BEBOP

BEYOND STATE-OF-THE-ART EFFICIENCY BY IMPROVING BALANCE OF PLANT COMPONENTS

Project ID	101192365
PRR 2026	Pillar 3 - H_2 End Uses - Transport
Call Topic	HORIZON-JTI-CLEANH$_2$-2024-03-01
Project Total Costs	4 609 050.32
Clean H_2 JU Max. Contribution	3 983 049.07
Project Period	01-01-2025 - 30-06-2028
Coordinator Beneficiary	SINTEF AS, NO
Beneficiaries	DEUTSCHES ZENTRUM FÜR LUFT - UND RAUMFAHRT e. V., FPT INDUSTRIAL S.P.A., FREUDENBERG FILTRATION TECHNOLOGIES GMBH & CO. KG, GARRETT MOTION FRANCE SAS, FREUDENBERG TECHNOLOGY INNOVATION SE & CO. KG, FPT MOTORENFORSCHUNG AG, SILVER ATENA GMBH

https://bebop-hydrogen.eu/

PROJECT AND GENERAL OBJECTIVES

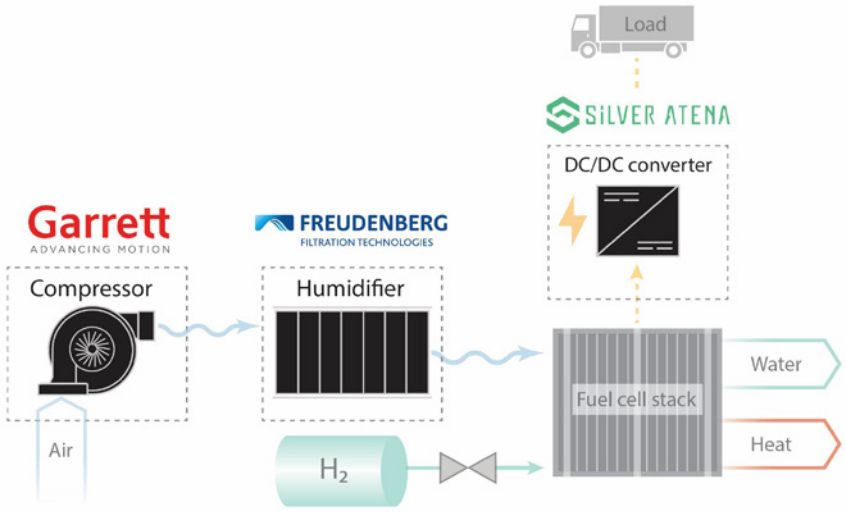
The Horizon Europe project **BeBoP** (Beyond State-of-the-Art Efficiency by Improving Balance of Plant Components) aims to improve efficiency, durability, and cost-effectiveness of fuel cell systems for heavy-duty applications.

The project focuses on key balance-of-plant components, including the air compressor, humidifier, and DC/DC converter, to enhance overall system performance. These developments target optimisation at both component and system levels, addressing efficiency, durability, and cost.

In addition, BeBoP explores next-generation fuel cell concepts through advanced modelling, including improved compressor configurations and operation with enriched air. This supports increased system efficiency and scalability across heavy-duty transport applications.

NON-QUANTITATIVE OBJECTIVES

- Develop a balance of plant solutions to improve the efficiency and durability of heavy-duty fuel cell systems (100 kW+) for integration into prototype vehicles by 2030.
- Build on existing research to refine and adapt modelling tools for the development of novel fuel cell system architectures optimised for performance and cost.
- Use flexible modelling tools to optimise PEM fuel cell balance of plant design and operating strategies.
- Prepare for the introduction of commercial- and industrial-scale PEM fuel cell systems in the heavy-duty transport sector and other applications.
- Enhance and consolidate European leadership in the understanding and optimisation of balance of plant architectures for heavy-duty fuel cell systems.
- Demonstrate the efficiency and applicability of hydrogen fuel cell solutions in heavy-duty transport applications.
- Improve key balance of plant components for fuel cell systems in heavy-duty applications, including the development and testing of novel air compressors, air humidifiers, and DC/DC converters suitable for commercialisation.



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- Contribute to the achievement of the objectives and KPIs of the call and the Clean Hydrogen JU Strategic Research and Innovation Agenda.

PROGRESS, MAIN ACHIEVEMENTS AND RESULTS

A preliminary simulation-based architecture evaluation was completed based on representative requirements for fuel cell systems in heavy-duty applications.

- Two compressor units were designed, functionally tested, and delivered, each demonstrating performance improvements.
- Evaluation of several humidifier membranes has started, including accelerated ageing tests, with results to be incorporated into further humidifier development.
- Coupled inductors were designed, prototyped, and functionally validated. The Electrochemical Impedance Spectroscopy (EIS) concept was developed, and an existing DC/DC converter was modified to validate it. Requirements for a new DC/DC prototype were defined in alignment with consortium needs.
- Mechanical and software integration of the first electric turbocharger prototype into the advanced 200 kW FPT fuel cell system was completed.
- Preliminary models for the compressor, DC/DC converter, and air humidifier were implemented in the VirtualFCS library. In addition, a custom medium was developed to improve fuel cell mass balance and moisture condensation modelling in the air system.

FUTURE STEPS AND PLANS

- Development of a validated fuel cell stack model to account for degradation as a constraint in the sizing of balance-of-plant components.
- Optimisation of the compressor design based on feedback from FPT.
- Completion of humidifier membrane evaluation, followed by housing design and optimisation through simulations.
- Finalisation of the DC/DC converter design in Q1 2026, with a prototype available for testing and further optimisation by mid-2026.
- Testing of the first electric turbocharger prototype on the FPT fuel cell system to evaluate performance improvements.
- Implementation of degradation models for the fuel cell and key balance-of-plant components, to optimise control algorithms and extend system lifetime.

PROJECT TARGETS

Target source	Parameter	Unit	Target	Target achieved?
Project's own objectives	FC module durability	hours	25 000	
	Cost of FC module	€/kW	300	
	FC system electrical Efficiency	%	60 with SoA PEMFC stack initial performance (a real power density between 1 and 1.2 W/cm² @ 0.675V)	

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BRAVA

BREAKTHROUGH FUEL CELL TECHNOLOGIES FOR AVIATION

Project ID	101101409
PRR 2026	Pillar 3 - H_2 End Uses - Transport
Call Topic	HORIZON-JTI-CLEANH$_2$-2022-03-06
Project Total Costs	19 986 841.75
Clean H_2 JU Max. Contribution	19 986 841.75
Project Period	01-12-2022 - 30-06-2026
Coordinator Beneficiary	AIRBUS OPERATIONS GMBH, DE
Beneficiaries	MADIT METAL SOCIEDAD LIMITADA, STICHTING KONINKLIJK NEDERLANDS LUCHT - EN RUIMTEVAARTCENTRUM, LIEBHERR AEROSPACE TOULOUSE SAS, SPECIALTY OPERATIONS FRANCE, SYENSQO LABORATOIRE DU FUTUR SAS, RHODIA OPERATIONS, AEROSTACK GMBH, AIRBUS DEFENCE AND SPACE GMBH, SYENSQO SPECIALTY POLYMERS ITALY S.P.A., Heraeus Precious Metals GmbH and Co. KG, CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE CNRS, TECHNISCHE UNIVERSITAT BERLIN,UNIVERSITE DE MONTPELLIER, MORPHEUS DESIGNS SOCIEDAD LIMITADA, AIRBUS OPERATIONS SL

http://brava-project.eu/

PROJECT AND GENERAL OBJECTIVES

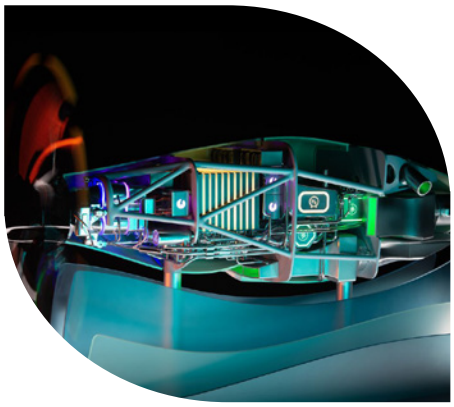
- Define fuel-cell based Power Generation system architecture and safety requirements based on the higher-level fuel cell propulsion system requirements (considering weight balance).
- Design, develop, test and validate a 2-phase cooling system for a fuel cell stack.
- Design, develop, test and validate compact and form-flexible (air to liquid) heat exchangers via additive manufacturing.
- Develop, optimise, test and validate a high-performance fuel cell stack.
- Develop, test and validate 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 integration of developed subsystems.

NON-QUANTITATIVE OBJECTIVES

Within the scope of BRAVA, we will embark on a preliminary design phase to conceptualise a complete PGS that seamlessly integrates the various subsystems. While the project's focus remains on subsystem-level advancements, we acknowledge that further integration into the power propulsion system and eventual aircraft-level implementation lies outside the project's immediate purview. The underlying concepts, models, assumptions, and methodologies for the fuel cell stack form the project's bedrock and work in harmony with developments in the other subsystems (air supply and thermal management system) to ensure the realisation of BRAVA's overall objectives.

PROGRESS, MAIN ACHIEVEMENTS AND RESULTS

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 (TMS) employs a 2-PC design and incorporates a newly engineered fuel cell stack. By prioritising compactness and weight reduction, we aim to minimise fuel consumption and maximise efficiency significantly.
- Advanced heat exchangers. We introduce the Advanced Heat Exchanger technology, optimising heat rejection while ensuring seamless integration, reduced weight, and minimal aerodynamic drag. This breakthrough innovation enhances 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, durability, and operational temperature capabilities. These advancements facilitate the integration of new membrane electrode assemblies (MEAs) 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 tai

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- lored to aviation requirements. This forward-thinking approach minimises parasitic power, reduces weight, and ultimately lowers fuel consumption and equipment costs.
- 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 will measure our progress and accomplishments in subsystem development. By surpassing the performance of the reference subsystems and meeting the key performance indicators defined early in the project, BRAVA will be well-positioned to undertake a follow-on project, such as Phase 2 of the Clean Aviation programme. The follow-up project will focus on developing an integrated fuel cell propulsion system, encompassing both ground and flight testing. This ambitious endeavour will elevate the 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.

PROJECT TARGETS

Target source	Parameter	Unit	Target	Achieved to date by the project	Target achieved?
Project's own objectives	FC system gravimetric power density (ecl, electrical and thrust generation)	KW_el/kg	> 1.5	-	
	FC system durability	hours	20 000	-	
	Additive Manufactured Heat Exchanger (HEX) mass reduction vs standard HEX	%	> 20	-	
	Additive Manufactured Heat exchanger (HEX) volume reduction vs standard HEX	%	> 30	-	
	Protonic conductivity ionomer (> 100 °C < 20%RH)	S/cm	> 0.1	0.278- 0.285 (@RH95% @80 °C)	
	MEA performance	A/Cm^2 @0.74V	1.3	0.5-0.6	
	Compression ratio air supply system	ratio	5.2	> 5.2 (in simulated performance)	
	Two-phase cooling system weight reduction vs conventional cooling systems	%	20	25% (incl. accumulator of 2-PC), without accumulator can be higher (> 50%)	✓
	Pt mass activity catalysts in FC stack	A/mg Pt @ 0.9V	0.6	> 0.6 (small scale, depending on catalyst synthesis method)	

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CLEANH$_2$SHIPPING

DEMONSTRATION OF CAPEX- AND OPEX-EFFICIENT HYDROGEN FUEL CELL-POWERED INLAND SHIPPING USING SWAPPABLE H$_2$TANK-TAINERS AND BUILDING AN H$_2$ ECOSYSTEM IN AND AROUND PORTS

Project ID	101192306
PRR 2026	Pillar 3 - H$_2$ End Uses - Transport
Call Topic	HORIZON-JTI-CLEANH$_2$-2024-03-04
Project Total Costs	7 450 500.75
Clean H$_2$ JU Max. Contribution	5 770 214.33
Project Period	01-04-2025 - 31-03-2028
Coordinator Beneficiary	UNIVERSITÀ DI PISA, IT
Beneficiaries	ANLEG GMBH, AUTORITÄT DI SISTEMA PORTUALE DEL MAR TIRRENO SETTENTRIONALE, DELTAPORT GMBH and CO. KG, ZENTRUM FÜR BRENNSTOFFZELLEN-TECHNIK GMBH, NORTH SEA PORT NETHERLANDS N.V., NORTH SEA PORT FLANDERS, COMMISSARIAT À L'ÉNERGIE ATOMIQUE ET AUX ÉNERGIES ALTERNATIVES, EURA AG, MTS DÜSBURG GMBH, DÜSBURGER HAFEN AKTIENGESELLSCHAFT

https://www.cleanh2shipping.eu

PROJECT AND GENERAL OBJECTIVES

The CleanH$_2$Shipping project aims to develop and implement a viable hydrogen ecosystem to demonstrate and operate a hydrogen fuel cell-powered container vessel for inland waterborne transport. The main challenges are the following:

- No international regulations for safe use of hydrogen at sea, rivers or in ports.
- The volume required to power marine vessels is of an order of magnitude larger than for road transport.
- Any potential accident could have far-reaching consequences.
- High investment costs for production and port infrastructure and high operating costs of hydrogen-powered vessels represent significant barriers.

CleanH$_2$Shipping will demonstrate the complete hydrogen supply chain, create a blueprint for replication in other European ports and ships, and involve policymakers and authorities to advocate for harmonised regulations. Innovative swappable hydrogen fuel tank containers ("H$_2$Tank-Tainers") will be used; no direct investment in port infrastructure is required. A 610 TEU inland container ship, featuring a 1.2 MW fuel-cell main drive, will showcase sustainable shipping. Further standardisation, efficiency improvements, scaling, and AI-driven container logistics will reduce CAPEX and OPEX for building an H$_2$ ecosystem.

NON-QUANTITATIVE OBJECTIVES

- Develop and demonstrate a hydrogen ecosystem in and around ports, including fuel/hydrogen-carrier logistics and integrated refuelling/bunkering solutions supported by shore-based infrastructure for zero-carbon fuels.
- Assess safety aspects and risks of hydrogen (and hydrogen-based fuels) use on vessels, including health hazards and operational risks, to support safe deployment.
- Select an appropriate ship segment and define a technical concept for the demonstration, including suitable propulsion power levels.
- Design and integrate power conversion and storage systems (fuel cells, batteries, and hybrid solutions) with smart energy and power management systems.
- Demonstrate the scalability of a modular fuel-cell power architecture towards MW-scale applications and develop suitable balance-of-plant configurations.
- Integrate hydrogen storage and fuel-cell systems onboard (below deck or via interchangeable tank containers on deck), covering storage from hundreds of kilograms to tons, ensuring minimum onboard energy storage for autonomy.
- Operate the vessel under realistic end-user conditions while supporting safe operation and contributing to regulatory framework development.
- Support ports in achieving approval processes for hydrogen bunkering and establishing corresponding infrastructure.
- Establish technical and economic feasibility for replication and scale-up across European ports, supporting standardisation and regulation for vessels and infrastructure.
- Provide open-access operational data (e.g., hydrogen storage, bunkering, sailing data) and instrumentation to support modelling tools and protocols.
- Assess environmental impacts and quantify potential GHG reductions at the European scale under full deployment scenarios.

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	Hydrogen End User - PEM System CAPEX	€/kW	1 500		2 000	2020
	Maritime FCS Lifetime	hours	40 000		20 000	2020
	FC Power Rating	MW	1.2		0.5	2020
	Hydrogen Bunkering Rate	tH_2/h	3		N/A	2020
	Product design reaching type approval	Number	6 H_2 Transtainers			2020
	NO_x Emissions	ppm @15% O2 dry	< 25		< 25	2020
	Road transport of compressed hydrogen - operating pressure	bar	500		300	2020
	Operation of demonstrator ship under realistic end-user conditions	hours	2 000		1 000	2020

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COCOLIH$_2$T

COMPOSITE CONFORMAL LIQUID H_2 TANK

Project ID	101101404
PRR 2026	Pillar 3 - H_2 End Uses - Transport
Call Topic	HORIZON-JTI-CLEANH$_2$-2022-03-07
Project Total Costs	8 726 769.50
Clean H_2 JU Max. Contribution	8 726 769.50
Project Period	01-02-2023 - 31-10-2026
Coordinator Beneficiary	COLLINS AEROSPACE IRELAND, LIMITED, IE
Beneficiaries	UNIFIED INTERNATIONAL, NOVOTECH AEROSPACE ADVANCED TECHNOLOGY SRL, UTC AEROSPACE SYSTEMS WROCLAW SPOLKA Z OGRANICZONA ODPOWIEDZIALNOSCIA, MICROTECNICA SRL, STICHTING KONINKLIJK NEDERLANDS LUCHT - EN RUIMTEVAARTCENTRUM, CROMPTON TECHNOLOGY GROUP LTD, Simmonds Precision Products, Inc., a part of Collins Aerospace, AVIONS DE TRANSPORT REGIONAL GIE, GOODRICH AEROSPACE EUROPE SAS, TECHNISCHE UNIVERSITEIT DELFT

https://www.cocolih2t.eu/

PROJECT AND GENERAL OBJECTIVES

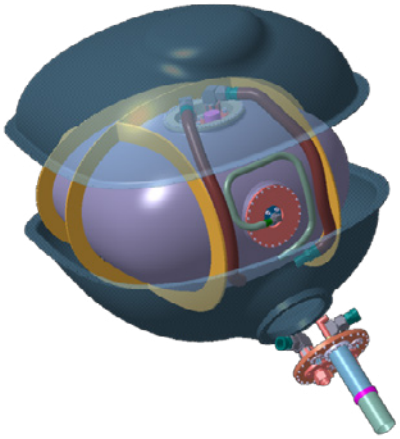
Improvements to existing state-of-the-art solutions include better utilisation of the available space for fuel storage, adequate insulation techniques to minimise heat leak, continued safe operations, and weight reduction through the use of low-weight materials, such as thermoset or thermoplastic composites,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

NON-QUANTITATIVE OBJECTIVES

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

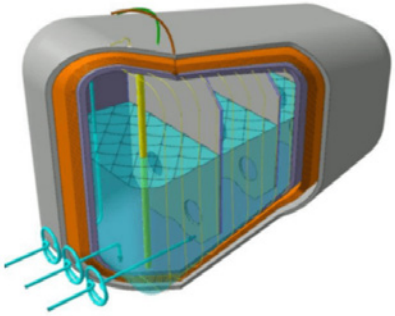
PROGRESS, MAIN ACHIEVEMENTS AND RESULTS

- Completion of preliminary critical design and manufacturing readiness level reviews of the COCOLIH$_2$T liquid hydrogen storage system.
- TRL3 development of cryogenic valves, prognostic health monitoring algorithms and liquid hydrogen fuel gauging technology.



FUTURE STEPS AND PLANS

A manufacturing readiness level review is planned, and the first demonstrator system is planned to be tested in the Netherlands Aerospace Centre in Q2. The second manufacturing demonstrator will be completed by 2026.



PROJECT TARGETS

Target source	Parameter	Unit	Target	Target achieved?
Project's own objectives	Venting rate	%/ day	< 2	
	Dormancy	hours	> 24	
	Min Operating Pressure	bar	1.5-2 (pump fed) 2-3 (pressure fed)	
	Max Operating Pressure	bar	3-4 (pump fed) 4-8 (pressure fed)	
	LH_2 Tank Capacity	kgs	57	✓

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FLAGSHIPS

CLEAN WATERBORNE TRANSPORT IN EUROPE

Project ID	826215
PRR 2026	Pillar 3 - H_2 End Uses - Transport
Call Topic	FCH-01-2-2018
Project Total Costs	6 766 811.83
Clean H_2 JU Max. Contribution	4 999 978.75
Project Period	01-01-2019 - 30-09-2026
Coordinator Beneficiary	TEKNOLOGIAN TUTKIMUSKESKUS VTT OY, FI
Beneficiaries	ABB OY, BALLARD POWER SYSTEMS EUROPE AS, SOGESTRAN, MARITIME CLEANTECH, Compagnie Fluviale de Transport, LMG MARIN AS, FUTURE PROOF SHIPPING BV, NORLED AS, PERSEE, SOGESTION, KONGSBERG MARITIME AS, SEAM AS, LMG MARIN FRANCE

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, and the Rotterdam demonstration vessel is a container vessel transporting goods between Rotterdam and Duisburg. The Rotterdam demonstrator began operations in April 2024, and the Paris demo will follow in 2026.

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.

PROGRESS, MAIN ACHIEVEMENTS AND RESULTS

- The FCwave fuel cell module has gained type approval from DNV.
- The H_2 Barge II demonstration in Rotterdam was launched and started its operation in April 2024.
- The Zulu demonstration vessel in Paris is ready and started operations in April 2026.

FUTURE STEPS AND PLANS

- Completion of the demonstration of Zulu 06 in commercial operation.
- Analysis of the results.

PROJECT TARGETS

Target source	Parameter	Unit	Target	Achieved to date by the project	Target achieved?
Project's own objectives	Develop necessary safety measures for H_2 and FC vessels to enable their class's approval	-	Class approval gained	CCNR approval gained for both vessels	✓
	Demonstrate the operation of a hydrogen-fuelled 1.2 MW power class cargo vessel in the Rotterdam-Duisburg route for at least 18 months	Months	18	21	
	Demonstrate the operation of a hydrogen-fuelled 400 kW power class self-propelled barge in the Paris area, France, for at least 18 months	Months	18	-	⚙

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H2ACCELERATE TRUCKS

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

Project ID	101101446
PRR 2026	Pillar 3 - H_2 End Uses - Transport
Call Topic	HORIZON-JTI-CLEANH$_2$-2022-03-03
Project Total Costs	128 382 980.31
Clean H_2 JU Max. Contribution	29 991 488.50
Project Period	01-02-2023 - 31-07-2030
Coordinator Beneficiary	SINTEF AS, NO
Beneficiaries	OMV DOWNSTREAM GMBH, Hyundai Hydrogen Mobility Germany GmbH, TOTALENERGIES GAS MOBILITY BV, SHELL NEDERLAND VERKOOPMAATSCHAPPIJ BV, UNION INTERNATIONALE DES TRANSPORTS ROUTIERS (IRU), FEDERAZIONE ITALIANA AUTOTRASPORTATORI PROFESSIONALI, ENVIRONMENTAL RESOURCES MANAGEMENT LIMITED, TEAL MOBILITY, UNIUNEA NATIONALA A TRANSPORTATORILOR RUTIERI DIN ROMANIA, WIRTSCHAFTSKAMMER OSTERREICH, EVERFUEL A S, LINDE GMBH, VOLVO LASTVAGNAR AB, DAIMLER TRUCK AG, DAIMLER TRUCK AG, ERM FRANCE, FIAP SERVICE SRL SOCIETA BENEFIT, HYLIKO, IVECO S.P.A., SCANIA CV AB, VOLVO TECHNOLOGY AB, TEKNOLOGIAN TUTKIMUSKESKUS VTT OY, ELEMENT ENERGY LIMITED

https://h2accelerate.eu/trucks/

PROJECT AND GENERAL OBJECTIVES

The overall project goal 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 125 fuel cell trucks weighing between 41 t and 44 t in nine European countries by the end of 2030.
- Operate the trucks on an HRS network designed for zero-emission truck deployment.
- 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, MAIN ACHIEVEMENTS AND RESULTS

The project is still in its early phase. Multiple activities have been initiated and carried out, including:

- Adaptation of manufacturing facilities to accommodate fuel cell truck production
- Preparations for homologation and type approval
- Initial OEM preparations for fleet launch

Main achievements and results so far include:

- Engagement with heavy-duty truck end-users and hydrogen refuelling station network operators
- Development and agreement of protocols for data monitoring and analysis
- Transfer of the first batch of “artificial” truck operation data to VTT for assessment
- Assessment of HSE aspects and submission of an appropriate safety plan
- Launch of the project website, LinkedIn and X (Twitter) channels
- Establishment of a dissemination and exploitation plan
- Submission of OEM annual progress reports



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PROJECT TARGETS

Target source	Parameter	Unit	Target	Target achieved?
Project's own objectives	Deployed HD Trucks' gross weight	t	> 65 % of the trucks exceeding 40 tonnes	
	Vehicle range under heavy load	km	> 400 km for compressed H_2 (350 bar) and > 600 km for compressed H_2 (700 bar)	
	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 trucks with users not on the project	Number	3	
	Dataset covering the performance of 125 trucks	Number	Shareable separate reports (including regular updates) of the technical, economic performance of and end users' attitudes to, hydrogen trucks in day-to-day operation	
	Trucks cost	€	< 450 000	
	Central and eastern European potential truck operators in end-user groups	Number	> 20	
	Vehicle availability	%	> 95	
	Green hydrogen demand created	t/year	1750	
	Data monitoring and analysis of trucks' performance.	% of deployed trucks	20 (corresponding to 25 trucks of the full fleet of 125 trucks)	
	Monitored operational period per truck	Months	24	
	Demand for electrolyser capacity created	MW	26 (assuming 50% load factor to match green supply)	
	Dedicated truck road tour visits in EU Member States.	Number of MS	5	
	Number of H_2/FC-powered HD trucks deployed	Number	125	
	Presentations at events and conferences	Number/ year	5	✓
	Visible social media and web presence	Number	2	

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H2HAUL

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

Project ID	826236
PRR 2026	Pillar 3 - H_2 End Uses - Transport
Call Topic	FCH-01-1-2018
Project Total Costs	28 110 688.98
Clean H_2 JU Max. Contribution	12 000 000.00
Project Period	01-02-2019 - 31-12-2026
Coordinator Beneficiary	ENVIRONMENTAL RESOURCES MANAGEMENT LIMITED, UK
Beneficiaries	AIR LIQUIDE ADVANCED TECHNOLOGIES SA, BAYERISCHE MOTOREN WERKE AKTIENGESELLSCHAFT, TOTALENERGIES MARKETING DEUTSCHLAND GMBH, COLRUYT GROUP, COLRUYT GROUP, IVECO S.P.A., UNION INTERNATIONALE DES TRANSPORTS ROUTIERS (IRU), ELEMENT ENERGY, DATS 24, ERM FRANCE, ELEMENT ENERGY LIMITED, FPT MOTORENFORSCHUNG AG, TEAL MOBILITY, ROBERT BOSCH GMBH, IRU PROJECTS ASBL, AIR LIQUIDE FRANCE INDUSTRIE, AIR LIQUIDE ADVANCED BUSINESS, OPMOBILITY H_2-POWER AUSTRIA GMBH, EOLY, SPHERA SOLUTIONS GMBH, FPT INDUSTRIAL S. P.A., HYDROGEN EUROPE, VDL SPECIAL VEHICLES BV, Powercell Sweden AB, H_2 ENERGY AG, HYDROGENICS GMBH, VDL ENABLING TRANSPORT SOLUTIONS BV, ELRINGKLINGER AG, WATERSTOFNET

http://www.h2haul.eu

PROJECT AND GENERAL OBJECTIVES

H_2Haul brings together two major European truck OEMs (IVECO and VDL) and three fuel cell stack/system suppliers (Plastic Omnium, Bosch and PowerCell) to develop and demonstrate fleets of heavy-duty trucks in day-to-day commercial operations 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 HRS funded by the project are expected to be deployed in the next few 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 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 European roads. Original truck OEMs are working closely with hydrogen safety experts and relevant certification bodies to secure all necessary safety approvals to operate 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 sector's commercialisation. The business case will 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 technology's costs. Analysis will be carried out to highlight the economics of a more ambitious deployment of tens of vehicles or more.
- H_2Haul aims to prepare the European market for the further roll-out of fuel cell trucks through (i) the development of innovative commercial models and (ii) the dissemination of information from the project to a wide audience of relevant stakeholders. H_2Hauls' dissemination activities will share key findings with relevant audiences to prepare the market for the wider commercial roll-out of fuel cell trucks.
- Communication activities during the first and second years of the project have generated significant interest among relevant audiences.

PROGRESS, MAIN ACHIEVEMENTS AND RESULTS

- The fuel cell truck technical specifications were finalised. Data were collected on the technical specifications of the fuel cell trucks and hydrogen refuelling stations (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 Iveco beta trucks are currently being assembled with Bosch fuel cells and will serve as prototypes for the 12 gamma trucks, which will be delivered to end users in France, Switzerland and Germany.
- The H_2Haul will continue 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	WtW CO_2 emissions	kg CO_2/km	kg CO_2/ vehicle km (per vehicle type, average across fleet)	

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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 2026	Pillar 3 - H_2 End Uses - Transport
Call Topic	HORIZON-JTI-CLEANH$_2$-2023-03-01
Project Total Costs	6 563 805.00
Clean H_2 JU Max. Contribution	4 990 769.76
Project Period	01-01-2024 - 31-12-2027
Coordinator Beneficiary	INSTITUTO TECNOLÓGICO DE ARAGÓN, ES
Beneficiaries	HIDROMEK-HYDROLIK VE MEKANIK MAKINA IMALAT SANAYI VE TICARET ANONIM SIRKETI, ASOCIACION ESPANOLA DE FABRICANTES EXPORTADORES DE MAQUINARIA PARA CONSTRUCCION, OBRAS PUBLICAS Y MINERIA, BALLARD POWER SYSTEMS EUROPE AS, Powercell Sweden AB, FUNDACION PARA EL DESARROLLO DE LAS NUEVAS TECNOLOGIAS DEL HIDROGENO EN ARAGON, ZAMALBIDESERVICE2021 SL, MANN + HUMMEL GMBH, TALLERES ZB S.A., HIDROMEK MAQUINARIA DE CONSTRUCCION ESPAÑA S.L., TAMPEREEN KORKEAKOULUSAATIO SR

https://h2mac.eu/

PROJECT AND GENERAL OBJECTIVES

In H_2MAC, two machines, an excavator and a shredder for the construction and mining sector, will be newly designed to integrate a fuel cell powertrain and the related subsystems. The selected machines will demonstrate an innovative, efficient, scalable, silent, and modular powertrain concept.

The excavator will be powered by a fuel cell system consisting of a single module rated at around 120 kW. At the same time, the shredder will scale the concept to two modules, reaching approximately 240 kW. The two machines are complementary in their operation: the excavator has a dynamic load profile linked to its movement, whereas the shredder operates under more static conditions.

At the proposal stage, a preliminary assessment of duty cycles was performed to identify the most suitable use cases and to size the systems to be developed. These early analyses help reduce project risks and support efficient resource planning.

The simultaneous 1 000-hour demonstration of both machines in a real operational environment will enable the development of solutions applicable across sectors and operating patterns, thereby strengthening the project's impact and future commercial exploitation.

The consortium brings together technology providers, component and machinery manufacturers, and associations supporting communication, dissemination, and standardisation activities.

NON-QUANTITATIVE OBJECTIVES

Zero-emission solutions for heavy-duty mobile machinery in the mining and construction sectors.

PROGRESS, MAIN ACHIEVEMENTS AND RESULTS

The main technical achievements by the end of 2025 are:

- **Robust off-road fuel cell system with horizontal stack and turbo compressor:** Development of a fuel cell system prototype for off-road applications, progressing from TRL 4 to TRL 6. The design integrates a horizontally positioned stack and turbo compressor, combining proven solutions in a new configuration. Developed in line with the StaSHH standard, the system targets robustness, extended lifetime, and strict CAPEX requirements, delivering reliable and competitive fuel cell technology for demanding environments. *(Main developer: POWERCELL)*
- **Improved cathode air filter system for heavy-duty environments:** Development of a novel combination of particle and molecular filtration, with optimised layout and design for heavy-duty fuel cell applications, progressing from TRL 4 to TRL 6. *(Main developer: MHDE)*
- **Digital twin of modular and scalable powertrain and auxiliaries:** Development of a multiphysics simulation model covering the full powertrain and auxiliary systems (fuel cell, motor, inverter, thermal systems, hydrogen components). The model enables performance prediction for H_2 fuel cell powertrains in non-road mobile machinery, supporting component sizing, integration, and optimisation of energy storage control strategies. *(Main developer: ITA)*

FUTURE STEPS AND PLANS

- Presentation of partial results of H_2MAC at the European Hydrogen Energy Conference 2026 (Seville, Spain, 13 March 2026).
- Presentation of partial results of H_2MAC at the 20th International Exhibition of Public Works, Construction and Mining Machinery (SMOPYC, Spain, 15 – 18 April 2026).
- H_2MAC General Assembly in Zaragoza, Spain (15 – 18 April 2026).

PROJECT TARGETS

Target source	Parameter	Unit	Target	Target achieved?
Project's own objectives	Noise reduction	dBA	< 100	
	New technology is feasible and commercially viable	Number/project	2	
	Emission reduction	CO_2-eq /year	0	
	FC system efficiency (TCO reduction)	%	50	

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H_2MARINE

HYDROGEN PEM FUEL CELL STACK FOR MARINE APPLICATIONS

Project ID	101137965
PRR 2026	Pillar 3 - H_2 End Uses - Transport
Call Topic	HORIZON-JTI-CLEANH$_2$-2023-03-02
Project Total Costs	7 499 171.50
Clean H_2 JU Max. Contribution	7 499 171.50
Project Period	01-01-2024 - 30-06-2027
Coordinator Beneficiary	ETHNIKO KENTRO EREVNAS KAI TECHNOLOGIKIS ANAPTYXIS, EL
Beneficiaries	Powercell Sweden AB, CLUSTER VIOOIKONOMIAS KAI PERIVALLONTOS DYTIKIS MAKEDONIAS, EH GROUP ENGINEERING SA, ZENTRUM FÜR SONNENENERGIE- UND WASSERSTOFF-FORSCHUNG BADEN-WURTTEMBERG, TEKNOLOGIAN TUTKIMUSKESKUS VTT OY, ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE, GREENERITY GMBH, ALBERT-LUDWIGS-UNIVERSITÄT FREIBURG, REINZ-DICHTUNGS GMBH, TKMS GMBH, Beyond Gravity Schweiz AG, CLEOS IDIOTIKI KEFALAIOUCHIKI ETAIREIA

https://h2marineproject.eu/

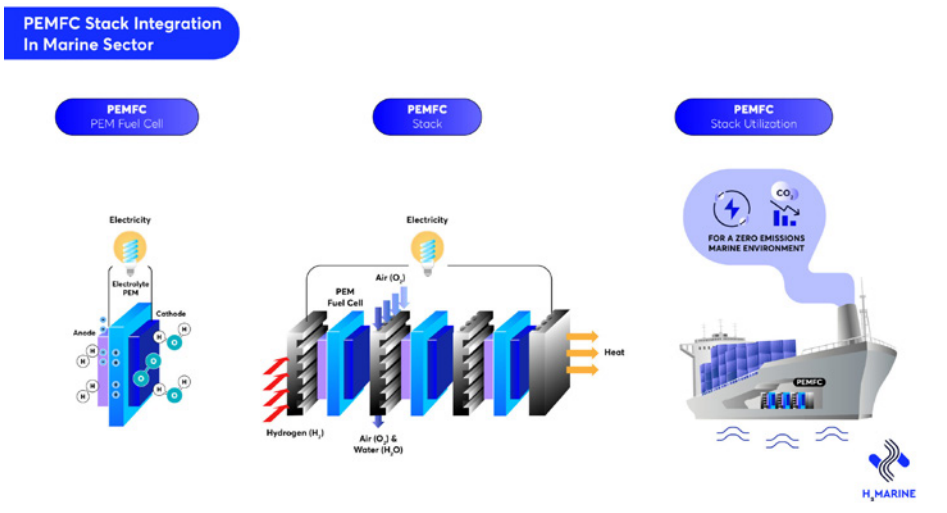
PROJECT AND GENERAL OBJECTIVES

The overarching objective of the H_2MARINE project is to design, build, test, and validate two PEM stacks generating 250-300 kW of electrical power for marine applications. The H_2MARINE project takes a top-down approach, building on a proof of concept for two PEM stacks 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 dual cell stacks will have to be tested against, using the combined knowledge of a major ship-building industry (Thyssen-Krupp Marine Systems) and ship owners (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 PEMFC stacks, and advance and scale up the system to reach ambitious targets set in the call which 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 represent actual marine conditions.
- Design the stack modules in an optimum manner for up-scaling up to 10 MW power train systems.
- Test several diagnostics for the integrity of the stack and overall system and for the health status of critical components.
- Assess the technology and economic feasibility of the solution 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

- Testing of the proposed solutions in a relevant marine environment, representative of real operational conditions.
- Design of stack modules optimised for upscaling to 10 MW systems.
- Testing of diagnostic tools for stack and system integrity monitoring, as well as health status prognosis of critical components.



PRR 2026 PILLAR
H_2 End Uses - Transport

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- Assessment of the technical, economic, and environmental feasibility of the solution to determine viable end-use applications.

PROGRESS, MAIN ACHIEVEMENTS AND RESULTS

Definition of the marine environment and operational requirements for representative marine vessels.

- Selection of three accelerated stress test (AST) procedures and proof-of-concept measurements for one selected procedure.
- Market review and acquisition of humidity, hydrogen sensors, and CVM systems to improve online diagnostics and prognostics of PEM fuel cell stacks.
- Development of air filtration and diagnostic solutions for maritime PEMFC systems.
- Literature review on stressors, degradation mechanisms, and post-mortem analysis methods for PEMFCs.
- Selection of methods, methodology, and conditions for post-mortem analysis of marine fuel cell components.
- Post-mortem analysis of fresh and degraded MEAs.
- Selection, design, and scale-up of a high-durability MEA concept with reduced PFSA content.
- Development of a large-footprint bipolar plate design for marine conditions with durable coatings.
- GDL material modifications and design optimisation, including production studies, material selection, and performance validation.
- Definition of relevant marine operating conditions for performance and durability testing at both sub-scale and stack level.
- Definition and reporting of stack integration concepts and design of PEM fuel cell stack enclosures.
- Establishment of evaluation criteria for marine multi-stack system architectures.
- Preliminary design of the fuel cell system balance of plant.
- Definition of the first LH_2 vessel case study.
- Identification of hazardous incidents for hazard analysis implementation.
- Development of methodology and requirements for hazard analysis of multi-stack architecture impacts.

FUTURE STEPS AND PLANS

- Development of two PEM fuel cell stacks with power output ≥ 250 kW and target durability ≥ 40 000 hours, validated through dedicated accelerated stress tests under maritime conditions.
- Testing of fuel cell stacks under marine-relevant environmental conditions.
- Development of advanced diagnostic and air filtration solutions, including implementation of CVM systems and additional diagnostic units.
- Design of a multi-modular stack concept enabling interconnection of 250 kW fuel cell blocks into a “superstack”, where up to four modules can be combined to form a 1 MW system treated as a single stack by the system integrator.
- Achievement of a PEM fuel cell system CAPEX target of 1 500 EUR/kW, supported by upscaling and system optimisation studies.

PROJECT TARGETS

Target source	Parameter	Unit	Target	Target achieved?
Project’s own objectives	Module Rating	kW	250	
	Hours of test for each FC	hours	2 000	

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H_2PORTS

IMPLEMENTING FUEL CELLS AND HYDROGEN TECHNOLOGIES IN PORTS

Project ID	826339
PRR 2026	Pillar 3 - H_2 End Uses - Transport
Call Topic	FCH-03-1-2018
Project Total Costs	4 117 197.50
Clean H_2 JU Max. Contribution	3 999 947.50
Project Period	01-01-2019 - 31-12-2025
Coordinator Beneficiary	FUNDACIÓN DE LA COMUNIDAD VALENCIANA PARA LA INVESTIGACIÓN, PROMOCIÓN Y ESTUDIOS COMERCIALES DE VALENCIAPORT, ES
Beneficiaries	CANTIERI DEL MEDITERRANEO S.P.A., ENAGAS SA, CENTRO NACIONAL DE EXPERIMENTACIONDE TECNOLOGIAS DE HIDROGENO Y PILASDE COMBUSTIBLE CONSORCIO, UNIVERSITA DEGLI STUDI DI NAPOLI PARTHENOPE, SCALE GREEN ENERGY S L, HYSTER-YALE NEDERLAND BV, GRIMALDI EUROMED S.P.A., UNIVERSITA DEGLI STUDI DI SALERNO, BALLARD POWER SYSTEMS EUROPE AS, ATENA SCARL - DISTRETTO ALTA TECNOLOGIA ENERGIA AMBIENTE, SOCIEDAD ESPANOLA DE CARBUROS METALICOS SA, MEDITERRANEAN SHIPPING COMPANY TERMINAL VALENCIA SA, AGENZIA NAZIONALE PER LE NUOVE TECNOLOGIE, L'ENERGIA E LO SVILUPPO ECONOMICO SOSTENIBILE, AUTORIDAD PORTUARIA DE VALENCIA, VALENCIA TERMINAL EUROPA SA

https://h2ports.eu/

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 daily during real operational activities at the Port of Valencia. The required hydrogen will be supplied via a mobile hydrogen refuelling station (HRS) designed and built during the project.

NON-QUANTITATIVE OBJECTIVES

- The project aims to disseminate H_2 technologies to the port and maritime sector. This goal has been achieved by organising the stakeholder advisory group.
- H_2Ports will gather information on the use of H_2 in port environments.
- H_2Ports will gather information on the use of H_2 as fuel for vessels.

PROGRESS, MAIN ACHIEVEMENTS AND RESULTS

Both the reach stacker and yard tractor have been commissioned.

FUTURE STEPS AND PLANS

It is envisaged that the two applications (reach stacker and 4 x 4 terminal tractor) will undergo a two-year pilot under normal operating conditions.

PROJECT TARGETS

Target source	Parameter	Unit	Target	Target achieved?
Project's own objectives	Amount of H_2 dispensed	kg/day	60	
	Tank to wheel efficiency	%	50	
	Hydrogen storage cost	€/kg	650	
	HRS daily capacity	kg/day	60	
	Reach stacker vehicle Power	kW	90	
	Vehicle Power	kW	70	
	Noise level	dBa	< 60	
	Specific maintenance cost	€/output	TBD	
	Hydrogen refuelling time	minutes	< 30	
	Vehicle over cost (target percentage over CNG and diesel port trucks)	%	100	
	Cost of fuel cell system	€/kW	3 500	
	Duration of the testing period	hours-years	5 000-2	
	Total installed power of the FC system	kW	175-205 (225-285)	
	HRS-specific maintenance cost	€/kg	1	
	HRS CAPEX	€	575 000	

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H_2UPSCALE

HIGH-POWER HYDROGEN FUEL CELL SYSTEM BALANCE OF PLANT COMPONENT UP-SCALE AND OPTIMISATION

H2UpScale

Project ID	101192481
PRR 2026	Pillar 3 - H_2 End Uses - Transport
Call Topic	HORIZON-JTI-CLEANH$_2$-2024-03-02
Project Total Costs	3 998 498.77
Clean H_2 JU Max. Contribution	3 998 498.77
Project Period	01-01-2025 - 31-12-2027
Coordinator Beneficiary	NEDERLANDSE ORGANISATIE VOOR TOEGEPAST NATUURWETENSCHAPPELIJK ONDERZOEK TNO, NL
Beneficiaries	FEV EUROPE GMBH, PANKL TURBOSYSTEMS GMBH, CUMMINS LTD, COVENTRY UNIVERSITY, MANN+HUMMEL INNENRAUMFILTER GMBH and CO. KG, STICHTING KONINKLIJK NEDERLANDS LUCHT - EN RUIMTEVAARTCENTRUM, CUMMINS ELECTRIFIED POWER EUROPE LTD., MANN + HUMMEL GMBH, Infineon Technologies Romania and CO. Societate in Comandita Simpla, RHEINISCH-WESTFAELISCHE TECHNISCHE HOCHSCHULE AACHEN, FEV CONSULTING GMBH,FORD OTOMOTIV SANAYI ANONIM SIRKETI, DAMEN RESEARCH DEVELOPMENT and INNOVATION BV, HYDROGENICS GMBH, ACONDICIONAMIENTO TARRASENSE ASOCIACION

https://h2upscale.eu/

PROJECT AND GENERAL OBJECTIVES

H_2UpScale develops next-generation high-power PEM fuel cell technology by advancing key Balance-of-Plant (BoP) components and scalable system architectures for power levels above 250 kW. The project designs, builds, and validates high-performance components, including hydrogen recirculation devices, air management units, thermal management systems, and sensors tailored for heavy-duty applications. By addressing efficiency, durability, weight, and integration challenges, H_2UpScale supports the deployment of robust fuel cell systems for long-haul road transport, maritime vessels, and aviation platforms. The project brings together leading European research organisations, universities, and industry partners to accelerate the transition to clean, high-power hydrogen mobility.

Specific objectives:

- Definition of three standards for modular and scalable PEMFC architectures ≥ 250 kW, based on holistic optimisation of electrical power supply architectures and waste heat management system designs.
- Development of efficient upscaled BoP components optimised for PEMFC systems ≥ 250 kW.
- Enhancement of BoP component durability.
- Development of modular and scalable BoP components compatible with single- and multi-stack platforms.
- Validation of BoP component durability under application-specific load cycles for heavy-duty use cases.
- Techno-economic assessment of the impact of developed BoP components on heavy-duty markets.



NON-QUANTITATIVE OBJECTIVES

The overarching objective of the H_2UpScale project is to design, build, test, and validate key Balance-of-Plant (BoP) components for high-power PEM fuel cell systems suitable for a range of transport-related applications.

The targeted advancements for BoP components include improved efficiency, reduced weight and volume, and simplified system architecture. The components are designed to meet end-user requirements and to support both single- and multi-stack platforms, with scalability and modularity as key principles, enabling integration into multi-megawatt systems.

Through these developments, H_2UpScale aims to provide the critical technological building blocks required to create a TRL 7 demonstrator from 2027 onwards.

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H2UpScale

PROGRESS, MAIN ACHIEVEMENTS AND RESULTS

The project has made strong technical progress in its first year. The consortium defined the key performance and application requirements for designing next-generation fuel cell systems and their supporting components. Building on this foundation, the electrical and thermal requirements of upscaled fuel cell architectures were analysed, and system models for both stationary and mobile applications were initiated.

Work on the hydrogen loop has advanced through a detailed assessment of the components required for safe and efficient hydrogen recirculation. In parallel, air supply activities focus on compressors, filters, and other air-loop components, with an emphasis on scalability and modularity across multiple use cases.

Together, these activities are establishing a coherent technical basis for the development and integration of future high-power fuel cell systems.

FUTURE STEPS AND PLANS

The next phase of the project will focus on several key technical developments across the fuel cell system. The project team will refine the electrical and thermal architecture of the upscaled fuel cell system to ensure that power delivery and heat management support higher performance levels.

System-level modelling will be expanded to include both stationary and transient fuel cell models, together with hybrid energy management strategies that enable scalable operation across different applications. Work on the hydrogen loop will advance by optimising the recirculation pump, ejector, and leakage-detection sensors to improve efficiency and safety.

In parallel, the air supply subsystem will be developed using modular concepts for the water separator, air filter, humidifier, and compressor, supported by early health-monitoring software. Additional activities will include simulation-based optimisation of the hydrogen dissipator and coolant pathways, as well as the commissioning and use of a hardware-in-the-loop test bench to validate Balance-of-Plant components under realistic operating conditions.

PROJECT TARGETS

Target source	Parameter	Unit	Target	Target achieved?
Project's own objectives	Gravimetric power density	kW/kg	1.5	
	System electrical efficiency @ peak power	%	50	

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HIGHLANDER

HIGH PERFORMING ULTRA-DURABLE MEMBRANE ELECTRODE ASSEMBLIES FOR TRUCKS

Project ID	101101346
...26	Pillar 3 - H_2 End Uses - Transport

Project ID	101101346
Call Topic	HORIZON-JTI-CLEANH$_2$-2022-03-02
Project Total Costs	3 331 247.50
Clean H_2 JU Max. Contribution	3 331 247.50
Project Period	01-01-2023 - 31-12-2025
Coordinator Beneficiary	CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE CNRS, FR
Beneficiaries	ELMARCO SRO, UNIVERSITE DE MONTPELLIER, SYENSQO LABORATOIRE DU FUTUR SAS, SPECIALTY OPERATIONS FRANCE, SYENSQO SPECIALTY POLYMERS ITALY S.P.A., ROBERT BOSCH GMBH, TECHNISCHE UNIVERSITAT BERLIN, FORSCHUNGSZENTRUM JULICH GMBH, JOHNSON MATTHEY PLC, RHODIA OPERATIONS, PRETEXO, JOHNSON MATTHEY HYDROGEN TECHNOLOGIES LIMITED

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 design, fabricate, and validate the HDV MEAs at the cell and short-stack levels against heavy-duty-relevant accelerated stress and load-profile test protocols. Materials screening efforts will be supported by the development and use of improved predictive degradation models that bridge scales from reaction sites to the cell level. Model parameterisation is implemented using experimental characterisation data at the materials, component, and cell levels. HIGHLANDER aims to achieve a significant reduction in stack cost and fuel consumption by improving catalyst-coated membrane performance and developing a new, lower-cost single-layer gas diffusion layer. It also aims to achieve the 1.2 W/cm^2 at 0.65 V performance target at 0.3 g Pt/kW or less, meeting a lifetime target of 20 000h. Sustainability considerations include benchmarking fluorine-free membranes for HDV MEA application and the reuse of platinum in the context of a circular economy.

NON-QUANTITATIVE OBJECTIVES

HIGHLANDER has launched a website, published two annual newsletters, disseminated results through 14 conference presentations (with 4 additional presentations planned), and published 9 journal articles to date. A project workshop has been organised.

PROGRESS, MAIN ACHIEVEMENTS AND RESULTS

Libraries of novel ordered intermetallic electrocatalysts for the oxygen reduction reaction at the fuel cell cathode were prepared and characterised ex situ and in situ for activity and durability using internationally recognised accelerated stress test protocols. Cathode catalyst layers were developed, showing reduced voltage decay rates in single-cell testing under AST conditions and improved tolerance to multiple (air–air) start-up cycles compared to the project baseline.

Polymer nanofibre-reinforced perfluoro sulfonic acid membranes were fabricated on a development coating line, demonstrating target performance and durability properties. In parallel, three generations of novel sulfonated hydrocarbon ionomers were developed and benchmarked against reference perfluoro sulfonic acid membranes.

A physics-based modelling framework for predicting PEM fuel cell performance and degradation over lifetime was developed and validated, fully coupling electrochemical, structural, and transport phenomena across multiple scales, from catalyst particles to full membrane electrode assemblies.

A new low-cost single-layer gas diffusion layer for both anode and cathode was developed. Manufactured with fewer, less expensive process steps and optimised material selection and pore structure, it demonstrates benchmark performance of up to 2 A/cm² under relevant conditions.

Final full-size cell catalyst-coated membranes were manufactured using a volume-manufacturing-compatible process, incorporating upscaled catalyst and membrane materials, along with a low-cost GDL. These were tested in a short stack using a 500-hour accelerated stress test protocol correlated with a load profile developed in the IMMORTAL project.

The HIGHLANDER MEA achieved 96% of the final performance target (1.16 W/cm² at 1.85 A/cm²), with a catalyst loading of 0.26 g Pt/kW—approximately a factor of two lower than the 0.5 g Pt/kW baseline requirement. The observed degradation enables a lifetime prediction exceeding 20 000 hours.

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Overall, the HIGHLANDER project successfully meets its KPIs for performance, precious metal group (PGM) loading, and durability, aligned with the 2022 work programme and SRIA low-TRL targets for heavy-duty vehicle applications.

FUTURE STEPS AND PLANS

The project was completed on 31/12/2025, achieving all KPIs and the objectives of the 2022 Annual Work Programme and the SRIA 2024 low-TRL targets.

PROJECT TARGETS

Target source	Parameter	Unit	Target	Achieved to date by the project	Target achieved?
Project's own objectives	Durability	hours	20 000	Predicted lifetime >30 000 hours based on 500 hours of accelerated stress testing on full-size short stacks	✓

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JIVE 2

JOINT INITIATIVE FOR HYDROGEN VEHICLES ACROSS EUROPE 2

Project ID	779563
PRR 2026	Pillar 3 - H_2 End Uses - Transport
Call Topic	FCH-01-5-2017
Project Total Costs	86 926 760.59
Clean H_2 JU Max. Contribution	25 000 000.00
Project Period	01-01-2018 - 30-06-2025
Coordinator Beneficiary	ENVIRONMENTAL RESOURCES MANAGEMENT LIMITED, UK
Beneficiaries	REGIONALVERKEHR KOLN GMBH, TRANSPORTS DE BARCELONA SA,MESSER SE and CO. KGAA, RHEINSCHE BAHNGESSELLSCHAFT AKTIENGESELLSCHAFT, ELEMENT ENERGY, BRIGHTON and HOVE BUS AND COACH COMPANY LIMITED, NOORD-BRABANT PROVINCIE, HYDROGEN EUROPE, WSW MOBIL GMBH, CA DE L'AUXERROIS, Provincie Zuid-Holland, REBELGROUP ADVISORY BV, MESTNA OBCINA VELENJE, OBCINA SOSTANJ, HYPORT, SPHERA SOLUTIONS GMBH, TRANSDEV OCCITANIE OUEST, RUTER AS, UNION INTERNATIONALE DES TRANSPORTS PUBLICS, ZEROBUS OU, ERM FRANCE, ERM FRANCE, VATGAS SVERIGE IDEELL FORENING,DMT ENERGY ENGINEERS GMBH, CONNEXXION VLOOT BV, TWYNSTRA GUDDE MOBILITEIT and INFRASTRUCTUUR BV, OPENBAAR LICHAAM OV-BUREAU GRONINGEN EN DRENTHE, STRAETO BS, KOLDING KOMMUNE, DUNDEE CITY COUNCIL, LANDSTINGET GAVLEBORG, ELEMENT ENERGY LIMITED, PAU BEARN PYRENEES MOBILITES, SOCIETE PUBLIQUE LOCALE D'EXPLOITATION DES TRANSPORTS PUBLICS ET DES SERVICES A LA MOBILITE DE L'AGGLOMERATION PALOISE, RIGAS PASVALDIBAS SABIEDRIBA AR IEROBEZOTU ATBILDIBU RIGAS SATIKSME, ENGIE ENERGIE SERVICES, PETROGAL SA, CONNEXXION OPENBAAR VERVOER NV

https://www.fuelcellbuses.eu/

PROJECT AND GENERAL OBJECTIVES

The objective of the JIVE 2 project, together with its sister project JIVE, is to accelerate the large-scale commercialisation of fuel cell buses across Europe. A total of 157 fuel cell buses (FCBs) were planned for deployment across 11 locations. Combined, the two projects aim to deploy nearly 300 fuel cell buses at 16 sites, representing the largest deployment of its kind 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.
- JIVE 2 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 to monitor discussions and best practices emerging from the project. This will ensure continued momentum for FCB uptake in Europe beyond the project.
- JIVE 2 aims to deliver positive environmental impacts by operating FCBs for extended periods. As per the project's objective, all buses deployed thus far are diesel-powered. This means that the buses will lead to CO_2 abatement and will not simply operate as a 'visible extra'.

PROGRESS, MAIN ACHIEVEMENTS AND RESULTS

- All 157 fuel cell buses (FCBs) were delivered and deployed, with an additional two buses procured and deployed in the final project phase.
- As of March 2025, the JIVE 2 buses have collectively travelled more than 14 million km.



- Fuel consumption performance exceeded project targets, with standard buses recording between 5.8 and 8.3 kg/100 km (target: <9 kg/100 km), and articulated buses achieving an average below 9 kg/100 km (target: <14 kg/100 km).
- Seven sites have been operating FCBs for more than three years, demonstrating long-term operational capability.
- Jelgava joined as a new demonstration site following participation in an FCB Roadshow under the "Stimulating Further Demand" activities. After the initial deployment, the city placed an additional FCB order.
- Hydrogen infrastructure continued to expand across partner regions, supporting further growth of FCB fleets.
- Extensive dissemination activities were carried out across Europe and internationally, including FCB Roadshows, participation in major events such as European Hydrogen Week, and workshops such as "Hydrogen Solutions for European Cities: Learnings

- from JIVE II and REVIVE for Future Buses and Trucks" (November 2024), as well as presence at the 6th edition of the European ZEB Conference (October 2025).

FUTURE STEPS AND PLANS

- Continued operation of the buses beyond the project's completion, with expected further expansion of fuel cell bus fleets and hydrogen refuelling station (HRS) networks across several sites.
- Implementation of activities to retain and capitalise on project knowledge, including the creation of a digital platform to store key reports and data, the development of speaker briefs for consortium members, and the production of a short video highlighting the JIVE projects.

PROJECT TARGETS

Target source	Parameter	Unit	Target	Achieved to date by the project	Target achieved?
Project's own objectives	Vehicle operational lifetime	years	8	-	
	Distance travelled	km/year/bus	> 50 000	11 583 km (This corresponds to 6 months, as the project ended in June 2025)	
	Operating hours per fuel cell system	hours/bus	> 20 000	945 (Only data for 0.5 years and no available from several sites).	
	Availability	%	> 90	84.2	
	Efficiency	%	> 42	-	
	Specific fuel consumption	kg/100km/bus	< 9.0	7.9	✓
	Vehicle CAPEX	€	< 625 000	-	
	Vehicle OPEX	€	max. 100% more than the diesel bus OPEX	-	
	Mean time (distance) between failures (MDBF)	km/bus	> 3500	19 469	

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MEASURED

ADVANCED MEAS ENSURING HIGH EFFICIENCY HDV

Project ID	101101420
PRR 2026	Pillar 3 - H_2 End Uses - Transport
Call Topic	HORIZON-JTI-CLEANH$_2$-2022-03-02
Project Total Costs	2 989 060.00
Clean H_2 JU Max. Contribution	2 989 060.00
Project Period	01-06-2023 - 31-05-2026
Coordinator Beneficiary	ADVANCED ENERGY TECHNOLOGIES AE EREUNAS and ANAPTYXIS YLIKON and PROIONTONANANEOSIMON PIGON ENERGEIAS and SYNAFON SYMVOULEFTIKON Y PIRESION, EL
Beneficiaries	UNIVERSITY OF STUTTGART, UNIVERSITAT POLITECNICA DE VALENCIA, UNIVERZA V LJUBLJANI, HONEYWELL INTERNATIONAL SRO, AVL LIST GMBH, TECHNISCHE UNIVERSITAET GRAZ, AVL-AST NAPREDNE SIMULACIJSKE TEHNOLOGIJE DOO

https://measured-horizon.eu/

PROJECT AND GENERAL OBJECTIVES

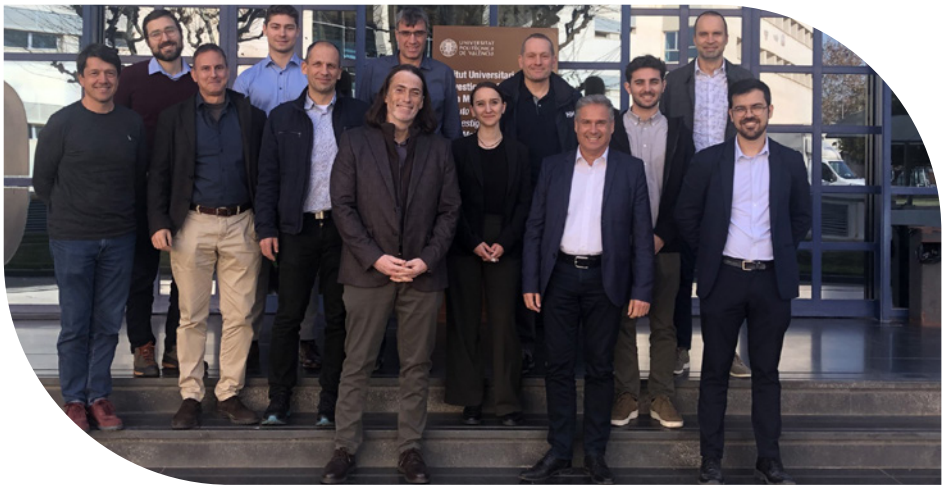
MEAsureD aims to advance High-Temperature membrane electrode assemblies (MEAs) for heavy-duty vehicles. The focus is on the development of a cost-effective MEA that operates above 160 °C, features minimal phosphoric acid uptake, and maintains a stable porous ionomer microstructure, combined with novel platinum-based catalysts. The MEA will be integrated into a short stack, and its performance will be evaluated against the project's key performance indicators. In parallel, fuel cell stack integration will be validated under heavy-duty vehicle conditions to ensure operational reliability. The project will also define optimal configurations for balance-of-plant components tailored to high-temperature proton exchange membranes (HT-PEM) systems. Beyond automotive applications, the potential of fuel cell technology will be explored for use in the aviation, maritime, and rail sectors. To support these efforts, advanced digital tools will be developed for system design and performance monitoring, including simulations of flow field behaviour and degradation mechanisms. In addition, MEAsureD will develop design and monitoring modelling and simulation tools and carry out testing, harmonisation, and standardisation-related activities. Finally, MeasureD will conduct an environmental assessment of the fuel cell manufacturing process, with a focus on cost reduction and improved recycling of waste materials.

NON-QUANTITATIVE OBJECTIVES

- Ensure innovation and collaboration among project partners to advance the MEA's technical development.
- 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.
- Check and promote sustainability and economic viability, integrating environmental and economic assessments to guide decision-making and promote responsible innovation.
- Enhance the project's visibility and impact through strategic communication and dissemination efforts, engaging stakeholders and fostering dialogue to maximise the project's reach and influence.
- Implement project management practices, promoting efficiency, transparency and accountability to ensure smooth project execution and the timely achievement of milestones.

PROGRESS, MAIN ACHIEVEMENTS AND RESULTS

During the first nine months of the project, key foundations have been established to support



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efficient implementation and coordination. Project management structures and quality procedures have been defined, including monthly meetings for each work package to ensure steady progress.

Significant progress has been achieved in communication, dissemination, and exploitation activities, including the development of the project website, social media channels, newsletters, booklets, and promotional materials, as well as the definition of the Communication, Dissemination, and Exploitation Plan.

Key deliverables submitted to date include:

- **Requirements and KPIs for polymer membranes** for high-temperature fuel cells for aerospace applications.
- **Requirements for heavy-duty fuel cell electric vehicle (FCEV) system architecture**, including performance, lifetime, component sizing, and characterisation.
- **Project communication and dissemination outputs**, including:
  - Project logo and visual identity
  - Website and social media presence
  - Project newsletter
  - Promotional materials
  - Communication, dissemination, and exploitation plan
- **Project management and governance documents**, including:
  - Project Management Handbook
  - Quality Management Plan
  - Risk Management Plan
  - Data Management Plan

FUTURE STEPS AND PLANS

- Continued advancement of MEA development (membrane and electrode) and single-cell assembly through experimental work and rigorous testing to optimise performance.
- Development of digital models to simulate the behaviour of the innovations, supporting design optimisation and performance prediction.
- Execution of vehicle-level simulations to assess system integration and overall performance in real application contexts.
- Conduct of environmental and techno-economic assessments to evaluate impact, recyclability, and manufacturing costs, supporting informed decision-making.
- Further development and refinement of communication, dissemination, and exploitation activities to maximise project visibility and impact.
- Ongoing project management to ensure adherence to timelines, efficient resource allocation, and achievement of project objectives.

PROJECT TARGETS

Target source	Parameter	Unit	Target	Target achieved?
Project's own objectives	Fuel Cell stack cost	€/kW	< 75	
	Power density	W/cm²	1.2 W/cm² @ 0.65 V	
	Stack durability	hours	20 000	
	PGM loading for low TRL	g/kW	< 0.30	
	MEA operating in a temperature > 160 °C with minimum PA uptake and stable porous microstructure ionomer	°C	> 160 °C preferentially > 200 °C	✓

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MORELIFE

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

Project ID	101007170
PRR 2026	Pillar 3 - H_2 End Uses - Transport
Call Topic	FCH-01-2-2020
Project Total Costs	3 288 941.24
Clean H_2 JU Max. Contribution	3 499 913.75
Project Period	01-09-2021 - 28-02-2025
Coordinator Beneficiary	AVL LIST GMBH, AT
Beneficiaries	UNIVERZA V LJUBLJANI, TECHNISCHE UNIVERSITEIT EINDHOVEN, EKPO FUEL CELL TECHNOLOGIES GMBH, MEBIUS, RAZISKOVALNO RAZVOJNA DEJAVNOST, ZASTOPANJE IN TRGOVINA, DOO, TECHNISCHE UNIVERSITAET MUENCHEN, NEDSTACK FUEL CELL TECHNOLOGY BV

https://morelife-info.eu/

PROJECT AND GENERAL OBJECTIVES

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

- Perform accelerated stress tests for the shortened test duration for lifetime verification.
- Make improvements at the material and operation strategy levels.
- Create advanced degradation models.
- Find the optimal operating conditions and validate them based on the improved materials.
- Achieve a predicted lifetime for fuel cells of 30 000 hours.

PROGRESS, MAIN ACHIEVEMENTS AND RESULTS

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

FUTURE STEPS AND PLANS

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

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NAVHYS

LH_2 STORAGE AND FUEL SYSTEM BELOW DECK, INTEGRATED IN A SERVICE OPERATING VESSEL

Project ID	101192425
PRR 2026	Pillar 3 - H_2 End Uses - Transport
Call Topic	HORIZON-JTI-CLEANH$_2$-2024-03-03
Project Total Costs	4 999 047.28
Clean H_2 JU Max. Contribution	4 999 049.00
Project Period	01-01-2025 - 31-12-2027
Coordinator Beneficiary	ARIANEGROUP GMBH, DE
Beneficiaries	THE UNIVERSITY OF BIRMINGHAM, GAS AND HEAT S.P.A., BENKEI, BUREAU VERITAS MARINE and OFFSHORE REGISTRE INTERNATIONAL DE CLASSIFICATION DE NAVIRES ET DE PLATEFORMES OFFSHORE, ACONDICIONAMIENTO TARRASENSE ASSOCIACION, NORTH STAR SHIPPING (ABERDEEN) LIMITED, ENGIE, RISE RESEARCH INSTITUTES OF SWEDEN AB, VARD DESIGN AS, INSTITUT NATIONAL DE L ENVIRONNEMENT INDUSTRIEL ET DES RISQUES - INERIS, ARIANEGROUP SAS, MARITIMES CLUSTER NORDDEUTSCHLAND EV, EUROPEAN RESEARCH INSTITUTE FOR GAS AND ENERGY INNOVATION

https://navhys.eu/



PROJECT AND GENERAL OBJECTIVES

NavHyS is a European initiative aiming to demonstrate the feasibility, safety, and performance of liquid hydrogen (LH_2) as a zero-emission fuel for maritime applications. The project focuses on the design of a Service Operation Vessel (SOV) integrating a below-deck LH_2 storage tank (200–300 m³) and an advanced fuel distribution system to enable long-duration offshore missions.

The project aims to design a zero-emission vessel with more than 10 days of autonomy, and to develop and validate a next-generation LH_2 fuel system, including pumps, distribution architecture, buffer tanks, and safety systems. In parallel, NavHyS will establish a high-performance LH_2 supply chain and bunkering solution capable of high flow rates with minimised energy consumption and boil-off.

Key objectives also include ensuring compliance with maritime safety regulations through comprehensive risk assessments and Approval in Principle (AIP), as well as evaluating environmental, economic, and operational performance through LCA, TCO, and system modelling. The project will further define scaling pathways for larger vessels and other heavy-duty sectors, while supporting standardisation, dissemination, and market uptake of hydrogen technologies in maritime transport.

NON-QUANTITATIVE OBJECTIVES

- Safety, risk, and regulatory compliance: Conduct HAZID and risk analyses, improve risk methodologies, ensure compliance with maritime regulations (MSC.1/Circ.1455, IGF Code, SOLAS), and obtain Approval in Principle (AIP) for LH_2 systems and vessel integration.
- Environmental and sustainability assessment: Perform LCA and techno-economic analyses of the LH_2 value chain and develop guidelines to reduce boil-off losses and improve sustainability.
- Economic and market uptake: Assess CAPEX, OPEX, and TCO, evaluate feasibility, and explore business models for LH_2 maritime deployment.
- Scaling and spill-over: Define scale-up pathways for larger vessels and assess applications in other sectors (road, rail, aviation, offshore).
- Dissemination, communication, and standardisation: Carry out dissemination activities, support standardisation, and engage with industry and advisory bodies.
- Social acceptance and stakeholder engagement: Promote acceptance, engage stakeholders, and assess societal readiness.
- Knowledge transfer and capacity building: Develop training, strengthen academia–industry links, and support workforce development.

PROGRESS, MAIN ACHIEVEMENTS AND RESULTS

The project has made strong progress, with all key tools, processes, and governance structures established and operational. Coordination is ensured through regular consortium and management meetings, and the External Advisory Board has been set up with all required NDAs in place. Minor delays have occurred, but no critical issues are expected.

In ship operations, high-level requirements have been validated, supported by nearly one year of operational data analysis. The Life Cycle Assessment (LCA) framework has also been defined and validated.

In the LH_2 supply chain, the full system design and bunkering station requirements have been completed, with support from initial modelling and boil-off analysis.

The conceptual ship design has advanced with the general arrangement, hydrogen system requirements, and 3D ship render completed. The preliminary design of the LH_2 storage system is also finalised, including two 97.5 m³ tanks and associated structural, insulation, and boil-off studies.

The LH_2 fuel system design has completed its first phase, including concept definition, trade-off analysis, and selection of a reference architecture based on safety and operational criteria.

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Communication and dissemination activities are progressing well, with over 72 000 website visits and 224 000 views, strong social media engagement, participation in 22 events, 16 publications, and the creation of a dedicated LH_2 topic group through clustering activities.

FUTURE STEPS AND PLANS

During the next phase of the project, NavHyS will move from preliminary design and framework definition to consolidation, validation, and preparation of key technical deliverables and the associated approval processes. Activities will focus on maturing LH_2 technologies (tank, fuel system, and bunkering station), finalising initial ship integration studies, strengthening safety analyses, and continuing communication and dissemination efforts.

PROJECT TARGETS

Target source	Parameter	Unit	Target	Target achieved?
Project's own objectives	Ship power train efficiency	%	≥ 50 (vs LH_2 chemical energy)	
	Operational autonomy	Days	≥ 10	
	Delivered GH_2 quality	% GH_2	≥ 99.99	
	Boil-Off Gas (BOG) losses	%	< 2	
	Station energy consumption	kWh/kg	< 0.6	
	Station LCOH contribution	€/kg	< 1.5	
	Bunkering flow	t H_2/h	≥ 10	
	Supply high-quality H_2	% H_2	> 99.99	
	Conceptual SOV design below deck LH_2 tank capacity	m³	200 – 300	
	Power	MW/kW	2 MW (max)/ 1 MW (nominal) / 550 kW (idle)	
	Carrying capacity	t of LH_2	12 - 18	
	Max pressure	bar	≤ 5 (option 3–4 is considered)	
	BOR	%/day	< 1	
	System volumetric capacity	g H_2/L	60 (incl. voids exceeds SRIA 2030 target 45 g/L)	
	CAPEX	€/kg H_2	250 – 300	
	Output GH_2	bar	5 bar, ambient T° (FC baseline ICE/gas turbine compatible)	
	Flow	g/s	33 g/s max 17 g/s nominal 9 g/s idle (≥ 30 kg H_2/h minimum supply)	
	H_2 quality (distribution level)	% H_2	≥ 99.99	
	TRL of the fuel tank	-	6	
	TRL of the fuel distribution system	-	6	
	H_2 quality (prototype level)	% H_2	> 99.99	
	Quantified H_2 loss-of-containment scenarios	scenarios	≥ 5 (frequency × consequence)	

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NIMPHEA

NEXT GENERATION OF IMPROVED HIGH TEMPERATURE MEMBRANE ELECTRODE ASSEMBLY FOR AVIATION

Project ID	101101407
PRR 2026	Pillar 3 - H_2 End Uses - Transport
Call Topic	HORIZON-JTI-CLEANH$_2$-2022-03-08
Project Total Costs	4 942 898.50
Clean H_2 JU Max. Contribution	4 942 898.50
Project Period	01-01-2023 - 31-12-2026
Coordinator Beneficiary	SAFRAN POWER UNITS, FR
Beneficiaries	UNIVERSITÉ DE STRASBOURG, CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE CNRS, COMMISSARIAT À L'ÉNERGIE ATOMIQUE ET AUX ÉNERGIES ALTERNATIVES, SAFRAN SA, FRAUNHOFER GESELLSCHAFT ZUR FÖRDERUNG DER ANGEWANDTEN FÖRSCHUNG EV, ADVANCED ENERGY TECHNOLOGIES AE EREUNAS and ANAPTYXIS YLIKON and PROIONTONANANEOSIMON PIGON ENERGEIAS and SYNAFON SYMVOULEFTIKON Y PIRESION, Fundación IMDEA Energía

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 developed MEA will operate above 120°C, thereby overcoming 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 performance of the new-generation MEA developed at TRL4.
- Evaluate and validate the suitability of the new-generation MEA by performing a complete life-cycle assessment.

PROGRESS, MAIN ACHIEVEMENTS AND RESULTS

- 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. The first generation of NIMPHEA MEAs has been produced and tested.
- The expected results have not been achieved; however, less platinum has been used in the catalysts compared to the project's state-of-the-art.
- Components have been identified for the second-generation MEA, which shows an increasing performance at the lab scale.

FUTURE STEPS AND PLANS

- Assembly and characterisation of the second-generation MEA.
- Development of the third-generation MEA components.
- Maturation of the LCA model.

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	Power density (nominal conditions)	W/cm^2	0.75	0.13 (160°C, 0.75V)		0.1 W/cm^2 (160°C, 0.65V)	2024
	Power density (optimal conditions)	W/cm^2	1.25	0.3 (180°C, 0.5V)		0.29 W/cm^2 (180°C, 0.5V)	2024
	Degradation rate	µV/h	3-5	-			
	Membrane uniformity (thickness)	%	± 7	-		N/A	N/A
	GDE uniformity (PGM variation)	%	± 5	1.7			

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PEMTASTIC

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

PEMTASTIC

Project ID	101101433
PRR 2026	Pillar 3 - H_2 End Uses - Transport
Call Topic	HORIZON-JTI-CLEANH$_2$-2022-03-02
Project Total Costs	2 748 608.75
Clean H_2 JU Max. Contribution	2 998 608.50
Project Period	01-02-2023 - 30-11-2026
Coordinator Beneficiary	DEUTSCHES ZENTRUM FÜR LUFT- UND RAUMFAHRT E. V., DE
Beneficiaries	Heraeus Precious Metals GmbH and Co. KG, COMMISSARIAT A L ENERGIE ATOMIQUE ET AUX ENERGIES ALTERNATIVES, IRD FUEL CELLS A/S, CHEMOURS FRANCE SAS, IMERYS GRAPHITE and CARBON SWITZERLAND SA, CHEMOURS BELGIUM, THE Mobility F.C. Membranes Company GmbH - A BWT Chemours Company, THE CHEMOURS COMPANY FC, LLC, ZURCHER HOCHSCHULE FUR ANGEWANDTE WISSENSCHAFTEN, IMERYS GRAPHITE and CARBON BELGIUM, SYMBIO FRANCE

https://pemtastic-project.eu/

PROJECT AND GENERAL OBJECTIVES

PEMTASTIC aims to tackle the key technical challenges to increase the durability of membrane electrode assemblies (MEAs) for heavy-duty applications. These challenges are addressed through 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 high temperatures (105 °C). The quantitative targets correspond to a durability of 20 000 hours, maintaining a state-of-the-art power density of 1.2 W/cm^2 at 0.65 V at a Pt loading of 0.30 g/kW.

NON-QUANTITATIVE OBJECTIVES

- Definition of fuel cell operation protocols and cycling tests for heavy-duty applications.
- Definition of operational strategy for high fuel efficiency.
- Parametrisation of degradation models to predict MEA lifetime and identify specific improvements of the CCM and its components.
- Development of a robust catalyst (Pt/C) support deposition process for oxygen reduction reaction catalysts.
- Development of membrane and ionomer for operation at high temperature.
- Catalyst layers and CCM with increased durability and state-of-the-art performance tailored for heavy-duty operation.
- Dissemination and promotion of project results, through ad-hoc strategies, through target groups and key stakeholders and definition of an exploitation strategy of the PEMTASTIC outcomes.

PROGRESS, MAIN ACHIEVEMENTS AND RESULTS

- Definition of protocols for testing of materials, as well as single cells and stacks, made available to other projects.
- Development of a multiscale modelling approach to predict cell performance and degradation processes from the mesoscale to the single-cell level, including identification of required characterisation data for model parametrisation.
- Definition of a dataset for the parametrisation of degradation models.
- Implementation and validation of testing protocols to ensure reproducibility among testing partners.
- Application of the PEMTATIC HD load cycle to Gen0, Gen1, and Gen2 MEAs, combined with in-situ and ex-situ characterisation.
- Execution of specific stressor tests (voltage cycling, relative humidity, and temperature) to provide input data for degradation models.
- Use of innovative materials from IMERYS, Heraeus, and FCMC/Chemours for the design of Gen1 and Gen2 MEAs.
- First conclusions for the design of Gen3 MEA based on experimental results and model-based recommendations.
- Strong visibility of PEMTASTIC achieved through the website, >300 LinkedIn followers, 26 workshop/conference contributions, and participation in 5 fairs/exhibitions.

FUTURE STEPS AND PLANS

- Further improvement of catalyst stability and catalyst layer formulation.
- Provision of additional model-based recommendations for the selection of Gen3 materials.
- Organisation of a project workshop to gather external input for Gen3 MEA development.
- Production of Gen3 MEAs for validation in single-cell and short-stack testing.
- Dissemination of project results in conferences and journals.

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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	MEA Durability	hours	20 000	Performance models extended to degradation models. Gen2 Pt/C outperforms Gen1 without compromising durability. A stable prototype membrane used with 2.5-fold higher AST durability. An HD-load profile to benchmark durability (500-1500 h) was developed		15 000	2020
	PGM loading	mg cm-2	0.3	Pt loading of project MEA Gen1 was reduced to 0.3		0.4	2020
	Power density	W cm-2	1.2@0.65 V	Adjustment of the I/C ratio to optimise performance. In differential conditions, Gen1 exhibits a power of 1.2 W cm-2 at 650 mV and a Pt loading of 0.3		1.0 @ 0.65 V	2020
	Operation temperature	°C	95-105	Gen1 MEA equipped with highly stable prototype membrane. HD-cycling and Stressor test will be carried out at 105°C to identify degradation at the targeted temperature		N/A	N/A

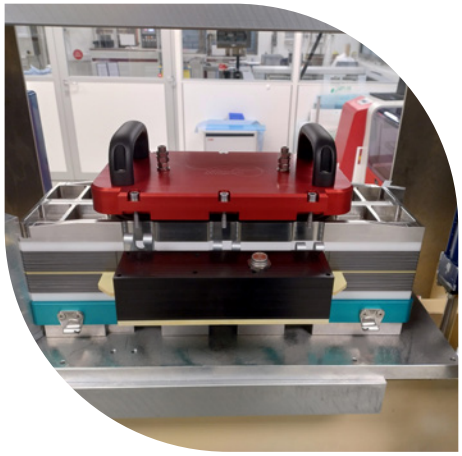
REALHYFC

RELIABLE DURABLE HIGH POWER HYDROGEN FUELED PEM FUEL CELL STACK

RealHyFC

Project ID	101111904
PRR 2026	Pillar 3 - H_2 End Uses - Transport
Call Topic	HORIZON-JTI-CLEANH$_2$-2022-03-01
Project Total Costs	3 487 157.50
Clean H_2 JU Max. Contribution	3 487 156.00
Project Period	01-06-2023 - 31-12-2026
Coordinator Beneficiary	COMMISSARIAT À L'ÉNERGIE ATOMIQUE ET AUX ÉNERGIES ALTERNATIVES, FR
Beneficiaries	DEUTSCHES ZENTRUM FÜR LUFT- UND RAUMFAHRT e. V., AVL LIST GMBH, ZENTRUM FÜR SONNENENERGIE- UND WASSERSTOFF-FORSCHUNG BADEN-WURTTEMBERG, Powercell Sweden AB, UNIVERZA V LJUBLJANI, DYNERGIE, UNITED MOTION IDEAS, IRD FUEL CELLS A/S

https://realhyfc-project.eu/



PROJECT AND GENERAL OBJECTIVES

RealHyFC has targets for efficiency, reliability, and durability of proton exchange membrane fuel cell (PEMFC) stacks towards cost-competitive exploitation in heavy-duty transport. Key improvements are:

A new stable stack design, taking advantage of two consolidated technologies with carbon and metal bipolar plates, from stationary and light duty applications respectively, with improved balance of the stack, to hinder irreversible degradation of components.

- Optimised operational monitoring options precluding avoidable performance losses.
- In line with the Clean Hydrogen JU SRIA, the proposed solutions will demonstrate key performance indicators in terms of efficiency, performance (>1W/cm² at 0.675V) and durability (over 20 000 hrs with less than 10% losses), assessed in both representative conditions and scale based on heavy-duty use-cases with at least 280 cm² cells in stacks of 3 to 10 kW advancing towards a TRL5 of the technical components and tools developed at stack level and at stack/system interface.

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 of the unit cell (leading to irreversible losses) with significant risk of actual corrosion due to longer and harsher usage.
- Increased local issues due to appreciable heterogeneities associated with the large surface area needed to achieve a high-power demand 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 imposed degradation rates.
- The investigations and further developments will be carried out using metallic bipolar plates and move towards carbon-based bipolar plates. Preventing local degradation of stack components and better controlling stack operations to hinder conditions that promote reversible or irreversible losses are the predominant means to improve the stack's lifetime. Meanwhile, to enable heavy-duty-vehicle-specific improvements targeting selected use-cases, RealHyFC's research and innovation will yield generic ideas and versatile solutions, enabling the PEMFC stack to be recognised as a building block for all heavy-duty transport. This will be achieved by including an open-design approach and understanding-based developments.

NON-QUANTITATIVE OBJECTIVES

- Identification of performance and durability issues for the metal and carbon stack reference platforms for heavy-duty transport applications.
- Development of model-based new diagnostics and monitoring tools with the aim of optimising hybridisation and operating strategies.
- Improvement of two complementary key stack components: using best-suited bipolar plates to reduce corrosion risk and optimising mechanical assembly to address heterogeneity issues, thereby enhancing overall stack durability.
- Demonstration of performance and durability improvements in representative conditions at the stack scale.
- Reduction of risks related to industrial empowerment based on RealHyFC results, through identification of pain points, and strategies on how to manage them to ensure industrial exploitation.
- Increased awareness of hydrogen for heavy-duty applications in all relevant scopes (industries, regulatory bodies, policy makers, citizens).

PROGRESS, MAIN ACHIEVEMENTS AND RESULTS

PEMFC reference stacks were defined and manufactured, and a common project-specific MEA was selected for all investigated platforms (CDM, ODM, and ODC).

- Heavy-duty relevant test protocols were defined, with initial results confirming similar beginning-of-life (BoL) performance across all stack designs and achievement of the BoL KPI target.
- Full sensitivity testing on CDM, ODM, and ODC stacks provided comparative datasets, confirming consistent trends across designs and improved understanding of operating condition impacts.
- ODM and ODC stacks were equipped with S++ current density mapping systems to analyse spatial heterogeneities in performance and ageing.
- The reference ODM stack was operated up to 2 300 hours, showing an initial rapid degradation

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RealHyFC

- phase followed by stabilisation, with degradation rates of 7.5 µV/h over 2 000 hours and 3.75 µV/h over the last 800 hours, meeting durability KPIs.
- Ageing analysis showed increasing sensitivity and heterogeneity effects over time.
- The CDM stack was tested for more than 500 hours (50 cycles), showing strong reversible losses and non-reversible losses comparable to ODM results (test ongoing).
- Catalyst degradation and metal bipolar plate corrosion models were further developed for integration into system-level fuel cell models.
- Advanced control and monitoring methods were developed, including spatial operating condition observers (SoOC), state-of-health (SoH) estimation, remaining useful life (RUL) prediction using machine learning, and reduced-order models (ROMs) for energy management systems.
- A full tool-chain integration approach was developed, including Model-in-the-Loop and Hardware-in-the-Loop validation using test benches under representative operating conditions.
- Development of Open Design Carbon (ODC) stacks progressed, including manufacturing and testing of a first functional stack and the design of an improved I-ODC bipolar plate based on fluidic optimisation and manufacturing constraints.
- Mechanical simulations showed that ODC stacks exhibit more homogeneous stress distribution compared to ODM designs.
- Communication and dissemination activities included website and social media updates, scientific publications, two stakeholder workshops (2024 and 2025), and market surveys supporting industrial uptake of RealHyFC results.

FUTURE STEPS AND PLANS

- Additional testing on available CDM, ODM, and ODC short-stacks using selected protocols and test programmes (performance, sensitivity, and durability) to generate comparative results and a consolidated database supporting carbon stack development and diagnostics/management tools.
- Ex-situ analyses of pristine and aged MEAs from project stacks, as well as metal bipolar plates from external sources, to identify degradation mechanisms and provide validation data for in-situ performance results and degradation models of stack core materials.
- Validation of models and algorithms using RealHyFC stack performance data.
- Continued reduction and implementation of models for development of state observers and control algorithms (state of operating conditions, state of health, remaining useful life).
- Continued optimisation of control and energy management systems based on representative application conditions and usage profiles.
- Validation of control, diagnostic, and monitoring tools, including algorithm integration, tool-chain development, and completion through Model-in-the-Loop and Hardware-in-the-Loop testing using test benches.
- Continued development of Open Design Carbon Bipolar Plates and stacks, including manufacturing and testing of improved carbon bipolar plates (new I-ODC design).
- Validation of simulation models for heterogeneity coupling (performance and mechanical constraints) in the open design stack, including proposal of additional tests to better understand stack heterogeneity and balance.
- Further dissemination and communication activities, including scientific publications, continuous website updates, LinkedIn posts on project and hydrogen market developments, and organisation of the final public event (end of 2026).

PROJECT TARGETS

Target source	Parameter	Unit	Target	Achieved to date by the project	Target achieved?
Project's own objectives	Power density at BoL	kW/cm²	1	1	✓
	Voltage degradation rate (10% for 20 000 hours)	µV/h	3	7.5	⚙

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RH_2IWER

RENEWABLE HYDROGEN FOR INLAND WATERWAY EMISSION REDUCTION

Project ID	101101358
PRR 2026	Pillar 3 - H_2 End Uses - Transport
Call Topic	HORIZON-JTI-CLEANH$_2$-2022-03-05
Project Total Costs	20 531 971.50
Clean H_2 JU Max. Contribution	14 998 541.38
Project Period	01-03-2023 - 31-08-2027
Coordinator Beneficiary	TEKNOLOGIAN TUTKIMUSKESKUS VTT OY, FI
Beneficiaries	STICHTING PROJECTEN BINNENVAART, DFDS AS, SOGESTION, NEDSTACK FUEL CELL TECHNOLOGY BV, L AIR LIQUIDE SA, AIR LIQUIDE BV, THEO POUW BV, Compagnie Fluviale de Transport, MTS DUISBURG GMBH, BALLARD POWER SYSTEMS EUROPE AS, L'AIR LIQUIDE BELGE, UNIVERSITA DEGLI STUDI DI GENOVA, FUTURE PROOF SHIPPING BV, H_2BOAT SRL, VERENIGDE TANKREDERIJ B.V.

http://rh2iwer.eu/

PROJECT AND GENERAL OBJECTIVES

RH_2IWER aims to create a solid basis for the acceleration of hydrogen fuel cell-powered vessels 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. RH_2IWER 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, RH_2IWER will create a basis for the shipping industry to significantly reduce its environmental footprint and eliminate emissions from its entire fleet in the future.

NON-QUANTITATIVE OBJECTIVES

- Demonstration of the use of inland waterway vessels powered by hydrogen fuel cells.
- Accelerated adoption by facilitating cooperation and exploiting synergies within the European maritime sector.
- Promotion of 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, MAIN ACHIEVEMENTS AND RESULTS

RH_2IWER partners have been working to develop the general design of the demonstration vessels as well as the business cases. Partners have also begun developing standardised fuel cell and hydrogen storage containers to mitigate future risks for shipowners when adopting these technologies.

FUTURE STEPS AND PLANS

Moving forward in the project, the hydrogen and fuel cell systems on board the vessels will be designed in greater detail; subsequently, the vessels will be built or retrofitted, and their use will be demonstrated.

PROJECT TARGETS

Target source	Parameter	Unit	Target	Target achieved?
Project's own objectives	H_2andFC vessels demonstrated	Number	6	⚙
	Maritime FCH lifetime	hours	40 000	
	Safety, PNR/RCS workshops	Number/ year	1	✓

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STASHH

STANDARD-SIZED HEAVY-DUTY HYDROGEN

Project ID	101005934
PRR 2026	Pillar 3 - H_2 End Uses - Transport
Call Topic	FCH-01-4-2020
Project Total Costs	14 310 447.80
Clean H_2 JU Max. Contribution	7 500 000.00
Project Period	01-01-2021 - 28-02-2025
Coordinator Beneficiary	SINTEF AS, NO
Beneficiaries	Proton Motor Fuel Cell GmbH, TOYOTA MOTOR EUROPE NV, VDL SPECIAL VEHICLES BV, VOLVO CONSTRUCTION EQUIPMENT AB, AVL LIST GMBH, INTELLIGENT ENERGY LIMITED, COMMISSARIAT A L ENERGIE ATOMIQUE ET AUX ENERGIES ALTERNATIVES, FREUDENBERG FST GMBH, VDL ENABLING TRANSPORT SOLUTIONS BV, FEV EUROPE GMBH, SYMBIO, NEDSTACK FUEL CELL TECHNOLOGY BV, FUTURE PROOF SHIPPING BV, OPMOBILITY H_2-POWER AUSTRIA GMBH, FREUDENBERG FUEL CELL E POWER SYSTEMS GMBH, SCHEEPSWERF DAMEN GORINCHEM BV, HYSTER-YALE ITALIA S.P.A., DAMEN RESEARCH DEVELOPMENT and INNOVATION BV, AKTIEBOLAGET VOLVO PENTA, CETENA SPA CENTRO PER GLI STUDI DI TECNICA NAVALE, NEDERLANDSE ORGANISATIE VOOR TOEGEPAST NATUURWETENSCHAPPELIJK ONDERZOEK TNO, SOLARIS BUS and COACH SPOLKA Z OGRANICZONA ODPOWIEDZIALNOSCIA, ALSTOM TRANSPORT SA, FEV SOFTWARE AND TESTING SOLUTIONS GMBH, FCP FUEL CELL POWERTRAIN GMBH, HYDROGENICS GMBH, WATERSTOFNET, VOLVO TECHNOLOGY AB, DAMEN GLOBAL SUPPORT BV, VDL ENERGY SYSTEMS, BALLARD POWER SYSTEMS EUROPE AS, HYUNDAI MOTOR EUROPE TECHNICAL CENTER GMBH

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 using agreed-upon methods. The project has produced three documents for standards covering sizes, interfaces, and communication. All fuel cell module suppliers have provided their prototypes, and all have undergone rigorous testing.

NON-QUANTITATIVE OBJECTIVES

- The project aims to disseminate the standard. It has established contact with the Society of Automotive Engineers and the International Organisation for Standardisation.
- StasHH has submitted the standard to IEC TC105.

PROGRESS, MAIN ACHIEVEMENTS AND RESULTS

- A standard definition has been agreed upon.
- Eight fuel cell modules have been designed, built and tested.
- A truck prototype has been deployed at VDL.
- Publication of several public reports, including a detailed overview of regulations, codes and standards, an OEM best practices manual, a techno-economic analysis, a market assessment, X-in-the-loop software and a test report.

FUTURE STEPS AND PLANS

Finalisation of the last public designs for FCMs.



PROJECT TARGETS

Target source	Parameter	Unit	Target	Target achieved?
Project's own objectives	Standard documents	Pcs	3	✓
	Number of FC module partners	Pcs	8	
	Units tested	Pcs	8	

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