3EMOTION

ENVIRONMENTALLY FRIENDLY, EFFICIENT ELECTRIC MOTION

Project ID:	**633174**
PRD 2023:	**Panel 3 – H2 end uses – transport**
Call topic:	**SP1-JTI-FCH.2013.1.1: Large-scale demonstration of road vehicles and refuelling infrastructure VI**
Project total costs:	**EUR 38 181 930.72**
Clean H_2 JU max. contribution:	**EUR 14 999 983.00**
Project period:	**1.1.2015–31.12.2022**
Coordinator:	**Van Hool NV, Belgium**
Beneficiaries:	Aalborg Kommune, Acetilene & Gastecnici Di Bagnoli Maria & C. SAS, Agenzia nazionale per le nuove tecnologie, l'energia e lo sviluppo economico sostenibile, Air Liquide Advanced Business, Air Liquide Advanced Technologies SA, Autocars Dominique, Azienda per la mobilità del Comune di Roma SpA, B.E. Green, Centro Interuniversitario di Ricerca Per lo Sviluppo sostenibile, Commissariat à l'énergie atomique et aux énergies alternatives, Communauté urbaine de Cherbourg, Commune de Cherbourg-en-Cotentin, Compagnia Trasporti Laziali, Connexxion Openbaar Vervoer NV, Connexxion Vloot BV, Dantherm Power AS, Fit Consulting SRL, London Bus Services Limited, Provincie Zuid-Holland, Regione Lazio, Region Nordjylland, Rotterdamse Elektrische Tram NV, Services Automobile de la Vallée de Chevreuse SAS, Syndicat mixte des transports urbains de Pau-Porte des Pyrénées, Università degli Studi di Roma 'La Sapienza', Vlaamse Vervoersmaatschappij De Lijn, WaterstofNet VZW

http://www.3emotion.eu/

PROJECT AND OBJECTIVES

3Emotion aims to operate 29 fuel cell buses (FCBs) in five leading European cities – Aalborg, London, Pau, Rotterdam (with intercity links throughout the province of South Holland) and Versailles – and develop three new hydrogen refuelling stations (HRSs).

Objectives:

- lower H_2 consumption to < 9 kg/100 km;
- integrate the latest drivetrain, fuel cell and battery technologies to lower the total cost of ownership and increase FCBs' lifetimes;
- ensure FCB availability of > 90 %;
- increase warranties (> 15 000 hours) and improve the delivery times of the key components;
- reduce bus investment costs to < EUR 850 000 for a 13 m bus.

PROGRESS AND MAIN ACHIEVEMENTS

- All 29 FCBs and all three HRSs are in operation.
- The project has engaged three manufacturers of original bus equipment to make two different fuel cells at the price per bus set in the initial call, operating at various EU sites.
- The buses are largely meeting their targets on H_2 consumption, average consumption and availability.

FUTURE STEPS AND PLANS

- The project was finalised on 31 December 2022.
- 3Emotion will meet the expectation of having higher capacities at the HRSs. In the final year of the project, as restrictions related to the COVID-19 pandemic have been lifted, the operation of the buses will be resumed, and full operation of HRSs can be achieved.
- The project will perform the data monitoring and gathering of operational and performance indicators for the FCBs and the HRSs.

QUANTITATIVE TARGETS AND STATUS

Target source	Parameter	Unit	Target	Achieved to date by the project	Target achieved?
Project's own objectives	Lower H_2 consumption for FCBs to < 9 kg/100 km	kg/100 km	9	Average: 8	✓
	Ensure availability of > 90 %	%	90	Average: ≤ 80	⚙
	Increased warranties (> 15 000 hours)	hours	15 000	15 000	✓
	Investment cost of EUR < 850 000 for a 13 m bus	€	850 000	850 000	✓

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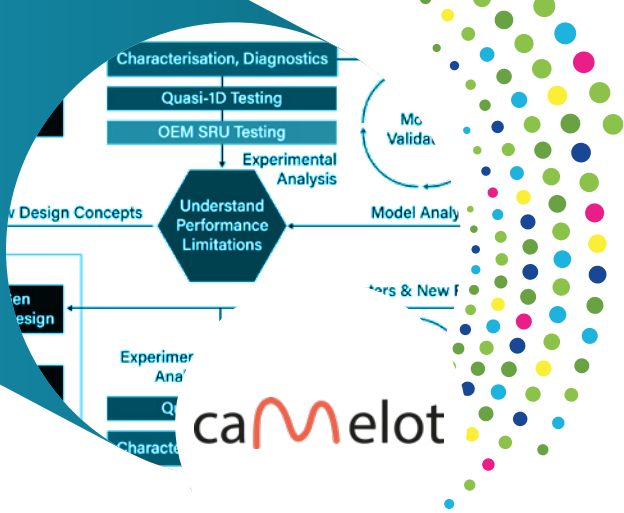
CAMELOT

UNDERSTANDINGCHARGE,MASSANDHEATTRANSFER IN FUEL CELLS FOR TRANSPORT APPLICATIONS



Project ID:	875155
PRD 2023:	Panel 3 – H2 end uses – transport
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:	EUR 2 589 273.50
Clean H_2 JU max. contribution:	EUR 2 295 783.50
Project period:	1.1.2020–31.12.2023
Coordinator:	Sintef AS, Norway
Beneficiaries:	Albert-Ludwigs-Universitaet Freiburg, Bayerische Motoren Werke AG, Fast Simulations UG, FCP Fuel Cell Powertrain GmbH, Johnson Matthey Hydrogen Technologies Limited, Johnson Matthey plc, PowerCell Sweden AB, Pretexo, Technische Universität Chemnitz

http://camelot-fuelcell.eu

PROJECT AND OBJECTIVES

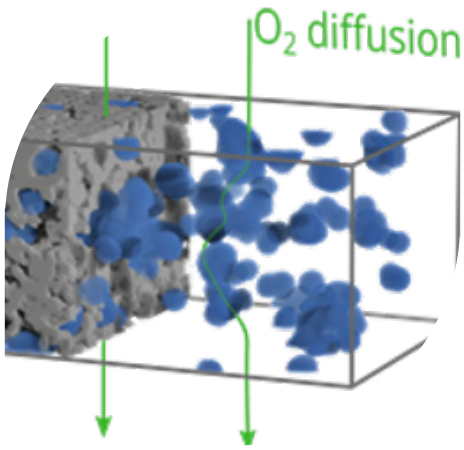
Camelot brings together highly experienced research institutes, universities, fuel cell membrane electrode assembly suppliers and transport original equipment manufacturers to improve understanding of the limitations of fuel cell electrodes. The purpose of this is to provide guidance on the next generation of membrane electrode assemblies required to achieve the 2024 performance targets.

PROGRESS AND MAIN ACHIEVEMENTS

- Ultra-thin membrane electrode assembly construction: the target is < 10 µm; it is currently stable down to 8 µm, with ongoing testing down to 6 µm.
- X-Y-Z graded catalyst-coated membrane layer construction: the initial catalyst-coated membranes have been made with graded catalyst content and graded ionomer content.
- The membrane permeability test set-up has been established.
- X-ray fluorescence and high-resolution scanning electron microscope characterisation of graded catalyst layers have been carried out.

FUTURE STEPS AND PLANS

- The project was on hold for 10 months in 2021 and restarted on 1 January 2022.
- The project timeline was extended by 12 months.



QUANTITATIVE TARGETS AND STATUS

Target source	Parameter	Unit	Target	Achieved to date by the project	Target achieved?
Project's own objectives	Membrane thickness	µm	< 10	6	✓
AWP 2019	Total MEA Pt loading	mgPt/cm²	< 0.08	0.18	⚙
	Power density	W/cm²	> 1.8	0.75	⚙

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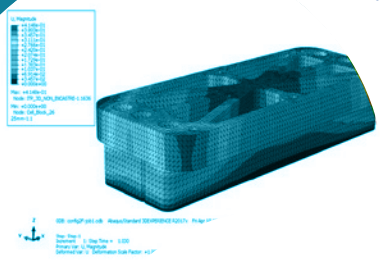
DOLPHIN

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



DOLPHIN

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

Project ID:	**826204**
PRD 2023:	**Panel 3 – H2 end uses – transport**
Call topic:	**FCH-01-6-2018: Game changer fuel cell stack for automotive applications**
Project total costs:	**EUR 3 244 066.25**
Clean H_2 JU max. contribution:	**EUR 2 962 681.25**
Project period:	**1.1.2019–31.12.2022**
Coordinator:	**Commissariat à l'énergie atomique et aux énergies alternatives, France**
Beneficiaries:	Chemours Belgium, Chemours France SAS, Chemours International Operations SARL, DMG MORI Additive GmbH, Faurecia Systemes d'Echappement SAS, Hexcel Composites GmbH & Co KG, Hexcel Composites Ltd, Hexcel Reinforcements SAS, Symbio, Symbio France, University of Manchester, Zentrum für Sonnenenergie- und Wasserstoff-Forschung Baden-Württemberg

http://www.dolphin-fc.eu/

PROJECT AND OBJECTIVES

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

NON-QUANTITATIVE OBJECTIVES

Evaluate interest in and limitations of different material and manufacturing technologies for PEMFC stacks.

PROGRESS AND MAIN ACHIEVEMENTS

- Performance has been increased to ~ 2 W/cm² validated on a 100 cm² single cell thanks to downsized rib/channel dimensions, a new membrane, new catalyst layer materials and formulation, and alternative operating conditions (Next generation automotive membrane electrode assemblies (GAIA) project).
- Interest in and limitations of different components and manufacturing processes for PEMFC stacks have been identified.
- Potentially even more efficient flow fields and catalyst layer manufacturing processes have been designed.
- The two best solutions have been defined for the manufacture of two stacks (5 kW).

FUTURE STEPS AND PLANS

- Manufacturing, assembly and testing of the 5 kW stacks based on the two technologies selected, for evaluation of the key performance indicators (kW/l, kW/kg, W/cm², €/kW, µV/h), are still to be carried out.
- In parallel, an assessment will be conducted to gauge interest in graphene coating of the membrane.
- Define and test an additional set of operating conditions as a trade-off between high stack efficiency (high Sto and RH, as for GAIA) and high system efficiency (as used in Dolphin).

QUANTITATIVE TARGETS AND STATUS

Target source	Parameter	Unit	Target	Target achieved?	SoA result achieved to date (by others)	Year of SoA target
AWP 2018	Weight-specific power density	kW/kg	4		3.4	2017 (by Auto-Stack CORE)
	Volume-specific power density	kW/l	5		4.1	
	Surface power density	W/cm²	2		1.13	
	Durability	hours	6 000		3 500	
	Stack cost	€/kW	20		36.8	

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FCH$_2$RAIL

FUEL CELL HYBRID POWERPACK FOR RAIL APPLICATIONS

Project ID:	**101006633**
PRD 2023:	**Panel 3 – H2 end uses – transport**
Call topic:	**FCH-01-7-2020: Extending the use cases for FC trains through innovative designs and streamlined administrative framework**
Project total costs:	**EUR 18 137 313.98**
Clean H_2 JU max. contribution:	**EUR 9 999 999.12**
Project period:	**1.1.2021–31.12.2024**
Coordinator:	**Deutsches Zentrum für Luft- und Raumfahrt EV, Germany**
Beneficiaries:	Administrador de Infraestructuras Ferroviarias, CAF Digital & Design Solutions SA, CAF Power & Automation SL, CAF Turnkey & Engineering SL, Centro de Ensayos y Analisis Cetest SL, Centro Nacional de Experimentación de Tecnologías de Hidrógeno y Pilas de Combustible Consorcio, Construcciones y Auxiliar de Ferrocarriles Investigacion y Desarrollo SL, Construcciones y Auxiliar de Ferrocarriles, SA, Faiveley Transport Leipzig GmbH & Co. KG, Infraestruturas de Portugal SA, Renfe Operadora, Renfe Viajeros SA, Stemmann-Technik GmbH, Toyota Motor Europe NV

www.fch2rail.eu

PROJECT AND OBJECTIVES

The project consortium is developing and testing a new train prototype. At the heart of the project is a hybrid, bimodal drive system that combines the advantages of an electrical power supply from the overhead line with a hybrid power pack consisting of fuel cells and batteries. This system allows for more sustainable and energy-efficient rail transport. The project will show that this type of bimodal power pack is a competitive and environmentally friendly alternative to diesel power.

NON-QUANTITATIVE OBJECTIVES

An expert network with external stakeholders was held in 2022 to support the analysis of gaps in the normative framework.

PROGRESS AND MAIN ACHIEVEMENTS

- Fuel cell hybrid powerpack (FCHPP) development and tests on the CNH_2 test bench were successfully completed.
- Physical integration of two FCHPPs into the demonstrator train was successfully completed.
- The first static test of FCHPP in the demonstrator train has been conducted.

FUTURE STEPS AND PLANS

- Dynamic testing of the demonstrator train on closed tracks will be carried out.
- The implementation of the hydrogen refuelling station will be completed.
- The first test runs of the demonstrator train on open tracks will take place.

QUANTITATIVE TARGETS AND STATUS

Target source	Parameter	Achieved to date by the project
Project's own objectives	System lifetime/durability	
	Hydrogen and electricity consumption	

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FLAGSHIPS

CLEAN WATERBORNE TRANSPORT IN EUROPE

Project ID:	**826215**
PRD 2023:	**Panel 3 – H2 end uses – transport**
Call topic:	**FCH-01-2-2018: Demonstration of fuel cell applications for midsize passenger ships or inland freight**
Project total costs:	**EUR 6 766 811.83**
Clean H_2 JU max. contribution:	**EUR 4 999 978.75**
Project period:	**1.1.2019–31.3.2025**
Coordinator:	**Teknologian tutkimuskeskus VTT Oy, Finland**
Beneficiaries:	VTT, ABB Oy, Ballard Power Systems Europe AS, Compagnie Fluviale de Transport, Future Proof Shipping BV, LMG Marin AS, LMG Marin France, Maritime CleanTech, Norled AS, Persee, Seam AS Sogestion, Sogestran

https://flagships.eu/

PROJECT AND OBJECTIVES

Two commercially operated hydrogen fluvial fuel cell vessels will be demonstrated, one in France (Paris) and one in the Netherlands (Rotterdam). The Paris demonstrator (*Zulu*) is a self-propelled barge operating as a goods transport vessel in the city centre; the Rotterdam demonstrator (*FPS WAAL*) is a container vessel transporting goods between Rotterdam and Duisburg. The Paris demonstrator vessel has been built, and H_2 fuel cell systems and storage will be installed. The Rotterdam demonstrator entered the project at the end of 2021, and the design work for that vessel has begun.

PROGRESS AND MAIN ACHIEVEMENTS

- The FCwave fuel cell module has gained the necessary approval from DNV.
- The *Zulu* vessel design was completed, and the vessel has been built. It is at the yard in Le Havre. ABB and Ballard Power Systems Europe systems are in place and installation work has started.

FUTURE STEPS AND PLANS

- The process of gaining approval for the *Zulu* vessel is ongoing, involving Bureau Veritas, CCNR and local authorities.
- The project will demonstrate the *Zulu* vessel in commercial operation. Operations were expected to begin in Autumn 2023.
- The project will finalise the design and retrofitting of the *FPS WAAL* vessel. Work started at the beginning of 2022 after an amendment was accepted. It is expected to be finalised in 2023–2024.

QUANTITATIVE TARGETS AND STATUS

Target source	Parameter	Unit	Target	Target achieved?
MAWP (2014–2020)	PEMFC system lifetime	hours	25 000	
Project's own objectives	Fuel cell systems demonstrated in on-board vessel in commercial operation	months	2 × 18	
	Develop necessary safety measures of H_2 and FC vessels to enable their class approval	–	Class approval gained	⚙
	PEMFC system availability	%	95	
	Cost of a complete FC and H_2 system	€/kW	4 000	

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FLHYSAFE

FUEL CELL HYDROGEN SYSTEM FOR AIRCRAFT EMERGENCY OPERATION

FLHY SAFE

Project ID:	**779576**
PRD 2023:	**Panel 3 – H2 end uses – transport**
Call topic:	**FCH-01-1-2017: Development of fuel cell system technologies for achieving competitive solutions for aeronautical applications**
Project total costs:	**EUR 7 296 552.51**
Clean H_2 JU max. contribution:	**EUR 5 063 023.00**
Project period:	**1.1.2018–30.6.2023**
Coordinator:	**Safran Power Units, France**
Beneficiaries:	ARTTIC, Commissariat à l'énergie atomique et aux énergies alternatives, Deutsches Zentrum für Luft- und Raumfahrt EV, Instituto Nacional de Técnica Aeroespacial Esteban Terradas, Safran Aerotechnics, Universität Ulm

https://www.flhysafe.eu/

PROJECT AND OBJECTIVES

In the shift towards 'more electric aircraft', 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 aeroplane, providing enhanced safety functionalities. In addition, the project has the ambition of virtually demonstrating that the system can be integrated, respecting both installation volumes and maintenance constraints, using current aircraft designs.

NON-QUANTITATIVE OBJECTIVES

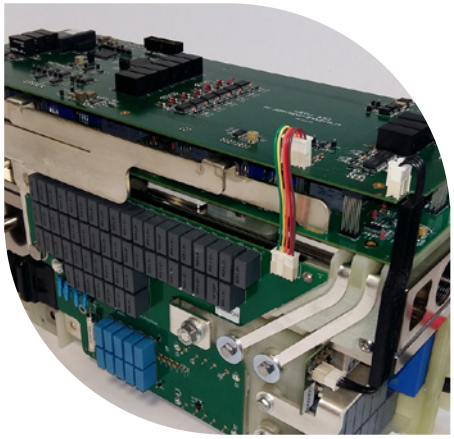
The project aims to demonstrate the capability of a fuel cell system to hold a profile load of a RAT in a demonstrator. Operational tests are ongoing, and a partial environmental test plan is in progress.

PROGRESS AND MAIN ACHIEVEMENTS

- The short stack was validated by H_2/O_2 tests.
- A critical design review of the low-temperature module for the fuel cell system was performed (theoretical A/C system specification has been completed).
- A demonstrator critical design review (for major subsystems) was performed.
- The first module campaign test was performed.
- The fuel cell stack was produced, and the converter integrated.
- The final demonstrator was assembled.

FUTURE STEPS AND PLANS

Operational and environmental tests of the FLHYSAFE demonstrator are ongoing.



QUANTITATIVE TARGETS AND STATUS

Target source	Parameter	Unit	Target	Achieved to date by the project	Target achieved?
Project's own objectives	EPU weight	kg	150	220	⚙
	System power density	W/kg	≤ 100	78	⚙
	Nominal continuous electrical power	kW	18.1	18.1	✓

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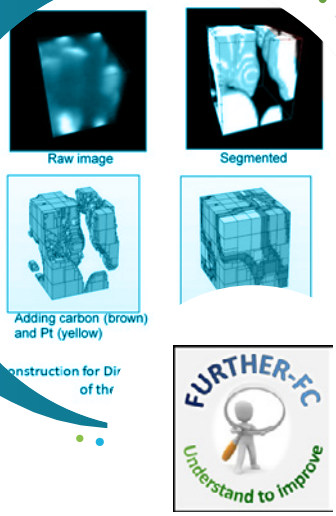
FURTHER-FC

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



Project ID:	**875025**
PRD 2023:	**Panel 3 – H2 end uses – transport**
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:	**EUR 3 122 598.75**
Clean H_2 JU max. contribution:	**EUR 2 199 567.35**
Project period:	**1.1.2020–29.2.2024**
Coordinator:	**Commissariat à l'énergie atomique et aux énergies alternatives, France**
Beneficiaries:	Centre national de la recherche scientifique, Chemours France SAS, Deutsches Zentrum für Luft- und Raumfahrt EV, École Nationale Supérieure de Chimie de Montpellier, Hochschule Esslingen, Imperial College of Science Technology and Medicine, Institut National Polytechnique de Toulouse, Paul Scherrer Institut, Chemours Company FC LLC, Toyota Motor Europe NV, Université de Montpellier, University of Calgary

https://further-fc.eu/

PROJECT AND OBJECTIVES

FURTHER-FC proposes complete experimental and modelling coupled platforms to better understand the performance limitations of the cathode catalyst layers (CCLs) of low-Pt-loaded proton-exchange membrane fuel cells. Based on this, CCL improvements will be discussed and tested. Up-to-date references and some customised membrane electrode assemblies (different ionomer-to-carbon ratio, thickness, etc.) have been produced, models of the CCLs are progressing based on their structural characterisation, and the first effective properties have been derived.

PROGRESS AND MAIN ACHIEVEMENTS

- Progress has been made on the characterisation of the CCLs (atomic force microscopy, Raman thermography, three-dimensional focused ion beam scanning electron microscopy, limiting current, etc.), including reference and first customised MEAs.
- Three-dimensional (3D) images of the GDL (with MPL) have been produced, and 3D images of CCLs are in progress.
- Modelling has been done on GDL, based on 3D images of fibrous substrate (X-ray) and of MPL (FIB-SEM), as has the evaluation of transport properties.
- Modelling of CCLs is ongoing (LBM, DNS). This is also based on 3D images.
- The definition and validation of test protocols allows for reliable comparison between the partners.
- Limiting-current analysis is ongoing (differential cells) to better understand the main contributors to the performance limitations.
- Progress has been made on the ultra-low loading catalyst layers, enabling a better understanding of the ORR kinetics.
- Bulk in-plane and through-plane electronic conductivities as a function of relative humidity and compression have been determined, as have through-plane proton conductivities as a function of relative humidity.
- The hydrophilicity and solvophilicity of the catalyst and catalyst layers have provided insights into the water sorption of these powders and layers during ink formulation and testing.
- The calibration of Raman thermography on the membrane has been achieved.

FUTURE STEPS AND PLANS

- The finalisation of the characterisations of customised membrane electrode assemblies is ongoing.
- The finalisation of the modelling of the CCLs at different scales is ongoing.
- The definition of the most performance-limiting mechanisms is ongoing.
- The upscaling of the models has started and will continue.
- Reproducibility of the fuel cell thermal behaviour is being checked.

QUANTITATIVE TARGETS AND STATUS

Target source	Parameter	Unit	Target	Target achieved?	SoA result achieved to date (by others)	Year for reported SoA result
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/cm^2	1.8		1.13	
	Cost	€/kW	20		36.8	
	Durability	hours	6 000		3 500	
	Total Pt loading	mg/cm^2	0.144		0.4	
	Total Pt loading	g/kW	0.08		0.35	
	Pt efficiency	A/mg	15		4.5	

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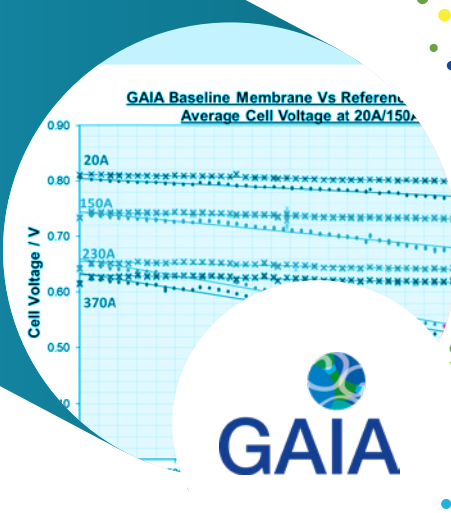
GAIA

NEXT GENERATION AUTOMOTIVE MEMBRANE ELECTRODE ASSEMBLIES



Project ID:	**826097**
PRD 2023:	**Panel 3 – H2 end uses – transport**
Call topic:	**FCH-01-5-2018: Next generation automotive MEA development**
Project total costs:	**EUR 5 065 614.39**
Clean H_2 JU max. contribution:	**EUR 4 493 025.00**
Project period:	**1.1.2019–30.6.2022**
Coordinator:	**Centre national de la recherche scientifique, France**
Beneficiaries:	3M Deutschland GmbH, Bayerische Motoren Werke AG, Dyneon GmbH, Elmarco SRO, Freudenberg Performance Materials SE & Co. KG, Johnson Matthey Hydrogen Technologies Limited, Johnson Matthey plc, Pretexo, Technische Universität München, Technische Universität Berlin, Université de Montpellier, Zentrum für Sonnenenergie- und Wasserstoff-Forschung Baden-Württemberg

https://www.gaia-fuelcell.eu/

PROJECT AND OBJECTIVES

GAIA aims to develop high-performance automotive membrane electrode assemblies (MEAs) capable of achieving a 6 000-hour lifetime. By month 42, GAIA had developed new carbon support, catalyst, ionomer, membrane, reinforcement, gas diffusion and microporous layer components that were incorporated in MEAs and tested using optimised automotive drive cycle protocols in full automotive-sized 4-cell stacks and 10-cell short stacks. This testing demonstrated that the GAIA MEAs achieved a world-leading power density of 1.8 W/cm^2 at 0.6 V. By reaching this high power density without increasing platinum loading, the Pt-specific power density was reduced from 0.45 g Pt/kW to 0.25 g Pt/kW. Taking catalyst and ionomer recycling into consideration, the cost per kW of the final GAIA MEA approaches the €6/kW target of the 2019 Fuel Cells and Hydrogen 2 Joint Undertaking annual work plan. Furthermore, the voltage loss rate of a short stack with the GAIA MEAs was within the target range over the first 600 hours of operation of an automotive drive cycle, including at 105 °C, to achieve a predicted 6 000 hours of operation.

NON-QUANTITATIVE OBJECTIVES

- The project aimed to perform outreach through two videos. The first was on catalyst preparation and characterisation by rotating disc electrode and catalyst integration into MEAs and testing/diagnostics. It was prepared by Technische Universität Berlin and Technische Universität München. The second was on electrospun nanofibre reinforcement development and fabrication of reinforced membranes at scale. It was prepared by Centre national de la recherche scientifique, Elmarco, Dyneon and Johnson Matthey plc.
- The project aimed to disseminate the results through articles in international journals; eight articles have been published to date, and others will follow.
- It also aimed to communicate results through the publication of newsletters on its website; three newsletters are available for download.

PROGRESS AND MAIN ACHIEVEMENTS

- GAIA developed MEAs that provide 1.8 W/cm^2 at 0.6 V, corresponding to a Pt-specific power density of 0.25 g Pt/kW.
- The GAIA MEA cost approaches the €6/kW target, based on the assumptions of a high-volume production of 1 million m^2 MEA per year and the potential for platinum group metal and ionomer recycling.
- The stack voltage decay rate with GAIA MEAs was within the target range over the first 600 hours of automotive drive cycle testing, including at 105 °C, which represents a step change for the industry, especially for incursions at higher temperatures.

FUTURE STEPS AND PLANS

GAIA ended on 30 June 2022. However, the advances in materials, components and MEAs are being transferred to the heavy-duty transport projects IMMORTAL and HIGHLANDER.

QUANTITATIVE TARGETS AND STATUS

Target source	Parameter	Unit	Target	Achieved to date by the project	Target achieved?
AWP 2019	Power density at 0.6 V	W/cm^2	1.8	1.8	✓
	Stack durability (voltage decay rate)	%	< 10 after 6 000 hours of operation, as extrapolated from 1 000 hours of actual testing	Voltage decay rate within target to achieve a predicted 6 000 hours of operation over the first 600 hours of automotive drive cycle	⚙
	MEA cost	€/kW	6	9	✓

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H2HAUL

HYDROGEN FUEL CELL TRUCKS FOR HEAVY-DUTY, ZERO EMISSION LOGISTICS

Project ID:	**826236**
PRD 2023:	**Panel 3 – H2 end uses – transport**
Call topic:	**FCH-01-1-2018: Large scale demonstration of H2 fueled HD trucks with high capacity hydrogen refueling stations (HRS)**
Project total costs:	**EUR 33 274 858.50**
Clean H_2 JU max. contribution:	**EUR 12 000 000.00**
Project period:	**2.1.2019–31.12.2025**
Coordinator:	**Element Energy Limited, United Kingdom**
Beneficiaries:	ERM France, Dats 24, Plastic Omnium New Energies Wels GmbH, H2 Energy AG, Air Liquide France Industrie, VDL Enabling Transport Solutions BV, VDL Special Vehicles BV, EOLY, FPT Motorenforschung AG, Hydrogenics GmbH, IRU Projects ASBL, FPT Industrial SpA, Air Liquide Advanced Technologies SA, Sphera Solutions GmbH, IVECO SpA, Elringklinger AG, Etablissementen Franz Colruyt NV, WaterstofNet VZW, Air Liquide Advanced Business, Totalenergies Marketing Deutschland GmbH, PowerCell Sweden AB, Union Internationale des Transports Routiers (IRU), Bayerische Motoren Werke AG, Robert Bosch GmbH, Hydrogen Europe

https://www.h2haul.eu/

PROJECT AND OBJECTIVES

H2Haul brings together two major European truck OEMs (IVECO and VDL) and three fuel cell stack/system suppliers (Plastic Omnium, Bosch and PowerCell) to develop and demonstrate fleets of heavy-duty trucks in day-to-day commercial operations at four sites across four countries. The overall objective of H2Haul is to prove that hydrogen trucks can be a practical zero-emission and zero-carbon solution for much of Europe's trucking needs and, in doing so, pave the way for the commercialisation of fuel cell trucks in Europe. The project is currently at the end of the planning and pre-deployment phase, and all trucks and hydrogen refuelling stations (HRSs) funded in the project are expected to be deployed in the next 12 months.

NON-QUANTITATIVE OBJECTIVES

- H2Haul aims to develop long-haul heavy-duty (26 t and 44 t) fuel cell trucks that meet customers' requirements in a range of operating environments. The truck designs and specifications are being finalised in alignment with specific customer requirements and mission profiles. The objectives are expected to be met.
- The project aims to homologate three fuel cell truck types to certify that they are safe to use on Europe's roads. Truck OEMs are working closely with hydrogen safety experts and the relevant certification bodies to secure all necessary safety approvals for using the trucks on public roads in Europe.
- It aims to develop the business case for the further roll-out of heavy-duty fuel cell trucks. H2Haul will provide a valuable database of real-world performance information and insights into the next steps required for the commercialisation of this sector. The business case is to be developed based on fuel cell truck designs that meet customers' needs. The operation of fuel cell trucks and the subsequent data collection will highlight the costs involved in the technology. Analysis will be carried out to highlight the economics of more ambitious deployments of many tens of vehicles or more.
- H2Haul aims to prepare the European market for the further roll-out of fuel cell trucks through (i) the development of innovative commercial models and (ii) the dissemination of information from the project to a wide audience of relevant stakeholders. Communication activities in the first and second years of the project have stimulated significant interest from relevant audiences.

PROGRESS AND MAIN ACHIEVEMENTS

- The fuel cell truck technical specifications were finalised. Data were gathered on the technical specifications of the fuel cell trucks and HRSs.
- The first project HRS was deployed.
- The second observer group meeting took place.

FUTURE STEPS AND PLANS

- H2Haul will deploy the VDL and IVECO trucks. The VDL trucks were due to be delivered to Colruyt between March and June 2023, to start commercial operation. The IVECO beta trucks are currently being assembled with fuel cells from Bosch and will serve as prototypes for the 12 gamma trucks that will be delivered to end users in France, Germany and Switzerland between November 2023 and March 2024.
- The project will commission and start the operation of all remaining project HRSs. Currently, one HRS is in operation in Switzerland; the Belgian and French HRSs are planned to be commissioned by the beginning of summer 2023. The HRSs in Germany are currently being planned, and supplier selection is ongoing. Deployment is expected to take place at the end of 2023 or beginning of 2024.
- H2Haul will continue high-profile dissemination and lobbying work through attending and delivering presentations at key conferences and events. The next observer group meeting was due to be held in April 2023, and other stakeholder engagement activities will continue. The results will be disseminated extensively.

QUANTITATIVE TARGETS AND STATUS

Target source	Parameter	Unit	Target	Target achieved?
Project's own objectives and MAWP addendum (2018–2020)	Truck operational period	months	Start of operation including ramp-up phase: minimum of 24	
	Truck distance travelled	km	Minimum of 30 000 per truck and year, on average per site	
	Truck availability	%	> 90 on a fleet basis after an initial ramp-up phase of a maximum of 6 months	
	Truck-specific fuel consumption	kg/100 km	< 7.5 (rigid, @ 30–50 % load, inner-city delivery (< 25 km/h on average)) < 8.5 (tractor with semi-trailer @ 30–50 % load, long-haul delivery (> 65 km/h on average))	
	Availability of HRSs (by end of project)	%	99	⚙
	MDBF	km	> 2 500	
	Well-to-wheel CO_2 emissions of < 50 % of those of diesel trucks	kg CO_2/km	kg CO_2/vehicle-km (per vehicle type, average across fleet) < 50 % compared with a diesel truck	
	Speed of hydrogen dispensing	kg/min	> 2.5 kg/min	
	Cost of hydrogen dispensed to HRS	€/kg	≤ €7.50/kg dispensed (excl. taxes) at end of project – in practice, lower values are expected	
	Amount of hydrogen dispensed to project trucks	kg/year	> 2 500 kg per truck per year	

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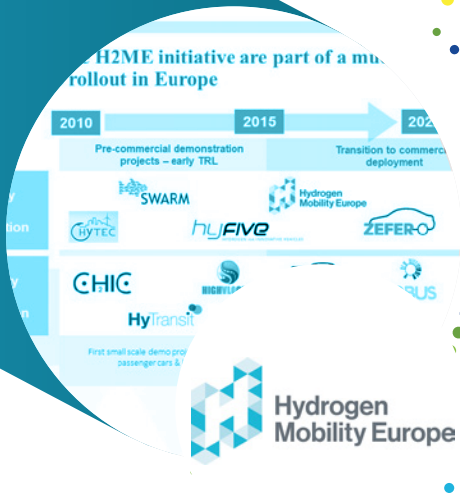
H2ME 2

HYDROGEN MOBILITY EUROPE 2



Project ID:	**700350**
PRD 2023:	**Panel 3 – H2 end uses – transport**
Call topic:	**FCH-03.1-2015: Large scale demonstration of hydrogen refuelling stations and FCEV road vehicles – including buses and on site electrolysis**
Project total costs:	**EUR 100 015 655.40**
Clean H_2 JU max. contribution:	**EUR 34 999 548.50**
Project period:	**1.5.2016–31.12.2023**
Coordinator:	**Element Energy Limited, United Kingdom**
Beneficiaries:	ERM France, HYGO – Hydrogene Grand Ouest, R-Hynoca, Hysetco, Reseau GDS, Toyota Norge AS, Toyota Danmark AS, Mercedes-Benz AG, McPhy Energy Italia Società a Responsabilità Limitata, Element Energy, Stichting Cenex Nederland, B. Kerkhof & ZN BV, Tech Transports Compagnie, Air Liquide France Industrie, Alphabet Fuhrparkmanagement GmbH, Linde Gas GmbH, Islenska Vetnisfelagid EHF, Communauté Urbaine du Grand Nancy, Stedin Diensten BV, HYPE, H2 Mobility Deutschland GmbH & Co. KG, HYOP AS, Brintbranchen, New Nel Hydrogen AS, Compagnie Nationale du Rhone SA, Hydrogene De France, Honda R&D Europe (Deutschland) GmbH, Gnvert SAS, AGA AB, Symbio, Air Liquide Advanced Technologies SA, Elogen, Société d'économie mixte des transports en commun de l'agglomération nantaise (Semitan), Ministerie van Infrastructuur en Waterstaat, Intelligent Energy Limited, Manufacture Francaise des Pneumatiques Michelin, ITM Power (Trading) Limited, CENEX – Centre of Excellence for Low Carbon and Fuel Cell Technologies, Københavns Kommune, hySOLUTIONS GmbH, McPhy Energy, Mercedes-Benz Fuel Cell GmbH, WaterstofNet VZW, Nissan Motor Manufacturing (UK) Limited, Air Liquide Advanced Business, Renault Trucks SAS, NEL Hydrogen AS, Icelandic New Energy Ltd, Eifer Europäisches Institut für Energieforschung EDF KIT EWIV, Stedin Netbeheer BV, Renault SAS, Bayerische Motoren Werke AG, Audi AG, Open Energi Limited, Daimler AG, The University of Manchester

https://h2me.eu/

PROJECT AND OBJECTIVES

H2ME 2 brings together actions in 10 countries in a 7-year collaboration to deploy 20 hydrogen refuelling stations (HRSs) and around 1 000 vehicles. The project has performed a large-scale market test of a large fleet of fuel cell electric vehicles operated in real-world customer applications across multiple European regions. In parallel, it has demonstrated that the hydrogen mobility sector can support the wider European energy system via electrolytic hydrogen production.

NON-QUANTITATIVE OBJECTIVES

- A minimum of 1 000 fuel cell vehicles and 20 HRSs are to be deployed by the end of the project.
- The project aimed to demonstrate the electrolyser-integrated HRS operating in grid balancing. H2ME 2 included a dedicated work package to assess how electrolytic hydrogen production in the mobility sector can link to the wider energy system.
- Multiple original equipment manufacturers (OEMs) supplied vehicles, including cars and utility vehicles. H2ME 2 aimed to deploy cars and light-duty vans from OEMs including Mercedes, Honda, Symbio (Renault and Stellantis), Hyundai and Toyota.
- H2ME 2 aimed to ensure the cross-fertilisation of knowledge acquired in the project. A dedicated work plan and a dissemination and exploitation plan were developed to achieve this. Three observer countries are included in the coalition.

PROGRESS AND MAIN ACHIEVEMENTS

- There were c. 800 vehicles and 15 HRSs in operation as of Q1 2023 (in the H2ME 2 project alone).
- Demonstration in real-world operation has been under way since 2015 – jointly with H2ME – for over 1 100 vehicles from five OEMs (Mercedes, Honda, Hyundai, Symbio and Toyota) across 10 countries and c. 50 HRSs from 10 suppliers across six countries (Denmark, France, Iceland, the Netherlands, Sweden and the United Kingdom).
- The demonstration of positive business cases under H2ME 2 has led to further commitments from partners to expand fleets in Denmark, Germany and France.
- The project is building a rich dataset for Europe, jointly with H2ME. Since 2015, 25 million km have been driven and 377 t of H_2 distributed in 148 600 events (figures from November 2022).

FUTURE STEPS AND PLANS

- All 20 planned HRSs are expected to have been commissioned and be in operation by the end of the project. The commissioning of new HRSs has been affected by the COVID-19 pandemic and by the lack of experience at the local level for reviewing and approving permits.
- Over 1 100 vehicles are planned for deployment in H2ME 2 by the end of the project. The deployment of vehicles has been affected by the COVID-19 pandemic and its restrictions (lockdowns, curfews), which have delayed delivery and affected demand.
- The project has built a solid and growing base of operational data from vehicles and HRSs, and undertaken further fact-based analysis of vehicles' and HRSs' performances.
- Prior to H2ME, there were few large deployments of fuel cell hydrogen vehicles in Europe. The H2ME projects have contributed to the deployment of one third of fuel cell hydrogen vehicles on the road and 20 % of operational HRSs in Europe. In addition, H2ME has encouraged further activity in other vehicle segments (including buses and trucks) by supporting the deployment of HRSs.
- Across H2ME and H2ME 2, c. 100 reports have been prepared, with the majority publicly available on the project's website.

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 of SoA target
Project's own objectives, MAWP addendum (2018–2020) and AWP 2015	**HRSs**						
	HRS availability	%	98	96	⚙	98	2017
	Min. HRS operation	months	36	58	✓	32	
	Hydrogen purity	%	99.99	99.99	✓	99.99	
	Fuel cell vehicles						
	Min. vehicle operation during the project	months	36	60	✓	12	2017
	Vehicle availability	%	98	≈ 100	✓	98	

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H2PORTS

IMPLEMENTING FUEL CELLS AND HYDROGEN TECHNOLOGIES IN PORTS

Project ID:	**826339**
PRD 2023:	**Panel 3 – H2 end uses – transport**
Call topic:	**FCH-03-1-2018: Developing fuel cell applications for port/harbor ecosystems**
Project total costs:	**EUR 4 265 947.50**
Clean H_2 JU max. contribution:	**EUR 3 999 947.50**
Project period:	**1.1.2019–31.12.2024**
Coordinator:	**Fundación de la Comunidad Valenciana para la Investigación, Promoción y Estudios Comerciales de Valenciaport, Spain**
Beneficiaries:	Agenzia Nazionale per le Nuove Tecnologie, l'Energia e lo Sviluppo Economico Sostenibile, Atena Scarl – Distretto Alta Tecnologia Energia Ambiente, Autoridad Portuaria de Valencia, Ballard Power Systems Europe AS, Cantieri del Mediterraneo SpA, Centro Nacional de Experimentación de Tecnologías de Hidrógeno y Pilas de Combustible Consorcio, Enagás SA, Grimaldi Euromed SpA, Hyster-Yale Nederland BV, Mediterranean Shipping Company Terminal Valencias SA, Sociedad Española de Carburos Metálicos SA, Università degli Studi di Napoli Parthenope, Università degli Studi di Salerno, Valencia Terminal Europa SA

https://h2ports.eu/

PROJECT AND OBJECTIVES

H2Ports will demonstrate and validate two innovative solutions based on fuel cell technologies. A reach stacker and a terminal tractor will be tested on a daily basis during 2 years of real operational activities at the Port of Valencia, and a mobile hydrogen refuelling station (HRS) designed and built during the project will provide the required hydrogen. All three elements are currently in advanced stages of building, and the piloting period is planned to start in summer 2023.

NON-QUANTITATIVE OBJECTIVES

- The project aims to disseminate H_2 technologies to the ports and maritime sector. This goal has been accomplished through the organisation of the stakeholder advisory group.
- H2Ports will gather information on the use of H_2 in port environments.
- It will gather information on the use of H_2 as fuel for vessels.

PROGRESS AND MAIN ACHIEVEMENTS

H2Ports has completed the HRS construction phase and is currently undertaking safety testing prior to the start of the operative period.

The fuel cell Reach Stacker is at a very advanced construction stage. The fuel cell's commissioning process has started, and the testing phase has been scheduled, prior to the delivery of the machine to the Port of Valencia.

The design and component selection of the terminal tractor has been completed; it is entering the final stage of the construction process, and the commissioning of the machine, the safety tests and CE certification will take place before its delivery to the Port of Valencia.

FUTURE STEPS AND PLANS

The pilot period was expected to start in August 2023.

QUANTITATIVE TARGETS AND STATUS

Target source	Parameter	Unit	Target	Target achieved?
Project's own objectives	HRS daily capacity	kg/day	60	
	Reach stacker vehicle power	kW	90	
	Vehicle power	kW	70	

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HEAVEN

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

Project ID:	826247
PRD 2023:	Panel 3 – H2 end uses – transport
Call topic:	FCH-01-4-2018: Fuel cell systems for the propulsion of aerial passenger vehicle
Project total costs:	EUR 6 953 835.06
Clean H_2 JU max. contribution:	EUR 3 995 305.00
Project period:	1.1.2019–30.9.2023
Coordinator:	H2FLY, Germany
Beneficiaries:	Air Liquide Advanced Technologies SA, Deutsches Zentrum für Luft- und Raumfahrt EV, Ekpo Fuel Cell Technologies GmbH, Fundación Ayesa, Air Liquide SA, Pipistrel Vertical Solutions Doo Podjetje Za Napredne Letalske Resitve

https://heaven-fch-project.eu/

PROJECT AND OBJECTIVES

The overall objective of this project is to address the gap between the research and product stages of a zero-emission fuel-cell-based propulsion technology to achieve emission- and noise-reduction scenarios, and meet the 2050 environmental goals for aviation. To that end, a high-efficiency, high-power-density, fuel-cell-based serial hybrid-electric propulsion architecture will be combined with the high energy density of cryogenic hydrogen storage. It will be advanced up to TRL6.

NON-QUANTITATIVE OBJECTIVES

- HEAVEN aims to increase the credibility of the solution for the propulsion of passenger aircraft and UAVs.
- The project aims to advance towards zero-emission hydrogen-powered regional commuter airliners.

PROGRESS AND MAIN ACHIEVEMENTS

- The cryogenic systems have been manufactured and the GSE has been developed.
- The cryogenic system was tested and verified.
- The powertrain was integrated into the aircraft.

FUTURE STEPS AND PLANS

- Fuel cell and hydrogen fuel system coupling and testing with liquid hydrogen (March 2023).
- Ground tests (June 2023).
- Flight test (September 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	2.7 (stack including end plates)	✓
	FC power density in volume	kW/l	3.5	4.1 (stack including end plates)	
	Air subsystem	%	> 50	Preliminary results are in compliance with this value but have not been achieved yet	
	Power converter	kW/kg	8	Preliminary results are in compliance with this value but have not been achieved yet	
	System lifetime	hours	500 (stack)	N/A	
	Hydrogen system	wt%	> 5.5	11.50	✓

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HYSHIP

DEMONSTRATING LIQUID HYDROGEN FOR THE MARITIME SECTOR

Project ID:	**101007205**
PRD 2023:	**Panel 3 – H2 end uses – transport**
Call topic:	**FCH-01-6-2020: Demonstration of liquid hydrogen as a fuel for segments of the waterborne sector**
Project total costs:	**EUR 13 409 121.25**
Clean H_2 JU max. contribution:	**EUR 7 993 942.00**
Project period:	**1.1.2021–31.12.2025**
Coordinator:	**Wilh. Wilhelmsen Holding ASA, Norway**
Beneficiaries:	Air Liquide Norway AS, Diana Shipping Services SA, DNV AS, DNV GL SE, Eidgenössische Technische Hochschule Zürich, Equinor Energy AS, Kongsberg Maritime AS, LMG Marin AS, LMG Marin France, Maritime Cleantech, Massterly AS, National Center For Scientific Research 'Demokritos', Norled AS, Norsea Group AS, Persee, Stolt Tankers B.V., University of Strathclyde, Wilhelmsen Ship Management Norway AS

https://hyship.eu/

PROJECT AND OBJECTIVES

HyShip is building a vessel that will run on liquid hydrogen (LH_2). The vessel will transport goods from port to port along the west coast of Norway, and transport LH_2 for bunkering stations for other vessels/trucks running on hydrogen. The project aims to replace trucks on the roads between the ports, demonstrate the use of LH_2 on a vessel and distribute LH_2 to ports to facilitate a LH_2 supply chain. The main key performance indicator of the project is the demonstration of 3 000 hours of operation of 3 MW fuel cells. The design of the vessel is ongoing, and the vessel has not been ordered yet.

NON-QUANTITATIVE OBJECTIVES

- HyShip aims to conceptually design a full range of vessel and hydrogen systems.
- It aims to develop and describe a business ecosystem with a timeline for cost-efficient operation.
- It also aims to integrate the demonstrator into a larger sociotechnical system – with business models, policy models and LH_2 supply – that will help move towards use of LH_2.
- The project aims to use further robust holistic design approach (RHODA) ship design methods, lowering the cost of estimating complex projects with novel fuel and infrastructure, and allowing real-time data collection on the effects of the use of novel fuels (no real-time data provided yet).
- It aims to develop input to the International Maritime Organization, which will help the systems transition to its rules instead of following the alternative design approach.

PROGRESS AND MAIN ACHIEVEMENTS

The preliminary design of vessel and LH_2 propulsion systems is complete.

FUTURE STEPS AND PLANS

- The ship-building contract will be signed.
- The vessel will be delivered.
- Vessel operation will begin.

QUANTITATIVE TARGETS AND STATUS

Target source	Parameter	Unit	Target	Target achieved?
Project's own objectives	Fuel cell power output	MW	3.0	
	Hours of operation of LH_2-powered propulsion	hours	3 000	
	Development of an intelligent energy management system that reduces the CAPEX of the energy system by > 5 %	%	5	
	Reduction of > 40 % of cost of design and ship integration cost related to the hydrogen/fuel cell systems themselves	%	40	

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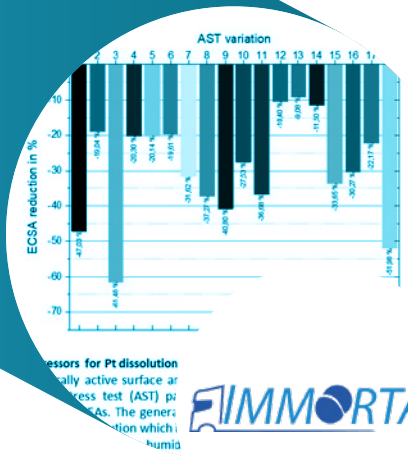
IMMORTAL

IMPROVED LIFETIME STACKS FOR HEAVY DUTY TRUCKS THROUGH ULTRA-DURABLE COMPONENTS



Project ID:	**101006641**
PRD 2023:	**Panel 3 – H2 end uses – transport**
Call topic:	**FCH-01-2-2020: Durability-lifetime of stacks for heavy duty trucks**
Project total costs:	**EUR 4 461 953.75**
Clean H_2 JU max. contribution:	**EUR 3 825 927.50**
Project period:	**1.1.2021–31.12.2023**
Coordinator:	**Centre national de la recherche scientifique, France**
Beneficiaries:	Albert-Ludwigs-Universität Freiburg, AVL List GmbH, FPT Industrial SpA, FPT Motorenforschung AG, Johnson Matthey Hydrogen Technologies Limited, Johnson Matthey plc, Pretexo, Robert Bosch GmbH, Université de Montpellier

https://immortal-fuelcell.eu

PROJECT AND OBJECTIVES

IMMORTAL aims to develop high-performance and high-durability membrane electrode assemblies (MEAs), and their components, specifically designed for heavy-duty truck application. By month 14, an initial set of accelerated and load profile cell and stack tests had been developed and applied to baseline MEAs. Selected actual truck missions were simulated to produce load profiles that will be used to produce updated load profile testing procedures. By month 18, new materials (support, catalyst, membrane), which were integrated into an initial heavy-duty MEA, had been developed. The performance of these MEAs comes within 93 % of the final power density target of 0.675 V in short-stack testing.

NON-QUANTITATIVE OBJECTIVES

IMMORTAL aims to contribute to activities on Mission Innovation's hydrogen innovation challenge through cooperation with the US Department of Energy's Million Mile Fuel Cell Truck Consortium. Several workshops have been held with the consortium, and with Japan's fuel cell platform, which included discussions on, inter alia, heavy-duty stressors, the second-generation Toyota Mirai and advanced characterisation techniques.

PROGRESS AND MAIN ACHIEVEMENTS

- IMMORTAL has developed highly stable catalyst layers at the target platinum loading (0.3 mg/cm^2) that achieve a decay rate due to irreversible losses ≥ 50 % lower than the reference catalyst-coated membrane (from the INSPIRE project) using a project accelerated stress test protocol (Milestone 5).
- IMMORTAL has developed and validated a highly durable reinforced membrane that has withstood > 100 000 wet/dry cycles in an MEA held at open circuit voltage at 90 °C.
- IMMORTAL has developed MEAs integrating these novel components that achieve 93 % of the final target power density in short-stack testing (target: 0.675 V).

FUTURE STEPS AND PLANS

- IMMORTAL will deliver further optimised materials for a second generation of heavy-duty-specific MEAs (expected spring 2023).
- It will deliver this second generation of heavy-duty-specific MEAs for single-cell and short-stack accelerated stress testing and load-profile testing as part of work package 2 (expected from June 2023).

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 of SoA target
AWP 2020	Cell voltage at 1.77 A/cm^2	V	0.675	0.661		0.675	2021
	Durability	hours	30 000 with < 10 % degradation	Durability testing is planned in RP2; MEAs have been developed for heavy-duty trucks		8 500 with < 10 % degradation	2020
Project's own objectives	Catalyst surface area and mass activity	cm^2/g of Pt and A/mg of Pt	Exceeding values of reference Pt and better retention after accelerated degradation cycles than reference Pt/C	Two catalyst designs achieve this objective	✓	N/A	N/A
	Membrane durability in MEA AST cycles	cycles	50 000	110 000	✓	No public result comes close to this number of cycles	N/A

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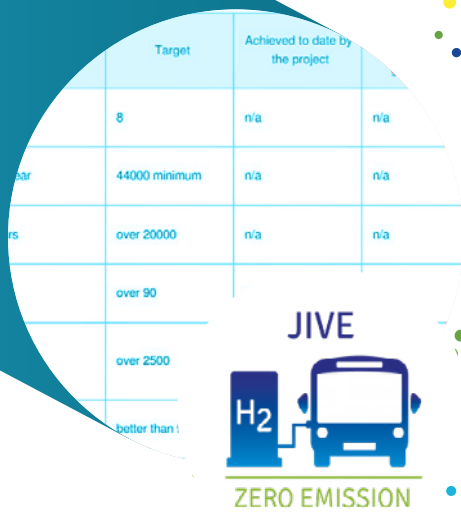
JIVE

JOINTINITIATIVEFORHYDROGENVEHICLESACROSS EUROPE



Project ID:	**735582**
PRD 2023:	**Panel 3 – H2 end uses – transport**
Call topic:	**FCH-01-9-2016: Large scale validation of fuel cell bus fleets**
Project total costs:	**EUR 88 770 205.25**
Clean H_2 JU max. contribution:	**EUR 32 000 000.00**
Project period:	**1.1.2017–30.6.2024**
Coordinator:	**Element Energy Limited, United Kingdom**
Beneficiaries:	Aberdeen City Council, Birmingham City Council, EE Energy Engineers GmbH, ESWE Verkehrsgesellschaft mbH, Fondazione Bruno Kessler, Gelderland, HyCologne – Wasserstoff Region Rheinland e.V., Hydrogen Europe, London Bus Services Limited, Planungsgruppe Energie und Technik GbR, Rebelgroup Advisory BV, Regionalverkehr Köln GmbH, Sphera Solutions GmbH, SASA SpA AG, Union Internationale des Transports Publics, WSW mobil GmbH

https://www.fuelcellbuses.eu/projects/jive

PROJECT AND OBJECTIVES

JIVE exists to assist the commercialisation of fuel cell buses (FCBs) as a zero-emission public transport option across Europe. The project aims to address the current high ownership cost of FCBs relative to conventionally powered buses and the lack of hydrogen refuelling infrastructure across Europe by supporting the deployment of 142 FCBs in eight locations. This will more than double the number of FCBs currently operating in Europe.

NON-QUANTITATIVE OBJECTIVES

- JIVE aims to demonstrate the suitability and provide experience of FCBs for wider roll-out. Through the publication of project deliverables such as a best practice and commercialisation report, information flows to interested observer parties have been established.
- The project aims to raise awareness of the readiness of fuel cell technology for wider roll-out – with a focus on bus purchasers and regulators. A strong observer group within the JIVE consortium has been established. This group monitors discussions and best practices emerging from the project. This will ensure that the momentum for FCB uptake in Europe continues beyond the project.
- JIVE aims to deliver positive environmental impacts by operating FCBs for extended periods. As per the project objectives, all buses deployed thus far in the project are replacing diesel technology. This means that the buses will lead to CO_2 abatement and will not simply operate as a 'visible extra'.

PROGRESS AND MAIN ACHIEVEMENTS

- All 142 buses have been ordered, from four bus manufacturers.
- In total, 132 buses have started operating, representing 93 % of all the buses.

FUTURE STEPS AND PLANS

- By the end of the first half of 2023, all buses are expected to be operational.
- To date, only one city does not yet have operational buses.
- Uncertainties around ongoing issues related to hydrogen supply (undelivered hydrogen, hydrogen prices, etc.) are expected to be clarified in the upcoming period to ensure that all buses are fully operational.

QUANTITATIVE TARGETS AND STATUS

Target source	Parameter	Unit	Target	Target achieved?
Project's own objectives and AWP 2016	Vehicle operational lifetime	years	8	
	Distance travelled	km/year	≥ 44 000	
	Operating hours per fuel cell system	hours	> 20 000	
	Availability	%	> 90	⚙
	MDBF	km	> 2 500	
	Specific fuel consumption	kg/100 km	> 9	
	Efficiency	%	> 42	
	Vehicle OPEX	€	Max. 100 % more than diesel bus OPEX	
	Vehicle CAPEX	€	< 650 000	✓

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JIVE 2

JOINTINITIATIVEFORHYDROGENVEHICLESACROSS EUROPE 2

Project ID:	779563
PRD 2023:	Panel 3 – H2 end uses – transport
Call topic:	FCH-01-5-2017: Large scale demonstration in preparation for a wider roll-out of fuel cell bus fleets (FCB) including new cities – phase two
Project total costs:	EUR 89 972 571.27
Clean H_2 JU max. contribution:	EUR 25 000 000.00
Project period:	1.1.2018–30.6.2025
Coordinator:	Element Energy Limited, United Kingdom
Beneficiaries:	ERM France, Transdev Occitanie Ouest, Hyport, Engie Energie Services, CA de l'Auxerrois, Connexxion Vloot BV, Société publique locale d'exploitation des transports publics et des services à la mobilité de l'agglomération paloise, TwynstraGudde Mobiliteit & Infrastructuur BV, Openbaar Lichaam OV-bureau Groningen en Drenthe, Pau Béarn Pyrénées Mobilités, Rebelgroup Advisory BV, Regionalverkehr Köln GmbH, Connexxion Openbaar Vervoer NV, Messer SE & Co. KGaA, WSW Mobil GmbH, Rīgas Pašvaldības Sabiedrība ar Ierobežotu Atbildību Rīgas Satiksme, Transports de Barcelona SA, EE Energy Engineers GmbH, Sphera Solutions GmbH, Brighton & Hove Bus and Coach Company Limited, Provincie Zuid-Holland, Vätgas Sverige Ideell Förening, Union Internationale des Transports Publics, Hydrogen Europe

https://www.fuelcellbuses.eu/projects/jive-2

PROJECT AND OBJECTIVES

JIVE 2 aims to deploy 156 fuel cell buses (FCBs). Combined, the JIVE projects will deploy nearly 300 FCBs in 16 cities across Europe by the end of the early 2020s – the largest deployment in Europe to date.

NON-QUANTITATIVE OBJECTIVES

- JIVE 2 aims to demonstrate the suitability and provide experience of FCBs for wider roll-out. Through the publication of project deliverables such as a best practice and commercialisation report, information flows to interested observer parties have been established.
- The project aims to raise awareness of the readiness of fuel cell technology for wider roll-out – with a focus on bus purchasers and regulators. A strong observer group within the JIVE consortium has been established. This group monitors discussions and best practices emerging from the project. This will ensure that the momentum for the FCB uptake in Europe continues beyond the project.
- JIVE 2 aims to deliver positive environmental impacts by operating FCBs for extended periods. As per the project objectives, all buses deployed thus far in the project are replacing diesel technology. This means that the buses will lead to CO_2 abatement and will not simply operate as a 'visible extra'.

PROGRESS AND MAIN ACHIEVEMENTS

- To date, 122 buses have been ordered.
- To date, 98 buses have become operational, representing 63 % of all the buses.
- To date, one site has been operating its fuel cell electric buses for more than 3 years.

FUTURE STEPS AND PLANS

- By Q2 2023, all buses will have been ordered.
- By Q3 2024, all buses will have been delivered and put into operation. At present, only one site does not yet have its buses in operation.

QUANTITATIVE TARGETS AND STATUS

Target source	Parameter	Unit	Target	Achieved to date by the project	Target achieved?
Project's own objectives and AWP 2017	Vehicle operational lifetime	years	8	N/A	
	Distance travelled	km/bus	> 50 000 minimum	27 627	
	Operating hours per fuel cell system	hours	> 20 000	2 015	
	Availability	%	> 90	86.10	⚙
	MDBF	km	< 3 500	10 242	
	Specific fuel consumption	kg/100 km	> 9.0	7.21	
	Efficiency	%	> 42	N/A	
	Vehicle OPEX	€	Max. 100 % more than diesel bus OPEX		
	Vehicle CAPEX	€	< 650 000		✓

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MARANDA

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

Project ID:	**735717**
PRD 2023:	**Panel 3 – H2 end uses – transport**
Call topic:	**FCH-01-5-2016: Develop new complementary technologies for achieving competitive solutions for marine applications at an economic scale of implementation**
Project total costs:	**EUR 3 704 757.50**
Clean H_2 JU max. contribution:	**EUR 2 939 457.50**
Project period:	**3.1.2017–31.3.2022**
Coordinator:	**Teknologian tutkimuskeskus VTT Oy, Finland**
Beneficiaries:	ABB OY, OMB Saleri SpA, Persee, PowerCell Sweden AB, Suomen ympäristökeskus, Swiss Hydrogen SA

https://projectsites.vtt.fi/sites/maranda/

PROJECT AND OBJECTIVES

In MARANDA, an emission-free hydrogen-fuelled proton-exchange-membrane-fuel-cell-based hybrid powertrain system (3 × 82.5 kW alternating current) was developed for marine applications. It was validated onshore, simulating offshore operation, and at a durability test site, as approval for testing the systems in the *Aranda* vessel was not granted. The project increased the market potential of hydrogen fuel cells in the marine sector. General business cases for different marine and harbour actors or fuel cell business actors were created.

NON-QUANTITATIVE OBJECTIVES

- The MARANDA project has already had a significant impact on the development of regulations, codes and standards.
- The fuel cell systems should be able to withstand the shocks, vibrations, saline environment and ship motions commonly encountered on the water, and other marine-application-relevant requirements.
- MARANDA aimed to evaluate the economic and environmental impacts for a prospective customer. A report on the business analysis of hydrogen fuel cells for marine applications has been prepared.
- The project aimed to formulate an initial go-to-market strategy. The report on the business analysis includes this strategy.
- MARANDA aimed to map opportunities for future demonstration actions. This mapping is included in the report on the business analysis.

PROGRESS AND MAIN ACHIEVEMENTS

- Three fuel cell systems from Swiss Hydrogen were assembled, delivered to Teknologian tutkimuskeskus VTT, integrated in containers and tested at the durability test site.
- A significant improvement in stack durability has been shown by PowerCell Sweden.
- Containers and equipment for the integration of fuel cell systems and hydrogen storage, including all safety systems, were designed, manufactured and tested.

FUTURE STEPS AND PLANS

All test runs were completed by the end of May 2022.

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	75	✓
	Stack durability	mV/1 000 h	4.6	1.7	
	Fuel-to-electricity efficiency (alternating current)	%	48	42	

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MORELIFE

MATERIAL, OPERATING STRATEGY AND RELIABILITY OPTIMISATION FOR LIFETIME IMPROVEMENTS IN HEAVY DUTY TRUCKS

Project ID:	101007170
PRD 2023:	Panel 3 – H2 end uses – transport
Call topic:	FCH-01-2-2020: Durability-lifetime of stacks for heavy duty trucks
Project total costs:	EUR 3 499 913.75
Clean H_2 JU max. contribution:	EUR 3 499 913.75
Project period:	9.1.2021–31.8.2024
Coordinator:	AVL List GmbH, Austria
Beneficiaries:	EKPO Fuel Cell Technologies GmbH, Mebius, Raziskovalno Razvojna Dejavnost, Zastopanje in Trgovina DOO, Nedstack Fuel Cell Technology BV, Technische Universität München, Technische Universiteit Eindhoven, Univerza v Ljubljani

https://morelife-info.eu/

PROJECT AND OBJECTIVES

MORELife is addressing the need for highly efficient material utilisation, maximised durability and optimised matching of the operation conditions for a proton-exchange membrane fuel cell in heavy-duty applications. The objectives are to:

- perform accelerated stress tests for the shortened test duration for lifetime verification;
- make improvements at the material and operation strategy levels;
- create advanced degradation models;
- find the optimised and validated operating conditions based on the improved materials;
- achieve a fuel cell predicted lifetime of 30 000 hours.

PROGRESS AND MAIN ACHIEVEMENTS

- Accelerated stress testing and accelerated durability testing protocols and accelerated stress tests for state-of-the-art (SoA) catalyst material have been created.
- Two generations of novel catalyst material have been created and are under investigation, with promising initial results in terms of performance. However, the catalyst is dealing with leaching of copper.
- Post-mortem analysis on aged SoA material has been performed in order to improve mechanistic degradation models created in this project.

FUTURE STEPS AND PLANS

- Accelerated stress testing protocols and accelerated stress tests for novel catalyst material will be created.
- A second generation of promising novel catalysts will be investigated. If performance is sufficient, a third generation will be created, with improvements based on the previous generations.
- If proven sufficient, the third generation of catalysts will be integrated in a 5- to 10-cell short stack for testing and validation, while a reference stack with SoA material will be built in order to compare durability and performance.

QUANTITATIVE TARGETS AND STATUS

Target source	Parameter	Unit	Target	Target achieved?
Project's own objectives	Power density cell	W/cm²	1.2 @ 0.675 V/cell	
	PGM loading	g/kW	< 0.3 Pt loadings of corresponding 0.36 mgPt/cm² MEA	

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REVIVE

REFUSE VEHICLE INNOVATION AND VALIDATION IN EUROPE

Project ID:	**779589**
PRD 2023:	**Panel 3 – H2 end uses – transport**
Call topic:	**FCH-01-7-2017: Validation of fuel cell trucks for the collect of urban wastes**
Project total costs:	**EUR 10 566 750.68**
Clean H_2 JU max. contribution:	**EUR 4 993 851.00**
Project period:	**1.1.2018–30.6.2024**
Coordinator:	**Tractebel Engineering, Belgium**
Beneficiaries:	Azienda Servizi Municipalizzati di Merano SpA, Commissariat à l'énergie atomique et aux énergies alternatives, Element Energy Limited, Engie Impact Belgium, E-Trucks Europe, Gemeente Amsterdam, Gemeente Breda, Gemeente Groningen, Gemeente Noordenveld, PowerCell Sweden AB, Prezero Nederland Holding BV, Proton Motor Fuel Cell GmbH, Renova AB, Saver NV, Servizi Energia Ambiente Bolzano SpA, Stad Antwerpen, WaterstofNet VZW

https://h2revive.eu/

PROJECT AND OBJECTIVES

REVIVE will significantly advance the state of development of fuel cell bin lorries by integrating fuel cell powertrains into 14 vehicles and deploying them at eight sites across Europe. The project will deliver substantial technical progress by integrating fuel cell systems from four major suppliers and by developing effective hardware and control strategies to meet highly demanding refuse truck duty cycles. Today, three trucks are in operation, and the remaining ones will be deployed in the coming months.

NON-QUANTITATIVE OBJECTIVES

- The project aims to involve EU fuel cell suppliers. Currently, two such suppliers are involved in the project: Proton Motor and PowerCell Sweden. In addition, two trucks are equipped with Hydrogenics FC systems.
- The project aims to demonstrate a route to high utilisation of hydrogen refuelling stations to support the roll-out of H_2 mobility for light vehicles. Even with limited running hours, the three trucks deployed in the project have already consumed 1 t of H_2 during the project.

PROGRESS AND MAIN ACHIEVEMENTS

- Trucks are in the building phase.
- The first Proton Motor fuel cell system has been delivered and successfully integrated.
- The first REVIVE truck has been deployed.

FUTURE STEPS AND PLANS

- **Deployment preparation.** At the project consortium level, experience and relevant documentation are being shared to fully prepare for truck deployment.
- **Increased dissemination activities.** To catch up following the delays experienced in 2020, a plan for dissemination will be developed.
- **Decrease in teething issues.** The trucks are being tested thoroughly before delivery.

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	Number of FCs deployed in the project	–	15	6	⚙	6
	FC power	kW	> 40	45	✓	90
	Lifetime	hours	25 000	N/A	⚙	> 25 000
	Tank-to-wheel efficiency	%	50	45	⚙	N/A
	Availability	%	90	81.5	⚙	
	Driving distance between failures	km	3 500	785	⚙	

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SH_2APED

STORAGE OF HYDROGEN: ALTERNATIVE PRESSURE ENCLOSURE DEVELOPMENT

Project ID:	**101007182**
PRD 2023:	**Panel 3 – H2 end uses – transport**
Call topic:	**FCH-01-1-2020: Development of hydrogen tanks for electric vehicle architectures**
Project total costs:	**EUR 2 146 925.00**
Clean H_2 JU max. contribution:	**EUR 1 993 550.00**
Project period:	**1.1.2021–31.12.2023**
Coordinator:	**Plastic Omnium Advanced Innovation and Research, Belgium**
Beneficiaries:	Bundesanstalt für Materialforschung und -prüfung, Misal SRL, OMB Saleri SpA, Optimum CPV, University of Ulster

https://sh2aped.eu/

PROJECT AND OBJECTIVES

The goal of SH_2APED is to develop and test at technology readiness level 4 a conformable and cost-effective 70 MPa hydrogen storage system with increased efficiency and advanced safety performance.

NON-QUANTITATIVE OBJECTIVES

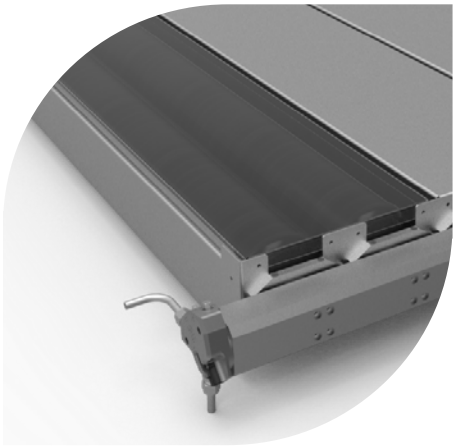
Regarding certification procedures, the project aims to contribute to the revision of regulations.

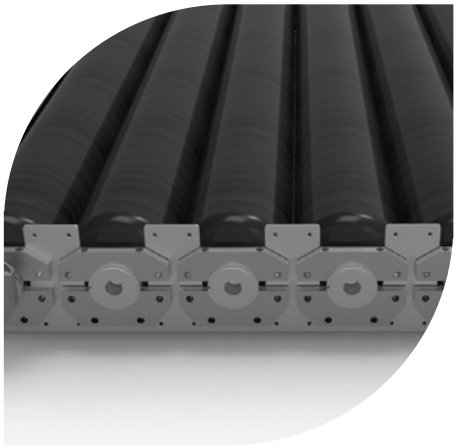
PROGRESS AND MAIN ACHIEVEMENTS

- The first assembly design – vessel design, and manifold and thermal pressure relief device design – has been finalised.
- Vessel prototypes are available.
- System testing of the model's reaction to fire is in progress.

FUTURE STEPS AND PLANS

Frame design is ongoing.





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 of SoA target
Project's own objectives	Cost of tank system	€/kg of H_2	< 400	> 580	⚙	< 500	2022
	Permeation	$Ncm^3/l/h$ @ 55 °C	< 46	Not yet available	⚙	N/A	N/A
	Hydraulic pressure cycle test at 87.5 MPa, 20 °C	–	22 000	> 22 000	✓	Not published	Not published

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SHIPFC

PILOTING MULTI MW AMMONIA SHIP FUEL CELLS

Project ID:	**875156**
PRD 2023:	**Panel 3 – H2 end uses – transport**
Call topic:	**FCH-01-2-2019: Scaling up and demonstration of a multi-MW fuel cell system for shipping**
Project total costs:	**EUR 3 179 056.25**
Clean H_2 JU max. contribution:	**EUR 9 975 477.50**
Project period:	**1.1.2020–31.12.2025**
Coordinator:	**Maritime Cleantech, Norway**
Beneficiaries:	Eidesvik Shipping AS, Wärtsilä Gas Solutions Norway AS, Sustainable Energy AS, North Sea Shipping AS, Star Bulk Ship Management Co. (Cyprus) Ltd, Wärtsilä Norway AS, Capital-Executive Ship Management Corp., Maritime CleanTech, Persee, Prototech AS, Equinor Energy AS, Yara International ASA, University of Strathclyde, National Center for Scientific Research 'Demokritos', Fraunhofer-Gesellschaft zur Förderung der angewandten Forschung EV

https://shipfc.eu/

PROJECT AND OBJECTIVES

ShipFC's main mission is to prove and show the case for large-scale zero-emission shipping through developing, piloting and replicating a modular 2 MW fuel cell technology using ammonia as fuel. The project will also prove the case for large-scale zero-emission fuel infrastructure through a realistic business model. Currently, the fuel cells are being scaled up and going through laboratory testing. The onboard fuel system design is in progress, together with the integration design for the fuel cell power system. ShipFC is building the knowledge base for the development of a global green ammonia fuel infrastructure.

NON-QUANTITATIVE OBJECTIVES

- The fourth iteration of the design for the container ship is now complete.
- Concept evaluations of bulk carriers are ongoing.

PROGRESS AND MAIN ACHIEVEMENTS

- The detailed design of the fuel system is under development.
- The detailed vessel design is under development. This includes the hazard identification process with class and the Norwegian Maritime Authority.

FUTURE STEPS AND PLANS

A challenging supply chain situation for fuel cell stacks is causing delays for the project. Full-scale testing has been delayed.

QUANTITATIVE TARGETS AND STATUS

Target source	Parameter	Unit	Target	Achieved to date by the project	Target achieved?
Project's own objectives	Greenhouse gas reduction as a result of using ammonia fuel	%	70	–	
	Ammonia SOFC system power	MW	2	1.3 kW	⚙
	MW-scale SOFC operational experience	hours	3 000	–	
Project's milestone/ objective	FC system approval in principle (AiP)	–	–	1.1.2023	✓

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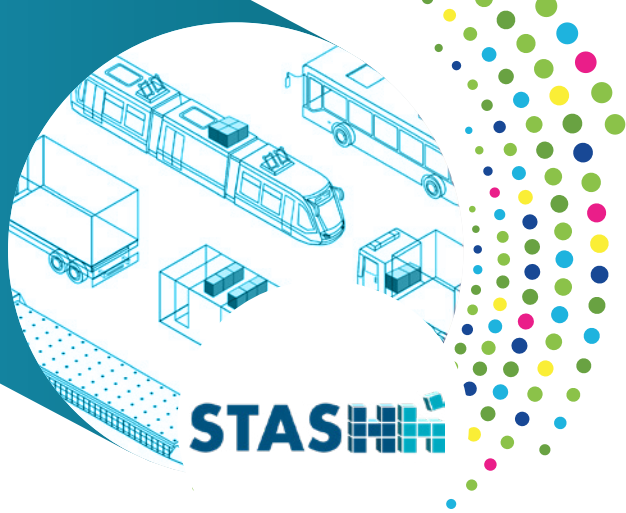
STASHH

STANDARD-SIZED HEAVY-DUTY HYDROGEN



Project ID:	101005934
PRD 2023:	Panel 3 – H2 end uses – transport
Call topic:	FCH-01-4-2020: Standard sized FC module for heavy duty applications
Project total costs:	EUR 14 315 057.05
Clean H_2 JU max. contribution:	EUR 7 500 000.00
Project period:	1.1.2021–30.6.2024
Coordinator:	Sintef AS, Norway
Beneficiaries:	Volvo Penta AB, Alstom Transport SA, AVL List GmbH, Ballard Power Systems Europe AS, CETENA SpA, Commissariat à l'énergie atomique et aux énergies alternatives, Damen Global Support BV, Damen Research Development & Innovation BV, FEV Europe GmbH, FEV Software and Testing Solutions GmbH, Freudenberg Fuel Cell e-Power Systems GmbH, Future Proof Shipping BV, Hyster-Yale Italia SpA, Hyundai Motor Europe Technical Center GmbH, Intelligent Energy Limited, Nederlandse Organisatie voor Toegepast Natuurwetenschappelijk Onderzoek, Plastic Omnium New Energies Wels GmbH, Proton Motor Fuel Cell GmbH, Scheepswerf Damen Gorinchem BV, Solaris Bus & Coach sp. z o.o., Toyota Motor Europe NV, VDL Enabling Transport Solutions BV, VDL Energy Systems, VDL Special Vehicles BV, Volvo Construction Equipment AB, Volvo Technology AB, WaterstofNet VZW

https://stashh.eu/

PROJECT AND OBJECTIVES

StasHH's objectives are to agree a standard for fuel cell modules across the heavy-duty sector (trucks, buses, ships, generators, trains, etc.), to build prototypes in accordance with this standard and to test them in accordance with agreed-upon methods. The project has produced three documents for standards – covering sizes, interfaces and communication – and several partners are already developing prototypes.

NON-QUANTITATIVE OBJECTIVES

- The project aims to disseminate the standard. This dissemination only recently started, as the standard was only recently agreed upon.
- StasHH plans to update the standard based on experience in 2023.

PROGRESS AND MAIN ACHIEVEMENTS

- Seven out of eight fuel cell modules have been designed.
- Protocols for factory acceptance and site acceptance testing have been prepared.
- The truck prototype has been deployed at VDL.

FUTURE STEPS AND PLANS

- Fuel cell module testing in three campaigns: two in 2023 and one in early 2024.
- Field demonstration in a heavy-duty vehicle.
- Production of an OEM best practice manual.
- Use of X-in-loop software.
- Finalisation of standard and designs.

QUANTITATIVE TARGETS AND STATUS

Target source	Parameter	Unit	Target	Achieved to date by the project	Target achieved?
Project's own objectives	Number of sizes	–	≤ 3	3	
	Number of fuel cell module partners	–	7	7	✓
	Fuel cell module power rating	kW	30–100	30–125	

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THOR

THERMOPLASTIC HYDROGEN TANKS OPTIMISED AND RECYCLABLE

Project ID:	**826262**
PRD 2023:	**Panel 3 – H2 end uses – transport**
Call topic:	**FCH-01-3-2018: Strengthening of the European supply chain for compressed storage systems for transport applications**
Project total costs:	**EUR 2 969 253.29**
Clean H_2 JU max. contribution:	**EUR 2 853 958.75**
Project period:	**1.1.2019–30.9.2022**
Coordinator:	**Faurecia Systemes d'Echappement SAS, France**
Beneficiaries:	Centre national de la recherche scientifique, Centre technique des industries mécaniques, Cetim Grand Est, COVESS NV, École Nationale Supérieure de Mécanique et d'Aérotechnique, ETIM, Air Liquide SA, Norges teknisk-naturvitenskapelige universitet, Rina Consulting – Centro Sviluppo Materiali SpA, Sirris het collectief centrum van de technologische industrie, Université de Poitiers

https://thor-fch2.eu/

PROJECT AND OBJECTIVES

The project aims to validate hydrogen technology and its associated process regarding a recyclable thermoplastic composite tank for the storage of high-pressure gaseous hydrogen for mobility.

NON-QUANTITATIVE OBJECTIVES

- THOR will conduct health and safety monitoring using optical fibres, for temperature control and fire detection. Tests were scheduled to take place in July 2022.
- The project aims to create a recycled panel of thermoplastic reinforced with carbon fibres. Recycling activities are scheduled to take place at the end of the project. The performance of the panels will be tested to define their best use.
- The tanks are intended to be recyclable.
- The project is working on the reuse of the end-of-life tank with a recycling process for producing carbon-fibre composite sheets (the materials and the manufacturing process for the reused sheets are being prepared).

PROGRESS AND MAIN ACHIEVEMENTS

- Fifteen tanks have been prepared by CETIM.
- Burst results were below the qualification threshold (94 % of the burst pressure), meaning hydrogen could not be used for the final test.
- Recycling activities: recycled panels have been manufactured and prototypes' formed parts have been prepared successfully.

FUTURE STEPS AND PLANS

The project ended in September 2022.

QUANTITATIVE TARGETS AND STATUS

Target source	Parameter	Unit	Target	Achieved to date by the project	Target achieved?
MAWP (2014–2020)	Gravimetric efficiency	%	> 6 %	4.35	
	Cost of tanks	€/kg of H_2	400	760	
	AWP 2018	Burst pressure	bar	1 575	

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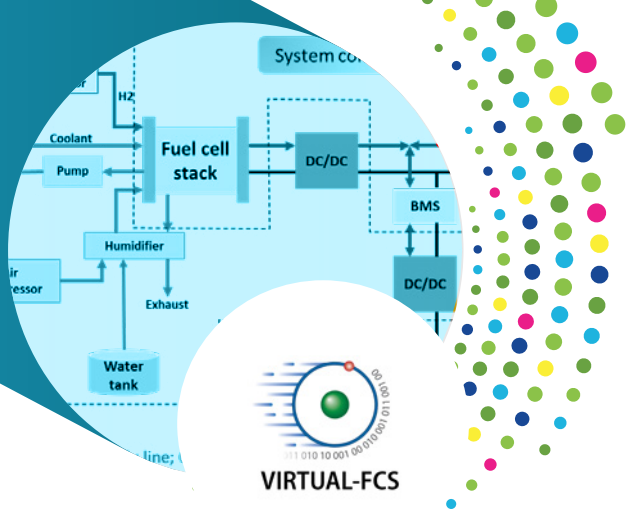
VIRTUAL-FCS

VIRTUAL & PHYSICAL PLATFORM FOR FUEL CELL SYSTEM DEVELOPMENT



Project ID:	**875087**
PRD 2023:	**Panel 3 – H2 end uses – transport**
Call topic:	**FCH-01-3-2019: Cyber-physical platform for hybrid fuel cell systems**
Project total costs:	**EUR 2 349 018.75**
Clean H_2 JU max. contribution:	**EUR 1 897 806.25**
Project period:	**1.1.2020–31.4.2023**
Coordinator:	**Sintef AS, Norway**
Beneficiaries:	Ballard Power Systems Europe AS, Banke APS, Communauté d'universités et d'établissements université Bourgogne-Franche-Comté, École nationale supérieure de mécanique et des microtechniques, SEAM AS, Solaris Bus & Coach sp. z o.o., Université de Franche-Comté, Université de technologie de Belfort-Montbéliard, Vivarail Ltd

https://www.sintef.no/projectweb/virtual-fcs/

PROJECT AND OBJECTIVES

The overall objective of VIRTUAL-FCS is to make the design 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 hybrid systems of proton-exchange membrane fuel cells and batteries. The platform will be entirely open source, allowing everyone in both industry and research to benefit from and contribute to the development of the framework. The software tools are being developed in close collaboration with end users and system integrators, securing widespread accessibility.

NON-QUANTITATIVE OBJECTIVES

- VIRTUAL-FCS aims for a significant reduction in development times for new fuel cell and battery hybrid systems. The advanced modelling, simulation and emulation tools developed in the project will enable end users with limited experience of fuel cell systems to design and implement new systems more quickly.
- The project aims to create a development platform for hybrid fuel cell systems with integration capabilities and corresponding simulation models. The real-time software platform combined with a full range of emulated components will enable end users to seamlessly integrate real, simulated and emulated components together in a mixed software–hardware system.
- It aims to create analytical tools and instrumentation to validate the different systems and energy management methodologies developed. VIRTUAL-FCS will validate different energy management systems on the mixed software–hardware system. The characterisation of the systems will be carried out using the standard techniques to validate system performance.
- VIRTUAL-FCS aims to create high-performance, real-time emulators of the dynamic behaviour of real components and subsystems. VIRTUAL-FCS will develop new and improved balance-of-plant and stack models capable of accurate real-time emulation of components' dynamic performance, along with their degradation.
- The project aims to enable the establishment of an EU-based supply industry for hybrid fuel cell system simulation and the experimental tool environment (X-in-the-loop platform) to boost the competitiveness of the EU fuel cell industry. The system simulation tools and methods for setting up and using the experimental platform will be available to the entire European industry free of charge to boost competitiveness.

PROGRESS AND MAIN ACHIEVEMENTS

- VIRTUAL-FCS has demonstrated cyber–physical hardware integration.
- The project has carried out fuel cell electric vehicle simulations.
- It has also carried out real-time system simulation.
- The project has carried out real-time system emulation. The project has demonstrated this capability by emulating a full-stack system with an energy management strategy that can take real-time input from a physical sensor, use this feedback for real-time control of a standard fuel cell stack test bench and simulate various load cycles on the physical stack.
- The project has integrated components from the physical hybrid system into the system simulated in the software tools and into those systems emulated on a controller.
- The project has arranged explanatory webinars and participated in conferences to demonstrate the feasibility of the VIRTUAL-FCS library.
- A simple-fuel cell stack degradation model has been developed.

FUTURE STEPS AND PLANS

- Full validation of the fuel cell stack, battery and balance-of-plant models will be carried out.
- An industrial workshop was arranged for 26 April 2023.

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ZEFER

ZERO EMISSION FLEET VEHICLES FOR EUROPEAN ROLL-OUT

Project ID:	**779538**
PRD 2023:	**Panel 3 – H2 end uses – transport**
Call topic:	**FCH-01-6-2017: Large scale demonstration of hydrogen refuelling stations and fuel cell electric vehicle (FCEV) road vehicles operated in fleet(s)**
Project total costs:	**EUR 13 676 254.48**
Clean H_2 JU max. contribution:	**EUR 4 998 843.00**
Project period:	**9.1.2017–31.8.2023**
Coordinator:	**Element Energy Limited, United Kingdom**
Beneficiaries:	ERM France, Drivr Danmark A/S, Air Liquide Advanced Technologies GmbH, Linde GmbH, Toyota Danmark AS, Element Energy, Green Tomato Cars Limited, Breath, Air Liquide France Industrie, Air Liquide Belge, Hype, Air Liquide Advanced Technologies SA, ITM Power (Trading) Limited, CENEX – Centre of Excellence for Low Carbon and Fuel Cell Technologies, Air Liquide Advanced Business, Ville de Paris, Linde AG, Bayerische Motoren Werke AG, Mayor's Office for Policing and Crime (London)

https://zefer.eu/

PROJECT AND OBJECTIVES

ZEFER aims to demonstrate viable business cases for fuel cell electric vehicles (FCEVs) in high-mileage fleet applications. The project aims to deploy 180 FCEVs into taxi, private-hire and emergency-service operations in three major European cities in which the operational benefits and zero-emission credentials of FCEVs can be monetised. The vehicles have used existing hydrogen refuelling station (HRS) networks to increase local utilisation levels and improve the business case for HRS operators. As of December 2022, the 180 vehicles had amassed 11.3 million km, and the prediction for the end of the project, in August 2023, is 13.9 million km.

NON-QUANTITATIVE OBJECTIVES

- ZEFER aims to develop comprehensive lessons from the deployment project. Public deliverables have been produced, covering topics such as customer acceptance, the business case for FCEVs and the technical performance of HRSs and FCEVs under high utilisation.
- The project aims to increase investor and policymaker confidence in FCEV and HRS roll-out. Analysis in ZEFER has proven that FCEVs and HRSs can meet the demands of high-mileage fleet operations. This has led to fleet operators increasing the number of FCEVs in their fleets. It has also attracted investors.
- Of the 15 ZEFER partners, 6 are small and medium-sized enterprises (SMEs). In particular, the three largest fleet operators are SMEs, and therefore a large proportion of the ZEFER funding (84 %) is allocated to SMEs.
- ZEFER aims to reduce the production cost of fuel cell systems to be used in transport applications, while increasing their lifetimes, to compete with conventional technologies. The project aims to demonstrate, at utilisation levels, a significantly longer lifetime of fuel cells in FCEVs than that of those currently deployed. The bulk procurement of FCEVs is expected to reduce their costs to their lowest level to date.
- The project aims to increase the energy efficiency of hydrogen production while reducing operating and capital costs so that the combined system can compete with alternatives on the market. ZEFER aims to reduce the hydrogen cost at the pump. This can be achieved by providing a stable demand for hydrogen at an HRS. The project also aims to trigger further cost reductions by creating a climate of investment in the low-cost green production systems required to drive down the overall cost.

PROGRESS AND MAIN ACHIEVEMENTS

- Nearly all 180 FCEVs have been deployed into everyday operation in Paris (60), London (10 in operation, 50 returned at lease end) and Copenhagen (32 in operation, 28 delivered).
- Most of the HRS upgrades have been completed, leading to improvements in the technical performance and customer experience of HRSs.
- Most deployment partners in the project have plans to scale up their FCEV fleets as a result of the ZEFER project.

FUTURE STEPS AND PLANS

- ZEFER will complete all activities in Q2 2023.
- The project is due to be successfully completed with an immense dataset collected for the FCEVs and HRSs in operation. Public findings from the project related to better understanding how performance is affected by long-term high utilisation. Reports analysing the business case for FCEVs in high-mileage applications, and customer value propositions can be found on the project website (https://zefer.eu/reports/).
- ZEFER contributed to increasing awareness of the business case for FCEVs in fleet applications. There are now many FCEV taxi projects in Europe.

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 of SoA target
Project's own objectives	**FCEVs**						
	Min. distance for vehicles	km/vehicle	90 000 (60 000 for Copenhagen deployment)	62 900	⚙	FCEVs operated as taxis in H2ME drive an average of ~ 45 000 km per year	2020
	Vehicle availability	%	> 98	> 99	✓	> 99	2021
	Range	km	500	470 in Mirai gen 1 and 530 in Mirai gen 2	✓	756	2020
	HRSs						
	HRS availability	%	> 98	94.3	⚙	98	2016
	Hydrogen purity	%	99.99	99.99	✓	99.99	2020
	Level of back-to-back vehicle refuelling	refuelling events/hour	6	6	✓	6	
	Cost of hydrogen	€/kg	≤ 10	10	✓	10	

Clean Hydrogen Partnership
Co-funded by the European Union