BRAVA

BREAKTHROUGH FUEL CELL TECHNOLOGIES FOR AVIATION

Project ID	101101409
PRR 2024	Pillar 3 – H_2 end uses: transport
Call topic	HORIZON-JTI-CLEANH2-2022-03-06: Development and optimisation of a dedicated fuel cells for aviation – from dedicated stack (100 s kW) up to full system (MWs)
Project total costs	EUR 19 986 841.75
FCH JU max. contribution	EUR 19 986 841.75
Project start - end	1.12.2022–30.11.2025
Coordinator	Airbus Operations GmbH, Germany
Beneficiaries	Airbus Operations SL, Aerostack GmbH, Centre national de la recherche scientifique, Université de Montpellier (affiliate of Centre national de la recherche scientifique), Heraeus Deutschland GmbH & Co. KG, Liebherr-Aerospace Toulouse SAS, Madit Metal SL, Morpheus Designs SL, Rhodia Laboratoire du Futur, Rhodia Operations, Stichting Koninklijk Nederlands Lucht- en Ruimtevaartcentrum, Solvay Specialty Polymers Italy SpA, Technische Universität Berlin

http://brava-project.eu/

PROJECT AND GENERAL OBJECTIVES

- Defining fuel-cell-based power generation system architecture and safety requirements based on the higher-level fuel cell propulsion system requirements (considering balance of weight).
- Designing, developing, testing and validating a two-phase cooling system for fuel cell stacks.
- Designing, developing, testing and validating compact and form-flexible (air to liquid) heat exchangers through additive manufacturing.
- Developing, optimising, testing and validating a high-performance fuel cell stack.
- Developing, testing and validating an air supply subsystem for a fuel cell system for aviation
- Design a fuel cell power generation system with high efficiency and high gravimetric power density compatible with aeronautical specifications and constraints based on the integration of developed subsystems.

NON-QUANTITATIVE OBJECTIVES

Within the scope of BRAVA, we will embark on a preliminary design phase, conceptualising a complete power generation system that seamlessly integrates the various subsystems. While the project's focus remains on subsystem-level advancements, we acknowledge that further integration into a power propulsion system and eventual aircraft-level integration lie outside the project's immediate purview.

The underlying concepts, models, assumptions and methodologies for the fuel cell stack that forms the bedrock of our project work in harmony with developments in the other subsystems (air supply and thermal management systems) to ensure the realisation of BRAVA's overall objectives.

PROGRESS AND MAIN ACHIEVEMENTS

Within BRAVA, the fuel cell subsystems will deliver a range of pivotal project results, revolutionising the future of aviation.

- **2-PC based thermal management system.** Our pioneering thermal management system embraces a 2-PC design, incorporating a newly engineered fuel cell stack. By prioritising compactness and weight reduction, we aim to significantly minimise fuel consumption and maximise efficiency.
- **Advanced head exchangers.** We introduce advanced heat exchanger technology, optimising heat rejection while ensuring seamless integration, reduced weight and minimal aerodynamic drag. This breakthrough innovation contributes to enhanced performance and fuel efficiency.
- **Advanced stack cell catalysts and membranes.** BRAVA pushes the boundaries of stack cell catalysts and membranes, unlocking higher levels of performance and durability, and better operational temperature capabilities. These advancements facilitate the integration of new membrane electrode assemblies that deliver unparalleled efficiency, compactness, reduced weight and extended lifetimes.
- **Innovative air supply architecture.** Our team has meticulously designed and optimised a state-of-the-art air supply architecture, bolstered by components specifically tailored to aviation requirements. This forward-thinking approach minimises parasitic power, reduces weight and ultimately lowers fuel consumption and the cost of equipment.
- **Optimised fuel cell system architecture.** Embracing a holistic approach, BRAVA presents an optimised fuel cell system architecture that encompasses innovative concepts such as anode and cathode path recirculation. These advancements promote compactness, lightweight design and elevated operational reliability, propelling aviation power systems to new heights.

FUTURE STEPS AND PLANS

In our pursuit of excellence, we will utilise a reference system – a robust MW fuel cell power generation system – developed, constructed and tested independently from the BRAVA project. This reference system will serve as the benchmark against which we measure our progress and accomplishments in subsystem development. By surpassing the achievements of the reference subsystems and meeting the key performance indicators defined at an early stage of the project, BRAVA will position itself to carry out a follow-up project, such as in phase 2 of the Clean Aviation programme.

The follow-up project will focus on the development of an integrated fuel cell propulsion system, encompassing both ground and flight testing. This ambitious endeavour will elevate the product specifications and performance of future aviation power generation systems to unprecedented heights. The result will be a revolutionary fuel cell system designed specifically for aviation applications, paving the way for a new era of high-performance, decarbonised flight through hydrogen fuel cell technology.

Clean Hydrogen Partnership
Co-funded by the European Union

CAMELOT

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

Project ID	875155
PRR 2024	Pillar 3 – H_2 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 2 295 783.50
FCH JU max. contribution	EUR 2 295 783.50
Project start - end	1.1.2020–31.12.2023
Coordinator	SINTEF AS, Norway
Beneficiaries	Albert-Ludwigs-Universität Freiburg, Bayerische Motoren Werke AG, Fast Simulations UG, Fuel Cell Powertrain GmbH, Johnson Matthey Hydrogen Technologies Ltd, Johnson Matthey plc, PowerCell Sweden AB, Pretexo, Technische Universität Chemnitz

http://camelot-fuelcell.eu

PROJECT AND GENERAL OBJECTIVES

Camelot brought together highly experienced research institutes, universities, fuel cell membrane electrode assembly suppliers and original transport equipment manufacturers to improve their understanding of the limitations of fuel cell electrodes. This enabled the partners to provide guidance on the next generation of membrane electrode assemblies required to achieve the 2024 performance targets.

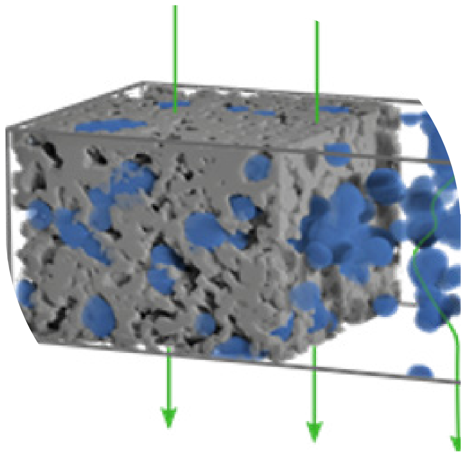
PROGRESS AND MAIN ACHIEVEMENTS

Next-generation proton-exchange membrane fuel cell catalyst-coated membranes were successfully manufactured at industrially relevant scales – that is, around 300 cm^2 – and validated in a 10-cell short stack exhibiting a peak power density of 1.04 W/cm^2, corresponding to a total catalyst load of 0.17 mgPt/W.

Advanced catalyst-coated membrane manufacturing techniques were developed to manufacture graded catalyst layers. It was shown that graded catalyst layers could be a promising strategy to homogenise current density and overcome oxygen concentration gradients that develop between the inlet and outlet of a proton-exchange membrane fuel cell.

FUTURE STEPS AND PLANS

The project has finished.



PROJECT TARGETS

Target source	Parameter	Unit	Target	Achieved to date by the project	Target achieved?	SOA result achieved to date(by others)	Year for reported SOA result
Project's own objectives	Membrane thickness	µm	< 10	6	✓	N/A	2022
	Total MEA Pt load	mg/cm^2	0.08	0.18	⚙	0.2	2020
	Power density	W/cm^2	> 1.8	1.42 (single cell) and 1.04 (short stack)	⚙	1.8	2021
SRIA (2021–2027)	Power density	W/cm^2 at 0.65 V	1.2	0.64	⚙	N/A	N/A
	PGM loading	g/kW	< 0.30	0.173 (short stack)	✓	N/A	N/A

Clean Hydrogen Partnership
Co-funded by the European Union

COCOLIH$_2$T

COMPOSITE CONFORMAL LIQUID H_2 TANK

Project ID	101101404
PRR 2024	Pillar 3 – H_2 end uses: transport
Call topic	HORIZON-JTI-CLEANH2-2022-03-07: Development of specific aviation cryogenic storage system with a gauging, fuel metering, heat management and monitoring system
Project total costs	EUR 8 726 769.50
FCH JU max. contribution	EUR 8 726 769.50
Project start - end	1.2.2023–31.1.2026
Coordinator	Collins Aerospace Ireland Ltd, Ireland
Beneficiaries	Avions de Transport Régional, Crompton Technology Group Ltd, Goodrichhy Aerospace Europe SAS, Microtecnica SRL, Novotech Aerospace Advanced Technology SRL, Simmonds Precision Products Inc. (a part of Collins Aerospace), Stichting Koninklijk Nederlands Lucht- en Ruimtevaartcentrum, Technische Universiteit Delft, Unified International, Utc Aerospace Systems Wroclaw Sp z.o.o.

https://www.cocolih2t.eu/

PROJECT AND GENERAL OBJECTIVES

Improvements to existing state-of-the-art solutions include better utilisation of the available space for fuel storage, adequate insulation techniques to minimise heat leak, continued safe operations and weight reduction through the use of low-weight materials – such as thermoset or thermoplastic composites – all while addressing those materials' inherent challenges (permeability, microcracking, thermal fatigue).

NON-QUANTITATIVE OBJECTIVES

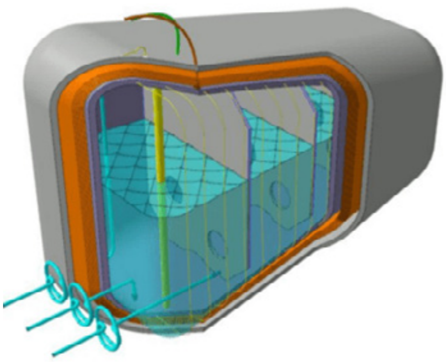
The project aims to push the boundaries of the composite design of liquid hydrogen storage systems, and those of pressure management systems, cryogenic fluid controls, prognostic and structural health systems, hazard analyses, integration and systems testing, gauging sensors, leak sensors and so much more.

PROGRESS AND MAIN ACHIEVEMENTS

- Completion of preliminary and critical design reviews of the Cocolih$_2$t liquid hydrogen storage system.
- Development to technology readiness level 3 of cryogenic valves, prognostic health monitoring algorithms and liquid hydrogen fuel gauging technology.

FUTURE STEPS AND PLANS

A manufacturing readiness review is planned for summer 2024, and the first demonstration system is planned to be shipped from Novotech in Italy to the Netherlands Aerospace Centre before the end of the year.



PROJECT TARGETS

Target source	Parameter	Unit	Target	Target achieved?
Project's own objectives	Maximum diameter	m	< 1	
	LH_2 tank capacity	kg	57	
	Boil-off	%/day	< 2	
	Tank gravimetric efficiency	%	0.25	
	Venting rate	%/day	< 2	
	Dormancy	hours	> 24	
	Insulation vacuum	mbar	10^{-5}	

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DOLPHIN

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

Project ID	826204
PRR 2024	Pillar 3 – H_2 end uses: transport
Call topic	FCH-01-6-2018: Game changer fuel cell stack for automotive applications
Project total costs	EUR 2 962 681.25
FCH JU max. contribution	EUR 2 962 681.25
Project start - end	1.1.2019–31.12.2023
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 systèmes d'échappement 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 GENERAL OBJECTIVES

The overall aim of the project was to validate disruptive technologies for 100 kW lightweight and compact fuel cell stack designs, achieving outstanding (specific and volume) power density while simultaneously ensuring enhanced durability (under automotive application conditions) compared with state-of-the-art (SOA) stacks and compatibility with large-scale/mass production of full-power stacks. The validation of Dolphin technologies was supported by the design and fabrication of an automotive stack of 5 kW, representative of 100 kW power stacks.

NON-QUANTITATIVE OBJECTIVES

Evaluate the interest and limitations of different material and manufacturing technologies for proton-exchange membrane fuel cell stacks.

PROGRESS AND MAIN ACHIEVEMENTS

Increase in performance up to around 2W/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 (those of the GAIA project).

Identification of interest and limitations of various components of and manufacturing processes for proton-exchange membrane fuel cell stacks.

Design of potentially even more efficient flow fields and catalyst layer manufacturing processes.

The two best solutions have been defined to manufacture two stacks (5 kW). Manufacturing, assembly and testing of the 5 kW stacks based on the two technologies selected, to evaluate the key performance indicators (kW/l, kW/kg, W/cm², €/kW, μV/h).

In parallel, assessment of the benefit of adding a graphene coating to the membrane.

Definition and testing of an additional set of operating conditions to facilitate a trade-off between high stack efficiency (high pressure, Sto and relative humidity, as in the GAIA project) and high system efficiency (as used in Dolphin).

FUTURE STEPS AND PLANS

The project has finished.

PROJECT TARGETS

Target source	Parameter	Unit	Target	Achieved to date by the project	Target achieved?	SOA result achieved to date (by others)	Year for reported SOA result
AWP 2018	Stack cost	€/kW	20	Evaluation is in progress and will be included in the final RP 4 documents		36.8	2017
	Durability	hours	6 000	Evaluation is in progress and will be included in the final RP 4 documents		3 500	2017
	Weight-specific power density	kW/kg	4	Projection based on TP 1 / TP 2 tests (to be checked at the stack level): 5–7 kW/kg		3.4	2017
	Volume-specific power density	kW/l	5	Evaluation will be included in the final RP 4 documents		4.1	2017
	Surface power density	W/cm²	2	2 (Dolphin components and GAIA operating conditions), validated on 100 cm² single cell		1.3 (AutoStack-Industry project) and 1.8 (GAIA project)	2017

FCH$_2$RAIL

FUEL CELL HYBRID POWERPACK FOR RAIL APPLICATIONS

Project ID	101006633
PRR 2024	Pillar 3 – H_2 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 13 378 484.93
FCH JU max. contribution	EUR 9 999 999.12
Project start - end	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 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 GENERAL OBJECTIVES

The project consortium is developing and testing a new train prototype. At the heart of the project is a hybrid, bimodal driving system that combines the advantages of an electrical power supply from an overhead line with a hybrid power pack consisting of fuel cells and batteries. This system enables 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 has been created to support the analysis of gaps in the normative framework. Work package 7 network meetings were held in 2023 and the gap analysis was shared with and commented on by the work package 7 network.

Exchanges and collaboration with other EU projects (standard-sized heavy-duty hydrogen (Stashh), Virtual & physical platform for fuel cell system development (Virtual-FCH), European hydrogen train the trainer programme for responders (Hyresponder), Europe's rail flagship project 4 – sustainable and green rail systems (Rail4Earth)) and national projects (H2goesrail, Use of hydrogen fuel cell drives in local transport in the district of Barnim, operated with 100 % renewable hydrogen (H2BAR)) have taken place.

PROGRESS AND MAIN ACHIEVEMENTS

- Fuel cell hybrid power pack (FCHPP) development and tests on a Centro Nacional del Hidrógeno test bench were successfully completed.
- The physical integration of two FCHPPs into the demonstration train was successfully completed.
- The first static test of a FCHPP in a train was conducted.
- The dynamic testing of the demonstration train on closed tracks was conducted.
- Technology readiness level 7 authorisation was obtained for the demonstration system for Spain.
- The functioning of the first H_2-powered train was demonstrated on the Spanish railway network.
- The train demonstration was finalised in Madrid and Galicia.
- Technology readiness level 7 authorisation was obtained for Portugal.
- More than 4 600 km were demonstrated in H_2 mode before the end of 2023.
- Train demonstration is ongoing on several lines in Spain.

FUTURE STEPS AND PLANS

- Demonstration of a bimodal train in Portugal.
- Receipt of theoretical track authorisation for Germany.

PROJECT TARGETS

Target source	Parameter	Target achieved?
Project's own objectives	System lifetime/durability	
	Hydrogen and electricity consumption	

FLAGSHIPS

CLEAN WATERBORNE TRANSPORT IN EUROPE

Project ID	826215
PRR 2024	Pillar 3 – H_2 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
FCH JU max. contribution	EUR 4 999 978.75
Project start - end	1.1.2019–31.3.2025
Coordinator	Teknologian tutkimuskeskus VTT Oy, Finland
Beneficiaries	ABB Oy, Ballard Power Systems Europe AS, Compagnie Fluviale De Transport, Future Proof Shipping BV, Kongsberg Maritime AS, LMG Marin AS, LMG Marin France, Maritime CleanTech, Norled AS, Persee, SEAM AS, Sogestion, Sogestran

https://flagships.eu/

PROJECT AND GENERAL OBJECTIVES

Two commercially operated hydrogen fuel cell vessels will be demonstrated, one in France (Paris) and one in the Netherlands (Rotterdam). The Paris demonstration vessel is a self-propelled barge operating as a goods transport vessel in the city centre; the Rotterdam demonstration vessel is a container vessel transporting goods between Rotterdam and Duisburg. The Paris demonstration vessel has been built and is en route to France, where hydrogen fuel cell systems will be installed. Work started on the Rotterdam demonstration vessel at the end of 2021, and the vessel was launched in February 2024.

NON-QUANTITATIVE OBJECTIVES

- The project aims to develop and demonstrate bunkering technologies based on swapping gaseous hydrogen fuel containers.
- Procedures for hydrogen bunkering by swapping hydrogen storage containers are being developed and will be demonstrated in 2024.

PROGRESS AND MAIN ACHIEVEMENTS

- The FCwave fuel cell module has been approved by the DNV.
- The *Zulu* (Paris demonstration vessel) was designed and built. The vessel is at the yard in Le Havre. ABB and Ballard Power Systems Europe systems are already there and installation work has started. The vessel has been granted a recommendation from the Central Commission for the Navigation of the Rhine.
- The *H_2 Barge II* demonstration vessel was launched and started operating in March 2024.

FUTURE STEPS AND PLANS

- The *Zulu 06* vessel will be launched in summer 2024.
- The commercial operation of both vessels will be demonstrated for 18 months.

PROJECT TARGETS

Target source	Parameter	Unit	Target	Target achieved?	SOA result achieved to date (by others)	Year for reported SOA result
Project's own objectives	Complete FC and H_2 system cost	€/kW	4 000	⚙	N/A	N/A
	FC systems demonstrated on board vessel in commercial operation	months	2 × 18	⚙	9	2023
	Develop necessary safety measures for H_2 and FC vessels to enable the approval of their class	-	Class approval gained	✓	Yes	2023
	PEMFC system availability	%	95	⚙	N/A	N/A
MAWP addendum (2018–2020)	PEMFC system lifetime	hours	25 000	⚙	N/A	N/A

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FLHYSAFE

FUEL CELL HYDROGEN SYSTEM FOR AIRCRAFT EMERGENCY OPERATION

Project ID	779576
PRR 2024	Pillar 3 – H_2 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
FCH JU max. contribution	EUR 5 063 023.00
Project start - end	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 GENERAL 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 was to demonstrate that a cost-efficient modular fuel cell system can replace the most critical safety systems and can be used as an emergency power unit aboard a commercial aeroplane, providing enhanced safety functions. In addition, the project had the objective of virtually demonstrating that the system can be integrated, respecting both installation volumes and maintenance constraints, into current aircraft designs.

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 (and theoretical air conditioning system specifications were produced).
- A critical review of the design of major subsystems of the demonstration system was performed.
- The first module campaign test was performed
- The final demonstration system was assembled
- Operational and environmental tests of the Flhysafe demonstration system were carried out.
- The use of fuel cell technology in an emergency power unit was found to be very challenging.
- Regulations are not mature enough.
- As regulations have not yet been issued by authorities, there is still a chance that the architecture proposed in Flhysafe may need to be adapted in the future. Safran and the Spanish National Institute for Aerospace Technology are taking part in discussions through working group 80 of Eurocae.
- Fuel cell system components are not yet ready for aeronautical use and need more specific studies and development.
- The technology is not mature enough for aeronautical needs.
- The applications of low-temperature proton exchange membranes for ground-based automotive applications are well understood, but the membranes cannot be applied to aeronautical systems without further research and design efforts.
- Ram air turbines have been established by major players as offering a reliable technology for aircraft. Other options, such as fuel cells, could be considered only for new hydrogen-powered aircraft.
- However, Flhysafe has contributed to a better understanding of fuel cell technology in various domains.
  - The French industrial supply chain is increasing its maturity in manufacturing some fuel cell stack parts (metallic bipolar plates and seals).
  - One patent is in progress (co-ownership between Safran and Sealicone).
  - Understanding of O_2 use in aeronautics is improving.
  - Safety analysis is improving (through the collaboration of Deutsches Zentrum für Luft- und Raumfahrt and Safran).
  - Smart solutions are needed to tackle integration challenges, and the CEA has developed an interesting option with its direct current–direct current system.

FUTURE STEPS AND PLANS

The project has finished.

PROJECT TARGETS

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

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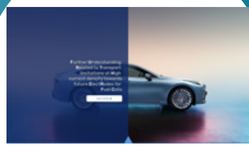
FURTHER-FC

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



Project ID	875025
PRR 2024	Pillar 3 – H_2 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 2 735 031.25
FCH JU max. contribution	EUR 2 199 567.35
Project start - end	1.1.2020–31.8.2024
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; The Chemours Company FC, LLC; Toyota Motor Europe NV; Université de Montpellier; University of Calgary

https://further-fc.eu/

PROJECT AND GENERAL OBJECTIVES

Further-FC proposes platforms coupling experimental study and modelling 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 (with different ionomer-to-carbon ratios, thicknesses, etc.) have been produced, models of the CCLs are progressing based on their structural characterisation and the first effective properties have been derived.

NON-QUANTITATIVE OBJECTIVES

- Better understand the performance limitations of proton-exchange membrane fuel cells.
- Set up numerical and modelling tools to do so, focusing on the cathode catalyst layer.

PROGRESS AND MAIN ACHIEVEMENTS

- Progress has been made in the characterisation of the CCLs (through atomic force microscopy, Raman spectroscopy, 3D focused ion beam scanning electron microscopy, etc.).
- Progress has been made in the modelling of CCLs at different scales.
- The definition and validation of test protocols enables reliable comparison between the partners.
- Various customised membrane electrode assemblies have been manufactured, tested and characterised (through cyclic voltammetry, linear sweep voltammetry, electrochemical impedance spectroscopy, life cycle assessment, etc.).

FUTURE STEPS AND PLANS

- The finalisation of the characterisations of reference and customised membrane electrode assemblies is ongoing.
- The finalisation of the modelling of the CCLs at different scales is ongoing.
- The determination of the most performance-limiting mechanisms is ongoing.
- The upscaling of the models has started.
- The combined analysis of experiments and modelling to explain the role of different ionomers and/or catalyst supports on performance is ongoing.

PROJECT TARGETS

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 (Auto-Stack CORE project)
	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 load	mg/cm²	0.144		0.4	
		g/kW	0.08		0.35	
	Pt efficiency	A/mg	15		4.5	

H_2ACCELERATE TRUCKS

LARGE SCALE DEPLOYMENT PROJECT TO ACCELERATE THE UPTAKE OF HYDROGEN TRUCKS IN EUROPE

Project ID	101101446
PRR 2024	Pillar 3 – H_2 end uses: transport
Call topic	HORIZON-JTI-CLEANH2-2022-03-03: Large scale demonstration of European H_2 heavy duty vehicle along the TEN-T corridors
Project total costs	EUR 110 946 587.25
FCH JU max. contribution	EUR 29 991 488.50
Project start - end	1.2.2023–31.1.2029
Coordinator	SINTEF AS, Norway
Beneficiaries	Daimler Truck AG, Element Energy Ltd, ERM France, Everfuel AS, Federazione Italiana Autotrasportatori Professionali, IVECO SpA, Linde GmbH, OMV Downstream GmbH, Shell Nederland Verkoopmaatschappij BV, Teknologian Tutkimuskeskus VTT Oy, TotalEnergies Gas Mobility BV, Union internationale des transports routiers, Uniunea Naţional a Transportatorilor Rutieri din România, Volvo Lastvagnar AB, Volvo Technology AB, Wirtschaftskammer Österreich

https://h2accelerate.eu/trucks/

PROJECT AND GENERAL OBJECTIVES

The overall goal of the project is to support the transition of fuel cell trucks from technically proven but high-cost demonstrators to a viable commercial choice for operators across Europe.

To achieve the above goal, the general objectives are to:

- deploy 150 fuel cell trucks weighing between 41 t and 44 t in nine European countries by the end of 2029;
- operate the trucks on a hydrogen refuelling station network designed for zero-emission truck deployment, operated by Everfuel, Shell and TotalEnergies;
- analyse technical, environmental, economic and attitudinal data to determine the viability of H_2 fuel cell trucks as a solution to decarbonise road freight;
- raise awareness of the benefits of using green H_2 for trucking in Europe through a wide range of targeted communication activities.

PROGRESS AND MAIN ACHIEVEMENTS

The project is still in its initial phase. Multiple activities have commenced, including:

- the adaptation of manufacturing facilities to accommodate fuel cell truck production;
- preparations for homologation and type approval;
- original equipment manufacturers' initial preparations for fleet launch.

Main achievements and results so far include:

- dialogue with heavy-duty truck end users and hydrogen refuelling station network operators;
- the development of and agreement on protocols for data monitoring and analysis;
- the assessment of health and safety issues and submission of an appropriate safety plan;
- the submission of original equipment manufacturers' annual progress reports.

Clean Hydrogen Partnership

Co-funded by the European Union

PROJECT TARGETS

Target source	Parameter	Unit	Target	Target achieved?
Project's own objectives	Gross weight of HD trucks deployed	t	41–44	
	Vehicle range under heavy load	km	> 600 km for compressed H_2 and > 1 000 km for liquid H_2	
	Distance driven per truck (during deployment phase)	km/year	≥ 60 000	
	Annual CO_2 emission savings	t/year	Confirmation (by LCA) of a saving across the fleet of 21 000 t/year	
	End-user groups to allow detailed discussion of hydrogen-powered trucks with users not involved in the project	number of events/ meetings	3	
	Dataset covering the performance of 150 trucks	number of reports	Shareable reports (including regular updates) of technical and economic performance of and end users' attitudes to hydrogen trucks in day-to-day operation	
	Cost of trucks	€	< 450 000	
	Central and eastern European potential truck operators in end-user groups	number	> 20	
	Green hydrogen demand created	t/year	2 100	
	Data monitoring and analyses of trucks' performance	% of deployed trucks	20 (corresponding to 30 trucks of the full fleet of 150 trucks)	
	Demand for electrolyser capacity created	MW	26 (assuming a 50 % load factor to achieve green supply)	
	FC module CAPEX	€/kW	605	
	FC stack durability	hours	20 000	
	Dedicated truck road tour visits in EU Member States	number of Member States	5	
	Distance driven across the entire fleet	km/year	15 million	
	Presentations at events and conferences	number per year	5	✓
SRIA (2021–2027)	Vehicle availability	%	> 95	
AWP 2022	Operational period monitored per truck	months	24	
	Visible social media and web presence	number	2	✓
	H_2/FC powered HD trucks deployed	number	150	

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H_2HAUL

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

Project ID	826236
PRR 2024	Pillar 3 – H_2 end uses: transport
Call topic	FCH-01-1-2018: Large scale demonstration of H_2 fuelled HD trucks with high capacity hydrogen refueling stations (HRS)
Project total costs	EUR 28 110 126.80
FCH JU max. contribution	EUR 12 000 000.00
Project start - end	1.2.2019–31.12.2025
Coordinator	Environmental Resources Management Ltd, United Kingdom
Beneficiaries	Air Liquide Advanced Business, Air Liquide Advanced Technologies SA, Air Liquide France Industrie, Bayerische Motoren Werke AG, DATS 24, Element Energy Ltd, ElringKlinger AG, EOLY, Environmental Resources Management France, Etablissementen Franz Colruyt NV, FPT Industrial SpA, FPT Motorenforschung AG, H2 Energy AG, Hydrogen Europe, Hydrogenics GmbH, IRU Projects ASBL, Iveco SpA, Plastic Omnium New Energies Wels GmbH, PowerCell Sweden AB, Robert Bosch GmbH, Sphera Solutions GmbH, TotalEnergies Marketing Deutschland GmbH, Union internationale des transports routiers, VDL Enabling Transport Solutions BV, VDL Special Vehicles BV, WaterstofNet VZW

https://www.h2haul.eu/

PROJECT AND GENERAL OBJECTIVES

H_2Haul brings together two major original equipment manufacturers for European trucks (Iveco and VDL) and the 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 in four sites across four countries. The overall objective of H_2Haul 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 by the project are expected to be deployed in the next 12 months.

NON-QUANTITATIVE OBJECTIVES

- H_2Haul 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 trucks' design 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. Original truck equipment manufacturers 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.
- The project aims to develop the business case for the further roll-out of heavy-duty fuel cell trucks. H_2Haul 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 of the technology. Analyses will be carried out to highlight the economics of the more ambitious deployment of many tens of vehicles or more.
- H_2Haul aims to prepare the European market for the further roll-out of fuel cell trucks through (i) developing innovative commercial models and (ii) disseminating information from the project to a wide audience of relevant stakeholders. H_2Haul's dissemination activities will share key findings with relevant audiences to prepare the market for the wider roll-out of fuel cell trucks on a commercial basis. Communication activities in the first and second years of the project 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.
- All three project-funded HRSs were deployed.
- The second observer group meeting took place.

FUTURE STEPS AND PLANS

- H_2Haul will deploy the VDL and Iveco trucks. The VDL trucks will be delivered to Colruyt in July 2024 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 May and June 2024.
- The H_2Haul team will continue their high-profile dissemination and lobbying work through attending and delivering presentations at key conferences and events. Other stakeholder engagement activities will also continue. The results will be disseminated extensively.

PROJECT TARGETS

Target source	Parameter	Unit	Target	Target achieved?
Project's own objectives and MAWP addendum (2018–2020)	Operational period of trucks	months	With the period of operation including the ramp-up phase: ≥ 24	⚙
	Distance travelled by trucks	km	≥ 30 000 per truck per year, on average per site	
	Availability of trucks	%	> 90 % for the fleet after an initial ramp-up phase lasting a maximum of 6 months	
	Specific fuel consumption of trucks	kg / 100 km	Rigid truck at 30–50 % load, for inner city delivery (< 25 km/h on average): < 7.5; tractor with semi-trailer at 30–50 % load, for long-haul delivery (> 65 km/h on average): < 8.5	
	Availability of stations (by end of project)	%	99	
	MDBF	km	> 2 500	
	WTW CO_2 emissions	$kgCO_2/km$	$kgCO_2/km$ (per vehicle type; average across fleet)	
	Speed of hydrogen dispensing	kg/min	> 2.5	
	Cost of hydrogen dispensed to HRS	€/kg	7.5	
	Amount of hydrogen dispensed to trucks deployed in the project	kg/year	> 2 500	

H_2MAC

HYDROGEN FUEL CELL ELECTRIC NON-ROAD MOBILE MACHINERY FOR MINING AND CONSTRUCTION: AN INNOVATIVE, EFFICIENT, SCALABLE, SILENT AND MODULAR POWER-TRAIN CONCEPT

Project ID	101137786
PRR 2024	Pillar 3 – H_2 end uses: transport
Call topic	HORIZON-JTI-CLEANH2-2023-03-01: Real environment demonstration of non-road mobile machinery (NRMM)
Project total costs	EUR 6 278 930.00
FCH JU max. contribution	EUR 4 990 769.76
Project start - end	1.1.2024–31.12.2027
Coordinator	Instituto Tecnológico de Aragón, Spain
Beneficiaries	Asociación Española de Fabricantes Exportadores de Maquinaria para Construcción, Obras Publicas y Mineria; Ballard Power Systems Europe AS; Fundación para el Desarrollo de las Nuevas Tecnologías del Hidrógeno en Aragón; Hidromek Maquinaria de Construccion España SL; Hidromek – Hydrolik Ve Mekanik Makina Imalat Sanayi Ve Ticaret AS; Mann + Hummel GmbH; Talleres ZB SA; Tampereen Korkeakoulusaatio SR; Zamalbideservice2021 SL

https://h2mac.eu

PROJECT TARGETS

Target source	Parameter	Unit	Target	Target achieved?
Project's own objectives	Noise reduction	dB	< 100	
	New technologies feasible and commercially viable	number/project	2	
	Emission reduction	CO_2eq/year	0	
	FC system efficiency (TCO reduction)	%	50	
SRIA (2021–2027)	Safety reporting	%	100	
	FC module CAPEX	€/W	< 800	
	FC module availability	%	80	
	FC stack durability	hours	16 000	
	Impact on standards at scope	number/project	1	

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H_2MARINE

HYDROGEN PEM FUEL CELL STACK FOR MARINE APPLICATIONS

Project ID	101137965
PRR 2024	Pillar 3 – H_2 end uses: transport
Call topic	HORIZON-JTI-CLEANH2-2023-03-02: Development of a large fuel cell stack for maritime applications
Project total costs	EUR 7 499 171.50
FCH JU max. contribution	EUR 7 499 171.50
Project start - end	11.1.2024–30.6.2027
Coordinator	Ethniko Kentro Erevnas kai Technologikis Anaptyxis, Greece
Beneficiaries	Albert-Ludwigs-Universität Freiburg, Beyond Gravity Schweiz AG, Cleos Idiotiki Kefalaiouchiki Etaireia, Cluster Viooikonomias kai Perivallontos Dytikis Makedonias, École polytechnique fédérale de Lausanne, EH Group Engineering SA, Greenerity GmbH, PowerCell Sweden AB, Reinz-Dichtungs GmbH, Teknologian Tutkimuskeskus VTT Oy, ThyssenKrupp Marine Systems GmbH, Zentrum für Sonnenenergie- und Wasserstoff-Forschung Baden-Württemberg

https://h2marineproject.eu

PROJECT AND GENERAL OBJECTIVES

The overarching objective of the H_2Marine project is to design, build, test and validate two proton-exchange membrane stacks generating 250–300 kW electrical power designed for marine applications. The H_2Marine project takes a top-down approach, building on a proof of concept of two proton-exchange stacks that are being developed in the EU and Switzerland. The H_2Marine project will:

- identify the requirements for the tests and conditions as well as load curves that the fuel cell stacks will have to be tested against, using the combined knowledge of a major ship-building company (ThyssenKrupp Marine Systems) and a shipowner (Cleos);
- enable both the PowerCell and the EH Group stack manufacturers to benefit from a great consortium surrounding their development, testing and upscaling with unique testing facilities (Beyond Gravity, Zentrum für Sonnenenergie- und Wasserstoff-Forschung Baden-Württemberg, Greenerity, University of Freiburg), industrial partners such as DANA, the upscaling of stacks by Ethniko Kentro Erevnas kai Technologikis Anaptyxis and École polytechnique fédérale de Lausanne, and novel diagnostics development by VTT, which will allow them to enhance the state of the art of proton-exchange membrane fuel cell stacks, and advance and scale up the system to reach ambitious targets set in the call that will be disseminated by CLUBE (a member of numerous fuel cell and hydrogen projects);
- test the proposed solutions in a relevant environment/ecosystem, designed to fully represent the actual implementation conditions;
- design the stack modules in an optimum manner for upscaling to 10 MW train systems;
- test several diagnostics for the integrity of the stack and overall system and for the prognosis of the health status of critical components;
- assess the technology and economic feasibility of the solution, in order to determine its valuable end use, which will allow the partners to research the potential market(s) and identify the best opportunities.

NON-QUANTITATIVE OBJECTIVES

- Test the proposed solutions in a relevant environment/ecosystem, representing actual marine conditions.
- Design the stack modules in an optimum manner for upscaling to 10 MW.
- Test several diagnostics for the integrity of the stack and overall system and for the prognosis of the health status of critical components.
- Assess the technology, and the economic and environmental feasibility of the solution, in order to determine its valuable end use.

PROJECT TARGETS

Target source	Parameter	Unit	Target	Target achieved?
Project's own objectives	Module rating	kW	250	
	Hours of testing for each FC	hours	2 000	
	PEMFC system CAPEX	€/kW	< 1 500	
	FC power rating	MW	10	
	Maritime FCS lifetime	hours	> 40 000	

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H$_2$ME 2

HYDROGEN MOBILITY EUROPE 2

Hydrogen Mobility Europe

Project ID	700350
PRR 2024	Pillar 3 – H_2 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 106 490 818.38
Clean H_2 JU max. contribution	EUR 34 999 548.50
Project period	1.5.2016–31.12.2023
Coordinator	Environmental Resources Management (ERM) Ltd, United Kingdom
Beneficiaries	AGA AB, Air Liquide Advanced Business, Air Liquide Advanced Technologies SA, Air Liquide France Industrie, Alphabet Fuhrparkmanagement GmbH, Audi AG, B. Kerkhof & Zn. BV, Bayerische Motoren Werke AG, Brintbranchen, Centre of Excellence for Low Carbon and Fuel Cell Technologies, Communauté Urbaine du Grand Nancy, Compagnie Nationale du Rhône SA, Daimler AG, Eifer Europäisches Institut für Energieforschung EDF KIT EWIV, Element Energy, ERM UK, Elogen, ERM France, GNVERT SAS, H2 Mobility Deutschland GmbH & Co. KG, Honda Motor Europe Ltd, Honda R&D Europe (Deutschland) GmbH, Hydrogene De France SA, Hydrogène Grand Ouest, HYOP AS, Hype, Hype Assets, Hysetco, Hysolutions GmbH, HYSSY, Icelandic New Energy Ltd, Intelligent Energy Ltd, Íslenska Vetnisfélagið EHF, ITM Power (Trading) Ltd, Københavns Kommune, Linde Gas GmbH, Manufacture Française des Pneumatiques Michelin, McPhy Energy, McPhy Energy Italia SRL, Mercedes-Benz AG, Mercedes-Benz Fuel Cell GmbH, Ministerie van Infrastructuur en Waterstaat, Nel Hydrogen AS, Nel Hydrogen Electrolyser AS, Nissan Motor Manufacturing (UK) Ltd, Open Energi Ltd, Renault SAS, Renault Trucks SAS, Reseau GDS, R-Hynoca, Société d'économie mixte des transports en commun de l'agglomération nantaise, Stedin Diensten BV, Stedin Netbeheer BV, Stichting Cenex Nederland, Symbio, Tech Transports Compagnie, University of Manchester, Toyota Danmark AS, Toyota Norge AS, Waterstofnet VZW

www.h2me.eu

PROJECT AND GENERAL OBJECTIVES

H$_2$ME 2 brings together actions in eight countries in a 7-year collaboration to deploy 20 hydrogen refuelling stations (HRSs) and > 1 100 vehicles. The project has performed a large-scale market test of a large fleet of fuel cell electric vehicles operating in real-world customer-focused environments across multiple European regions. In parallel, it has demonstrated that the hydrogen mobility sector can support the wider European energy system through electrolytic hydrogen production.

Prior to H$_2$ME, there were few large deployments of fuel cell hydrogen vehicles in Europe. The H$_2$ME projects have contributed to deploying one third of fuel cell hydrogen vehicles on the road and 20 % of HRSs open today in Europe. In addition, H$_2$ME has encouraged application to other types of vehicles (including buses and trucks) by supporting the construction of HRSs.

NON-QUANTITATIVE OBJECTIVES

- More than 1 100 fuel cell vehicles and 20 HRSs will be deployed by the end of the project.
- The project aims to demonstrate the electrolyser-integrated HRS operating to allow grid balancing. H$_2$ME 2 includes a dedicated work package to assess the way in which electrolytic hydrogen production in the mobility sector can link to the wider energy system.
- Multiple original equipment manufacturers (OEMs) supply vehicles, including cars and utility vehicles. H$_2$ME 2 aimed to deploy cars and light-duty vans from OEMs including Mercedes, Honda, Symbio, Hyundai and Toyota.
- H$_2$ME 2 aimed to ensure the circulation of knowledge acquired in the project. A dedicated work plan and dissemination and exploitation plan were developed to achieve this. Three observer countries are included in the project coalition.

PROGRESS AND MAIN ACHIEVEMENTS

- All 20 HRSs planned for the project had been commissioned and were in operation by the end of the project. Combined with the HRS deployed in H$_2$ME, this constitutes the first step in constructing a European infrastructure network.
- Over 1 100 vehicles were deployed in H$_2$ME 2. Further deployment and collaboration are expected beyond the end of the project.
- Demonstration in real-world operation started in 2015 – carried out jointly with H$_2$ME – for over 1 400 vehicles from five OEMs (Mercedes, Honda, Hyundai, Symbio and Toyota) across eight countries and 50 HRSs from 10 suppliers across six countries (Denmark, France, Iceland, the Netherlands, Sweden and the United Kingdom).
- The fuel cell electric vehicles worked reliably, with new models offering increased performance becoming available on the market.
- The project generated a vast base of operational data from vehicles and HRSs, and involved further fact-based analyses of vehicles' and HRSs' performance. Since 2015, > 40 million kilometres have been driven and 915 t of H_2 distributed in 360 000 events (figures from January 2024).
- Green mass mobility and logistics solutions were proven to be effective in cities and regions, with ranges and refuelling times similar to those of conventional vehicles. The experience gained gives a robust springboard for further roll-outs.
- Across H$_2$ME and H$_2$ME 2, around 100 reports were prepared, with the majority publicly available on the project's website.

FUTURE STEPS AND PLANS

The project has finished.

PROJECT TARGETS

Target source	Parameter	Unit	Target	Achieved to date by the project	Target achieved?	SOA result achieved to date (by others)	Year for reported SOA result
HRSs							
Project's own objectives, MAWP addendum (2018–2020) and AWP 2015	Minimum period of HRS operation	months	36	58	✓	32	2017
	HRS availability	%	98	96	⚙	98	2017
	Hydrogen purity	%	99.99	99.99	✓	99.99	2017
FC vehicles							
Project's own objectives, MAWP addendum (2018–2020) and AWP 2015	Minimum period of vehicle operation during project	months	36	60	✓	12	2017
	Vehicle availability	%	98	Around 100	✓	98	2017

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H_2PORTS

IMPLEMENTING FUEL CELLS AND HYDROGEN TECHNOLOGIES IN PORTS

Project ID	826339
PRR 2024	Pillar 3 – H_2 end uses: transport
Call topic	FCH-03-1-2018: Developing fuel cell applications for port/harbour ecosystems
Project total costs	EUR 4 117 197.50
FCH JU max. contribution	EUR 3 999 947.50
Project start - end	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; Enagas SA; Grimaldi Euromed SpA; Hyster-Yale Nederland BV; Mediterranean Shipping Company Terminal Valencia 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/about/

PROJECT AND GENERAL OBJECTIVES

The H_2Ports project 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 real operational activities at the Port of Valencia. The required hydrogen will be provided through a mobile hydrogen refuelling station (HRS) designed and built during the project. All three elements are currently in advanced stages of building, and the piloting period is planned to start in 2024.

NON-QUANTITATIVE OBJECTIVES

- The project aims to disseminate H_2 technologies to the port and maritime sector. This goal will be accomplished through the organisation of a stakeholder advisory group.
- H_2Ports will gather information on the use of H_2 in port environments.
- It will also gather information on the use of H_2 as fuel for vessels.

PROGRESS AND MAIN ACHIEVEMENTS

Both the reach stacker and the yard tractor have been commissioned, and their demonstration could start in the first half of 2024.

FUTURE STEPS AND PLANS

It is envisaged that the two applications (reach stacker and 4 × 4 terminal tractor) will undergo 2 years of piloting under normal operative conditions. The piloting period is expected to start in 2024.

PROJECT TARGETS

Target Source	Parameter	Unit	Target	Target Achieved?
Project's own objectives, MAWP addendum (2018–2020) and AWP 2018	Amount of H_2 dispensed	kg/day	60	
	MTBF	days	-	
	Tank-to-wheel efficiency	%	50	
	Hydrogen consumption	kg/h	RS: 3.33; YT: 2.34	
	Hydrogen storage cost	€/kg	650	
Project's own objectives	HRS daily capacity	kg/day	60	
	Reach stacker vehicle power	kW	90	
	Vehicle power	kW	70	
	Noise level	dBA	< 60	
	HRS MBTF	days	50	
	Availability	%	90	
	HRS availability	%	> 98	
	Specific maintenance cost	€/output	TBD	
	Hydrogen refuelling time	minutes	< 30	
	Vehicles over cost (target percentage over CNG and diesel port trucks)	%	100	
	Cost of fuel cell system	€/kW	3 500	
	Duration of the testing period	h–years	5 000–2	
	Total installed power of fuel cell system	kW	175–205 (225–285)	
	HRS-specific maintenance cost	€/kg	1	
	HRS CAPEX	€	575 000	

HEAVEN

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

Project ID	**826247**
PRR 2024	**Pillar 3 – H_2 end uses: transport**
Call topic	**FCH-01-4-2018: Fuel cell systems for the propulsion of aerial passenger vehicle**
Project total costs	**EUR 6 903 128.81**
FCH JU max. contribution	**EUR 3 995 305.00**
Project start - end	**1.1.2019–30.9.2023**
Coordinator	**H_2FLY GmbH, 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 d.o.o. Podjetje Za Napredne Letalske Resitve, Elringklinger AG**

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

PROJECT AND GENERAL OBJECTIVES

The overall objective of this project was to address the gap between the research and product stages of a zero-emission fuel-cell-based propulsion technology to achieve emission reduction 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 was combined with the high energy density of cryogenic hydrogen storage. It was advanced up to technology readiness level 6.

NON-QUANTITATIVE OBJECTIVES

- Heaven aimed to increase the credibility of the solution for the propulsion of passenger aircraft and unmanned aerial vehicles.
- The project also aimed to advance towards zero-emission hydrogen-powered regional commuter airliners.

PROGRESS AND MAIN ACHIEVEMENTS

- Manufacturing of cryogenic systems and development of the ground support equipment.
- Testing and verification of the cryogenic system.
- Integration of the powertrain into the aircraft.
- Modification of aircraft system to couple a cryogenic fuel system with the GH2 fuel system.
- Procurement of a permit for flight testing.
- Ground and flight demonstration of HY4 aircraft with liquid hydrogen on board.
- Fuel cell and hydrogen fuel system coupling and testing with liquid hydrogen (March 2023).
- Ground tests (June 2023).
- Flight test (September 2023).

FUTURE STEPS AND PLANS

The project has finished.

PROJECT TARGETS

Target source	Parameter	Unit	Target	Achieved to date by the project	Target achieved?
Project's own objectives and AWP 2018	Power mass density of FC stack	kW/kg	2	2.7 (stack, including end plates)	✓
	Power volume density of FC	kW/l	3.5	4.1 (stack, including end plates)	✓
	Air subsystem	%	> 50	Preliminary results in compliance with this value but not achieved yet	⚙
	Power converter	kW/kg	8	Preliminary results in compliance with this value but not achieved yet	⚙
	System lifetime	hours	500	N/A	⚙
	Hydrogen system	wt%	> 5.5	115	✓

HIGHLANDER

HIGH PERFORMING ULTRA-DURABLE MEMBRANE ELECTRODE ASSEMBLIES FOR TRUCKSMARITIME SECTOR

Project ID	101101346
PRR 2024	Pillar 3 – H_2 end uses: transport
Call topic	HORIZON-JTI-CLEANH2-2022-03-02: Innovative and optimised MEA components towards next generation of improved PEMFC stacks for heavy duty vehicles
Project total costs	EUR 3 331 247.50
FCH JU max. contribution	EUR 3 331 247.50
Project start - end	1.1.2023–31.12.2025
Coordinator	Centre national de la recherche scientifique, France
Beneficiaries	Elmarco s.r.o., Forschungszentrum Jülich GmbH, Johnson Matthey Hydrogen Technologies Ltd, Johnson Matthey plc, Pretexo, Rhodia Laboratoire du Futur, Rhodia Operations, Robert Bosch GmbH, Solvay Specialty Polymers Italy SpA, Speciality Operations France, Technische Universität Berlin, Université de Montpellier

https://highlander-fuelcell.eu/

PROJECT AND GENERAL OBJECTIVES

The objective of Highlander is to develop membrane electrode assemblies (MEAs) for heavy-duty vehicles (HDVs) with disruptive, novel components, targeting stack cost and size, durability and fuel efficiency. The project will involve the design, fabrication and validation of the HDV MEAs at the cell and short-stack levels using accelerated stress test and load profile test protocols for heavy-duty vehicles. Material-screening efforts will be supported by the development and use of improved predictive degradation models bridging scales from the reaction site level to the cell level. Model parameterisation will be implemented using experimental characterisation data at the materials, component and cell levels. Highlander aims to bring about a significant reduction in stack cost and fuel consumption through improving catalyst-coated membrane performance and developing a new, lower-cost single-layer gas diffusion. It also aims to achieve the 1.2 W/cm² at 0.65 V performance target at 0.3 gPt/kW or less, meeting a lifetime target of 20 000 h. Sustainability considerations include benchmarking fluorine-free membranes for HDV MEA application and the reuse of platinum in the context of a circular economy.

PROGRESS AND MAIN ACHIEVEMENTS

- Implementation of liquid and gas phase characterisation tools online involving the electrochemical cycling of project catalysts to identify degradation products and determine correlations between them and electrochemical potential, and implementation of measurement methods for convective transport, electrical bulk conductivity and contact resistance of gas diffusion layers.
- Development of a series of novel ordered intermetallic catalysts on novel heteroatom-doped carbon and on reference carbon for the project that display a higher retained mass activity and electrochemical surface area than the reference catalyst for the project.
- Progress in the development of two series of novel sulfonated hydrocarbon ionomers for fluorine-free membranes and their benchmarking against perfluorosulfonic acid membranes.
- Advancement in the elaboration of low-cost gas diffusion layers with the development of a low-cost anode gas diffusion layer (GDL) giving identical performance to commercial GDLs.
- Formulation of a hierarchical degradation modelling framework and its implementation as a software code, available in the open access modelling platform (GitLab).

FUTURE STEPS AND PLANS

- Upscaling of selected catalysts for catalyst layer development and single-cell characterisation.
- Preparation of initial nanofibre-reinforced membrane and its delivery for catalyst coating and testing of initial project MEAs against project performance and durability targets.
- Pursuit of development of a novel low-cost cathode GDL, catalyst and ionomer, along with support materials and other membrane components.

PROJECT TARGETS

Target source	Parameter	Unit	Target	Achieved to date by the project	Target achieved?	SOA result achieved to date (by others)	Year for reported SOA result
SRIA (2021–2027) and AWP 2022	Durability of FC stack	hours	20	500 hours to end of test on single cell	⚙	30 000 (predicted based on 1 500 hours of actual load profile testing)	2023
	Power density	W/cm² at 0.65 V	1.2	N/A		1.2	2022
	PGM loading	g/kW	< 0.3	MEAs prepared with 0.42 mgPt/cm²		0.34	2023

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IMMORTAL

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

Project ID	101006641
PRR 2024	Pillar 3 – H_2 end uses: transport
Call topic	FCH-01-2-2020: Durability-lifetime of stacks for heavy duty trucks
Project total costs	EUR 3 825 927.50
FCH JU max. contribution	EUR 3 825 927.50
Project start - end	1.1.2021–31.3.2024
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 Ltd, Johnson Matthey plc, Pretexo, Robert Bosch GmbH, Université de Montpellier

https://immortal-fuelcell.eu

PROJECT AND GENERAL OBJECTIVES

Immortal aims to develop high-performance and high-durability membrane electrode assemblies (MEAs) and their components, specifically designed for use in heavy-duty trucks. The project intends to develop load profile tests specific to heavy-duty trucks, and apply these tests, and accelerated stress tests, to MEAs at both the subscale and the short-stack levels. The results of load profile testing will also be used to validate a novel lifetime prediction method, and the method used to predict the lifetime of project MEAs. The project will assess the results through a technoeconomic evaluation and facilitate heavy-duty fuel cell powertrain validation and provide system recommendations.

NON-QUANTITATIVE OBJECTIVES

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

PROGRESS AND MAIN ACHIEVEMENTS

- Developed a nanofibre-reinforced membrane with exceptional durability in an MEA in accelerated stress testing at 90 °C, comprising 120 000 wet/dry cycles at open-circuit voltage corresponding to 2 200 hours in an accelerated stress test, without rupture.
- Developed MEAs comprising project materials that reached the 2024 strategic research and innovation agenda target for heavy-duty vehicles of 1.2 W/cm^2 at 0.65 V, and came within 5 % of the annual work programme target of 1.2 W/cm^2 at 0.675 V (for generation 2 MEAs), giving a Pt load of 0.32 gPt/kW.
- Developed a regression model for fuel cell degradation forecasting with an emphasis on the prediction confidence interval (uncertainty).
- Developed a method for creating accelerated durability tests for fuel cells, based on Markov chains..
- Established a lifetime prediction method and validated it using 1 500 hours of load profile testing.
- Obtained a predicted power loss of 10 % after 30 000 hours (for baseline MEAs), which corresponds to the annual work programme target.
- Identified the principal contributor to power loss during load profile testing as the loss of electrochemically active surface area from the cathode catalyst.
- Developed a modal load profile test from actual truck mission profiles.
- Achieved more than 7 500 hours of load profile testing on short stacks without catastrophic failure.

FUTURE STEPS AND PLANS

Immortal finished in March 2024 and the final activities were:

- finish the stack test;
- complete post-mortem analytics of MEAs from the last stack load profile test;
- provide heavy-duty fuel cell powertrain validation and system recommendations;
- complete a techno-economic evaluation.

Future plans including carrying forward the learning and most prospective materials from Immortal to future heavy-duty MEA development projects, in particular 'High performing ultra-durable membrane electrode assemblies for trucks' (Highlander).

PROJECT TARGETS

Target source	Parameter	Unit	Target	Achieved to date by the project	Target achieved?	SOA result achieved to date (by others)	Year for reported SOA result
SRIA (2021–2027) and AWP 2020	Cell voltage at 1.77 A/cm^2	V	675	0.642 (within 5 % of project/AWP target)		675	2021
	Durability	hours	30	10 % power loss after 30 000 hours		8 500	2020
Project's own objectives	Catalyst surface area and mass activity	cm^2/gPt and A/mgPt	Exceeding reference Pt and with better retention after accelerated degradation cycles than reference Pt/C	Two catalyst designs achieved this objective	✓	N/A	N/A
	Membrane durability in MEA AST cycles	cycles	50 000	110 000		N/A	N/A
AWP 2020	Cell voltage at 1.77 A/cm^2	V	675	661		675	2021

JIVE

JOINT INITIATIVE FOR HYDROGEN VEHICLES ACROSS EUROPE

Project ID	735582
PRR 2024	Pillar 3 – H_2 end uses: transport
Call topic	FCH-01-9-2016: Large scale validation of fuel cell bus fleets
Project total costs	EUR 88 391 377.79
FCH JU max. contribution	EUR 32 000 000.00
Project start - end	1. 1. 2017–30. 6. 2024
Coordinator	Environmental Resources Management (ERM) Ltd (previously Element Energy Ltd), United Kingdom
Beneficiaries	Aberdeen City Council, Birmingham City Council, Dundee City Council, EE Energy Engineers GmbH, Element Energy Ltd, ERM France, ESWE Verkehrsgesellschaft MBH, EUE APS, Fondazione Bruno Kessler, Gelderland, Herning Kommune, HyCologne – Wasserstoff Region Rheinland EV, Hydrogen Europe, hySOLUTIONS GmbH, In-Der-City-Bus GmbH, Latvijas Ūdeņraža Asociācija, London Bus Services Ltd, Mainzer Verkehrsgesellschaft mbH, Planet Planungsgruppe Energie und Technik GbR, RebelGroup Advisory BV, Regionalverkehr Köln GmbH, Rigas Satiksme SIA, Societa Autobus Servizi d'Area SpA, Sphera Solutions GmbH, Südtiroler Transportstrukturen AG, Trentino Trasporti SpA, Union Internationale des Transports Publics, Verkehrs-Verbund Mainz-Wiesbaden GmbH, West Midlands Travel Ltd, WSW mobil GmbH

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

PROJECT AND GENERAL OBJECTIVES

The JIVE project 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 131 FCBs in seven 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 of 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's 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

- By October 2023, 100 % of buses had started operating in seven cities and four countries. The vehicles represent models from four European bus manufacturers.
- By the end of 2023, the JIVE FCBs had travelled 9 128 925 km across all deployment sites.
- Fuel cells have been operating for a total of 384 555 hours.
- Across all the project's hydrogen refuelling stations, 892 132 kg of hydrogen has been dispensed across 52 677 fills. Please note that the kilograms of hydrogen dispensed and the number of fills include the Cologne and Wuppertal sites, which are involved in both JIVE and Joint initiative for hydrogen vehicles across Europe 2 (JIVE 2).

FUTURE STEPS AND PLANS

- 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 in service.
- By the end of the project, it is expected that the total distance travelled will be 10 683 714 km.
- The total number of fuel cell hours by the end of the project is expected to be 414 253.
- Hydrogen refuelling stations involved in JIVE are projected to dispense 1 055 089 kg of hydrogen across 61 898 individual fills.

PROJECT TARGETS

Target source	Parameter	Unit	Target	Achieved to date by the project	Target achieved?
Project's own objectives	Vehicle operational lifetime	years	8	N/A	
	Distance travelled	km/year	> 44 000	N/A	
	Availability	%	> 90	85.1	
	MDBF	km	> 2 500	N/A	⚙
	Efficiency	%	> 42	N/A	
	Vehicle OPEX	€	≤ 100 % more than diesel bus OPEX	N/A	
	Operating hours per fuel cell system	hours	> 20 000	N/A	
	Specific fuel consumption	kg / 100 km	< 9.0	7.56	✓
	Vehicle CAPEX	€	< 650 000	N/A	

JIVE 2

JOINT INITIATIVE FOR HYDROGEN VEHICLES ACROSS EUROPE 2

Project ID	779563
PRR 2024	Pillar 3 – H_2 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 89 972 571.29
FCH JU max. contribution	EUR 25 000 000.00
Project start - end	1.1.2018–30.6.2025
Coordinator	Environmental Resources Management (ERM) Ltd (previously Element Energy Ltd), United Kingdom
Beneficiaries	Brighton & Hove Bus and Coach Company Ltd, Communauté d'agglomération de l'auxerrois, Connexxion Openbaar Vervoer NV, Connexxion Vloot BV, Dundee City Council, EE Energy Engineers GmbH, Element Energy, Element Energy Ltd, ENGIE Energie Services, ERM France, Hydrogen Europe, Hyport, Kolding Kommune, Landstinget Gavleborg, Messer SE & Co. KGaA, Mestna občina Velenje, Noord-Brabant Provincie, Občina Šoštanj, Openbaar Lichaam OV-Bureau Groningen en Drenthe, Pau Béarn Pyrénées Mobilités, Petrogal SA, Provincie Zuid-Holland, RebelGroup Advisory BV, Regionalverkehr Köln GmbH, Rheinische Bahngesellschaft AG, Rīgas satiksme, Ruter AS, Société publique locale d'exploitation des transports publics et des services à la mobilité de l'agglomération paloise, Sphera Solutions GmbH, Straeto BS, Transdev Occitanie Ouest, Transports de Barcelona SA, Twynstra Gudde Mobiliteit & Infrastructuur BV, Union Internationale des Transports Publics, Vatgas Sverige Ideell Forening, WSW mobil GmbH, Zerobus OÜ

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

PROJECT AND GENERAL OBJECTIVES

The JIVE 2 project aims to deploy 156 fuel cell buses (FCBs). Combined, the JIVE projects will deploy nearly 300 FCBs in 16 cities across Europe – 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 objective, 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 begun to operate, which represents 63 % of all the planned buses.
- To date, one site has been operating its FCBs for more than 3 years.
- In 2023, JIVE 2 FCBs travelled a total of 8 076 892 km.
- JIVE 2 fuel cells operated for 211 231 hours.
- At JIVE 2 hydrogen refuelling stations, 451 455 kg of hydrogen was dispensed across 29 229 individual fills.

FUTURE STEPS AND PLANS

- By the second quarter of 2023, all buses were ordered.
- By the third quarter of 2024, all buses will have been delivered and put into operation. To date, only one site does not yet have its buses in operation.
- By the end of the project in 2025, it is estimated that JIVE 2 FCBs will have travelled 15 522 872 km. The fuel cells are estimated to have been in operation for 314 932 hours.
- By the end of the project in 2025, it is estimated that the project's hydrogen refuelling stations will have dispensed 868 373 kg of hydrogen across 53 313 fills.
- It is expected by the end of the project that fuel consumption objectives will have been met by both the 12 m and the 18 m FBCs involved in the project.

PROJECT TARGETS

Target source	Parameter	Unit	Target	Achieved to date by the project	Target achieved?
Project's own objectives	Vehicle operational lifetime	years	8	N/A	
	Ensure availability >90%	%	90	<=80%	
	Distance travelled	km/year	> 50 000	27 627.3	
	Operating hours per fuel cell system	hours	> 20 000	2 014.81	⚙
	Availability	%	> 90	82.3	
	Efficiency	%	> 42	N/A	
	Vehicle OPEX	€	≤ 100 % more than diesel bus OPEX	N/A	
	MDBF	km	> 3 500	10 242	
	Specific fuel consumption	kg / 100 km	< 9.0	7.49	✓
	Vehicle CAPEX	€	< 625 000	N/A	

MEASURED

ADVANCED MEAS ENSURING HIGH EFFICIENCY HDV

MEAsureD
Advanced MEAs ensuring high efficiency HDV

Project ID	101101420
PRR 2024	Pillar 3 – H_2 end uses: transport
Call topic	HORIZON-JTI-CLEANH2-2022-03-02: Innovative and optimised MEA components towards next generation of improved PEMFC stacks for heavy duty vehicles
Project total costs	EUR 2 989 060.00
FCH JU max. contribution	EUR 2 989 060.00
Project start - end	1.6.2023–31.5.2026
Coordinator	Advanced Energy Technologies AE Ereunas & Anaptyxis Ylikon & Proiontonananeosimon Pigon Energeias & Synafon Symvouleftikon y Piresion, Greece
Beneficiaries	AVL List GmbH, AVL-AST Napredne Simulacijske Tehnologije d.o.o., Honeywell International s.r.o., Technische Universitaet Graz, Universitat Politècnica de València, University of Stuttgart, Univerza v Ljubljani

https://measured-horizon.eu/

PROJECT AND GENERAL OBJECTIVES

At Measured, we strive to improve the efficiency and lifespan of high-temperature membrane electrode assemblies (MEAs) for heavy-duty vehicles through a combination of experiments and simulations. Our focus is on developing and optimising MEA components to enhance the overall performance of fuel cells. Specifically, we aim to use high-temperature proton-exchange membranes (HT-PEMs), which we believe is the best scientific direction for the heavy-duty vehicle (HDV) industry. We plan to achieve key performance indicators beyond the current state of the art (SOA) by developing the ion-pair concept. Our consortium, led by Advent, an MEA manufacturer, and comprising fuel cell technology experts, is dedicated to linking HT-PEMs with HDV applications. We will optimise technical aspects to deliver an advanced MEA with high-end potential for the HDV sector based on cost and environmental analyses.

Our research will focus on improving MEA durability and performance through experimental and theoretical approaches. Our ultimate objective is to demonstrate a cost-effective MEA that operates at high temperatures (> 160 °C) with high performance.

The project's objectives are as follows.

- Develop an MEA for a HT-PEM suitable for an HDV that operates at a temperature > 160 °C with minimum phosphoric acid uptake and a stable porous microstructure ionomer / new type of platinum catalyst.
- Integrate MEAs in a short stack. Project stack performance based on short-stack measurements. Evaluate MEAs' performance according to the project's key performance indicators. The environmental assessment of the fuel-cell-manufacturing procedure is focused on cost reduction and the recycling of waste products.
- Integrate fuel cell stacks in HDVs in real conditions. Identify balance-of-plant components based on HT-PEM needs. Analyse the use of fuel cell technology for other applications (aviation, maritime, rail).
- Develop design and monitoring modelling (flow field, degradation) simulation tools.
- Carry out testing-, harmonisation- and standardisation-related activities.

NON-QUANTITATIVE OBJECTIVES

- Cultivate expertise in digital modelling techniques, enabling the team to develop sophisticated simulations that enhance understanding and inform design decisions.
- Conduct vehicle-level simulations, fostering a deep understanding of system-wide implications and interdependencies.

PROJECT TARGETS

Target source	Parameter	Unit	Target	Target achieved?
Project's own objectives and SRIA (2021–2027)	Cost of FC stack	€/kW	< 75	
	PGM loading for low TRL	g/kW	< 0.30	
	Stack durability	hours	20 000	
	Power density	W/cm^2 at 0.65 V	1.2	

Clean Hydrogen Partnership

Co-funded by the European Union

MORELIFE

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

Project ID	101007170
PRR 2024	Pillar 3 – H_2 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
FCH JU max. contribution	EUR 3 499 913.75
Project start - end	1.9.2021–31.8.2024
Coordinator	AVL List GmbH, Austria
Beneficiaries	EKPO Fuel Cell Technologies GmbH; Mebius, Raziskovalno Razvojna Dejavnost, Zastopanje In Trgovina d.o.o.; Nedstack Fuel Cell Technology BV; Technische Universität München; Technische Universiteit Eindhoven; Univerza v Ljubljani

https://morelife-info.eu/

PROJECT AND GENERAL OBJECTIVES

The MORELife project addresses the need for highly efficient material utilisation, maximised durability and the optimised matching of operational conditions for proton-exchange membrane fuel cells in heavy-duty applications. Its objectives are to:

- perform accelerated stress tests for the shortened test duration for lifetime verification;
- make improvements at the material and operational strategy levels;
- create advanced degradation models;
- determine the optimal operating conditions and validate them based on the improved materials;
- achieve a predicted lifetime for fuel cells of 30 000 hours.

PROGRESS AND MAIN ACHIEVEMENTS

- Accelerated stress test and accelerated durability test protocols and aftertreatment systems for state-of-the-art and advanced catalyst material have been created.
- A third generation of novel catalyst material has been developed with promising first results of rotating disc electrode investigations.
- Post-mortem analyses on aged SOA material have been performed in order to improve mechanistic degradation models created in this project.

FUTURE STEPS AND PLANS

If proven sufficient, the third-generation catalyst will be integrated in a 5- to 10-cell short stack for validation in order to prove its durability and performance.

PROJECT TARGETS

Target source	Parameter	Unit	Target	Target achieved?
Project's own objectives and SRIA (2021–2027)	Power density per cell	W/cm² at 0.675 V / cell	1.2	⚙
	PGM loading	g/kW	0	

Clean Hydrogen Partnership
Co-funded by the European Union

NIMPHEA

NEXT GENERATION OF IMPROVED HIGH TEMPERATURE MEMBRANE ELECTRODE ASSEMBLY FOR AVIATION

Project ID	101101407
PRR 2024	Pillar 3 – H_2 end uses: transport
Call topic	HORIZON-JTI-CLEANH2-2022-03-08: Development and optimisation of a dedicated fuel cells for aviation: disruptive next-gen high temperature fuel cells technology for future aviation
Project total costs	EUR 4 942 898.75
FCH JU max. contribution	EUR 4 942 898.50
Project start - end	1.1.2023–31.12.2026
Coordinator	Safran Power Units, France
Beneficiaries	Advanced Energy Technologies AE Ereunas & Anaptyxis Ylikon & Proiontonananeosimon Pigon Energeias & Synafon Symvouleftikon y Piresion, Centre national de la recherche scientifique, Commissariat à l'Énergie Atomique et aux Énergies Alternatives, Fraunhofer Gesellschaft zur Förderung der Angewandten Forschung EV, Fundación IMDEA Energía, Safran SA, Université de Strasbourg

https://www.nimphea.eu/

PROJECT AND GENERAL OBJECTIVES

The overall objective of the Nimphea project is to develop and validate at technology readiness level 4 a new-generation high-temperature membrane electrode assembly (MEA) addressing the challenging requirements of fuel cells for aviation. The MEA developed will operate above 120 °C and thus overcome the thermal management issues of high-power systems.

NON-QUANTITATIVE OBJECTIVES

- Design the concept of the new-generation disruptive MEA operating above 120 °C and develop its components.
- Upscale the small-scale MEA with a view to preparing for manufacturing and future integration at the fuel cell stack level.
- Validate and demonstrate the performances of the new-generation MEA developed at technology readiness level 4.
- Evaluate and validate the suitability of the new-generation MEA by performing a complete life cycle assessment.

PROGRESS AND MAIN ACHIEVEMENTS

The technical specifications have been described for the new Nimphea MEA. The consortium has harmonised its testing strategy for all products. The components of the first-generation MEA have been developed and delivered for its assembly, which will be performed in the coming months.

FUTURE STEPS AND PLANS

The next steps are the assembly and characterisation of the first-generation MEA.

After that, the consortium will start working on developing the second-generation MEA components.

PROJECT TARGETS

Target source	Parameter	Unit	Target	Target achieved?
Project's own objectives	Power density	W/cm²	1.25	⚙
	Degradation rate	µV/h	3–5	

PEMTASTIC

ROBUST PEMFC MEA DERIVED FROM MODEL-BASED UNDERSTANDING OF DURABILITY LIMITATIONS FOR HEAVY DUTY APPLICATIONS

PEMTASTIC

Project ID	101101433
PRR 2024	Pillar 3 – H_2 end uses: transport
Call topic	HORIZON-JTI-CLEANH2-2022-03-02: Innovative and optimised MEA components towards next generation of improved PEMFC stacks for heavy duty vehicles
Project total costs	EUR 2 748 608.75
FCH JU max. contribution	EUR 2 748 608.50
Project start - end	1. 2. 2023 - 31. 1. 2026
Coordinator	Deutsches Zentrum für Luft- und Raumfahrt EV, Germany
Beneficiaries	Chemours Belgium; Chemours France SAS; Commissariat à l'Énergie Atomique et aux Énergies Alternatives; Heraeus Deutschland GmbH & Co. KG; Imerys Graphite & Carbon Belgium; Imerys Graphite & Carbon Switzerland SA; IRD Fuel Cells AS; Symbio France; The Chemours Company FC, LLC; Zürcher Hochschule für Angewandte Wissenschaften

https://pemtastic-project.eu/

PROJECT AND GENERAL OBJECTIVES

The research and development project Pemtastic aims to tackle the key technical challenges to increasing the durability of membrane electrode assemblies (MEAs) for heavy-duty applications. These challenges are approached using a combination of model-based design and the development of a durable catalyst-coated membrane (CCM) using innovative materials tailored for heavy-duty operation at a high temperature (105 °C). The quantitative targets correspond to a durability of 20 000 hours, maintaining a state-of-the-art (SOA) power density of 1.2 W/cm^2 at 0.65 V at a Pt load of 0.30 g/kW.

NON-QUANTITATIVE OBJECTIVES

- Define fuel cell operation protocols and cycling tests for heavy-duty applications and propose an operational strategy for high fuel efficiency.
- Parameterise degradation models to predict MEA lifetime and identify specific improvements in the CCM and its components.
- Develop a robust catalyst (Pt/C) support deposition process for oxygen reduction reaction catalysts.
- Develop membranes and ionomers that operate at high temperatures.
- Create catalyst layers and CCM with increased durability and state-of-the-art performance tailored for heavy-duty operation.

PROGRESS AND MAIN ACHIEVEMENTS

- The partners developed operation protocols for testing materials, single cells, and short stacks. These protocols are available as a public report and have been shared with other Clean H2 projects related to MEA or stack development.
- Specific in situ and ex situ tests were discussed among modellers and experimentalists.
- In the context of the modelling task, performance models were set up to extend to degradation based on the results for the Gen1 MEA.
- Significant effort was dedicated to implementing and debugging testing conditions for single cells into partner test benches to achieve sufficient reproducibility. Initial testing was conducted using a commercial MEA from IRD Fuel Cells, and durability tests were conducted using Pemtastic heavy-duty load cycling and characterisation protocols. The reproducibility of durability tests at different facilities will be assessed.
- The Gen1 MEA was designed using materials from Imerys, Heraeus, and Chemours. A Gen2 MEA will be designed in the second year, considering inputs from degradation models.
- The project was presented at three fairs, contributed to nine workshops or conferences, and was advertised on social media.

FUTURE STEPS AND PLANS

Next steps for the second year of project implementation are:

- Demonstrate reproducible durability among partners;
- Carry out specific accelerated stress tests for the parametrisation of degradation models;
- Identify the most important degradation mechanisms using the first-generation project MEA;
- Provide input for MEA improvement from degradation models;
- Identify specific improvements to be implemented in second-generation materials and components;
- start analysing second-generation MEAs and improve/extend degradation models.

PROJECT TARGETS

Target source	Parameter	Unit	Target	Target achieved?	SOA result achieved to date (by others)
SRIA (2021–2027)	Power density	W/cm^2 at 0.65 V	1.2		1.00
	PGM loading	g/kW	0.3		0.4
	Durability	hours	20		15
Project's own objectives	Operational temperature	°C	95–105 at low RH		80–85 °C

Clean Hydrogen Partnership
Co-funded by the European Union

REALHYFC

RELIABLE DURABLE HIGH POWER HYDROGEN FUELED PEM FUEL CELL STACK

Project ID	101111904
PRR 2024	Pillar 3 – H_2 end uses: transport
Call topic	HORIZON-JTI-CLEANH2-2022-03-01: Development and optimisation of reliable and versatile PEMFC stacks for high power range applications
Project total costs	EUR 3 487 157.50
FCH JU max. contribution	EUR 3 487 156.00
Project start - end	1.6.2023–31.5.2026
Coordinator	Commissariat a l'Énergie Atomique et aux Énergies Alternatives, France
Beneficiaries	AVL List GmbH, Deutsches Zentrum für Luft- und Raumfahrt EV, Dynergie, IRD Fuel Cells AS, PowerCell Sweden AB, United Motion Ideas, Univerza v Ljubljani, Zentrum für Sonnenenergie- und Wasserstoff-Forschung Baden-Wurttemberg

https://cordis.europa.eu/project/id/101111904

PROJECT AND GENERAL OBJECTIVES

The project's targeted key improvements are: (i) a new stable stack design, taking advantage of the two consolidated technologies with carbon and metal bipolar plates (from stationary and light-duty applications, respectively), coupled with improved balance of stacks, to hinder irreversible degradation of components; and (ii) optimised operational monitoring options precluding avoidable performance losses. SRIA solutions proposed will produce expected KPIs in terms of efficiency, performance and durability assessed in both representative conditions and scale.

In line with the Clean Hydrogen JU SRIA, RealHyFC will deliver evidence-based insights and models characterising the escalation of reversible and non-reversible losses attributed to critical characteristics of the heavy-duty use case:

- enhanced physical degradation of the core components (leading to irreversible losses), with significant risk of actual bipolar plate corrosion due to longer and harsher usage than in light-duty vehicles and stationary applications, respectively;
- increased local issues due to more significant heterogeneities associated with the large surface area needed to achieve a high power and coupled to driving cycles;
- more challenging control of operating conditions at the stack–system interface within acceptable boundaries for preventing faults and sustaining ultra-low degradation rates.

NON-QUANTITATIVE OBJECTIVES

- Identify performance and durability issues for heavy-duty transport applications;
- Develop model-based new diagnostic and monitoring tools with the aim of optimising hybridisation and operating strategies;
- Improve two key complementary items of the stack itself – use the best-suited bipolar plates to reduce corrosion risk, and optimise mechanical assembly to overcome heterogeneity issues to further enhance stack durability;
- Demonstrate performance and durability improvements in representative conditions at the stack scale;
- Ensure the exploitation of results and the increase of awareness of H2 for heavy-duty applications

PROGRESS AND MAIN ACHIEVEMENTS

- Manufacturing has starting using MEA components defined by the consortium.
- Relevant protocols and operating conditions for testing and modeling were considered so as to comply with the durability and control requirements.
- Degradation mechanisms related to core components and operating conditions have been modelled .
- The development of open-design carbon bipolar plates started.

FUTURE STEPS AND PLANS

- Delivery of MEAs and stacks, and assembly of reference stacks.
- Performance, sensitivity and durability testing based on selected protocols and definition of fuel cell diagnosis algorithms
- Modelling of stack performance and simulation of durability
- Manufacture of first open-design carbon bipolar plates.

PROJECT TARGETS

Target source	Parameter	Unit	Target	Target achieved?	SOA result achieved to date (by others)	Year for reported SOA result
AWP 2022	Degradation for a projected durability of 20 000 hours with fewer than 10 % losses	%	10	⚙ (in progress)	N/A	2024
	Power density	W/cm² at 0.675 V at BOL	1		1	2024

REVIVE

REFUSE VEHICLE INNOVATION AND VALIDATION IN EUROPE

Project ID	779589
PRR 2024	Pillar 3 – H_2 end uses: transport
Call topic	FCH-01-7-2017: Validation of fuel cell trucks for the collect of urban wastes
Project total costs	EUR 9 760 023.65
FCH JU max. contribution	EUR 4 993 851.00
Project start - end	1.1.2018–31.12.2024
Coordinator	Tractebel Engineering (Tractebel), Belgium
Beneficiaries	Azienda Servizi Municipalizzati di Merano SpA, Commissariat à l'Énergie Atomique et aux Énergies Alternatives, Element Energy Ltd, ENGIE Impact Belgium, Environmental Resources Management Ltd, ERM France, E-Trucks Europe, Gemeente Amsterdam, Gemeente Breda, Gemeente Groningen, Gemeente Noordenveld, Plastic Omnium New Energies Fribourg SA, PowerCell Sweden AB, Prezero Nederland Holding BV, Proton Motor Fuel Cell GmbH, Renova Aktiebolag, Saver NV, Servizi Energia Ambiente Bolzano SpA, Stad Antwerpen, Symbio, Tractebel Belgium, Waterstofnet VZW

https://h2revive.eu/about-revive/

PROJECT AND GENERAL OBJECTIVES

Revive will significantly advance the state of development of fuel cell bin lorries by integrating fuel cell powertrains into 11 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, all trucks are in operation.

NON-QUANTITATIVE OBJECTIVES

- The project aims to involve EU fuel cell suppliers. Currently, two EU fuel cell suppliers are involved in the project: Proton Motor and PowerCell Sweden. In addition, two trucks are equipped with Hydrogenics fuel cell systems.
- The project aims to demonstrate a route to the high utilisation of hydrogen refuelling stations to support the roll-out of H_2 mobility for light-duty vehicles. Even with limited running hours, the three trucks deployed in the project have already consumed 4.2 t of H_2 during the project.

PROGRESS AND MAIN ACHIEVEMENTS

- The first Proton Motor fuel cell system has been delivered and successfully integrated.
- The first Revive trucks have been deployed.
- A new electric driveline has been developed, tested and deployed.
- All trucks have been constructed and have all the certifications required to be deployed.

FUTURE STEPS AND PLANS

- Increase dissemination activities. To catch up following the delays experienced in 2020, a plan for dissemination will be developed.
- Decrease teething issues.
- Carry out an in-depth performance analysis of truck deployment and focus on completing the remaining deliverables.

PROJECT TARGETS

Target source	Parameter	Unit	Target	Achieved to date by the project	Target achieved?	SOA result achieved to date (by others)	Year for reported SOA result
AWP 2017	Driving distance between FC failures	km	3 500	6 210	✓	N/A	N/A
	FC power	kW	> 40	45		90	N/A
	Tank-to-wheel efficiency	%	50	55		N/A	N/A
	Lifetime	hours	25 000	N/A		> 25 000	2020
	FCs deployed in the project	number	15	6		6	N/A
	Availability	%	90	77		N/A	N/A

RH_2IWER

RENEWABLE HYDROGEN FOR INLAND WATERWAY EMISSION REDUCTION

Project ID	101101358
PRR 2024	Pillar 3 – H_2 end uses: transport
Call topic	HORIZON-JTI-CLEANH2-2022-03-05: Large scale demonstration of hydrogen fuel cell propelled inland waterway vessels
Project total costs	EUR 20 531 971.25
FCH JU max. contribution	EUR 14 998 541.38
Project start - end	1.3.2023–31.8.2027
Coordinator	Teknologian Tutkimuskeskus VTT Oy, Finland
Beneficiaries	Air Liquide BV, Ballard Power Systems Europe AS, Compagnie Fluviale de Transport, DFDS AS, Future Proof Shipping BV, H_2Boat SRL, Air Liquide SA, Air Liquide Belge, Nedstack Fuel Cell Technology BV, Sogestion, Stichting Projecten Binnenvaart, Theo Pouw BV, Università degli Studi di Genova, Verenigde Tankrederij BV

http://rh2iwer.eu/

PROJECT AND GENERAL OBJECTIVES

The main aim of RH_2IWER is to create a solid basis for the acceleration of vessels powered by hydrogen fuel cells in inland waterway shipping by demonstrating six commercially operated vessels. These vessels are of varying lengths and types: 86 m, 110 m and 135 m; and container, bulk and tanker vessels with installed power ranging from 0.6 MW to around 2 MW. The project will also work to standardise containerised fuel cell and hydrogen solutions. Through demonstration, standardisation work and multilevel analyses, combined with vigorous dissemination and communication measures, the RH_2IWER project will create a basis on which the shipping industry can significantly reduce its environmental footprint and remove emissions from its entire fleet in the future.

NON-QUANTITATIVE OBJECTIVES

- Demonstrate the use of inland waterway vessels powered by hydrogen fuel cells.
- Accelerate adoption by facilitating cooperation and exploiting synergies within the European maritime sector.
- Promote the acceptance of inland waterway vessels powered by hydrogen fuel cells as a viable zero-emission solution.
- Increase the impact of inland waterway transport on decarbonisation.

PROGRESS AND MAIN ACHIEVEMENTS

RH_2IWER partners have been working to develop the demonstration vessels' general design, as well as with the business cases. Partners have also started to work on standardising fuel cell and hydrogen storage containers in order to alleviate the risks for shipowners in the future when adopting these technologies.

FUTURE STEPS AND PLANS

Next in the project, the hydrogen and fuel cell systems on board the vessels will be designed in more detail and then the vessels will built/retrofitted and their use demonstrated.

PROJECT TARGETS

Target source	Parameter	Unit	Target	Target achieved?
Project's own objectives	PEMFC system CAPEX	€/kW	1.35	
	H_2 and FC vessels demonstrated	number	6	
	Professionals trained	number	80	
	FC power rating	MW	2	
	Maritime FCH lifetime	hours	40	
	Safety, PNR and RCS workshops	number/year	1	
	Safety reporting	%	100	
	Projects with a proactive safety management process	%	100	
	Product design achieving type approval	number	2	

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SH_2APED

STORAGE OF HYDROGEN: ALTERNATIVE PRESSURE ENCLOSURE DEVELOPMENT

Project ID	101007182
PRR 2024	Pillar 3 – H_2 end uses: transport
Call topic	FCH-01-1-2020: Development of hydrogen tanks for electric vehicle architectures
Project total costs	EUR 1 993 550.00
FCH JU max. contribution	EUR 1 993 550.00
Project start - end	1.1.2021–30.9.2024
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 GENERAL OBJECTIVES

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

NON-QUANTITATIVE OBJECTIVES

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

PROGRESS AND MAIN ACHIEVEMENTS

- The first design of the assembly has been finalised (several types are available). The vessel design has also been completed and made available:
  - vessel design;
  - manifold and thermal pressure release device design;
  - vessel prototypes.
- System testing of the model's reaction to fire is in progress.

FUTURE STEPS AND PLANS

Frame design is ongoing.

PROJECT TARGETS

Target source	Parameter	Unit	Target	Achieved to date by the project	Target achieved?	SOA result achieved to date (by others)	Year for reported SOA result
Project's own objectives	Low-cost process for liner	€	1 million	1 million		3 million	2021
	Burst pressure (R134)	MPa	> 157.5	170	✓	157	2022
	Hydraulic pressure cycle test, 87.5 MPa at 20 °C	number of cycles	22 000	> 22 000		Not published	Not published
	H_2 storage volume of estimated design space	%	> 45	43		41	2021
	Cost of tank system	€/kgH_2	400	> 580	⚙	N/A	2022
	Permeation	Ncm³/l/h at 55 °C	-	Not yet available		N/A	N/A

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SHIPFC

PILOTING MULTI MW AMMONIA SHIP FUEL CELLS

Project ID	875156
PRR 2024	Pillar 3 – H_2 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 13 179 056.25
FCH JU max. contribution	EUR 9 975 477.50
Project start - end	1.1.2020–31.12.2025
Coordinator	Maritime CleanTech, Norway
Beneficiaries	Alma Clean Power AS, Capital-Executive Ship Management Corp, Clara Venture Labs AS, Eidesvik Shipping AS, Equinor Energy AS, Fraunhofer Gesellschaft zur Förderung der Angewandten Forschung EV, National Centre for Scientific Research 'Demokritos', North Sea Shipping AS, Persee, Star Bulk Shipmanagement Co. (Cyprus) Ltd, Sustainable Energy AS, University of Strathclyde, Wärtsilä Gas Solutions Norway AS, Wartsila Norway AS, Yara Clean Ammonia Norge AS, Yara International ASA

https://shipfc.eu/

PROJECT AND GENERAL OBJECTIVES

ShipFC's main mission is to prove and demonstrate 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.

NON-QUANTITATIVE OBJECTIVES

- ShipFC aims to integrate ammonia fuel cell and fuel systems into ship power systems. The integrated ship design is now used in the ongoing approval process for the vessel. Initial discussions with key players from the industry are complete and follow-up actions have been identified. The vessel design and approval process will contribute to updating knowledge in the industry, as this is the first vessel with MW-scale ammonia-powered solid oxide fuel cells (SOFCs) on board.
- For the replicators, the fourth-generation design for the container ship is now established.
- Concept evaluations of bulk carriers are ongoing
- The project aims to demonstrate the wider use of the system and the scale-up of the system by 20 MW. The first-generation design for the 5 000 twenty-foot equivalent unit container ship has been established. As the detailed designs of all systems for Viking Energy progress, the container ship design will be modified several times.
- As part of the work, the project will also perform a safety assessment of the ammonia fuel gas system and of the SOFC system.

PROGRESS AND MAIN ACHIEVEMENTS

- The project has signed an agreement for the delivery of green ammonia fuel for the duration of the project (not analysed or published).
- Detailed designs for the fuel system have been developed.
- The vessel design has been developed for the ammonia fuel cell installation, including the fuel gas system.
- The approval process for ammonia-powered vessels is ongoing with the class and the flag state.
- A purchase order for two MW SOFC stacks has been placed.

FUTURE STEPS AND PLANS

- ShipFC will scale up and test the SOFC.
- The project partner Alma is currently performing laboratory-scale testing of SOFCs, and is preparing for the first large-scale SOFC test (100 kW), to be commenced in 2024.
- The project partner Sustainable Energy has set up the test infrastructure required to facilitate the 100 kW test, including the necessary ammonia tank and fuel gas system.
- The consortium will follow up and monitor the delivery of stacks for the 2 MW system. A further plan is to refine the design for the 2 MW system based on results from the 100 kW tests.

PROJECT TARGETS

Target source	Parameter	Unit	Target	Achieved to date by the project	Target achieved?
Project's own objectives	GHG reduction by use of ammonia fuel	%	70	N/A	
	Power of ammonia SOFC system	MW	2	0.006	
	SOFC operational experience	hours	3 000	N/A	

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STASHH

STANDARD-SIZED HEAVY-DUTY HYDROGEN

Project ID	101005934
PRR 2024	Pillar 3 – H_2 end uses: transport
Call topic	FCH-01-4-2020: Standard sized FC module for heavy duty applications
Project total costs	EUR 14 303 172.80
FCH JU max. contribution	EUR 7 500 000.00
Project start - end	1.1.2021–31.12.2024
Coordinator	SINTEF AS, Norway
Beneficiaries	Aktiebolaget Volvo Penta, Alstom Transport SA, AVL List GmbH, Ballard Power Systems Europe AS, Centro per gli Studi di Tecnica Navale SpA, Commissariat à l'Énergie Atomique et aux Énergies Alternatives, Damen Global Support BV, Damen Research Development & Innovation BV, FCP Fuel Cell Powertrain GmbH, FEV Europe GmbH, FEV Software and Testing Solutions GmbH, Freudenberg FST GmbH, Freudenberg Fuel Cell e-Power Systems GmbH, Future Proof Shipping BV, Hydrogenics GmbH, Hyster-Yale Italia SpA, Hyundai Motor Europe Technical Center GmbH, Intelligent Energy Ltd, Nederlandse Organisatie voor Toegepast Natuurwetenschappelijk Onderzoek, Nedstack Fuel Cell Technology BV, Plastic Omnium New Energies Wels GmbH, Proton Motor Fuel Cell GmbH, Scheepswerf Damen Gorinchem BV, Solaris Bus & Coach Sp z.o.o., Symbio, 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 GENERAL OBJECTIVES

Stashh's objectives are to agree on 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; most fuel cell module suppliers have provided their prototypes, and some have already undergone testing.

NON-QUANTITATIVE OBJECTIVES

- The project aims to disseminate the standard. It has established contact with the Society of Automotive Engineers and the International Organization for Standardization.
- Stashh plans to update the standard in 2024, based on experience.

PROGRESS AND MAIN ACHIEVEMENTS

- A standard definition has been agreed.
- Stashh has created a comprehensive overview of regulations, codes and standards.
- All fuel cell modules have been designed, and two of the eight have been tested in accordance with the project's protocols.
- A truck prototype has been deployed at VDL.
- A best practices manual for original equipment manufacturers has been created.

FUTURE STEPS AND PLANS

- The final FCM testing campaigns will be conducted in 2024.
- The system will be demonstrated in the field.
- X-in-the-loop testing software will be created, and standard and designs will be finalised.

PROJECT TARGETS

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

VIRTUAL-FCS

VIRTUAL & PHYSICAL PLATFORM FOR FUEL CELL SYSTEM DEVELOPMENT

Project ID	875087
PRR 2024	Pillar 3 – H_2 end uses: transport
Call topic	FCH-01-3-2019: Cyber-physical platform for hybrid fuel cell systems
Project total costs	EUR 1 897 806.25
FCH JU max. contribution	EUR 1 897 806.25
Project start - end	1.1.2020–30.4.2023
Coordinator	SINTEF AS, Norway
Beneficiaries	Ballard Power Systems Europe AS, Banke ApS, Communauté d' universités et 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 GENERAL 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 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 future 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 to significantly reduce development times for new fuel cell and battery hybrid systems. The advanced modelling, simulation and emulation tools developed in Virtual-FCS 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 (XIL platform) to boost the competitiveness of the EU fuel cell industry. The system simulation tools and methods for making 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 cyberphysical hardware integration.
- The project has demonstrated fuel cell electric vehicle simulations.
- The project has demonstrated real-time system emulation. It 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 those emulated on a controller.
- The project has arranged explanatory webinars and participated in conferences to demonstrate the feasibility of the Virtual-FCS library. An industrial workshop on 26 April 2023 was arranged.
- A simple fuel cell stack degradation model has been developed.
- Full validation of the fuel cell stack, battery and balance-of-plant models.

FUTURE STEPS AND PLANS

The project has finished.

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ZEFER

ZERO EMISSION FLEET VEHICLES FOR EUROPEAN ROLL-OUT

Project ID	779538
PRR 2024	Pillar 3 – H_2 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
FCH JU max. contribution	EUR 4 998 843.00
Project start - end	1.9.2017–31.8.2023
Coordinator	Environmental Resources Management Ltd, United Kingdom
Beneficiaries	Air Liquide Advanced Business, Air Liquide Advanced Technologies GmbH, Air Liquide Advanced Technologies SA, Air Liquide France Industrie, Bayerische Motoren Werke AG, Breath, Centre of Excellence for Low Carbon and Fuel Cell Technologies, DRIVR Danmark AS, Element Energy, Element Energy Ltd, Environmental Resources Management France, Green Tomato Cars Ltd, Hype, ITM Power (Trading) Ltd, Air Liquide Belge, Linde AG, Linde GmbH, Mayor's Office for Policing and Crime (UK), Toyota Danmark AS, City of Paris

https://zefer.eu/

PROJECT AND GENERAL OBJECTIVES

The ZEFER project aimed to demonstrate the feasibility of hydrogen mobility from a technical and financial perspective, and hence to accelerate the roll-out of vehicles and hydrogen refuelling infrastructure across Europe. Through the project, the ZEFER partners aimed to:

- deploy 180 fuel cell passenger cars in fleet operations across three major cities in Europe: Paris, Copenhagen and London;
- test the performance of fuel cell electric vehicles (FCEVs) in high-mileage fleets, travelling millions of kilometres over the project period;
- prove that the fleet operation of FCEVs is a viable business model for high-mileage fleets in urban areas, bringing potential savings to the fleet operator when the externalities of choosing a zero-emission vehicle over an incumbent diesel vehicle are considered;
- gather data on the performance of FCEVs as high-mileage fleet vehicles to provide an evidence base that these vehicles are reliable and suitable to be deployed in major cities around Europe, and across the world;
- increase the utilisation of hydrogen refuelling systems (HRSs) to demonstrate the viable business models for early HRSs supported by captive fleets;
- test the performance of today's best-in-class hydrogen refuelling station technology under significantly increased loads compared with current levels, which will help to highlight the reliability of the stations and their ability to meet the demands of a growing number of FCEVs on the road;
- communicate the benefits of FCEVs in fleet operation through the widespread dissemination of the technical and business modelling research results, targeting decision-makers to initiate conversations in local authorities and to foster the acceptance of FCEV fleets.

NON-QUANTITATIVE OBJECTIVES

- The project aimed to increase the confidence of investors and policymakers 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.
- Six out of the 15 ZEFER partners are small or medium-sized enterprises (SMEs). In particular, the three largest fleet operators are SMEs, and therefore a large proportion of ZEFER's funding (84 %) is allocated to SMEs.
- ZEFER aimed 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 aimed 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 aimed to reduce the hydrogen cost at the pump. This could be achieved by providing a stable demand for hydrogen at an HRS. The project also aimed to trigger further cost reductions by creating a climate of investment in the low-cost green production systems required to drive the overall cost below this level.

PROGRESS AND MAIN ACHIEVEMENTS

- 180 FCEVs have been deployed in Paris (Hype), London (GTC and the Metropolitan Police) and Copenhagen (DRIVR).
- The ZEFER vehicles in service have been operated rigorously in everyday operation and had driven over 15 million kilometres as of August 2023.
- All HRS upgrades necessary to support the deployment of FCEVs in the project have been completed.
- HRSs in France (Air Liquide), in the United Kingdom (ITM Power) and in Denmark (Nel) had dispensed 149 000 kg of H_2 to ZEFER vehicles as of June 2023.
- The peak of number of data-reporting vehicles (104) was reached in the second quarter of 2022, thanks to the increase in vehicles through DRIVR's deployment in Copenhagen alongside Hype's and GTC's deployments.
- The project was successfully completed, with an immense dataset collected for the FCEVs and HRSs in operation.
- ZEFER contributed to increasing the awareness of the business case for FCEVs in fleet applications. Following the project, there was an increase in taxi projects in Europe.

FUTURE STEPS AND PLANS

The project has finished.

Hype continued in Paris. Hype is in the process of deploying additional vehicles in Paris with a fleet of 350 FCEVs overall at the beginning of 2024 and the objective of further expanding their operation in Paris to other European locations. The presence of these vehicles is, however, still most significant in Paris, with an associated distribution network of 26 stations to fuel the vehicles. Plans are also already in place for Hype to replicate the taxi business model in seven other cities in Europe: Le Mans, Bordeaux, Brussels, Madrid, Barcelona, Lisbon and Porto.

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ZEFER

PROJECT TARGETS

Target source	Parameter	Unit	Target	Achieved to date by the project	Target achieved?	SOA result achieved to date (by others)	Year for reported SOA result
FCEVs							
Project's own objectives	Minimum distance for vehicles	km/vehicle	90 000 (60 000 for those deployed in Copenhagen)	A strict KPI km per vehicle was hard to achieve given the challenges faced by the project, and therefore it was agreed that the average number across all ZEFER vehicles would be considered	✓	FCEVs in taxi operations in H_2ME drive on average around 45 000 km per year	2020
	Vehicle availability	%	> 98	> 99 %		> 99 %	2021
	Range	km	500	470 km in Mirai generation 1 and 530 km in Mirai generation 2		756	2020
HRSs							
Project's own objectives	Hydrogen purity	%	99.99	99.99	✓	99.99	2020
	Level of back-to-back vehicle refuelling	number of refuelling events per hour	6	6		6	2020
	HRS availability	%	> 98	96.2 %	⚙	98	2016
	Cost of hydrogen	€/kg	10	The project pump price target of € 10 / kg has not been achieved because of the energy crisis.		10	2020

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