHV methanol)	%	37-67	
	CAPEX	€/kWh	5 500	

GRASSHOPPER

GRID ASSISTING MODULAR HYDROGEN PEM POWER PLANT

Project ID:	**779430**
Call topic:	**FCH-02-7-2017** - Development of flexible large fuel cell power plants for grid support
Project total costs:	**€4 387 063.75**
FCH JU max. Contribution:	**€4 387 063.75**
Project start - end:	01/01/2018 - 30/06/2021
Coordinator:	**INEA INFORMATIZACIJA ENERGETIKA AVTOMATIZACIJA DOO, SI**
Website:	**www.grasshopperproject.eu/**

BENEFICIARIES: POLITECNICO DI MILANO, NEDSTACK FUEL CELL TECHNOLOGY BV, ABENGOA INNOVACION SOCIEDAD ANONIMA, ZENTRUM FUR BRENNSTOFFZELLEN-TECHNIK GMBH, JOHNSON MATTHEY FUEL CELLS LIMITED

PROJECT AND OBJECTIVES

The GRASSHOPPER project aims to create a next-generation MW-size fuel cell power plant (FCPP), which is more cost-effective and flexible in power output. The FCPP will be demonstrated in the field as a 100 kW sub-module pilot plant, implementing newly developed stacks with improved MEAs and BoP system components. The new stack design has been developed with increased power density and is undergoing short stack testing. The pilot plant is undergoing FAT testing and will run on H2 soon. A dynamic simulation model of the pilot plant has been developed to study further optimisation strategies.

NON-QUANTITATIVE OBJECTIVES

Operation flexibility and grid stabilisation capability via fast response. Operation strategy defined taking into account response time requirements for grid stabilisation.

PROGRESS AND MAIN ACHIEVEMENTS

- The pilot power plant is in the commissioning phase
- Both short stack and single cell testing with the new GH MEAs and cell plates show performance close to the target of 0.68 V @ 1 A/cm^2
- Grasshopper MEAs show excellent durability in AST testing.

FUTURE STEPS AND PLANS

- Assembly of the full stacks for the 100-kW plant. All parts for building the short stacks have arrived. Sealing application and cell plate manufacturing are ongoing for the full stacks
- Testing, relocation and start-up of the pilot plant. FAT testing is ongoing and the pilot plant will soon start testing with hydrogen
- Stack design verification and optimisation, pending full results from short stacks and first full stack
- Cost analysis of stacks and the system.

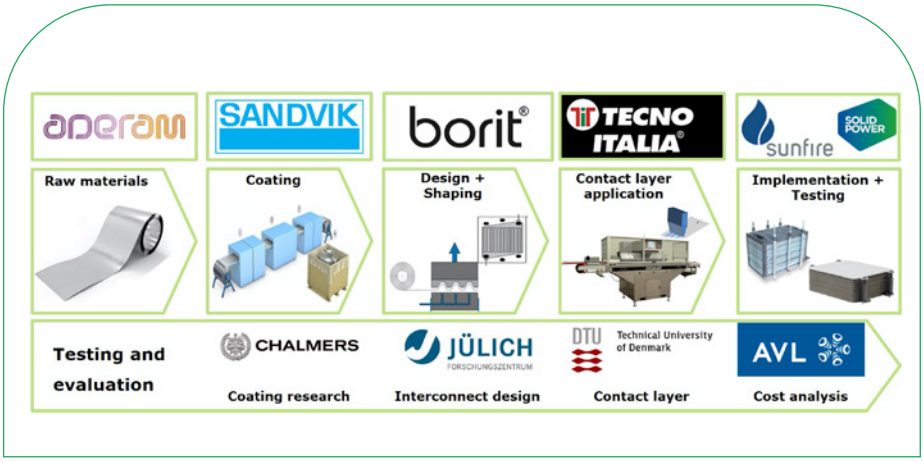
QUANTITATIVE TARGETS AND STATUS

TARGET SOURCE	PARAMETER	UNIT	TARGET	TARGET ACHIEVED?	SOA RESULT ACHIEVED TO DATE (BY OTHERS)	YEAR FOR SOA TARGET
Project's own objectives	MEA cost reduction	%	65		MEA cost price of electricity 0.04 €/kWh	2018
	Stack efficiency	%	55		55	
MAWP Addendum (2018-2020)	System electrical efficiency	%	50	✗	50	
	System CAPEX	€/kWe	1 500		3 000	
AWP 2017	Stack lifetime	Hours	20 000		16 000	

LOWCOST-IC

LOW COST INTERCONNECTS WITH HIGHLY IMPROVED CONTACT STRENGTH FOR SOC APPLICATIONS

Project ID:	**826323**
Call topic:	**FCH-02-6-2018** - Cost-effective novel architectures of interconnects
Project total costs:	**€2 335 997.50**
FCH JU max. Contribution:	**€2 335 997.50**
Project start - end:	01/01/2019 - 31/12/2021
Coordinator:	**DANMARKS TEKNISKE UNIVERSITET, DK**
Website:	**www.lowcost-ic.eu**



BENEFICIARIES: TECNO ITALIA SRL, SUNFIRE GMBH, SOLIDPOWER SPA, BORIT NV, APERAM STAINLESS FRANCE SA, AKTIEBOLAGET SANDVIK MATERIALSTECHONOLOGY, AVL LIST GMBH, CHALMERS TEKNISKA HOEGSKOLA AB, FORSCHUNGSZENTRUM JULICH GMBH

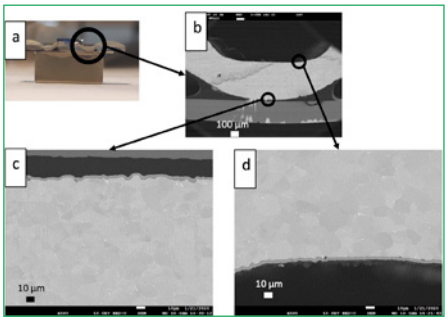
PROJECT AND OBJECTIVES

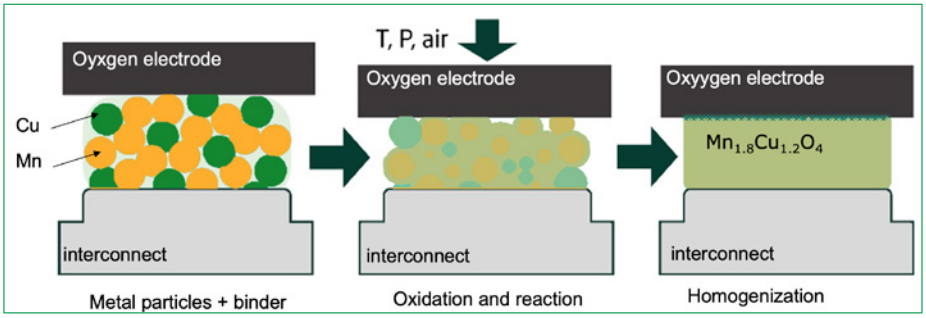
The overall objective of LOWCOST-IC is to contribute to the successful upscaling of widespread commercialisation of solid oxide cell (SOC) technologies by:

- increasing the robustness of the lifetime of SOC stacks – by developing novel high-robustness air electrode contact layers and testing new interconnect coatings in SOC stacks
- minimizing interconnect development and production costs – by introducing cheaper high-volume steel, applying state-of-the-art large-scale roll-to-roll manufacturing methods for SOC manufacturing and developing a novel interconnect shape design route.

PROGRESS AND MAIN ACHIEVEMENTS

- One new improved contact layer developed based on previously proposed contact layers
- Stack tested with roll-to-roll manufactured coatings from Sandvik
- New 3D fast multiphysics model adapted to Sunfire's stack design for further studies.
- Produce new interconnects with optimised geometry for Sunfire. Further mechanical investigations have shown that the original design approach did not work. New approach is ongoing. Borit will produce the interconnects as soon as the design is finished
- Cost target for large-scale manufacturing of SOC stack interconnects will be investigated. Current production methods have been analysed. Now the impact of scale will be considered
- Develop new coatings to minimise ASR increase from Si scale. Various Si scavengers have been tested and this work will continue.





FUTURE STEPS AND PLANS

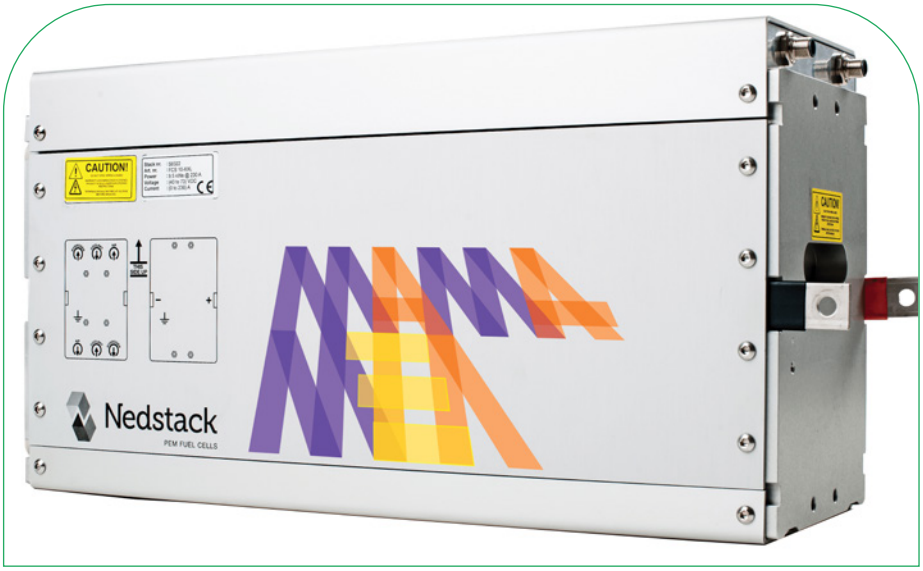
- Testing of second-generation contact layers in stacks. Contact layers have been tested in the lab with promising results

QUANTITATIVE TARGETS AND STATUS

TARGET SOURCE	PARAMETER	UNIT	TARGET	ACHIEVED TO DATE BY THE PROJECT	TARGET ACHIEVED?	SOA RESULT ACHIEVED TO DATE (BY OTHERS)	YEAR FOR SOA TARGET
Project's own objectives	Fracture energy	J/m^2	5.1	12	✓	1.7	2013
	Area-specific resistance at 750 °C	$mOhm.cm^2$	15	12	✓	15	2019
	Area-specific resistance at 850 °C	$mOhm.cm^2$	25	21	✓	N/A	N/A

MAMA-MEA

MASS MANUFACTURE OF MEAS USING HIGH SPEED DEPOSITION PROCESSES



Project ID:	**779591**
Call topic:	**FCH-02-8-2017** - Step-change in manufacturing of fuel cell stack components
Project total costs:	**€3 189 816**
FCH JU max. Contribution:	**€3 189 816**
Project start - end:	01/01/2018 - 30/06/2021
Coordinator:	**TECHNISCHE UNIVERSITAET CHEMNITZ, DE**
Website:	**www.mama-mea.eu**

BENEFICIARIES: SYSTEM SPA, JOHNSON MATTHEY FUEL CELLS LIMITED, INEA INFORMATIZACIJA ENERGETIKA AVTOMATIZACIJA DOO, NEDSTACK FUEL CELL TECHNOLOGY BV, UNIVERSITA DEGLI STUDI DI MODENA E REGGIO EMILIA, FRAUNHOFER GESELLSCHAFT ZUR FOERDERUNG DER ANGEWANDTEN FORSCHUNG EV

PROJECT AND OBJECTIVES

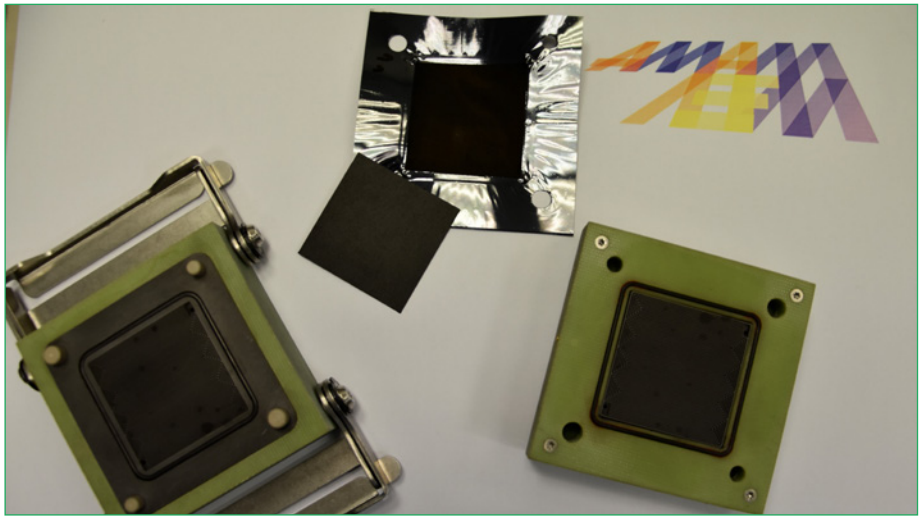
MAMA-MEA is developing an innovative additive layer deposition process integrating all main CCM components (membrane, catalyst layers, sealing) using a single, continuous roll-to-roll manufacturing process for the PEMFC industry to considerably increase the volume manufacturing rate, while also increasing key material utilisation and reducing materials and costs. The aim is to increase the MRL of the additive manufacturing process from 3 to 6. Techniques for the deposition of each layer were down-selected from mature technologies used in other industries. Design of the MAMA-MEA production line is ongoing.

PROGRESS AND MAIN ACHIEVEMENTS

- Evaluation and selection of inkjet inks suitable for the deposition of seal frames. Generation of samples with improved print quality for testing
- Produced MEAs for two stacks through an additive layer manufacturing process using a prototype direct coating line that performs on a par with the benchmark
- Additive layer trial CCMs assembled into two rainbow stacks were tested by NFCT in-house and then run for a longer period in a test facility.

FUTURE STEPS AND PLANS

- JMFC's production facility: under the current situation, construction is not guaranteed.



QUANTITATIVE TARGETS AND STATUS

TARGET SOURCE	PARAMETER	UNIT	TARGET	TARGET ACHIEVED?
AWP 2017	CAPEX	€/kW	55	✗
	Lifetime	Hours	20 000	
	Degradation rate	%/1 000 h	<1	✓
Project's own objectives	Production/web speed	lm/s	0.84	

NewSOC

NEXT GENERATION SOLID OXIDE FUEL CELL AND ELECTROLYSIS TECHNOLOGY

Picture of the 3D printed large area cells

Project ID:	**874577**
Call topic:	**FCH-02-6-2019** - New materials, architectures and manufacturing processes for Solid Oxide Cells
Project total costs:	**€4 999 726.25**
FCH JU max. Contribution:	**€4 999 726.25**
Project start - end:	01/01/2020 - 30/06/2023
Coordinator:	**DANMARKS TEKNISKE UNIVERSITET, DK**
Website:	**www.newsoc.eu/**

BeneficiarieS: TEKNOLOGIAN TUTKIMUSKESKUS VTT OY, SUNFIRE GMBH, CERES POWER LIMITED, SOLIDPOWER SPA, AKTSIASELTS ELCOGEN, FUNDACIO INSTITUT DE RECERCA DE L'ENERGIA DE CATALUNYA, HEXIS AG, ETHNIKO KENTRO EREVNAS KAI TECHNOLOGIKIS ANAPTYXIS, INSTYTUT ENERGETYKI, UNIVERSITA DEGLI STUDI DI SALERNO, ECOLE POLYTECHNIQUE FEDERALE DE LAUSANNE, POLITECNICO DI TORINO, NEDERLANDSE ORGANISATIE VOOR TOEGEPAST NATUURWETENSCHAPPELIJK ONDERZOEK TNO, COMMISSARIAT A L ENERGIE ATOMIQUE ET AUX ENERGIES ALTERNATIVES, IDRYMA TECHNOLOGIAS KAI EREVNAS

PROJECT AND OBJECTIVES

NewSOC aims to significantly improve the performance, durability and cost competitiveness of solid oxide cells and stacks compared to state of the art. In order to achieve these goals, NewSOC proposes 12 innovative concepts in the following areas: (i) structural optimisation and innovative architectures, (ii) alternative materials, and (iii) innovative manufacturing to reduce critical raw materials and the environmental footprint, while improving performance and lifetime. Despite the huge challenges due to the pandemic, we achieved progress in all areas.

NON-QUANTITATIVE OBJECTIVES

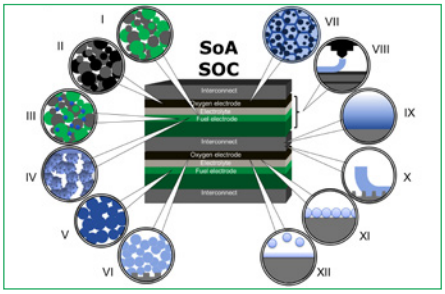
- Develop a modelling tool for microstructure optimisation. Achieved and used for improving the Ni-YSZ electrode
- Reduction of CRM materials in the SOC manufacturing (Co in the oxygen electrode). Achieved by the development of an LSF electrode
- Understanding of the underlying mechanisms under SOFC/SOEC and H_2O/CO_2 co-electrolysis operation. Understanding gained for individual CO_2 electrolysis and the contribution of the RWGS reaction to the production rate of CO during H_2O/CO_2 co-electrolysis.

PROGRESS AND MAIN ACHIEVEMENTS

- First-generation SOC with highly active oxygen electrodes with honeycomb structures manufactured and electrochemically tested at temperatures ranging from 650-750 oC
- Cells with optimised Ni-YSZ fuel electrode microstructure developed and tested, demonstrating intact Ni with no depletion after 900-1 000 h SOE operation
- 3D printed large-area electrolytes (58 cm^2) were electrochemically characterised in symmetrical and full cell configuration.

FUTURE STEPS AND PLANS

- Delivery of cells developed in WP2. Integration of highly active honeycomb structured oxygen electrodes into industrial half SOC for experimental verification and stack integration
- Delivery of cells developed in WP3. Integration of two optimized electrodes into a full cell for test and stack integration
- Durability improvement of cells with Ni-based fuel electrodes (WP2). Testing of cells with infiltrated, more tolerant and durable Ni/YSZ (Ni/GDC) fuel electrodes in rev SOC mode and SOE mode
- More tolerant and active fuel electrodes (WP2). Identification of materials and reference mapping with the target parameters, followed by electrode integration into full cells and short stacks
- Improvement of the electrochemical performance of the 3D printed large-area cells, including electrolyte and porous electrodes (WP4). Development of structures that help to hold the large electrolyte membrane and allow for an electrolyte with reduced thickness; development of optimum electrode pore structure.



QUANTITATIVE TARGETS AND STATUS

TARGET SOURCE	PARAMETER	UNIT	TARGET	ACHIEVED TO DATE BY THE PROJECT	TARGET ACHIEVED?
Project's own objectives	ASR	Ohm.cm² at 650°C	0.4	0.7	
	ASR	Ohm.cm² at 650°C	0.4	0.86	
	Electrolysis current for operation with degradation rate below 1 %/1 000 h	A/cm²	0.75-1	Nearly 5 % obtained at 725 °C and -1 A/cm²	
	Thermal cycling stability of IC/coating/ modified sealing/IC joined samples	Ohm.cm at 850°C	>1 x 10 E6 5 thermal cycles	>1 x E6 3 thermal cycles	

OxiGEN

NEXT-GENERATION SOLID OXIDE FUEL CELL STACK AND HOT BOX SOLUTION FOR SMALL STATIONARY APPLICATIONS

Project ID:	**779537**
Call topic:	**FCH-02-9-2017** - Development of next-generation SOFC stack for small stationary applications
Project total costs:	**€2 996 873.75**
FCH JU max. Contribution:	**€ 2,996,873.75**
Project start - end:	01/01/2018 - 30/06/2021
Coordinator:	**SAINT-GOBAIN CENTRE DE RECHERCHES ET D'ETUDES EUROPEEN, FR**
Website:	**oxigen-fch-project.eu/**

BENEFICIARIES: SINTEF AS, SOCIETE EUROPEENNE DES PRODUITS REFRACTAIRES, EIFER EUROPAISCHES INSTITUT FUR ENERGIEFORSCHUNG EDF KIT EWIV, ICI CALDAIE SPA, SAINT GOBAIN RECHERCHE SA, ENGIE, STIFTELSEN SINTEF, FRAUNHOFER GESELLSCHAFT ZUR FOERDERUNG DER ANGEWANDTEN FORSCHUNG EV, COMMISSARIAT A L'ENERGIE ATOMIQUE ET AUX ENERGIES ALTERNATIVES

PROJECT AND OBJECTIVES

OxiGEN aims to develop an innovative SOFC platform, including an all-ceramic stack design and a modular hotbox, thanks to its higher durability and simpler design for micro-CHP.
The objectives are:

- Define the most suitable hotbox functional specifications for residential and commercial segments (completed)
- Develop a higher power stack and modular hot box to build a 1-kWe prototype and assess the performances and durability targets (in progress)
- Propose material-based solutions for future long-term improvements (in progress)
- Study the cost of ownership of the solution.

NON-QUANTITATIVE OBJECTIVES

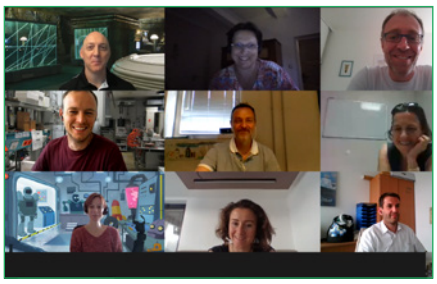
- Definition of market specifications for residential and small commercial applications and boundary limits of the hot box (completed)
- Stack design (completed)
- Hot box design (completed)
- GEN 3 short stack (in progress).

PROGRESS AND MAIN ACHIEVEMENTS

- Definition of market specifications for residential and small commercial applications and hot box boundary limits (ENGIE/SG/CEA)
- GEN 1 stack and hot box manufacturing (SG/IKTS) and pre-test at ICI Caldaie and GEN 1 short stack test at CEA
- Novel electrolyte development for better cell performances (SINTEF).

FUTURE STEPS AND PLANS

- Manufacturing of hot box with stack reaching DC efficiency of at least 55 % and a lifetime of about 2 500 h. Ongoing but with difficulties.
- Assessment of durability and performance of the stack and hot box combination.
- GEN 3 short stack with new materials in electrolyte and anode functional layers to improve the stack's performance.



QUANTITATIVE TARGETS AND STATUS

TARGET SOURCE	PARAMETER	UNIT	TARGET	ACHIEVED TO DATE BY THE PROJECT	TARGET ACHIEVED?	SOA RESULT ACHIEVED TO DATE (BY OTHERS)	YEAR FOR SOA TARGET
Project's own objective: short stack	DC electrical efficiency	%	59	50	✗	47	2016
Project's own objective: electrolyte	Conductivity	%	>30	30	✓	N/A	2016
Project's own objective: system efficiency	DC efficiency	%	55	0	✗	N/A	N/A

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 – 31/07/2020
Coordinator:	**TEKNOLOGIAN TUTKIMUSKESKUS VTT OY, FI**
Website:	**www.qsofc.eu/**

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

PROJECT AND OBJECTIVES

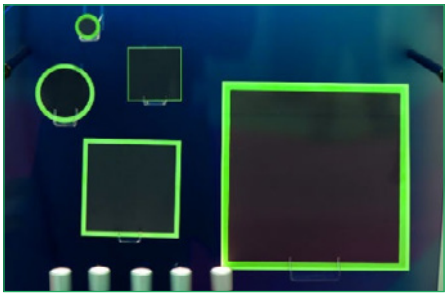
The qSOFC project focuses on SOFC stack cost reduction and quality improvement by replacing manual labour in all key parts of the stack manufacturing process with automated manufacturing and quality control. This will lead to a stack cost of 1 000 €/kW and create a further cost reduction potential down to 500 €/kW at mass production (2 000 MW/year). During the qSOFC project, key steps in cell and interconnect manufacturing and quality assurance have been optimised to enable mass manufacturing.

NON-QUANTITATIVE OBJECTIVES

- Cell mass-manufacturing process compliance with REACH regulations. New REACH-compliant compositions for mass manufacturing identified, tested and validated
- Development of stack quality assurance testing unit. Unit constructed and put into production use
- Optical inspection system developed and validated for cells. Technology can be utilised for cells and possibly other applications.

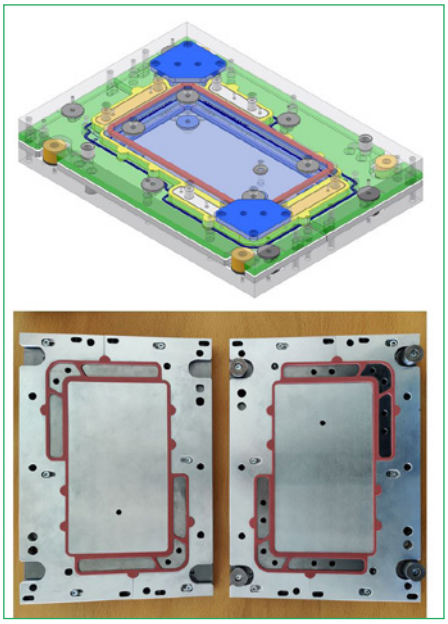
PROGRESS AND MAIN ACHIEVEMENTS

- Automated machine vision inspection system for cell manufacturing quality assurance
- Novel stack conditioning procedures have been developed, leading to about 70 % reduction in stack conditioning time and conditioning cost
- Cell manufacturing process has been modified to allow high-speed manufacturing necessary for mass production.



FUTURE STEPS AND PLANS

The project has finished.

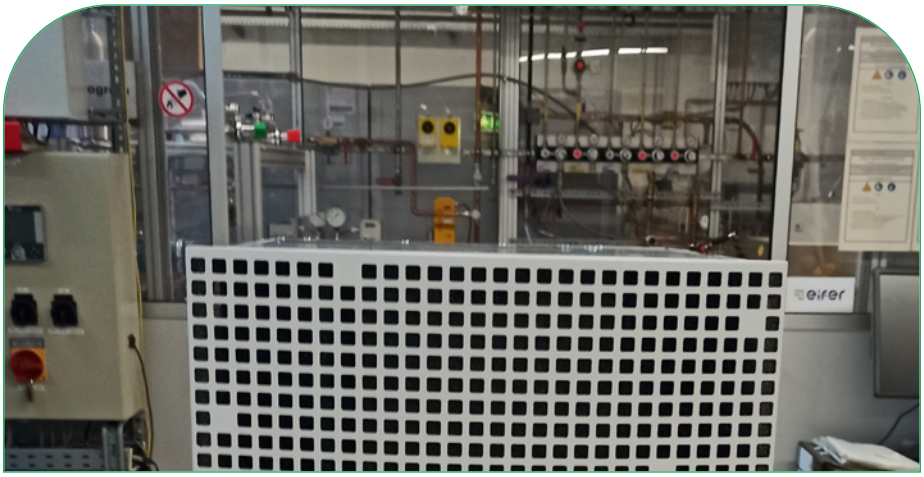


QUANTITATIVE TARGETS AND STATUS

TARGET SOURCE	PARAMETER	UNIT	TARGET	ACHIEVED TO DATE BY THE PROJECT	TARGET ACHIEVED?	SOA RESULT ACHIEVED TO DATE (BY OTHERS)	YEAR FOR SOA TARGET
Project's own objectives	Cell layer QC time	Second/cell layer	10	10	✓	N/A	N/A
	Stack production yield	%	99.5	100	✓	99.5	2015
	Production rate	Hours/stack	24	17	✓	24	2014
	Energy per conditioning cycle	kWh/cycle	300	213	✓	300	2015

RUBY

ROBUST AND RELIABLE GENERAL MANAGEMENT TOOL FOR PERFORMANCE AND DURABILITY IMPROVEMENT OF FUEL CELL STATIONARY UNITS



Project ID:	**875047**
Call topic:	**FCH-02-8-2019** -Enhancement of durability and reliability of stationary PEM and SOFC systems by implementation and integration of advanced diagnostic and control tools
Project total costs:	**€2 999 715**
FCH JU max. Contribution:	**€2 999 715**
Project start - end:	01/01/2020 - 31/12/2023
Coordinator:	**UNIVERSITA DEGLI STUDI DI SALERNO, IT**
Website:	**www.rubyproject.eu/**

BENEFICIARIES: COMMUNAUTE D'UNIVERSITES ET ETABLISSEMENTS UNIVERSITE BOURGOGNE - FRANCHE - COMTE, TEKNOLOGIAN TUTKIMUSKESKUS VTT OY, SOLIDPOWER SPA, BITRON SPA, BALLARD POWER SYSTEMS EUROPE AS, EIFER EUROPAISCHES INSTITUT FUR ENERGIEFORSCHUNG EDF KIT EWIV, FONDAZIONE BRUNO KESSLER, UNIVERSITE DE FRANCHE-COMTE, INSTITUT JOZEF STEFAN, ECOLE POLYTECHNIQUE FEDERALE DE LAUSANNE, COMMISSARIAT A L'ENERGIE ATOMIQUE ET AUX ENERGIES ALTERNATIVES

PROJECT AND OBJECTIVES

RUBY aims to develop and implement a tool able to perform integrated monitoring, diagnostic, prognostic and control functions for the production of μ-CHP and backup (BUP) systems, based on SOFC and PEMFC. The tool's key feature is the electrochemical impedance spectroscopy (EIS)-based advanced monitoring of both SOFC and PEMFC stacks. RUBY is working on the hardware integration with stack diagnostic and control algorithms as well as with fault detection algorithms for BOP. One-year tests will be conducted in a real-life environment for μ-CHP and for BUP installed in a controlled real field.

NON-QUANTITATIVE OBJECTIVES

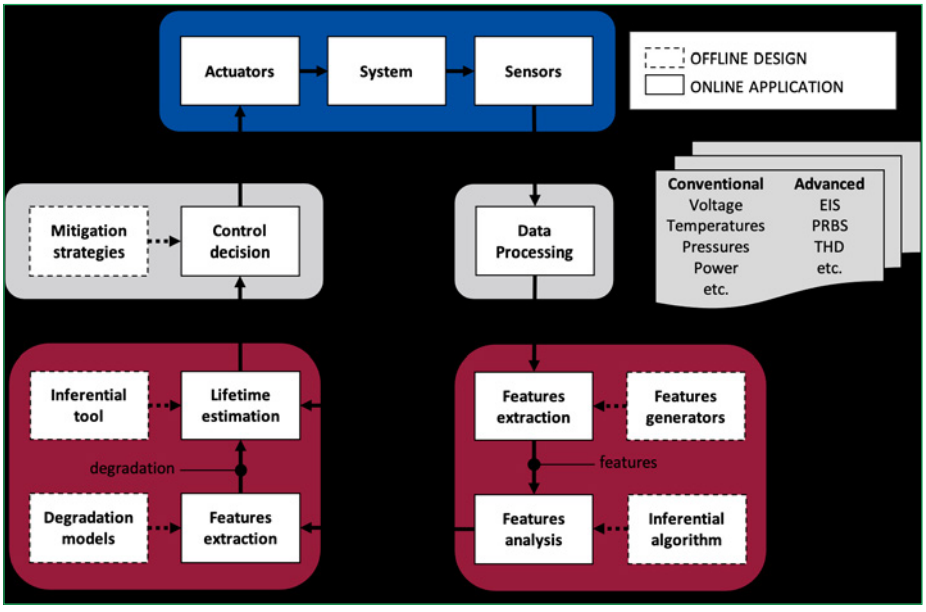
Analysis of historical data from the previous project. Data collection and elaboration for potential machine learning of the models.

PROGRESS AND MAIN ACHIEVEMENTS

- Database of system and stack measurement of conventional and EIS spectra shared among partners
- Test benches ready for system installation at partner premises
- PEMFC and SOFC stack delivered and under testing.

FUTURE STEPS AND PLANS

- EIS technique validated in laboratory. Main faults confirmed in laboratory with EIS
- Integrate RUBY tool into FCS. Tool integration completed for both FC technologies
- Validation test campaign started and checked at all test sites. Check the progress of the test campaign against the plan.

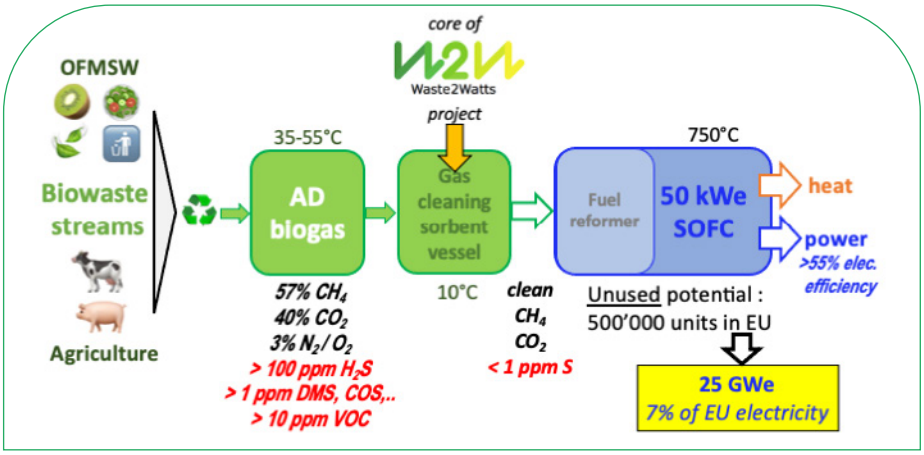


QUANTITATIVE TARGETS AND STATUS

TARGET SOURCE	PARAMETER	UNIT	TARGET	TARGET ACHIEVED?	SOA RESULT ACHIEVED TO DATE (BY OTHERS)	YEAR FOR SOA TARGET
Project's own objectives	Lifetime SOFC performance enhancement	Years	14		10	2019
	Lifetime PEMFC performance enhancement	Years	15		12	
	Maintenance costs SOFC reduction of the on-site maintenance interventions	€ cents/kWh	3.5		6	
	Maintenance costs PEMFC reduction of the on-site maintenance interventions	€/year	452		617	

WASTE2WATTS

UNLOCKING UNUSED BIO-WASTE RESOURCES WITH LOW COST CLEANING AND THERMAL INTEGRATION WITH SOLID OXIDE FUEL CELLS



Project ID:	**826234**
Call topic:	**FCH-02-7-2018** - Efficient and cost-optimised biogas-based cogeneration by high temperature fuel cells
Project total costs:	**€1 681 602.50**
FCH JU max. Contribution:	**€1 681 602.50**
Project start - end:	01/01/2019 - 31/12/2021
Coordinator:	**ECOLE POLYTECHNIQUE FEDERALE DE LAUSANNE, CH**
Website:	**waste2watts-project.net/**

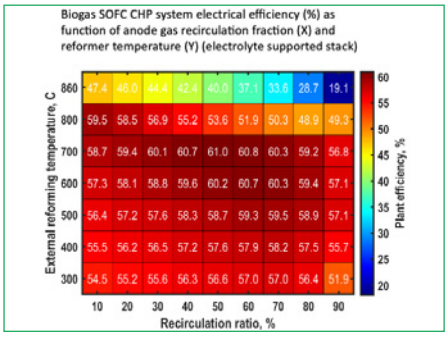
BENEFICIARIES: EREP SA, ETUDES ET APPLICATIONS D'ENERGIES RENOUVELABLES ET D'EPURATION, BIOKOMP SRL, AROL ENERGY, SUNFIRE GMBH, SOLIDPOWER SPA, SOLIDPOWER SA, POLITECNICO DI TORINO, AGENZIA NAZIONALE PER LE NUOVE TECNOLOGIE, L'ENERGIA E LO SVILUPPO ECONOMICO SOSTENIBILE, COMMISSARIAT A L'ENERGIE ATOMIQUE ET AUX ENERGIES ALTERNATIVES, PAUL SCHERRER INSTITUT

PROJECT AND OBJECTIVES

WASTE2WATTS aims to develop biogas cleaning technologies to make the gas compatible with solid oxide fuel cells (SOFC). It is characterising a series of solid sorbents (mainly based on activated carbon) in terms of how effectively they remove the sulphur contaminants H2S, CH3SH, CH3SCH3, COS as a function of the gas matrix and temperature. The project is testing SOFC cells and stacks from two suppliers, and reforming catalysts, with representative gas mixtures (based on calculations of the SOFC-CHP system layout) including contaminants. It is also exploring cleaning based on deep gas cooling and preparing a 6-kWe SOFC demo with agro-biogas.

NON-QUANTITATIVE OBJECTIVES

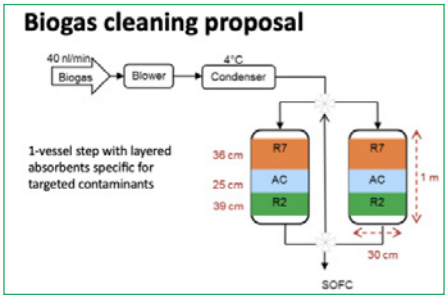
- Biogas policy. There is a clear need for bio-waste exploitation support, especially in agriculture, and for small-scale applications (25-50 kWe)



- Scale question. There is a scale segment (25-50 kWe) which would be favourable for exploitation with SOFCs, especially for farm clusters
- Sorbent question. Sorbents as a state-of-the-art solution for wet multi-contaminant ambient biogas cleaning have a low retention capacity and high OPEX
- Dry reforming capability. It is possible to reform recirculated biogas with low steam and high CO2 content on a specific catalyst.

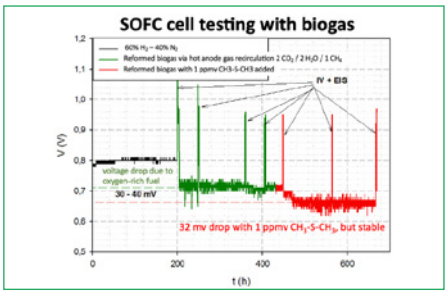
PROGRESS AND MAIN ACHIEVEMENTS

- There is a huge biogas resource in agriculture in Europe for use by small-scale SOFC (50 kWe, 0.5 M units or 25 GWe, 1 500 PJ = 8 % of EU natural gas)
- There is no easy or cheap way of using known commercial solid sorbents to clean biogas of all sulphur compounds to very low levels for SOFCs
- There are system layouts for biogas SOFC-CHP allowing to achieve >50 % electrical efficiency based on currently known performances.



FUTURE STEPS AND PLANS

- A new funding proposal for a pilot installation on a farm to operate a 6 kWe SOFC on agro-biogas is in preparation
- More research is being performed on the use of sorbents with wet biogas, including commercial solutions
- Clarify cleaning by deep cooling. More research is ongoing to clarify the feasibility (cost, performance) of deep cooling (-100 °C) of biogas to remove contaminants
- Reforming catalysts and solid oxide cells/stacks with contaminants. Thorough characterisation on cells and stacks continues, especially with contaminants, and especially for longer test durations
- Establishing a biogas installation with an advisory board SME partner. A project is in preparation with the SME partner to supply small-scale agro-biogas installations (with ICE). This installation is likely to succeed and will provide a basis for follow-up work.



QUANTITATIVE TARGETS AND STATUS

TARGET SOURCE	PARAMETER	UNIT	TARGET	ACHIEVED TO DATE BY THE PROJECT	SOA RESULT ACHIEVED TO DATE (BY OTHERS)
Project's own objectives	Biogas pollutant matrix	ppmv	<0.5 ppmv	COS is transparent to tested sorbents	Not known
	Biogas pollutant matrix	ppmv	<0.5 ppmv	DMS is the most relevant and tricky sulphur contaminant to deal with	Not known
	Sorbent capacity	g pollutant retained per g sorbent	0.1 g/g	Contaminant retention capacity of commercial sorbents is poor, especially for wet gas and contaminant mixtures	Steam added to biogas
	Gas cleaning cost	€/kWe	<1 000 €/kWe	Cost target will be difficult to meet on a small scale if biogas must be deep-chilled (4 °C)	1 000 €/kWe