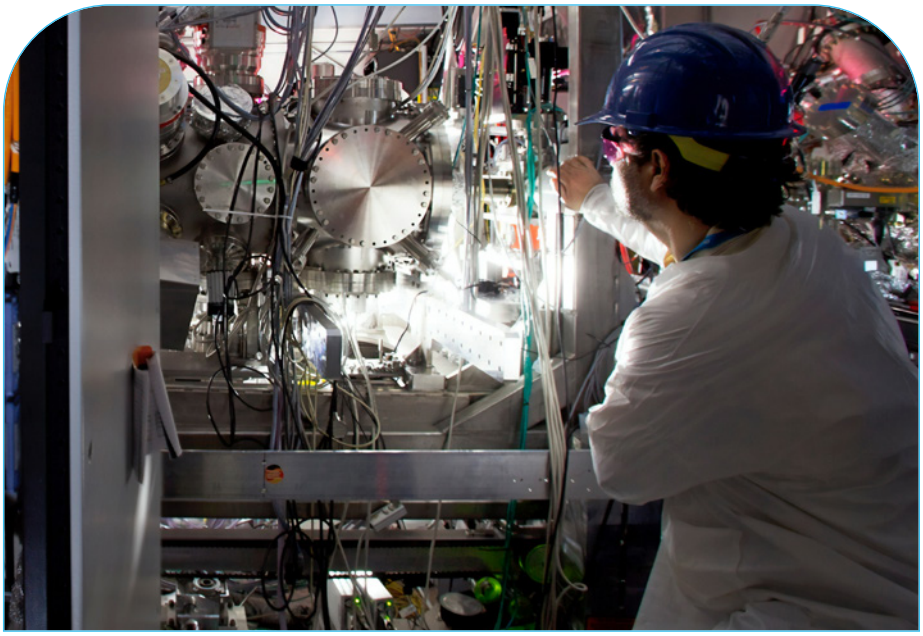
CAMELOT

UNDERSTANDING CHARGE, MASS AND HEAT TRANSFER IN FUEL CELLS FOR TRANSPORT APPLICATIONS

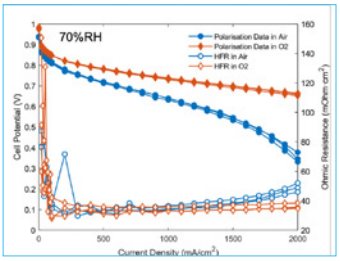


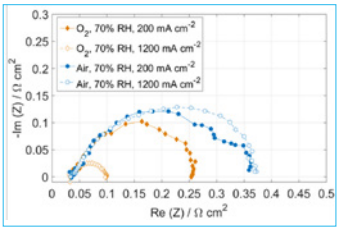
Project ID:	**875155**
Call topic:	**FCH-01-4-2019** - Towards a better understanding of charge, mass and heat transports in new generation PEMFC MEA for automotive applications
Project total costs:	**€2 295 783.50**
FCH JU max. Contribution:	**€2 295 783.50**
Project start - end:	01/01/2020 - 31/12/2022
Coordinator:	**SINTEF AS, NO**
Website:	**https://camelot-fuelcell.eu**

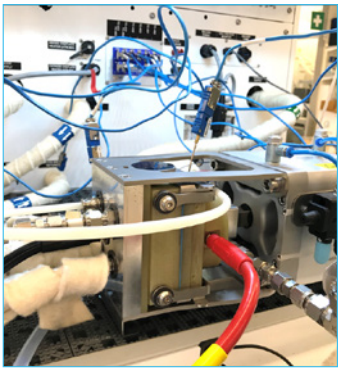
BENEFICIARIES: FCP FUEL CELL POWERTRAIN GMBH, JOHNSON MATTHEY FUEL CELLS LIMITED, PRETEXO, BAYERISCHE MOTOREN WERKE AKTIENGESELLSCHAFT, ALBERT-LUDWIGS-UNIVERSITAET FREIBURG, TECHNISCHE UNIVERSITAET CHEMNITZ, JOHNSON MATTHEY PLC

PROJECT AND OBJECTIVES

Fuel cell technology is advancing rapidly, providing energy-saving solutions in a wide range of applications including transport and mobility. However, there are limitations in fuel cell membrane electrode assembly (MEA, the core component in the electrochemical reaction) that must be overcome to improve performance. The CAMELOT project is a consortium of research institutes and universities, MEA suppliers and transport OEMs that aims to investigate ultra-thin and ultra-low loading layers required by future MEAs.







PROGRESS AND MAIN ACHIEVEMENTS

- Development of beyond state-of-the-art thin layer components for PEM technology
- Advanced characterisation of baseline materials to be used for model validation
- Development of membrane module for two-phase water transport.

FUTURE STEPS AND PLANS

- Project is currently on hold
- Restructuring of consortium is in progress.

QUANTITATIVE TARGETS AND STATUS

TARGET SOURCE	PARAMETER	UNIT	TARGET	TARGET ACHIEVED?
Project's own objectives	**Membrane thickness**	**µm**	**<10**	✗

PRD 2021 PANEL

Next Generation of Products - Transport

COSMHYC

COMBINED HYBRID SOLUTION OF MULTIPLE HYDROGEN COMPRESSORS FOR DECENTRALISED ENERGY STORAGE AND REFUELLING STATIONS

Project ID:	736122
Call topic:	**FCH-01-8-2016** - Development of innovative hydrogen compressor technology for small-scale decentralized applications for hydrogen refuelling or storage
Project total costs:	**€2 496 830**
FCH JU max. Contribution:	**€2 496 830**
Project start - end:	01/01/2017 - 28/02/2021
Coordinator:	**EIFER EUROPAISCHES INSTITUT FUR ENERGIEFORSCHUNG EDF KIT EWIV, DE**
Website:	**www.cosmhyc.eu**

BENEFICIARIES: STEINBEIS INNOVATION GGMBH, LUDWIG-BOELKOW-SYSTEMTECHNIK GMBH, NEL HYDROGEN AS, MAHYTEC SARL, STEINBEIS 2I GMBH

PROJECT AND OBJECTIVES

The COSMHYC project aims to answer the needs identified by the MAWP of the FCH2 JU of increasing the energy efficiency of hydrogen production while reducing operating and capital costs, in order to make hydrogen a competitive fuel for transport applications. COSMHYC will develop and test an innovative compression solution from 1 to 1 000 bar based on a hybrid concept, combining a conventional compressor with an innovative compression technology.

NON-QUANTITATIVE OBJECTIVES

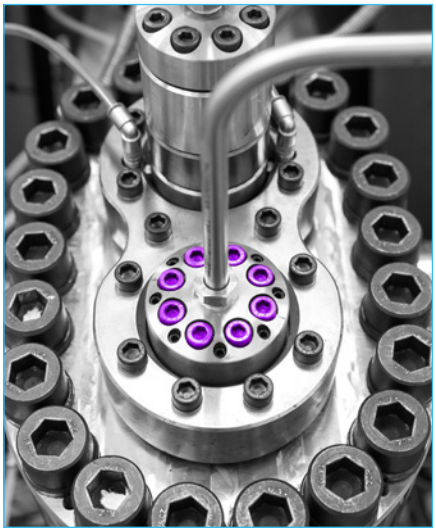
- Modular scalability. Design is intrinsically scalable
- No moving part in the innovative compressor
- Perform a cost of ownership assessment. Ongoing dedicated activities in the project.

PROGRESS AND MAIN ACHIEVEMENTS

- Rare-earth-free metal hydrides have been developed
- Techno-assessment of the relevant technology has been validated
- A prototype has been built and tested.

FUTURE STEPS AND PLANS

The project has finished.



QUANTITATIVE TARGETS AND STATUS

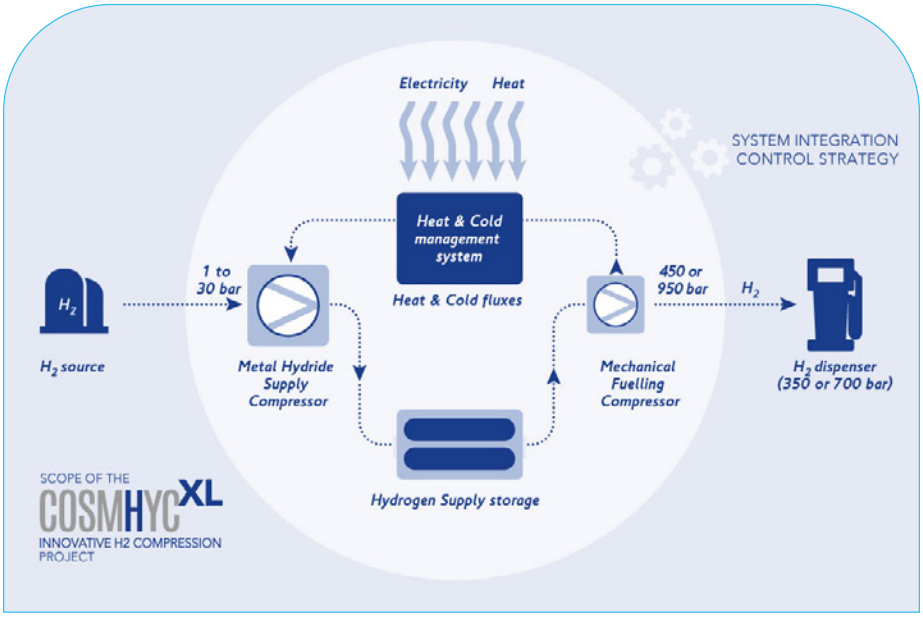
TARGET SOURCE	PARAMETER	UNIT	TARGET	ACHIEVED TO DATE BY THE PROJECT	TARGET ACHIEVED?	SOA RESULT ACHIEVED TO DATE (BY OTHERS)	YEAR FOR SOA TARGET
AWP 2016	Noise	dB	<60	53		85	2020
	TRL	-	5	5	✓	3	2017
Project's own objectives	Specific costs	k€/kg*day	N/A	3.7		5-12	2015

COSMHYC XL

COMBINED HYBRID SOLUTION OF METAL HYDRIDE AND MECHANICAL COMPRESSORS FOR EXTRA LARGE SCALE HYDROGEN REFUELLING STATIONS

Project ID:	**826182**
Call topic:	**FCH-01-7-2018** - Improvement of innovative compression concepts for large scale transport applications
Project total costs:	**€2 749 613.75**
FCH JU max. Contribution:	**€2 749 613.75**
Project start - end:	01/01/2019 - 31/12/2021
Coordinator:	**EIFER EUROPAISCHES INSTITUT FUR ENERGIEFORSCHUNG EDF KIT EWIV, DE**
Website:	**cosmhyc.eu/cosmhyc-xl-project**

BENEFICIARIES: STEINBEIS 2I GMBH, MAHYTEC SARL, NEL HYDROGEN AS, LUDWIG-BOELKOW-SYSTEMTECHNIK GMBH



PROJECT AND OBJECTIVES

Hydrogen mobility is one of the most promising solutions for a sustainable energy transition in large-scale transport modes, including trucks, buses, trains and professional vehicle fleets. For these applications, a dedicated hydrogen refuelling infrastructure is necessary, including hydrogen compressors able to meet challenging constraints in terms of flow rate and availability. COSMHYC XL aims to develop an innovative compression solution for extra-large hydrogen refuelling stations, based on the combination of a metal hydride compressor and a diaphragm compressor.

NON-QUANTITATIVE OBJECTIVES

- Hybrid system allowing different configurations. Economic optimisation from LBST demonstrates that different refuelling applications will require only very slightly adapted configurations and intermediate storage capacities to minimise total costs
- Increase reliability. No moving part in the innovative compressor
- Cost of ownership assessment. Ongoing dedicated activities in the project.

PROGRESS AND MAIN ACHIEVEMENTS

- Optimisation of rare-earth-free hydrides with better performances than COSMHYC
- Economic analysis shows that the hybrid system allows different configurations (e.g. intermediate pressure levels or intermediate storage sizes)
- Modelling and draft designs are available for the new mechanical compressor and for the large-scale-oriented system integration.

FUTURE STEPS AND PLANS

- Finalisation of design. Design has been drafted and main subsystems identified
- Construction of prototypes. Test site has been identified and is being prepared
- Long-term tests on prototypes have not yet started.

QUANTITATIVE TARGETS AND STATUS

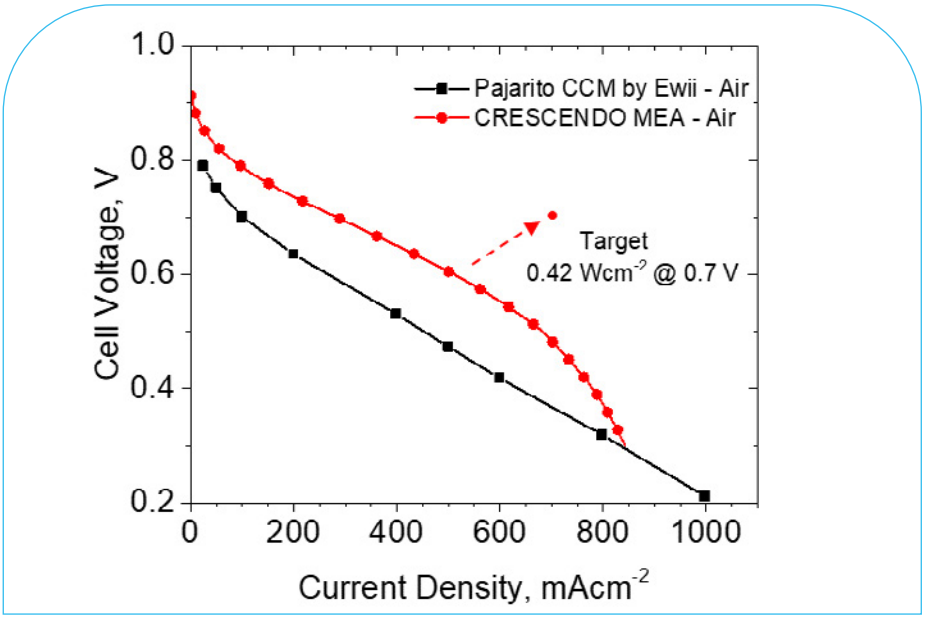
TARGET SOURCE	PARAMETER	UNIT	TARGET	TARGET ACHIEVED?	SOA RESULT ACHIEVED TO DATE (BY OTHERS)	YEAR FOR SOA TARGET
Project's own objective	Energy consumption	kWh/kg	6.18		8	2018
	Degradation	%/1 000 h	0.8		N/A	N/A
	Specific costs	k€/kg*day	1.47		3.7	2019
	Noise	dB	<60		85	2017

PRD 2021 PANEL

Next Generation of Products - Transport

CRESCENDO

CRITICAL RAW MATERIAL ELECTROCATALYSTS REPLACEMENT ENABLING DESIGNED POST-2020 PEMFC



Project ID:	**779366**
Call topic:	**FCH-01-2-2017 -** TTowards next generation of PEMFC: Non-PGM catalysts
Project total costs:	**€2 739 602.5**
FCH JU max. Contribution:	**€2 739 602.5**
Project start - end:	01/01/2018 - 30/06/2021
Coordinator:	**CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE CNRS, FR**
Website:	**www.crescendo-fuelcell.eu/**

BENEFICIARIES: UNIVERSITE DE MONTPELLIER, JOHNSON MATTHEY FUEL CELLS LIMITED, PRETEXO, BAYERISCHE MOTOREN WERKE AKTIENGESELLSCHAFT, JOHNSON MATTHEY PLC, TECHNISCHE UNIVERSITAT BERLIN, COMMISSARIAT A L'ENERGIE ATOMIQUE ET AUX ENERGIES ALTERNATIVES, IMPERIAL COLLEGE OF SCIENCE TECHNOLOGY AND MEDICINE, UNIVERSITA DEGLI STUDI DI PADOVA

PROJECT AND OBJECTIVES

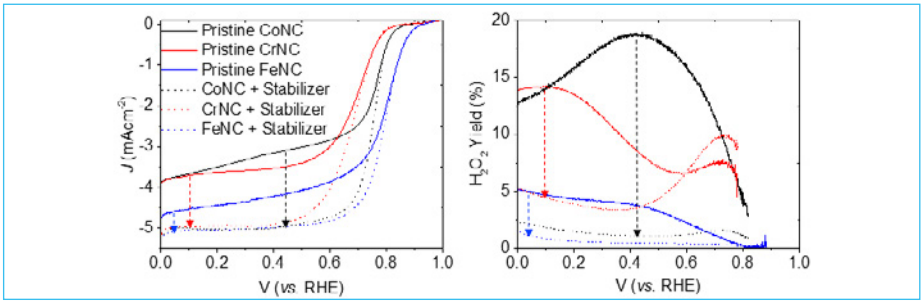
CRESCENDO aims to make progress in research on PGM-free fuel cell cathode catalysts, develop diagnostic methods to characterise their active site density and turnover frequency, and realise successful catalyst stabilisation approaches, as well as advance research on non-PGM and ultra-low PGM hydrogen oxidation catalysts. The reasons for the high losses with current PGM-free cathode catalyst layers have been analysed and the findings used to redesign the catalyst layer, with the objective of achieving 0.42 W/cm2 at 0.7 V in air, and 1000 h operation with the scaled-up catalyst and final configuration of the MEA.

PROGRESS AND MAIN ACHIEVEMENTS

- Achieved 210+ mV improvement at 600 mA/cm2 in H2/air over commercial MEA comprising commercial non-PGM cathode
- Produced 30 g scaled-up non-PGM catalyst, associated with stabilisation additive and used in newly developed catalyst layers
- Demonstrated 170 mA/cm2 (at 0.1 V with Ni-based bioinspired anode catalyst 36 A/mg Ni) anchored to functionalised carbon nanotubes.

FUTURE STEPS AND PLANS

- Optimise cathode catalyst layer with scaled-up catalyst. This is ongoing
- Evaluate MEAs with scaled-up project non-PGM cathode catalyst layers. Planned from M40
- Cost analysis. Planned from M42
- Demonstrate performance of MEA with PGM-free anode and PGM-free cathode after lockdown rules have been eased.



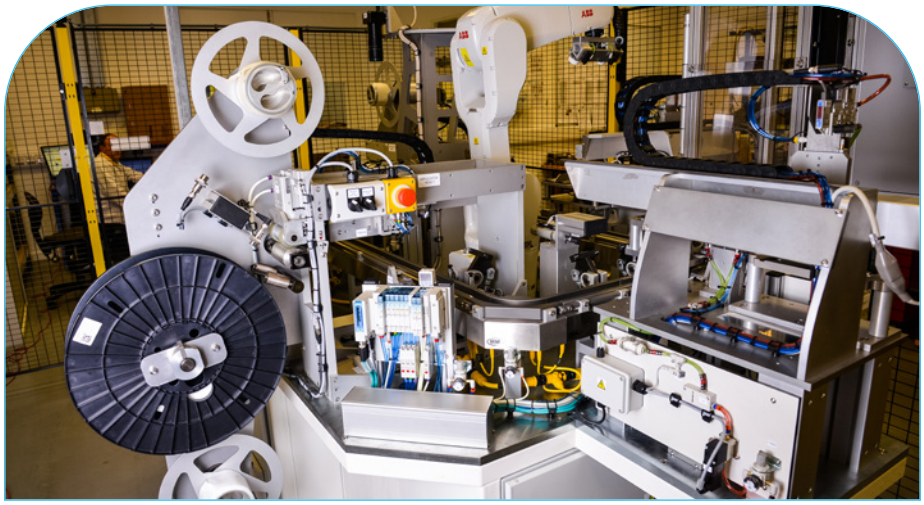
QUANTITATIVE TARGETS AND STATUS

TARGET SOURCE	PARAMETER	UNIT	TARGET	ACHIEVED TO DATE BY THE PROJECT	TARGET ACHIEVED?	SOA RESULT ACHIEVED TO DATE (BY OTHERS)	YEAR FOR SOA TARGET
AWP 2018	Current density at 0.7 V	mA/cm²	600	400	✗	228	2020
	Durability at 1.5 A/cm²	Hours	1000	Result due M45	✗	No data available at 1.5 A/cm²	N/A
Project's own objectives for non-PGM anode catalyst	Mass activity at 0.9 V IR-free	A/mg	35	36	✓	No data available with bioinspired Ni catalyst	N/A

DIGIMAN
DIGITAL MATERIALS CHARACTERISATION PROOF-OF-PROCESS AUTO ASSEMBLY

Project ID:	**736290**
Call topic:	**FCH-01-1-2016** - Manufacturing technologies for PEMFC stack components and stacks
Project total costs:	**€3 486 965**
FCH JU max. Contribution:	**€3 486 965**
Project start - end:	01/01/2017 - 30/06/2020
Coordinator:	**COMMISSARIAT A L'ENERGIE ATOMIQUE ET AUX ENERGIES ALTERNATIVES, FR**
Website:	**digiman.eu/**

BENEFICIARIES: INTELLIGENT ENERGY LIMITED, PRETEXO, FREUDENBERG PERFORMANCE MATERIALS SE & CO KG, TOYOTA MOTOR EUROPE NV, THE UNIVERSITY OF WARWICK



PROJECT AND OBJECTIVES

The project advances (MRL4>MRL6) the critical steps of the PEM fuel cell assembly processes and associated in-line QC and demonstrates a route to an automated volume process production capability within an automotive best practice context. This includes characterisation and digital codification of physical attributes of key materials (e.g. GDLs) to establish yield-impacting digital cause and effect relationships within the value chain Industry 4.0 standards. Main outputs are a proof of process and a blueprint design for beyond current state automotive PEM fuel cell manufacturing in Europe.

NON-QUANTITATIVE OBJECTIVES

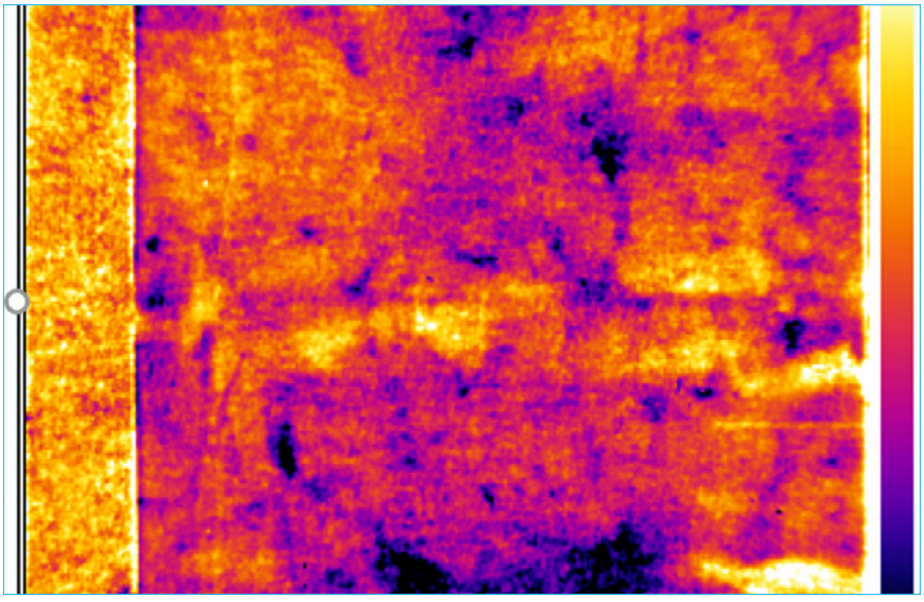
- Inline digital detection and marking of surface non-uniformities via Vision line. Process set up and in operation. Automated surface assessment shows meaningful results and sufficient resolution
- Integration of inline non-destructive quality control tools. Digital optical QC has already been installed with Freudenberg Performance Material's production line
- Development of beyond state technologies, specific to PEMFC stack production. Innovative floatation methods for pick and place handling and mechanical pre-alignment of non-rigid and porous GDL materials have been developed
- Improvement, modification and adaptation of component production steps. Development of digital boundary limits to empirically derived homogeneity data have been developed
- Development of QA strategies for the transport sector compatible with IATF 16949. Characterisation of structural anomalies (heterogeneities and detection techniques have been completed).

PROGRESS AND MAIN ACHIEVEMENTS

- KPIs have been agreed for: (i) fully automated stack assembly/test via automotive best practice; (ii) stack performance at handover to a production line
- Proof-of-process demonstrator equipment for the uplifted cell assembly automation has been manufactured and validated
- Deep characterisation of GDL properties has enabled the development of automatic scanning techniques for digital QC and characterisation.

FUTURE STEPS AND PLANS

The project has finished.



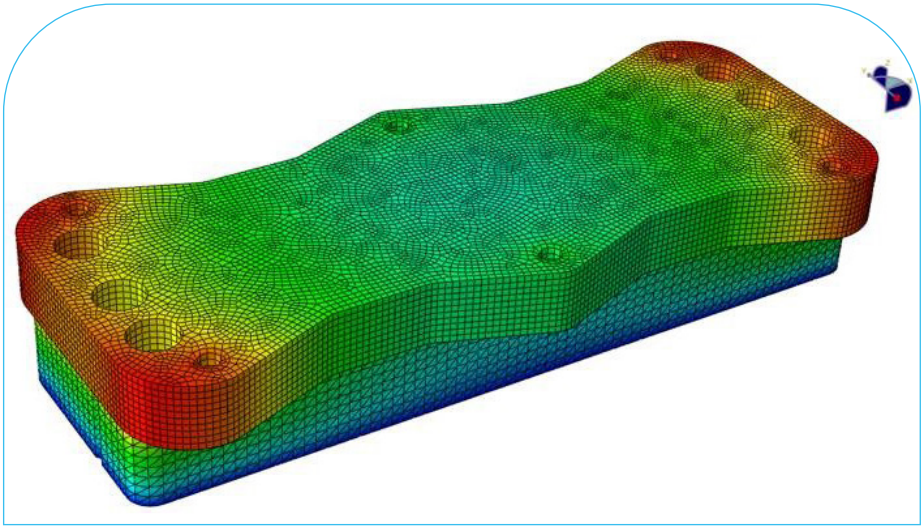
QUANTITATIVE TARGETS AND STATUS

TARGET SOURCE	PARAMETER	UNIT	TARGET	ACHIEVED TO DATE BY THE PROJECT	TARGET ACHIEVED?
Project's own objectives	Stack weight	kg	2.9	2.9	✓
	Stack volume	l	2.85	2.85	
	Stack capacity	t	2.1	2.1	

DOLPHIN

DISRUPTIVE PEMFC STACK WITH NOVEL MATERIALS, PROCESSES, ARCHITECTURE AND OPTIMIZED INTERFACES

Disruptive pemfc stack with nOvel materiaLs, Processes, arcHitecture and optimized INterfaces



Project ID:	**826204**
Call topic:	**FCH-01-6-2018** - Game changer fuel cell stack for automotive applications
Project total costs:	**€2 962 681**
FCH JU max. Contribution:	**€2 962 681**
Project start - end:	01/01/2019 - 31/12/2022
Coordinator:	**COMMISSARIAT A L'ENERGIE ATOMIQUE ET AUX ENERGIES ALTERNATIVES, FR**
Website:	**www.dolphin-fc.eu/**

BENEFICIARIES: CHEMOURS FRANCE SAS, CHEMOURS BELGIUM, CHEMOURS INTERNATIONAL OPERATIONS SARL, HEXCEL COMPOSITES GMBH & CO KG, DMG MORI ADDITIVE GMBH, SYMBIO, FAURECIA SYSTEMES D'ECHAPPEMENT SAS, HEXEL REINFORCEMENTS SAS, HEXCEL COMPOSITES LTD, ZENTRUM FUR SONNENENERGIE- UND WASSERSTOFF-FORSCHUNG BADEN-WURTTEMBERG, THE UNIVERSITY OF MANCHESTER

PROJECT AND OBJECTIVES

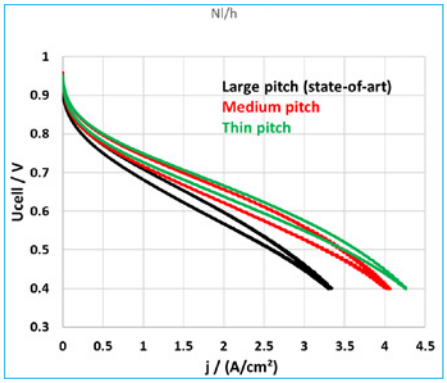
The overall aim of the project is to validate disruptive technologies for 100 kW light-weight and compact fuel cell stack designs, reaching outstanding (specific and volumetric) power density while simultaneously featuring enhanced durability (under automotive application conditions) compared to state of the art, and compatible with large scale/mass production of full power stacks. Validation of the DOLPHIN technologies will be supported by the design and manufacture of an automotive stack of 5 kW, representative of 100 kW power stacks.

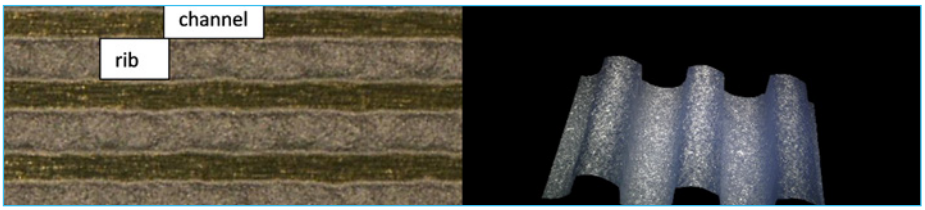
PROGRESS AND MAIN ACHIEVEMENTS

- Increased performance thanks to reduction in rib-channel dimensions
- Manufacturing methods (printing, additive manufacturing) to produce flow fields with thin dimensions on metallic or composite thin sheets
- Reduction of mass and volume of terminal plates thanks to composite materials.

FUTURE STEPS AND PLANS

- Selection of most promising components to be tested in short stack and 5 kW stack (2021, 2022). Some materials have already been selected; tests for other have been delayed due to supply delays
- Performance and durability tests of 5 kW stack (2022). Test protocols have been defined
- Experimental validation of the interest in the different routes of the project to increase performance and durability. This is ongoing. Life Cycle Analysis will also be taken into consideration for the evaluation.





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
AWP 2018	Weight-specific power density	kW/kg	4	N/A		3.4	2017 by Auto-Stack Core
	Volume-specific power density	kW/l	5			4.1	
	Surface power density	W/cm²	2	1.3		1.13	
	Durability	Hours	6 000	N/A		3 500	
	Stack cost	€/kW	20			36.8	

Fit-4-AMandA

FUTURE EUROPEAN FUEL CELL TECHNOLOGY: FIT FOR AUTOMATIC MANUFACTURING AND ASSEMBLY

Project ID:	735606
Call topic:	FCH-01-1-2016 - Manufacturing technologies for PEMFC stack components and stacks
Project total costs:	€2 999 185
FCH JU max. Contribution:	€2 999 185
Project start - end:	01/03/2017 - 29/11/2020
Coordinator:	UNIRESEARCH BV, NL
Website:	www.fit-4-amanda.eu

BENEFICIARIES: UPS EUROPE SA, AUMANN LIMBACH-OBERFROHNA GMBH, PROTON MOTOR FUEL CELL GMBH, IRD FUEL CELLS A/S, TECHNISCHE UNIVERSITAET CHEMNITZ, FRAUNHOFER GESELLSCHAFT ZUR FOERDERUNG DER ANGEWANDTEN FORSCHUNG EV

PROJECT AND OBJECTIVES

The main target of the project was to industrialise stack production by building a global new and unique machine that allows the serial production of the centrepiece of the fuel cell system: the stack. The project is officially finished and the machine completed and delivered, but final tests and data have been delayed and are still ongoing due to technical issues and the COVID-19 pandemic.

NON-QUANTITATIVE OBJECTIVES

- Feasibility study of commercial FC electrical vehicle that produces a summary of the conditions under which the fuel cell technology, especially the newly created stack, fits into an LCV from UPS
- Performance requirements are elaborated from the vehicle. Consolidate the technical requirements in detail for standard FC operation and need for special demands and find ways to integrate seamlessly to reduce costs.

PROGRESS AND MAIN ACHIEVEMENTS

- Development, manufacturing and testing of technology and machine system for the automatic assembly of PEMFC stacks
- Validation of designs, hardware, tools and software for the automated production of MEAs and automated stack assembly
- Design and development of an automated processing unit/system for the manufacturing of key/critical stack components, i.e. MEAs.

FUTURE STEPS AND PLANS

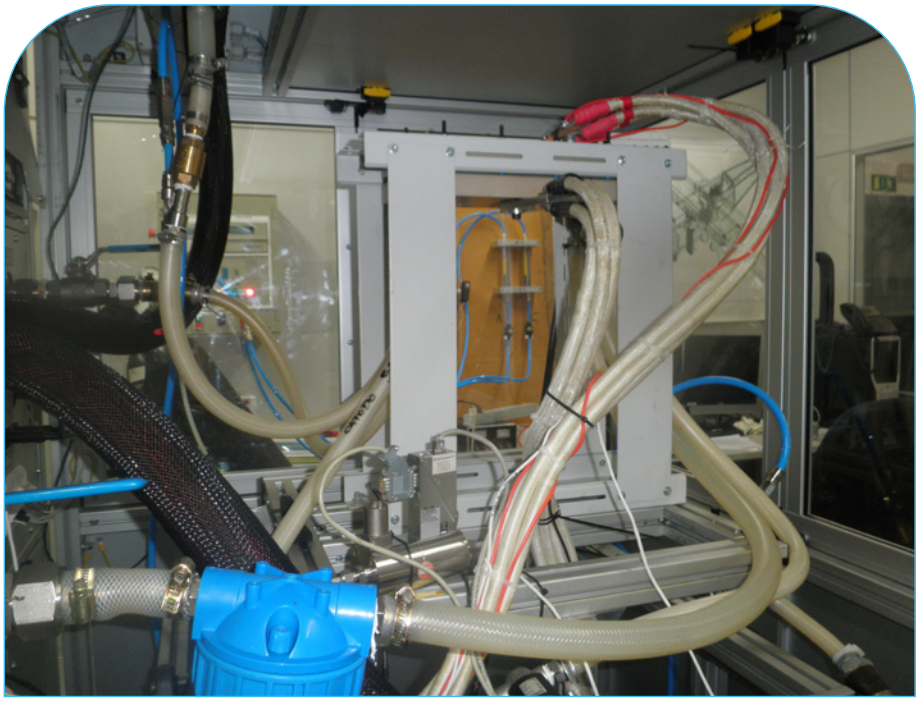
Finalisation of field tests which have already been planned between the PM and end users.

QUANTITATIVE TARGETS AND STATUS

TARGET SOURCE	PARAMETER	UNIT	TARGET	TARGET ACHIEVED?
Project's own objectives	Production time for one stack (throughput time)	Hours	<0.5	✓
	Automated production process steps	%	90	✓
	Specific FC system cost	€/kW	100	✗

FLHYSAFE

FUEL CELL HYDROGEN SYSTEM FOR AIRCRAFT EMERGENCY OPERATION



Project ID:	**779576**
Call topic:	**FCH-01-1-2017** - Development of fuel cell system technologies for achieving competitive solutions for aeronautical applications
Project total costs:	**€7 354 868.75**
FCH JU max. Contribution:	**€5 063 023**
Project start - end:	01/01/2018 - 30/09/2022
Coordinator:	**SAFRAN POWER UNITS, FR**
Website:	**www.flhysafe.eu**

BeneficiarieS: COMMISSARIAT A L'ENERGIE ATOMIQUE ET AUX ENERGIES ALTERNATIVES, DEUTSCHES ZENTRUM FUER LUFT- UND RAUMFAHRT EV, UNIVERSITAET ULM, ARTTIC, INSTITUTO NACIONAL DE TECNICA AEROESPACIAL ESTEBAN TERRADAS, SAFRAN AEROTECHNICS

PROJECT AND OBJECTIVES

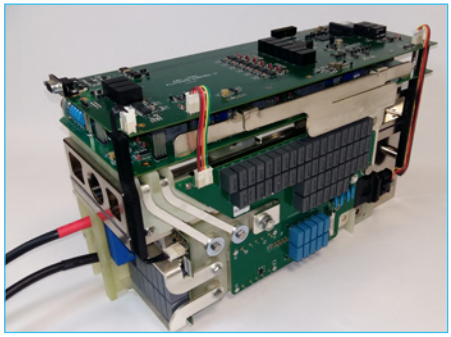
In the trend towards 'More Electric Aircraft' (MEA), fuel cell systems are considered one of the best options for efficient power generation. The main objective of FLHYSAFE is to demonstrate that a cost-efficient modular fuel cell system can replace the most critical safety systems and be used as an Emergency Power Unit aboard a commercial airplane and provide enhanced safety functionalities. Also, the project aims to virtually demonstrate that the system can be integrated, respecting both installation volumes and maintenance constraints, by using current aircraft designs.

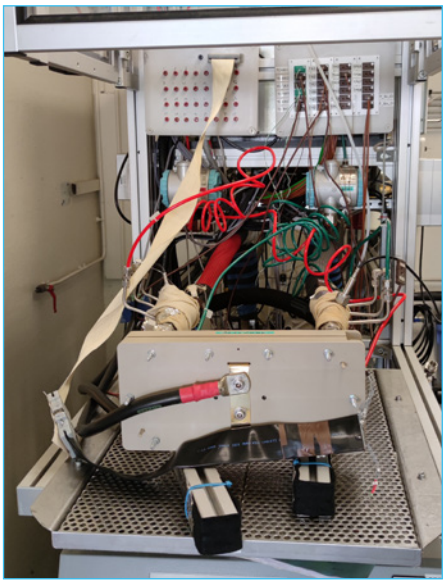
PROGRESS AND MAIN ACHIEVEMENTS

- Emergency Power Unit system specification, functional analysis and system architecture (P&ID drawing)
- Short stack test campaigns (durability, start/stop study, oxidant)
- Integrated power converter design and manufacturing.

FUTURE STEPS AND PLANS

- FCS-a design, assembly and testing. Assembly is scheduled for S1 2021 and testing for S2 2021
- FCS-b design, assembly and testing. Design and assembly are scheduled for 2021 and testing for 2022.





QUANTITATIVE TARGETS AND STATUS

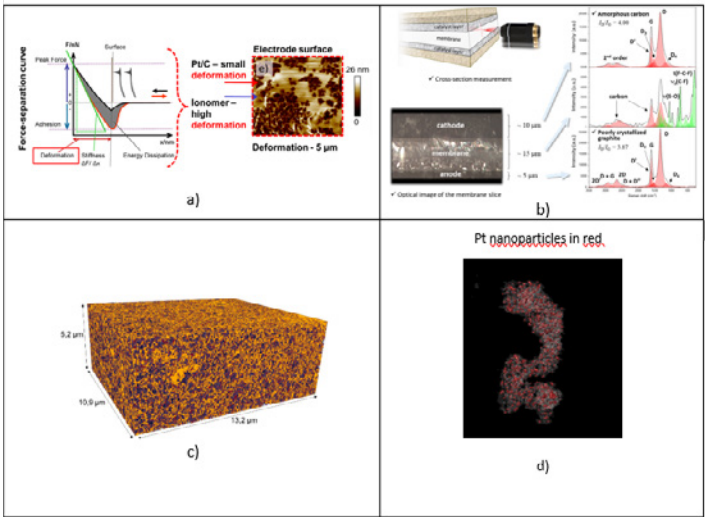
TARGET SOURCE	PARAMETER	UNIT	TARGET	TARGET ACHIEVED?
Project's own objectives	Weight (taking into account thermal management, electrical and power management but excluding hydrogen storage)	kg	150	
	Power density	W/kg	100	
	Volume	l	200	
	Efficiency at rated power	%	40	

PRD 2021 PANEL

Next Generation of Products - Transport

FURTHER-FC

FURTHER UNDERSTANDING RELATED TO TRANSPORT LIMITATIONS AT HIGH CURRENT DENSITY TOWARDS FUTURE ELECTRODES FOR FUEL CELLS



Project ID:	**875025**
Call topic:	**FCH-01-4-2019** - Towards a better understanding of charge, mass and heat transports in new generation PEMFC MEA for automotive applications
Project total costs:	**€2 735 031.25**
FCH JU max. Contribution:	**€2 199 567.35**
Project start - end:	01/01/2020 - 29/02/2024
Coordinator:	**COMMISSARIAT A L'ENERGIE ATOMIQUE ET AUX ENERGIES ALTERNATIVES, FR**
Website:	**further-fc.eu/**

BENEFICIARIES: CHEMOURS FRANCE SAS, THE CHEMOURS COMPANY FC, LLC, UNIVERSITE DE MONTPELLIER, HOCHSCHULE ESSLINGEN, TOYOTA MOTOR EUROPE NV, ECOLE NATIONALE SUPERIEURE DE CHIMIE DE MONTPELLIER, UNIVERSITY OF CALGARY, INSTITUT NATIONAL POLYTECHNIQUE DE TOULOUSE, DEUTSCHES ZENTRUM FUR LUFT- UND RAUMFAHRT EV, IMPERIAL COLLEGE OF SCIENCE TECHNOLOGY AND MEDICINE, PAUL SCHERRER INSTITUT, CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE CNRS

PROJECT AND OBJECTIVES

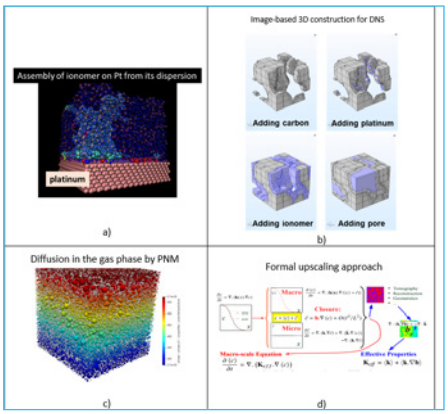
FURTHER-FC proposes complete experimental and modelling coupled platforms to better understand the performance limitations in the cathode catalyst layers (CCL) of low Pt loaded PEMFC. The concept starts with the design and manufacturing of customised CCL, which are to be intensively studied with the platforms to analyse their performance based on the knowledge of their structure and component distribution. Based on this, CCL improvements will be discussed and tested. So far, the first CCL have been produced and characterisation and modelling tools are currently being set up, improved, validated and applied.

PROGRESS AND MAIN ACHIEVEMENTS

- Progress on the characterisation of catalyst layers by AFM, Raman and 3D FIB-SEM
- Progress on the modelling of catalyst layers, especially by direct numerical modelling
- Definition and validation of test protocols and differential cell hardware as a common basis between the partners.

FUTURE STEPS AND PLANS

- Characterise reference and customised CCL. Work has started on the reference and needs to be completed; work on the customised CCL has yet to be done
- Model transport mechanisms from the ionomer film to the single cell. Models are progressing, with first results from MD and DNS, and need to be completed. Inputs from in-operando experiments on the characterisations and validation are used as and when available.



QUANTITATIVE TARGETS AND STATUS

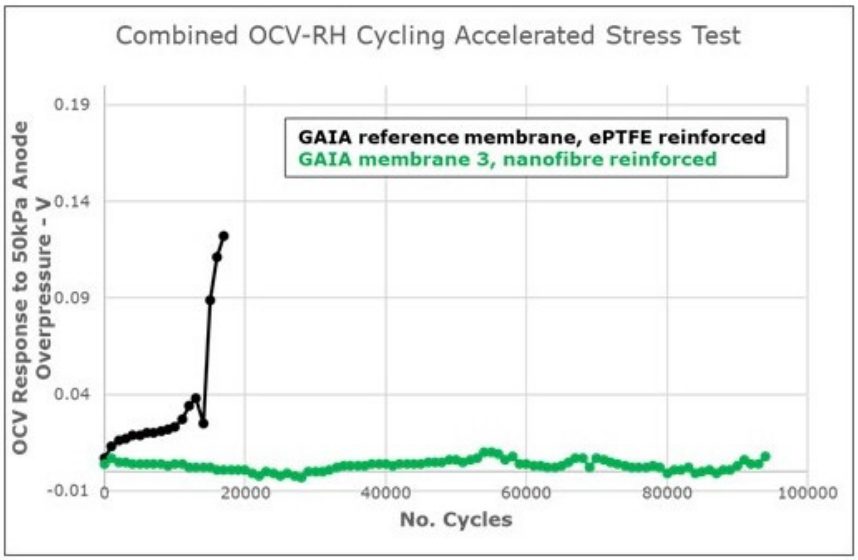
TARGET SOURCE	PARAMETER	UNIT	TARGET	TARGET ACHIEVED?	SOA RESULT ACHIEVED TO DATE (BY OTHERS)	YEAR FOR SOA TARGET
MAWP (2014-2020)	Volumetric power density	kW/l	9.3	✗	4.1	2017 by Auto-Stack Core
	Weight power density	kW/kg	4		3.4	
	Surface power density	W/cm²	1.8		1.13	
	Cost	€/kW	20		36.8	
	Durability	Hours	6 000		3 500	
	Total Pt loading	mg/cm²	0.144		0.4	
	Total Pt loading	g/kW	0.08		0.35	
	Pt efficiency	A/mg	15		4.5	

GAIA

NEXT GENERATION AUTOMOTIVE MEMBRANE ELECTRODE ASSEMBLIES

Project ID:	**826097**
Call topic:	**FCH-01-5-2018** - Next generation automotive MEA development
Project total costs:	**€4 493 025**
FCH JU max. Contribution:	**€4 493 025**
Project start - end:	01/01/2019 - 31/12/2021
Coordinator:	**CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE CNRS, FR**
Website:	**www.gaia-fuelcell.eu**

BENEFICIARIES: DYNEON GMBH, UNIVERSITE DE MONTPELLIER, JOHNSON MATTHEY FUEL CELLS LIMITED, PRETEXO, FREUDENBERG PERFORMANCE MATERIALS SE & CO KG, 3M DEUTSCHLAND GMBH, ELMARCO SRO, BAYERISCHE MOTOREN WERKE AKTIENGESELLSCHAFT, ZENTRUM FUR SONNENENERGIE- UND WASSERSTOFF-FORSCHUNG BADEN-WURTTEMBERG, JOHNSON MATTHEY PLC, TECHNISCHE UNIVERSITAET MUENCHEN, TECHNISCHE UNIVERSITAT BERLIN



PROJECT AND OBJECTIVES

GAIA aims to develop the next generation of automotive MEAs, delivering 1.8 W/cm2 at 0.6 V. The project intends to validate MEA performance and durability in full size cell short stacks, demonstrate the possibility of 6 000 hours lifetime, and provide a cost assessment that establishes that MEAs can achieve the cost target of 6 €/kW for a production rate of 1 million m2/year. Currently at M27, GAIA has validated its stack hardware and testing protocols, developed new carbon, catalyst, ionomer, membrane, gas diffusion and microporous layer components, and reached its first three milestones.

NON-QUANTITATIVE OBJECTIVES

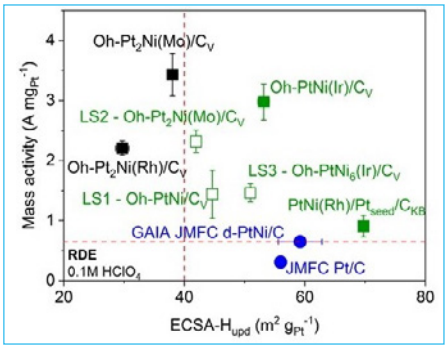
Outreach. Video on catalyst preparation and characterisation by RDE and catalyst integration into MEAs and testing/diagnostics, prepared by TUB and TUM (>1 460 views).

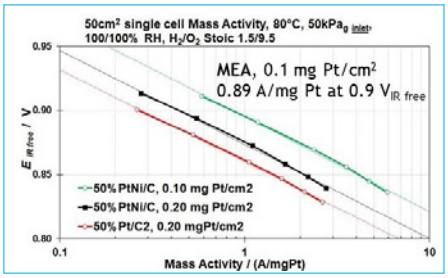
PROGRESS AND MAIN ACHIEVEMENTS

- Achieved 0.89 A/mg Pt in a 50 cm2 fuel cell, 0.10 mg Pt/cm2, giving 0.16 g Pt/kW, essentially reaching the project target
- Achieved 100 000 AST cycles (90 °C, OCV, wet/dry cycling) without failure with an MEA comprising an electrospun reinforced membrane, 5x target
- Generation 2 MEA provided improved performance in a short stack at all operation points, and improved stability at 105 °C compared with generation 1.

FUTURE STEPS AND PLANS

- Short stack testing with components specifically designed for performance to reach the performance target. CCMs prepared for delivery
- Short stack testing with components specifically designed for durability to reach the durability target. Planned for M29
- Implement new CCM coating methods. Benefit demonstrated in single cell testing
- Integrate most effective components in a short stack to achieve both performance and durability targets
- Cost analysis.





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
AWP 2019	Power density at 0.6 V	W/cm²	1.8	1.86	✓	No public data at 3 A/cm² under call conditions	N/A
	Durability (voltage decay rate)	%	<10 % after 6 000 hours operation	<3 % after 2 500 hours automotive drive cycle testing		10 % after 500 hours automotive drive cycle testing	2019
	MEA cost	€/kW	6	Cost evaluation for later in year 3. Target production rate for membrane reinforcement contributes to reaching cost target		13	2017

HEAVEN

HIGH POWER DENSITY FC SYSTEM FOR AERIAL PASSENGER VEHICLE FUELED BY LIQUID HYDROGEN

Project ID:	**826247**
Call topic:	**FCH-01-4-2018** - Fuel cell systems for the propulsion of aerial passenger vehicle
Project total costs:	**€4 600 881.68**
FCH JU max. Contribution:	**€3 995 305**
Project start - end:	01/01/2019 - 31/12/2022
Coordinator:	**FUNDACION AYESA, ES**
Website:	**heaven-fch-project.eu/**

BENEFICIARIES: PIPISTREL VERTICAL SOLUTIONS DOO PODJETJE ZA NAPREDNE LETALSKE RESITVE, H2FLY GMBH, AIR LIQUIDE ADVANCED TECHNOLOGIES SA, ELRINGKLINGER AG, AIR LIQUIDE SA, DEUTSCHES ZENTRUM FUER LUFT- UND RAUMFAHRT EV

PROJECT AND OBJECTIVES

HEAVEN's goal is to design, develop and integrate the first global aircraft powertrain based on a high-power-density FC system and high energy density liquid hydrogen fuel system into an existing 2- to 4- seater aircraft for testing in-flight operation. HEAVEN will focus on demonstrating the airworthiness and economic viability of an FC and cryogenic hydrogen-based solution for the propulsion of passenger aircraft. In addition, HEAVEN will provide reliability figures for future certification and relevant data for the development of a zero-emission hydrogen-powered aircraft.

NON-QUANTITATIVE OBJECTIVES

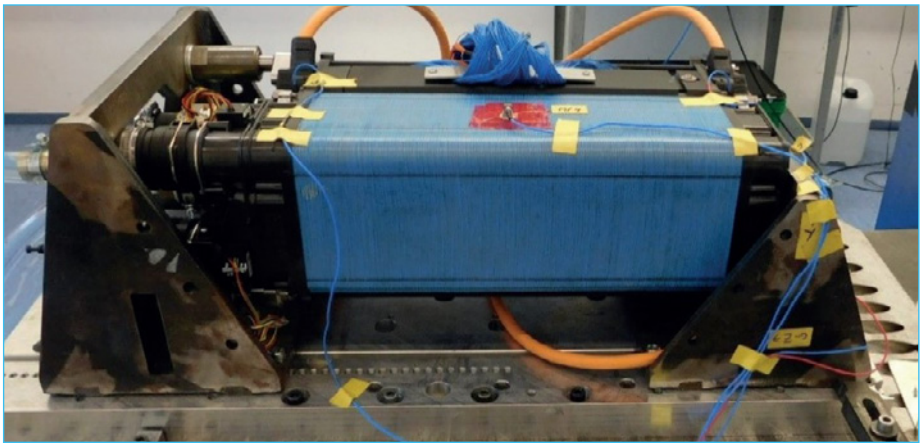
- Increase the credibility of the solution for the propulsion of passenger aircraft and UAVs
- Advance towards zero-emission hydrogen-powered regional commuter airliner.

PROGRESS AND MAIN ACHIEVEMENTS

- Conceptual design of the overall powertrain
- Full stack test system has been fully integrated in the test bench
- Aircraft safety studies are ongoing.

FUTURE STEPS AND PLANS

- Qualification and delivery: 2021-2022
- Ground/Flight tests: 2022-2023



QUANTITATIVE TARGETS AND STATUS

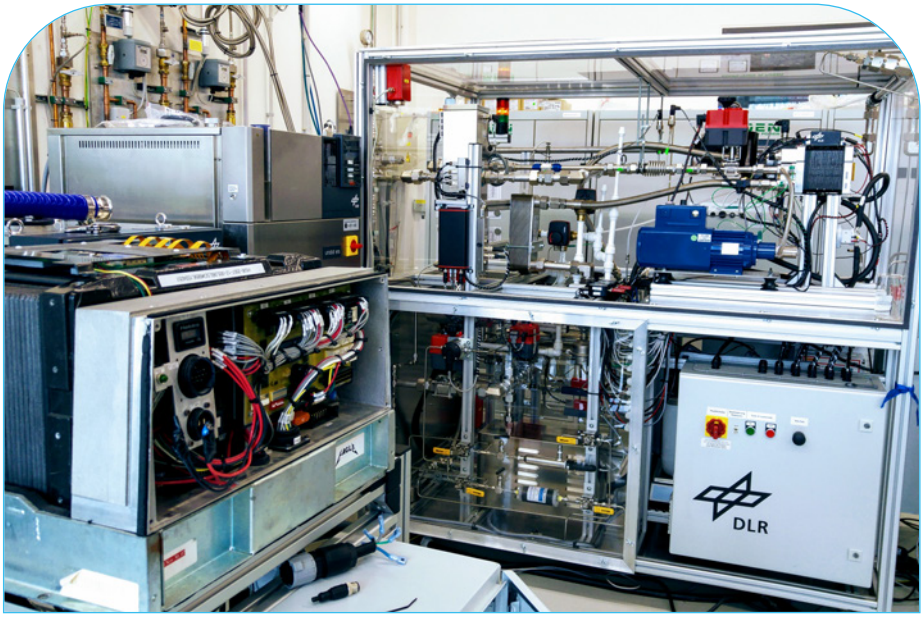
TARGET SOURCE	PARAMETER	UNIT	TARGET	ACHIEVED TO DATE BY THE PROJECT	TARGET ACHIEVED?
Project's own objectives and AWP 2018	FC stack power density in weight	kW/kg	2 kW/kg	2.7 kW/kg (stack incl. end plates)	
	FC power density in volume	kW/l	3.5 kW/l	4.1 kW/l (stack incl. end plates)	
	Air subsystem	%	> 50 %	Preliminary results in compliance with this value but not achieved yet	
	Power converter	kW/kg	8 kW/kg	Preliminary results in compliance with this value but not achieved yet	
	System lifetime	Hours	500 (stack)	N/A	

INN-BALANCE

INNOVATIVE COST IMPROVEMENTS FOR BALANCE OF PLANT COMPONENTS OF AUTOMOTIVE PEMFC SYSTEMS

Project ID:	**735969**
Call topic:	**FCH-01-4-2016** - Development of Industrialization-ready PEMFC systems and system components
Project total costs:	**€6 156 288.75**
FCH JU max. Contribution:	**€4 994 538.75**
Project start - end:	01/01/2017 - 31/01/2021
Coordinator:	**FUNDACION AYESA, ES**
Website:	**www.innbalance-fch-project.eu**

BENEFICIARIES: DEUTSCHES ZENTRUM FUER LUFT- UND RAUMFAHRT EV, UNIVERSITAT POLITECNICA DE CATALUNYA, AVL LIST GMBH, VOLVO PERSONVAGNAR AB, STEINBEIS INNOVATION GGMBH, POWERCELL SWEDEN AB, CELEROTON AG, BROSE FAHRZEUGTEILE GMBH & CO. KOMMANDITGESELLSCHAFT WURZBURG, STEINBEIS 2I GMBH, CHINA-EURO VEHICLE TECHNOLOGY AKTIEBOLAG



PROJECT AND OBJECTIVES

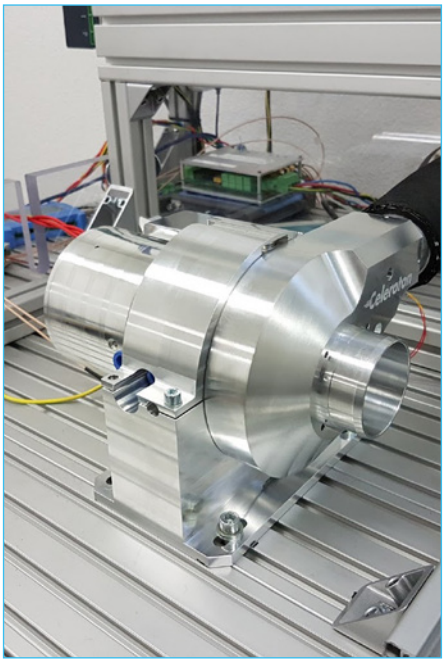
The project aims to commercialise H2-based electric vehicles by improving the efficiency and cost-effectiveness of automotive FC. INN-BALANCE integrates the latest trends in FC vehicle technology into the development of: a new air turbo compressor; combined H2 injection and recirculation; advanced control and diagnosis devices; and a new concept of thermal management. These will add up to an innovative FCS and greatly improve the cost, efficiency and reliability of FC-powered vehicles. Overall, the achievements of INN-BALANCE in improving FC will benefit climate protection and energy security.

PROGRESS AND MAIN ACHIEVEMENTS

- Tests of the INN-BALANCE modules at component level
- Commissioning and system-level tests in a PowerCell fuel cell test bed are currently being performed.

FUTURE STEPS AND PLANS

- A study on the improvement of manufacturing processes and cost reductions will be performed. An analysis will be carried out to see how the cost of single components affects the total cost of the hydrogen system. Results will be made available to the general public
- Integrate the different hardware and software modules. Some adaptations are required to ensure the interoperability of the different components
- Vehicle testing and project findings will be presented at the final conference that will take place towards the end of project in autumn 2021. This event will be public and further information will be communicated on our social media channels and project webpage in the coming months.



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	Cold start	°C	-40		-30	2015 (Toyota), 2019 (Hyundai)
	Peak energy efficiency*	%	85	✗	60	2010
	Durability in automotive drive cycle	Hours	6 000		3 900	2015

*Ratio of DC output energy to the lower heating value of the input fuel (hydrogen). Peak efficiency occurs at less than 25 % rated power

MARANDA

MARINE APPLICATION OF A NEW FUEL CELL POWERTRAIN VALIDATED IN DEMANDING ARCTIC CONDITIONS

Project ID:	735717
Call topic:	**FCH-01-5-2016** - Develop new complementary technologies for achieving competitive solutions for marine applications
Project total costs:	€3 704 757.5
FCH JU max. Contribution:	€2 939 457.5
Project start - end:	01/03/2017 - 28/02/2021
Coordinator:	TEKNOLOGIAN TUTKIMUSKESKUS VTT OY, FI
Website:	projectsites.vtt.fi/sites/maranda/

BENEFICIARIES: SWISS HYDROGEN SA, PERSEE, OMB SALERI SPA, POWERCELL SWEDEN AB, ABB OY, SUOMEN YMPARISTOKESKUS

PROJECT AND OBJECTIVES

The MARANDA project is developing an emission-free hydrogen-fuelled PEMFC-based hybrid powertrain system (3 x 82.5 kW AC) for marine applications. The system will be validated through both test bench experiments and on board the research vessel Aranda, including full-scale freeze start testing of the system. The project will increase the market potential of hydrogen fuel cells in the marine sector. General business cases for different actors in the marine and harbour or fuel cell business will be created. The project is currently in the system integration phase and the validation phase is being prepared.

NON-QUANTITATIVE OBJECTIVES

- The impact related to the development of RCS. MARANDA project has already made a significant contribution to the development of RCS
- Fuel cell systems should be able to withstand the shocks, vibrations, saline environment and ship motions commonly encountered on water as well as other requirements for marine application. FC system and hydrogen storage are designed to withstand these conditions
- Evaluation of the economic and environmental impact for a prospective customer. Report analysing the business aspects of hydrogen fuel cells for marine applications has been prepared
- The formulation of an initial go-to-market strategy. Report on the business analysis includes this
- Mapping opportunities for future demonstration actions. The work will be done in the final project year.

PROGRESS AND MAIN ACHIEVEMENTS

- Three FCS systems from Swiss Hydrogen have been assembled and all of them have been delivered to VTT for final integration
- The operation of the first FCS system was started (23 December 2021) and the first electricity was fed to the electricity grid
- Significant improvements in stack durability have been demonstrated by PowerCell Sweden.

FUTURE STEPS AND PLANS

- Restart of the first FC system operation at the durability test site (M49, March 2021). Before the restart, the safety analysis and education need to be completed
- Acceptance by the Finnish Transport Safety Agency (Trafi) of the installation of the FC system and hydrogen storage on Aranda (M51, May 2021). Final installations and the preparation of documents are ongoing
- Field trial started with target vessel (M52, June 2020)
- First FC system testing to be completed.
- Field trial with target vessel to be completed.

QUANTITATIVE TARGETS AND STATUS

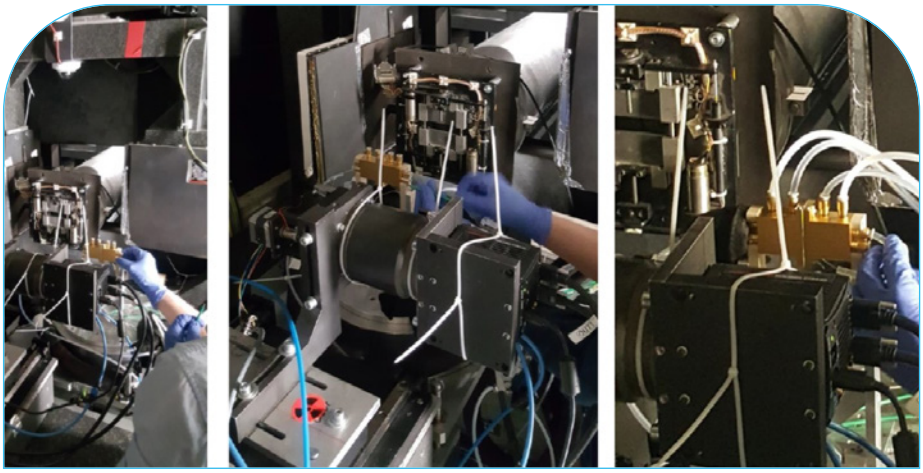
TARGET SOURCE	PARAMETER	UNIT	TARGET	ACHIEVED TO DATE BY THE PROJECT	TARGET ACHIEVED?
AWP 2016	Fuel cell system power	kW	75	82.5	✓
	Freeze start capability	°C	-35	N/A	✗
	Stack durability	mV/1 000h	4.6	1.7	✓
	Fuel-to-electricity efficiency (AC)	%	42	45	✓

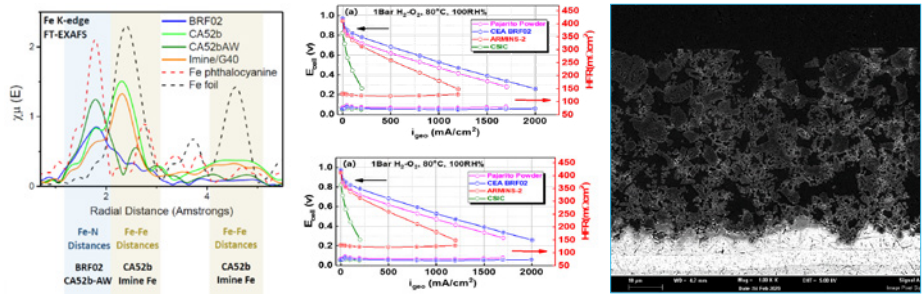
PEGASUS

PEMFC BASED ON PLATINUM GROUP METAL FREE STRUCTURED CATHODES

Project ID:	**779550**
Call topic:	**FCH-01-2-2017** - Towards next generation of PEMFC: Non-PGM catalysts
Project total costs:	**€2 829 016.88**
FCH JU max. Contribution:	**€2 829 016.88**
Project start - end:	01/02/2018 - 31/06/2021
Coordinator:	**COMMISSARIAT A L'ENERGIE ATOMIQUE ET AUX ENERGIES ALTERNATIVES, FR**
Website:	**www.pegasus-pemfc.eu/**

BENEFICIARIES: AGENCIA ESTATAL CONSEJO SUPERIOR DEINVESTIGACIONES CIENTIFICAS, DEUTSCHES ZENTRUM FUER LUFT- UND RAUMFAHRT EV, ASSOCIATION POUR LA RECHERCHE ET LE DEVELOPPEMENT DES METHODES ET PROCESSUS INDUSTRIELS, TECHNISCHE UNIVERSITAET MUENCHEN, ECOLE NATIONALE SUPERIEURE DES MINES DE PARIS, IRD FUEL CELLS A/S, TOYOTA MOTOR EUROPE NV, HERAEUS FUEL CELLS GMBH





PROJECT AND OBJECTIVES

PEGASUS is exploring a promising route towards the removal of Pt and other critical raw materials (CRM) from PEMFC and their replacements by non-critical elements. The overall goal of this project is to demonstrate the experimental proof of concept for novel catalyst material structure for the oxygen reduction reaction (ORR). Today the project reports ORR activity for the developed PGM-free material at the highest level compared to the international state of the art. Nevertheless, there is still some way to go to be competitive with Pt-based material.

NON-QUANTITATIVE OBJECTIVES

- Studying water management and quantifying the water saturation in PGM-free cathode MEA. This has been achieved. Neutron imaging was performed on the PEGASUS MEA. The profile of the water distribution in the MEA was determined
- Establishing diagnostic tools to quantify the key properties that govern transport losses in a PGM-free cathode. This was achieved, with ex situ quantification of electronic resistivity, in situ quantification of effective proton and O2 resistance
- Quantifying and qualifying the nature of the active site. This was achieved through XEFAS experiments (X-ray) and pulse CO chemisorption/temperature programmed desorption experiments.

PROGRESS AND MAIN ACHIEVEMENTS

- The best catalyst synthesised in the project is twice as active under air as the commercial reference. It has been prepared in multigram batches
- A catalyst showing ORR activity equivalent to that of the commercial reference has been made using a preparation route which requires just a few steps
- Studies of the water management in MEA integrating the PEGASUS catalyst were performed through neutron imaging.

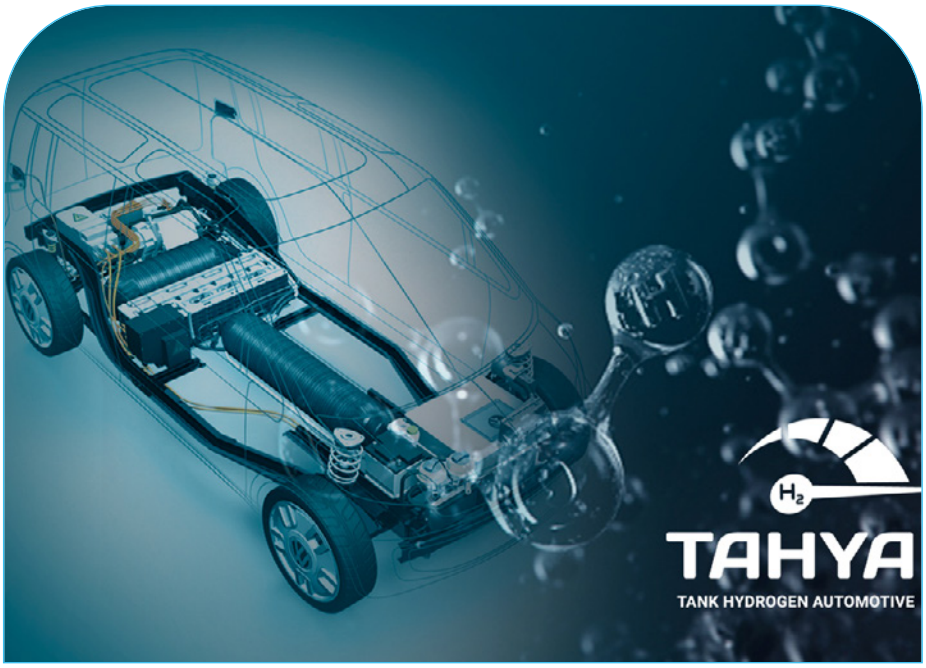
FUTURE STEPS AND PLANS

Assessment of the robustness of the PEGASUS materials. A degradation study, including accelerated stress tests, is in progress to assess the robustness of PEGASUS catalysts.Reduction of Pt loading. Development of PGM free catalysts (both for anode and cathode).

QUANTITATIVE TARGETS AND STATUS

TARGET SOURCE	PARAMETER	UNIT	TARGET	ACHIEVED TO DATE BY THE PROJECT	TARGET ACHIEVED?	SOA RESULT ACHIEVED TO DATE (BY OTHERS)
AWP 2017	catalyst activity (i geo @ 0.9 V under air)	mA/cm²	44	6.5	✗	N/A
	catalyst activity (i geo @ 0.7 V under air)	mA/cm²	600	50		
	catalyst activity (i geo @ 0.7 V under air)	mA/cm²	600	280		300
Project's own objectives	MEA performance @ 0.6 V under air	mA/cm²	highest	420	✓	380
	Electronic resistivity	Ohm.cm	<5	<5		N/A
	Proton resistance	Ohm.cm²	<0.1	0.14	✗	

TAHYA
TANK HYDROGEN AUTOMOTIVE



Project ID:	**779644**
Call topic:	**FCH-01-3-2017** - Improvement of compressed storage systems in the perspective of high volume automotive application
Project total costs:	**€3 996 943.75**
FCH JU max. Contribution:	**€3 996 943.75**
Project start - end:	01/01/2018 - 30/06/2021
Coordinator:	**OPTIMUM CPV, BE**
Website:	**tahya.eu/**

BENEFICIARIES: VOLKSWAGEN AG, TECHNISCHE UNIVERSITAET CHEMNITZ, BUNDESANSTALT FUER MATERIALFORSCHUNG UND -PRUEFUNG, RAIGI SAS, ANLEG GMBH, POLARIXPARTNER GMBH, ABSISKEY, AK GROUP

PROJECT AND OBJECTIVES

The TAHYA project, mainly led by industrial partners who are already involved in producing and manufacturing hydrogen solutions for the automotive and aviation industry, focuses on the development of a complete, competitive and innovative European H_2 storage system (a cylinder with a mounted on-tank-valve) for automotive applications that outperform the current Asian and US ones.

PROGRESS AND MAIN ACHIEVEMENTS

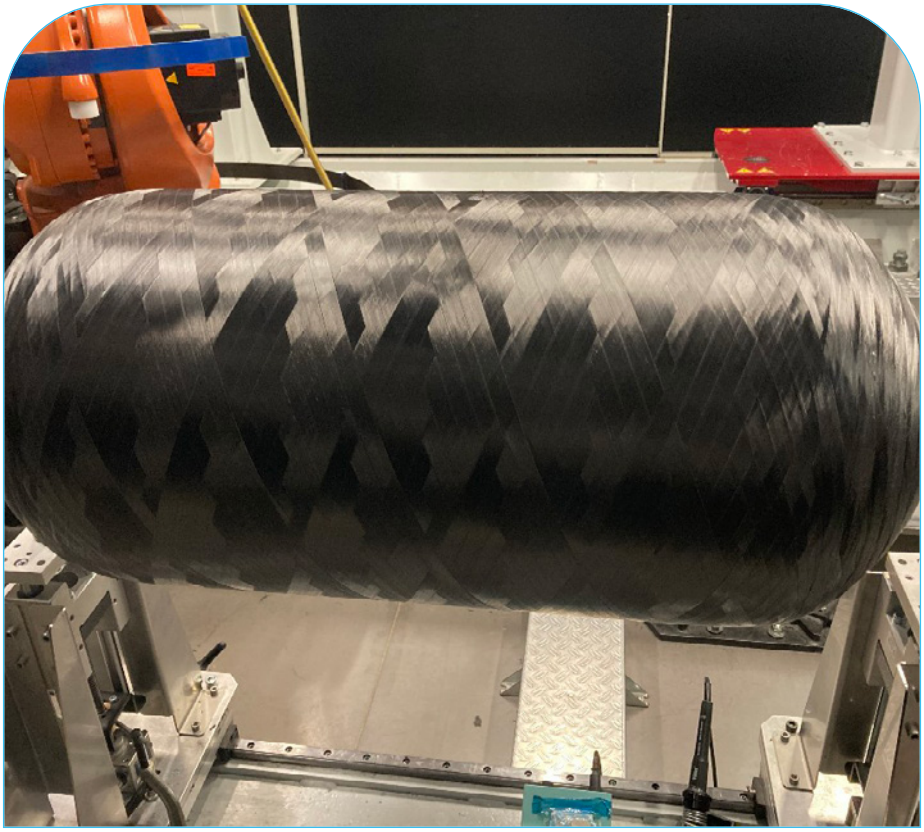
- Compatible H2 storage system with high performances, safe and health, safety, environment responsible.
- Cost-competitive H2 storage system for mass production
- RCS activities to propose updates to GRT13 and EC79 according to tests results obtained over the duration of the project.

FUTURE STEPS AND PLANS

The project will finish in June 2021. All objectives have been reached.

THOR

THERMOPLASTIC HYDROGEN TANKS OPTIMISED AND RECYCLABLE



Project ID:	826262
Call topic:	**FCH-01-3-2018** - Strengthening of the European supply chain for compressed storage systems for transport applications
Project total costs:	**€2 853 958.75**
FCH JU max. Contribution:	**€2 853 958.75**
Project start - end:	01/01/2019 - 31/12/2021
Coordinator:	**FAURECIA SYSTEMES D'ECHAPPEMENT SAS, FR**
Website:	**thor-fch2.eu/**

BENEFICIARIES: COVESS NV, CETIM GRAND EST, ECOLE NATIONALE SUPERIEURE DE MECANIQUE ET D'AEROTECHNIQUE, SIRRIS HET COLLECTIEF CENTRUM VAN DE TECHNOLOGISCHE INDUSTRIE, RINA CONSULTING - CENTRO SVILUPPO MATERIALI SPA, UNIVERSITE DE POITIERS, AIR LIQUIDE SA, NORGES TEKNISK-NATURVITENSKAPELIGE UNIVERSITET NTNU, CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE CNRS

PROJECT AND OBJECTIVES

The project aims to develop recyclable tanks based on thermoplastic resins. It is studying the best design to improve the performance of the gas storage tank for hydrogen (modelling of the wrapping and correlation with tests to define an optimised tank design). Other goals are the study and definition of the production line and cost calculations, investigating the application of recycling technology for the end of life of carbon-fibre overwrapped pressure vessels and the fire behaviour of the thermoplastic tank.

NON-QUANTITATIVE OBJECTIVES

- Recyclability of the tanks
- Project is working on the reuse of the end-of-life tank with a recycling process for producing carbon-fibre composite sheets (preparation of the material and process for the manufacturing of the reused sheets).

PROGRESS AND MAIN ACHIEVEMENTS

- Testing facilities in preparation for:
  - the EC79 test (such as thermal and mechanical tests at extreme temperatures)
  - fire behaviour
- Preparation of the optimised tank design for the first 64 l thermoplastic tank (winding pattern and bosses)
- First tanks have been manufactured. To be used for burst and ASR tests.

FUTURE STEPS AND PLANS

- Validate the type V H2 gas storage tank. Prototypes to be built and tested for modelling correlation
- Optimise design (performance, fire behaviour), with correlated soft, optimisation of the winding pattern and the tank design
- Definition of the production line with respect to the first results to prepare for the prototypes. Manufacturing the line layout.

QUANTITATIVE TARGETS AND STATUS

TARGET SOURCE	PARAMETER	UNIT	TARGET	ACHIEVED TO DATE BY THE PROJECT	TARGET ACHIEVED?
MAWP (2014-2020)	Volumetric capacity	kg/l	0.014	0.0141	✓
	Gravimetric capacity	%	5.4	4	✗
	Price	€/kg	400	N/A	✗

VIRTUAL-FCS

VIRTUAL & PHYSICAL PLATFORM FOR FUEL CELL SYSTEM DEVELOPMENT

Project ID:	**875087**
Call topic:	**FCH-01-3-2019** - Cyber-physical platform for hybrid Fuel Cell systems
Project total costs:	**€1 897 806.25**
FCH JU max. Contribution:	**€1 897 806.25**
Project start - end:	01/01/2020 - 31/12/2022
Coordinator:	**SINTEF AS, NO**
Website:	**www.sintef.no/projectweb/virtual-fcs/**

BENEFICIARIES: BANKE APS, VIVARAIL LTD, COMMUNAUTE D'UNIVERSITES ET ETABLISSEMENTS UNIVERSITE BOURGOGNE - FRANCHE - COMTE, WESTCON POWER AND AUTOMATION AS, BALLARD POWER SYSTEMS EUROPE AS, ECOLE NATIONALE SUPERIEURE DE MECANIQUE ET DES MICROTECHNIQUES, SOLARIS BUS & COACH SPOLKA Z OGRANICZONA ODPOWIEDZIALNOSCIA, UNIVERSITE DE TECHNOLOGIE DE BELFORT - MONTBELIARD, UNIVERSITE DE FRANCHE-COMTE

PROJECT AND OBJECTIVES

The overall objective of the VIRTUAL-FCS project is to make the design process of hybrid fuel cell and battery systems easier, cheaper and quicker. VIRTUAL-FCS will produce a toolkit combining software and hardware parts for designing and optimising PEM fuel cells and battery hybrid systems. The platform will be entirely open source, allowing everyone in both the industry and research to benefit from and contribute to the future development of the framework.

NON-QUANTITATIVE OBJECTIVES

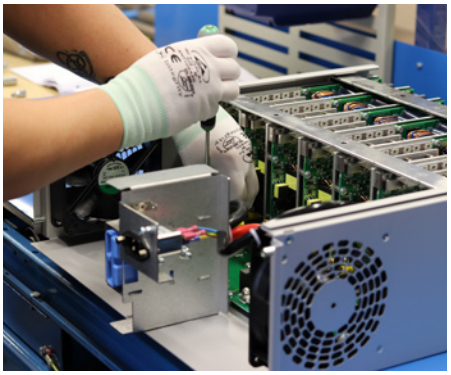
- Improve accuracy of estimates of system lifetime. Improve lifetime by gaining insight into the governing degradation processes and improving EMS. Method: academic publications and used for internal development at partners
- Better a priori understanding of hybridisation strategies and EMS on the performance, reliability and durability, for reference cases representing typical transport industrial applications. Increase efficiencies of existing applications by tailored control strategies to adapt to demanding operating profile. Method: academic publications, advice to end users as part of the strategy, enhanced competitiveness of FC suppliers. Advertise competitiveness of end-user partner's solutions
- SME partners working in the maritime, rail, bus and heavy-duty industry will have better system models and understanding of the benefits of the FC system. There will be interaction with end users' sales strategies and IPR.

PROGRESS AND MAIN ACHIEVEMENTS

- Definition and details of a hybrid system design and parameters to be used for initial platform and model development
- Establish a working model of a fuel cell system to serve as a foundation for the further development and implementation of the Virtual-FCS platform
- A critical review of existing BoP models.

FUTURE STEPS AND PLANS

- First release the code and documentation: soon to be released
- Release of training materials: soon to be released
- Real-time system simulation (the next step) and emulation
- Prognostics model, the main focus in 2022
- Interaction with the physical system hardware, planned for the first half of 2022.



QUANTITATIVE TARGETS AND STATUS

TARGET SOURCE	TARGET	TARGET ACHIEVED?
Project's own objectives	10 % reduction in system lifetime costs by better component sizing	
	50 % reduction in time for new sizing system	
	25 % reduction in time for EMS development	
	25 % reduction in time for prototyping system	