# BRAVA

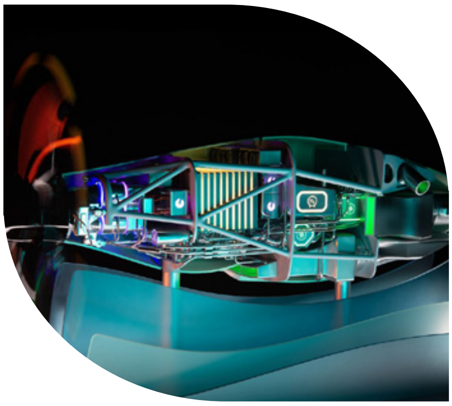
## BREAKTHROUGH FUEL CELL TECHNOLOGIES FOR AVIATION

| | |
|---|---|
| **Project ID** | 101101409 |
| **PRR 2025** | 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 - 31-12-2025 |
| **Coordinator Beneficiary** | AIRBUS OPERATIONS GMBH, DE |
| **Beneficiaries** | RHODIA OPERATIONS, SPECIALTY OPERATIONS FRANCE, AEROSTACK GMBH, MADIT METAL SOCIEDAD LIMITADA, UNIVERSITE DE MONTPELLIER, MORPHEUS DESIGNS SOCIEDAD LIMITADA, HERAEUS DEUTSCHLAND GMBH and CO KG, Rhodia Laboratoire du Futur, SOLVAY SPECIALTY POLYMERS ITALY SPA, AIRBUS OPERATIONS SL, LIEBHERR AEROSPACE TOULOUSE SAS, TECHNISCHE UNIVERSITAT BERLIN, STICHTING KONINKLIJK NEDERLANDS LUCHT - EN RUIMTEVAARTCENTRUM, AIRBUS DEFENCE AND SPACE GMBH, CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE CNRS |

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 2-phase cooling system for 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 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, conceptualising 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) embraces a 2-PC design, incorporating a newly engineered fuel cell stack. By prioritising compactness and weight reduction, we aim to significantly minimise fuel consumption and maximise efficiency.
- Advanced 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 contributes to enhanced performance and fuel efficiency.
- Advanced stack cell catalysts and membranes. BRAVA pushes the boundaries of stack cell catalysts and membranes, unlocking higher levels of performance, 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 tailored 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-up project, such as Phase 2 of the Clean Aviation programme. The follow-up project will focus on the development of an integrated fuel cell propulsion system, encompassing both ground and flight testing. This ambitious endeavour will elevate the product specifications and performance of future aviation power generation systems to unprecedented heights. The result will be a revolutionary fuel cell system designed specifically for aviation applications, paving the way for a new era of high-performance, decarbonised flight through hydrogen fuel cell technology.

## 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 deg C < 20%RH) | S/cm | > 0.1 | 0.278- 0.285 (@RH95% @80 deg 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) | |

# COCOLI$H_2$T

## COMPOSITE CONFORMAL LIQUID $H_2$ TANK

| | |
|---|---|
| Project ID | 101101404 |
| PRR 2025 | 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 - 31-01-2026 |
| Coordinator Beneficiary | COLLINS AEROSPACE IRELAND, LIMITED, IE |
| Beneficiaries | Simmonds Precision Products Inc., a part of Collins Aerospace, GOODRICH AEROSPACE EUROPE SAS, UNIFIED INTERNATIONAL, UTC AEROSPACE SYSTEMS WROCLAW SPOLKA Z OGRANICZONA ODPOWIEDZIALNOSCIA, MICROTECNICA SRL, CROMPTON TECHNOLOGY GROUP LTD, NOVOTECH AEROSPACE ADVANCED TECHNOLOGY SRL, AVIONS DE TRANSPORT REGIONAL, TECHNISCHE UNIVERSITEIT DELFT, STICHTING KONINKLIJK NEDERLANDS LUCHT - EN RUIMTEVAARTCENTRUM |

### PROJECT AND GENERAL OBJECTIVES

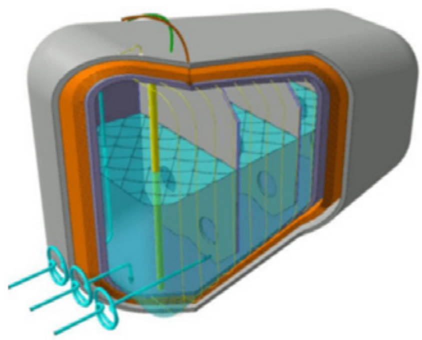
Improvements to existing state-of-the-art solutions include better utilisation of the available space for fuel storage, adequate insulation techniques to minimise heat leak, continued safe operations, and weight reduction through the use of low-weight materials, such as thermoset or thermoplastic composites,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

### NON-QUANTITATIVE OBJECTIVES

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

### PROGRESS, MAIN ACHIEVEMENTS AND RESULTS

- Completion of preliminary critical design and manufacturing readiness level reviews of the COCOLIH2T liquid hydrogen storage system.



- TRL3 development 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 Q4.

### PROJECT TARGETS

| Target source | Parameter | Unit | Target | Target achieved? |
|---|---|---|---|---|
| Project's own objectives | Maximum diameter | min | < 1 | |
| | Venting rate | %/ day | < 2 | |
| | Dormancy | hours | > 24 | |
| | Insulation vacuum | mbar | $10^{-5}$ | |



Clean Hydrogen Partnership
Co-funded by the European Union

# FCH$_2$RAIL

## FUEL CELL HYBRID POWERPACK FOR RAIL APPLICATIONS

| | |
|---|---|
| Project ID | 101006633 |
| PRR 2025 | Pillar 3 - $H_2$ End Uses - Transport |
| Call Topic | FCH-01-7-2020 |
| Project Total Costs | 13 378 484.93 |
| Clean $H_2$ JU Max. Contribution | 9 999 999.12 |
| Project Period | 01-01-2021 - 30-06-2025 |
| Coordinator Beneficiary | DEUTSCHES ZENTRUM FUR LUFT - UND RAUMFAHRT EV, DE |
| Beneficiaries | CONSTRUCCIONES Y AUXILIAR DE FERROCARRILES INVESTIGACION Y DESARROLLO SL, CAF DIGITAL and DESIGN SOLUTIONS SOCIEDAD ANONIMA, FAIVELEY TRANSPORT LEIPZIG GMBH and CO. KG, RENFE INGENIERIA Y MANTENIMIENTO SME, RENFE VIAJEROS SA, CENTRO DE ENSAYOS Y ANALISIS CETEST SL, CAF TURNKEY and ENGINEERING SOCIEDAD LIMITADA, CAF POWER and AUTOMATION SL, CENTRO NACIONAL DE EXPERIMENTACIONDE TECNOLOGIAS DE HIDROGENO Y PILASDE COMBUSTIBLE CONSORCIO, STEMMANN-TECHNIK GMBH, Renfe Operadora, TOYOTA MOTOR EUROPE NV, INFRAESTRUTURAS DE PORTUGAL SA, Construcciones y Auxiliar de Ferrocarriles S.A., ADMINISTRADOR DE INFRAESTRUCTURAS FERROVIARIAS |

https://www.fch2rail.eu/en/projects/fch2rail

### PROJECT AND GENERAL OBJECTIVES

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

### NON-QUANTITATIVE OBJECTIVES

An expert network with external stakeholders has been created to support the analysis of gaps in the normative framework. Network meetings were held in 2023 and the gap analysis was shared with and commented on by the WP7 network.

Exchanges and collaboration have taken place with other EU projects, including STASHH (standard-sized heavy-duty hydrogen), Virtual-FCH (virtual and physical platform for fuel cell system development), HyResponder (European hydrogen train-the-trainer programme for responders), and Rail4Earth (Europe's Rail Flagship Project 4 – sustainable and green rail systems), as well as national projects such as H2goesRail and H2BAR (use of hydrogen fuel cell drives in local transport in the Barnim district, operated with 100% renewable hydrogen).

### PROGRESS, MAIN ACHIEVEMENTS AND RESULTS

- Fuel cell hybrid power pack (FCHPP) development and tests on a Centro Nacional del Hidrógeno test bench were successfully completed.
- The physical Integration of two FCHPPs into the demonstrator train was successfully completed.
- The first static test of a FCHPP in a train was conducted.
- The dynamic testing of the demonstrator train on closed tracks was conducted.
- TRL7 authorisation was obtained for Spain's demonstrator system.
- The functioning of the first $H_2$-powered train was demonstrated on the Spanish railway network.
- The train demonstration was finalised in Madrid and Galicia.
- TRL7 authorisation for Portugal.
- More than 4 600 km were demonstrated in $H_2$ mode before the end of 2023.
- Train demonstration is ongoing on several lines in Spain.

### FUTURE STEPS AND PLANS

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




Clean Hydrogen Partnership
Co-funded by the European Union

# FLAGSHIPS

## CLEAN WATERBORNE TRANSPORT IN EUROPE

| | |
|---|---|
| **Project ID** | 826215 |
| **PRR 2025** | 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** | SOGESTRAN, SOGESTION, FUTURE PROOF SHIPPING BV, LMG MARIN FRANCE, LMG MARIN AS, NORLED AS, SEAM AS, MARITIME CLEANTECH, PERSEE, Compagnie Fluviale de Transport, BALLARD POWER SYSTEMS EUROPE AS, ABB OY, KONGSBERG MARITIME AS |

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 started its operation in April 2024 and the Paris demo will follow during 2025.

### 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 by DNV.
- The $H_2$ Barge II demonstration vessel (Rotterdam) has been launched and started its operation in April 2024.

- The Zulu demonstration vessel (Paris) is ready and taking its last steps in the approval process.

### FUTURE STEPS AND PLANS

- The commercial operation of both vessels will be demonstrated for 18 months.
- The results of the demonstration vessels will be analysed.

### PROJECT TARGETS

| Target source | Parameter | Unit | Target | Achieved to date by the project | Target achieved? |
|---|---|---|---|---|---|
| Project's own objectives | Develop necessary safety measures of $H_2$ and FC vessels to enable their class' 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 | 10 | ⚙ |
| | 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 | - | |

# FURTHER-FC

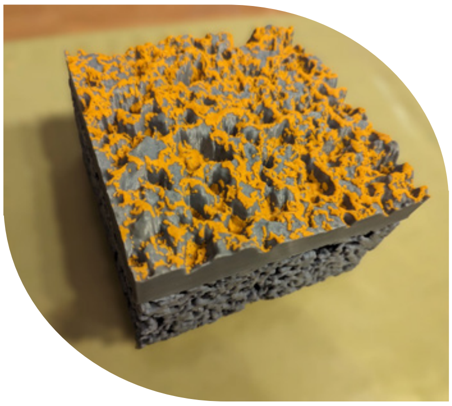
## FURTHER UNDERSTANDING RELATED TO TRANSPORT LIMITATIONS AT HIGH CURRENT DENSITY TOWARDS FUTURE ELECTRODES FOR FUEL CELLS

| | |
|---|---|
| **Project ID** | 875025 |
| **PRR 2025** | Pillar 3 - $H_2$ End Uses - Transport |
| **Call Topic** | FCH-01-4-2019 |
| **Project Total Costs** | 2 735 031.25 |
| **Clean $H_2$ JU Max. Contribution** | 2 199 567.35 |
| **Project Period** | 01-01-2020 - 31-08-2024 |
| **Coordinator Beneficiary** | COMMISSARIAT A L ENERGIE ATOMIQUE ET AUX ENERGIES ALTERNATIVES, FR |
| **Beneficiaries** | UNIVERSITE DE MONTPELLIER, UNIVERSITE DE MONTPELLIER, CHEMOURS FRANCE SAS, THE CHEMOURS COMPANY FC, LLC, HOCHSCHULE ESSLINGEN, TOYOTA MOTOR EUROPE NV, ECOLE NATIONALE SUPERIEURE DE CHIMIE DE MONTPELLIER, University of Calgary, INSTITUT NATIONAL POLYTECHNIQUE DE TOULOUSE, DEUTSCHES ZENTRUM FUR LUFT - UND RAUMFAHRT EV, IMPERIAL COLLEGE OF SCIENCE TECHNOLOGY AND MEDICINE, PAUL SCHERRER INSTITUT, CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE CNRS |

https://further-fc.eu/

### PROJECT AND GENERAL OBJECTIVES

FURTHER-FC proposes an innovative route towards a better understanding of performance limitations inside proton exchange membrane fuel cells (PEMFC), focusing on the performance cost and durability of the cathode catalyst layer (CCL) for innovative high performing low-Pt loaded PEMFCs for automotive application. The approach is based on the development of innovative and/or improved modelling and experimental tools to analyse the performance from the ionomer film layer scale to the full CCL scale.



### NON-QUANTITATIVE OBJECTIVES

- Combine original and advanced methods with fundamental characterisations and advanced models on CCL to investigate transport and electrochemical issues.
- Describe the CCL structure, transport properties and mechanisms, at its different scales.
- Characterise local conditions in the CCL during operation.
- Establish the link between the structure and properties of the CCL, local operating conditions, and performance.
- Validate CCL with improved catalyst efficiency and durability.

### PROGRESS, MAIN ACHIEVEMENTS AND RESULTS

Components and Testing:

- Development and testing of various membrane electrode assemblies (MEAs) with different Pt loadings, ionomer types (D2020 vs. HOPI), and carbon supports, and ultra-low catalyst loadings (10–50 µg/cm²) have been developed and tested.
- Performance analyses of MEAs using techniques like limiting current analysis, electrochemical impedance spectroscopy, and I-V curves.
- Selection and testing of a final high-performance MEA.

Ex-Situ Characterisation:

- Analysis of cathodic catalyst layers and gas diffusion layers through advanced imaging (X-ray, FIB-SEM, TEM, AFM, SAXS, SANS), focusing on Pt nanoparticle distribution, ionomer coverage, and microstructural properties.
- Measurement of key properties such as electronic, protonic, thermal conductivities, wettability, and oxygen transport resistance in thin ionomer films (~6.5 nm).

Performance Limitations and Water Management:

- Investigation of local water content and distribution during operation.
- Analysis of performance limits related to oxygen reduction reaction and hydrogen oxidation reaction kinetics.

Modelling, Simulation, and Development of multi-scale models:

- Sub-micron scale: Lattice-Boltzmann simulations of local ORR rates and transport processes.
- GDL/MPL scale: Heat conductivity and gas diffusion simulations based on 3D imaging.
- CCL scale: Modelling of oxygen diffusion, proton conductivity, and ionomer distribution.



Clean Hydrogen Partnership
Co-funded by the European Union

- Cell scale: Integration of these properties into performance models for improved accuracy.

Dissemination and Impact:

- Organisation of workshops, publication of 16 peer-reviewed articles, participation in 21 conferences, and sharing of results via newsletters and social media.
- Preparation of a 3D printed model consolidating data from project partners.

Advances Beyond State-of-the-Art:

- Enhanced electron tomography techniques for detailed 3D imaging of Pt distribution.
- Improved quantification of ionomer distribution using combined microscopy methods.
- Measurement of transport properties of ultra-thin ionomer films under various conditions.
- Used operando Small Angle Neutron Scattering (SANS) to characterise water content in MEAs.
- Development of advanced modelling tools linking microstructure to cell performance, validated by experiments.

Key Findings on CCL Structure and Transport:

- Achievement of a better agreement between simulations and experiments for proton conductivity using real microstructural images and ionomer reconstruction.
- Confirmation of significant proton transport through liquid water in primary pores.
- Computation of water retention curves consistent with experimental data based on microstructural imaging.

Performance Limitations and Future Work:

- Deeper understanding of the impact of ionomer type, carbon support, and catalyst loading under various conditions.
- Proposed explanations for performance limits, some that are validated and others that require further study.
- Suggested experiments to further improve catalyst layer performance and durability with reduced catalyst amounts.
- Manufactured CCLs showing enhanced performance and durability, notably with HOPI ionomer for automotive applications and heavy-duty conditions.

## FUTURE STEPS AND PLANS

- TOYOTA MOTOR EUROPE, a leading actor in fuel cell vehicles, provided FURTHER-FC access to a wide network of characterisation and modelling technologies.
- Knowledge developed by FURTHER-FC in terms of material developments, analysis of performance limitations and developments of innovative modelling tools has been provided to European industrial partners.
- A methodology developed within FURTHER-FC will be applied for batteries through the recruitment of a PhD student who was involved in FURTHER-FC.



Clean Hydrogen Partnership
Co-funded by the European Union

# $H_2$ACCELERATE TRUCKS

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

| | |
|---|---|
| **Project ID** | 101101446 |
| **PRR 2025** | Pillar 3 - $H_2$ End Uses - Transport |
| **Call Topic** | HORIZON-JTI-CLEANH$_2$-2022-03-03 |
| **Project Total Costs** | 110 961 308.68 |
| **Clean $H_2$ JU Max. Contribution** | 29 991 488.50 |
| **Project Period** | 01-02-2023 - 31-01-2029 |
| **Coordinator Beneficiary** | SINTEF AS, NO |
| **Beneficiaries** | FIAP SERVICE SRL SOCIETA BENEFIT, FEDERAZIONE ITALIANA AUTOTRASPORTATORI PROFESSIONALI, ERM FRANCE, EVERFUEL A S,SHELL NEDERLAND VERKOOPMAATSCHAPPIJ BV, TOTALENERGIES GAS MOBILITY BV, DAIMLER TRUCK AG, LINDE GMBH, UNIUNEA NATIONALA A TRANSPORTATORILOR RUTIERI DIN ROMANIA, TEKNOLOGIAN TUTKIMUSKESKUS VTT OY, OMV DOWNSTREAM GMBH, ENVIRONMENTAL RESOURCES MANAGEMENT LIMITED, IVECO SPA, ELEMENT ENERGY LIMITED, UNION INTERNATIONALE DES TRANSPORTS ROUTIERS (IRU), VOLVO LASTVAGNAR AB, WIRTSCHAFTSKAMMER OSTERREICH, VOLVO TECHNOLOGY AB |

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

### PROGRESS AND ACHIEVEMENTS

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

### MAIN RESULTS

- Dialogue with heavy-duty truck end users and HRS network operators.
- The development of, and agreement on, protocols for data monitoring and analysis.
- First batch of "artificial" truck operation data transferred to VTT for assessment.
- The assessment of health and safety issues and submission of an adequate safety plan.
- The launch of the project's website and LinkedIn, X accounts.
- The establishment of a dissemination and exploitation plan.
- The submission of OEMs annual progress reports.



Clean Hydrogen Partnership
Co-funded by the European Union

## PROJECT TARGETS

| Target source | Parameter | Unit | Target | Target achieved? |
|---|---|---|---|---|
| Project's own objectives | Deployed HD Trucks' gross weight | t | 41-44 | |
| | Vehicle range under heavy load | km | > 600 km for compressed $H_2$ and > 1 000 km for liquid hydrogen | |
| | 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 in the project. | Number | 3 | |
| | Dataset covering the performance of 150 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 | 2 100 | |
| | Data monitoring and analyses of trucks' performance. | % of deployed trucks | 20 (corresponding to 30 trucks of the full fleet of 150 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 | 150 | |
| | Presentations at events and conferences. | Number/ year | 5 | |
| | Visible social media and web presence. | Number | 2 | |

# H2HAUL

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

| | |
|---|---|
| Project ID | 826236 |
| PRR 2025 | Pillar 3 - $H_2$ End Uses - Transport |
| Call Topic | FCH-01-1-2018 |
| Project Total Costs | 28 110 126.80 |
| Clean $H_2$ JU Max. Contribution | 12 000 000.00 |
| Project Period | 01-02-2019 - 31-12-2025 |
| Coordinator Beneficiary | ENVIRONMENTAL RESOURCES MANAGEMENT LIMITED, UK |
| Beneficiaries | ELEMENT ENERGY, VDL SPECIAL VEHICLES BV, ERM FRANCE, DATS 24, PLASTIC OMNIUM NEW ENERGIES WELS GMBH, H2 ENERGY AG, AIR LIQUIDE FRANCE INDUSTRIE, VDL ENABLING TRANSPORT SOLUTIONS BV, VDL BUS EINDHOVEN BV, EOLY, FPT MOTORENFORSCHUNG AG, HYDROGENICS GMBH, IRU PROJECTS ASBL, FPT INDUSTRIAL SPA, AIR LIQUIDE ADVANCED TECHNOLOGIES SA, SPHERA SOLUTIONS GMBH, IVECO SPA, ELRINGKLINGER AG, ETABLISSEMENTEN FRANZ COLRUYT NV, WATERSTOFNET VZW, AIR LIQUIDE ADVANCED BUSINESS, TOTALENERGIES MARKETING DEUTSCHLAND GMBH, Powercell Sweden AB, ELEMENT ENERGY LIMITED, UNION INTERNATIONALE DES TRANSPORTS ROUTIERS (IRU), BAYERISCHE MOTOREN WERKE AKTIENGESELLSCHAFT, ROBERT BOSCH GMBH, HYDROGEN EUROPE |

http://www.h2haul.eu

### PROJECT AND GENERAL OBJECTIVES

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

### NON-QUANTITATIVE OBJECTIVES

- H2Haul aims to develop long-haul heavy-duty (26 t and 44 t) fuel cell trucks that meet customers' requirements in a range of operating environments. The trucks' design and specifications are being finalised in alignment with specific customer requirements and mission profiles. The objectives are expected to be met.
- The project aims to homologate three fuel cell truck types to certify that they are safe to use on European roads. Original truck OEMs are working closely with hydrogen safety experts and the relevant certification bodies to secure all necessary safety approvals for using the trucks on public roads in Europe.
- The project aims to develop the business case for the further roll-out of heavy-duty fuel cell trucks. H2Haul will provide a valuable database of real-world performance information and insights into the next steps required for the 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 more ambitious deployment of tens of vehicles or more.
- H2Haul aims to prepare the European market for the further roll-out of fuel cell trucks through (i) the development of innovative commercial models and (ii) the dissemination of information from the project to a wide audience of relevant stakeholders. H2Hauls dissemination activities will share key findings with relevant audiences to prepare the market for the wider roll-out of fuel cell trucks on a commercial basis.
- Communication activities in the first and second year of the project have stimulated significant interest from relevant audiences.

### PROGRESS, MAIN ACHIEVEMENTS AND RESULTS

- The fuel cell truck technical specifications were finalised. Data were gathered 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

- H2Haul will deploy the VDL and Iveco trucks. The Iveco beta trucks are currently being assembled with fuel cells from Bosch and will serve as prototypes for the 12 gamma trucks which will be delivered to end users in France, Switzerland and Germany.
- The H2Haul 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) | |



Clean Hydrogen Partnership
Co-funded by the European Union

# $H_2$MAC

## 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 2025 | 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 TECNOLOGICO DE ARAGON, ES |
| Beneficiaries | ASOCIACION ESPANOLA DE FABRICANTES EXPORTADORES DE MAQUINARIA PARA CONSTRUCCION, OBRAS PUBLICAS Y MINERIA, ZAMALBIDESERVICE2021 SL, TALLERES ZB S.A., HIDROMEK MAQUINARIA DE CONSTRUCCION ESPAÑA S.L., HIDROMEK-HYDROLIK VE MEKANIK MAKINA IMALAT SANAYI VE TICARET ANONIM SIRKETI, TAMPEREEN KORKEAKOULUSAATIO SR, MANN + HUMMEL GMBH, BALLARD POWER SYSTEMS EUROPE AS, Powercell Sweden AB, FUNDACION PARA EL DESARROLLO DE LAS NUEVAS TECNOLOGIAS DEL HIDROGENO EN ARAGON |

https://h2mac.eu/

### PROJECT AND GENERAL OBJECTIVES

- The objective of $H_2$Mac is to develop zero emissions heavy-duty mobile machinery for mining and construction sectors.
- Therefore, $H_2$MAC will develop an excavator and a shredder with integrated fuel cell powertrains and related subsystems.
- The power trains will be innovative, efficient, scalable, silent and modular. The excavator will be powered by one 120 kW fuel cell module. The shredder will upscale the concept using two modules to enlarge the power to 240 kW.
- The operation of both heavy-duty mobile machines is complementary, as the excavator has a load profile derived of its movement during operation, while the shredder is a more static machine when operating.
- $H_2$MAC includes a simultaneous demonstration of both machines during 1000 hours in a single real environment. The results should allow the $H_2$MAC consortium to develop solutions for operation in different sectors under different operational conditions.
- The consortium is composed of a variety of technological partners, component manufacturers, machinery manufacturers and associations that will help communication, dissemination and exploitation through standardisation.

### ACHIEVEMENT

- $H_2$MAC General Assembly in Tampere (Finland) on the 11th and 12th of March 2024.


### PROJECT TARGETS

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

# $H_2$MARINE

## HYDROGEN PEM FUEL CELL STACK FOR MARINE APPLICATIONS

| | |
|---|---|
| **Project ID** | 101137965 |
| **PRR 2025** | 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** | CLEOS IDIOTIKI KEFALAIOUCHIKI ETAIREIA, Beyond Gravity Schweiz AG, EH GROUP ENGINEERING SA, GREENERITY GMBH, TEKNOLOGIAN TUTKIMUSKESKUS VTT OY, CLUSTER VIOOIKONOMIAS KAI PERIVALLONTOS DYTIKIS MAKEDONIAS, THYSSENKRUPP MARINE SYSTEMS GMBH, Powercell Sweden AB, ZENTRUM FUR SONNENENERGIE- UND WASSERSTOFF-FORSCHUNG BADEN-WURTTEMBERG, ALBERT-LUDWIGS-UNIVERSITAET FREIBURG, REINZ-DICHTUNGS GMBH, ECOLE POLYTECHNIQUE FEDERALE DE LAUSANNE |

https://h2marineproject.eu/

### PROJECT AND GENERAL OBJECTIVES

The overarching objective of the $H_2$MARINE project is to design, build, test and validate two PEM stacks generating 250 - 300 kW electrical power designed for marine applications. The $H_2$MARINE project takes a top-down approach, building on a proof of concept of two PEM stacks that are being developed in the EU and Switzerland. The $H_2$MARINE 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, in order to determine its valuable end-use, which will allow the partners to research the potential market(s) and identify the best opportunities.

### PROGRESS, MAIN ACHIEVEMENTS AND RESULTS

The project officially started on January 1, 2024 and the associated work is on-going.

### 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 | |

# $H_2$PORTS

## IMPLEMENTING FUEL CELLS AND HYDROGEN TECHNOLOGIES IN PORTS

| | |
|---|---|
| Project ID | 826339 |
| PRR 2025 | 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 | FUNDACION DE LA COMUNIDAD VALENCIANA PARA LA INVESTIGACION, PROMOCION Y ESTUDIOS COMERCIALES DE VALENCIAPORT, ES |
| Beneficiaries | SCALE GAS SOLUTIONS, S.L., VALENCIA TERMINAL EUROPA SA,CANTIERI DEL MEDITERRANEO SPA, HYSTER-YALE NEDERLAND BV,ATENA SCARL - DISTRETTO ALTA TECNOLOGIA ENERGIA AMBIENTE, MEDITERRANEAN SHIPPING COMPANY TERMINAL VALENCIA SA, CENTRO NACIONAL DE EXPERIMENTACIONDE TECNOLOGIAS DE HIDROGENO Y PILASDE COMBUSTIBLE CONSORCIO, GRIMALDI EUROMED SPA, BALLARD POWER SYSTEMS EUROPE AS, SOCIEDAD ESPANOLA DE CARBUROS METALICOS SA, AUTORIDAD PORTUARIA DE VALENCIA, ENAGAS SA,UNIVERSITA DEGLI STUDI DI NAPOLI PARTHENOPE, UNIVERSITA DEGLI STUDI DI SALERNO, AGENZIA NAZIONALE PER LE NUOVE TECNOLOGIE, L'ENERGIA E LO SVILUPPO ECONOMICO SOSTENIBILE |

https://h2ports.eu/

### PROJECT AND GENERAL OBJECTIVES

The H2ports project will demonstrate and validate two innovative solutions based on fuel cell technologies. A reach stacker and a terminal tractor will be tested on a daily basis during real operational activities at the port of Valencia. The required hydrogen will be provided 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 accomplished through the organisation of the stakeholder advisory group.
- H2Ports will gather information on the use of $H_2$ in port environments.
- H2Ports 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 two years of piloting under normal operative 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 | min | < 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 fuel cell system | kW | 175-205 (225-285) | |
| | HRS specific maintenance cost | €/kg | 1 | |
| | HRS CAPEX | € | 575 000 | |



Clean Hydrogen Partnership
Co-funded by the European Union

# HIGHLANDER

## HIGH PERFORMING ULTRA-DURABLE MEMBRANE ELECTRODE ASSEMBLIES FOR TRUCKS

| | |
|---|---|
| **Project ID** | 101101346 |
| **PRR 2025** | Pillar 3 - $H_2$ End Uses - Transport |
| **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** | RHODIA OPERATIONS, SPECIALTY OPERATIONS FRANCE, UNIVERSITE DE MONTPELLIER, JOHNSON MATTHEY HYDROGEN TECHNOLOGIES LIMITED, PRETEXO, ELMARCO SRO, Rhodia Laboratoire du Futur, ROBERT BOSCH GMBH, SOLVAY SPECIALTY POLYMERS ITALY SPA, JOHNSON MATTHEY PLC, FORSCHUNGSZENTRUM JULICH GMBH, TECHNISCHE UNIVERSITAT BERLIN |

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 cell and short stack level against heavy-duty relevant accelerated stress test and load profile test protocols. Materials-screening efforts will be supported by the development and use of improved predictive degradation models bridging scales from reaction sites to cell level. Model parameterisation is implemented using experimental characterisation data at materials, component, and cell level. HIGHLANDER aims to bring about a significant reduction in stack cost and fuel consumption through improving catalyst-coated membrane performance and the development of 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 reuse of platinum in the context of a circular economy.

### NON-QUANTITATIVE RESULTS

HIGHLANDER launched a project website, published two annual newsletters, disseminated project results through ten presentations at conferences and has published five journal publications to date. A project workshop will be conducted in year 3.

### PROGRESS, MAIN ACHIEVEMENTS AND RESULTS

- Development of novel intermetallic electrocatalysts for the oxygen reduction reaction at the fuel cell cathode. Selected catalysts display better retention of electrochemical surface area and equivalent or higher mass activity in rotating disc electrode conditions than the project reference catalyst.
- Progress in the development of two series of novel sulfonated hydrocarbon ionomers for fluorine-free membranes and their benchmarking against perfluorosulfonic acid (PFSA) membranes.
- Formulation of a hierarchical degradation modelling framework and its implementation as a software code, available in the open access modelling platform (GitLab), accessible at https://go.fzj.de/jumper.
- Progress in the elaboration of low-cost gas diffusion layers (GDLs). The developed anode gas diffusion layer provides the same in situ performance as commercial GDLs, at a lower cost.
- Progress in the development of catalyst coated membranes. Baseline catalyst coated membranes have been submitted to load profile testing over 500 hours, demonstrating that the degradation rate of a membrane electrode assembly with a novel catalyst and the Syensqo PFSA ionomer was reduced to 50 µV/h. The final performance and platinum group metal loading targets of the project were achieved.

### FUTURE STEPS AND PLANS

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

### PROJECT TARGETS

| Target source | Parameter | Unit | Target | Achieved to date by the project | Target achieved? |
|---|---|---|---|---|---|
| Project's own objectives | Power density @ 0.65 V | W/cm$^2$ | 1.2 | 1.2 | ✓ |
| | PGM loading | g Pt/kW | < 0.3 | 0.292 | |
| | Durability | hours | 20 000 | Durability testing to take place in the project's last 6 months. | |



Clean Hydrogen Partnership

Co-funded by the European Union

# HYSHIP

## DEMONSTRATING LIQUID HYDROGEN FOR THE MARITIME SECTOR

| | |
|---|---|
| **Project ID** | 101007205 |
| **PRR 2025** | Pillar 3 - $H_2$ End Uses – Transport |
| **Call Topic** | FCH-01-6-2020 |
| **Project Total Costs** | 10 796 560.00 |
| **Clean $H_2$ JU Max. Contribution** | 7 993 942.00 |
| **Project Period** | 01-01-2021 - 31-12-2025 |
| **Coordinator Beneficiary** | WILH WILHELMSEN HOLDING ASA, NO |
| **Beneficiaries** | NORSEA GROUP AS, DIANA SHIPPING SERVICES SA, WILHELMSEN SHIP MANAGEMENT NORWAY AS, AIR LIQUIDE NORWAY AS, STOLT TANKERS B.V., MASSTERLY AS, LMG MARIN FRANCE, LMG MARIN AS, NORLED AS, MARITIME CLEANTECH, PERSEE, DNV SE, EQUINOR ENERGY AS, KONGSBERG MARITIME AS, DNV AS, UNIVERSITY OF STRATHCLYDE, NATIONAL CENTER FOR SCIENTIFIC RESEARCH “DEMOKRITOS”, EIDGENOESSISCHE TECHNISCHE HOCHSCHULE ZUERICH |

https://hyship.eu/

### PROJECT AND GENERAL OBJECTIVES

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

### NON-QUANTITATIVE OBJECTIVES

- Conceptually design a full range of vessel and hydrogen systems.
- Develop and describe a business ecosystem with a timeline for cost-efficient operation.
- Integrate the demonstration system into a larger sociotechnical system, with business models, policy models and $LH_2$ supply, that will help the transition towards the use of $LH_2$.
- Use robust holistic design methods, that lower the cost of conducting complex projects with novel fuel and infrastructure, allowing real-time data collection on the effects of the use of novel fuels (no real-time data provided yet).
- Develop input to the International Maritime Organization, which will help the systems transition to its rules instead of following the alternative design approach.

### PROGRESS, MAIN ACHIEVEMENTS AND RESULTS

The preliminary design of vessel and liquid hydrogen propulsion systems is complete.

### FUTURE STEPS AND PLANS

- The ship building contract will be signed.
- The vessels will be delivered.
- Vessel operations will begin.

### PROJECT TARGETS

| Target source | Parameter | Unit | Target | Target achieved? |
|---|---|---|---|---|
| Project’s own objectives | Develop an intelligent Energy Management Systems that lets us reduce CAPEX of the energy system by more than 5%. | % | 5 | |
| | Reduction of design and ship integration costs related to the hydrogen/fuel cell systems by more than 40%. | % | 40 | |

# IMMORTAL

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

| | |
|---|---|
| **Project ID** | 101006641 |
| **PRR 2025** | Pillar 3 - $H_2$ End Uses - Transport |
| **Call Topic** | FCH-01-2-2020 |
| **Project Total Costs** | 3 825 927.50 |
| **Clean $H_2$ JU Max. Contribution** | 3 825 927.50 |
| **Project Period** | 01-01-2021 - 31-03-2024 |
| **Coordinator Beneficiary** | CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE CNRS, FR |
| **Beneficiaries** | UNIVERSITE DE MONTPELLIER, UNIVERSITE DE MONTPELLIER, FPT MOTORENFORSCHUNG AG, FPT INDUSTRIAL SPA, JOHNSON MATTHEY HYDROGEN TECHNOLOGIES LIMITED, PRETEXO, ALBERT-LUDWIGS-UNIVERSITAET FREIBURG, ROBERT BOSCH GMBH, JOHNSON MATTHEY PLC, AVL LIST GMBH |

http://www.immortal-fuelcell.eu

### PROJECT AND GENERAL OBJECTIVES

IMMORTAL aimed to develop high-performance and high-durability membrane electrode assemblies (MEAs), and their components, specifically designed for use in heavy-duty (HD) truck applications. The project intended to develop load profile tests specific to HD truck application, and apply these tests, and accelerated stress tests, to MEAs at both sub-scale and short stack levels. The results of load profile testing have also been used to validate a novel lifetime prediction method, and the method used to predict the lifetime of project MEAs. The project assessed the results through a technoeconomic evaluation and provided HD fuel cell powertrain validation and system recommendations.

### NON-QUANTITATIVE OBJECTIVES

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

### PROGRESS, MAIN ACHIEVEMENTS AND RESULTS

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

### FUTURE STEPS AND PLANS

IMMORTAL finished in March 2024. Future plans include carrying forward the learning and most prospective materials from IMMORTAL to future heavy-duty MEA development projects, in particular in 'High performing ultra-durable membrane electrode assemblies for trucks' (HIGHLANDER).

### PROJECT TARGETS

| Target source | Parameter | Unit | Target | Achieved to date by the project | Target achieved? |
|---|---|---|---|---|---|
| Project's own objectives | Catalyst surface area and mass activity | cm$^2$/g Pt and A/mg Pt | Exceeds the performance of reference Pt and demonstrates better retention after accelerated degradation cycles than reference Pt/C. | 2 catalyst designs achieve this objective | ✓ |
| | Membrane durability in MEA AST cycles | cycles | 50 000 | 110 000 | |



Clean Hydrogen Partnership

Co-funded by the European Union

# JIVE

## JOINT INITIATIVE FOR HYDROGEN VEHICLES ACROSS EUROPE

| | |
|---|---|
| **Project ID** | 735582 |
| **PRR 2025** | Pillar 3 - $H_2$ End Uses - Transport |
| **Call Topic** | FCH-01-9-2016 |
| **Project Total Costs** | 89 176 155.23 |
| **Clean $H_2$ JU Max. Contribution** | 32 000 000.00 |
| **Project Period** | 01-01-2017 - 30-06-2024 |
| **Coordinator Beneficiary** | ENVIRONMENTAL RESOURCES MANAGEMENT LIMITED, UK |
| **Beneficiaries** | IN-DER-CITY-BUS GMBH, ESWE VERKEHRSGESELLSCHAFT MBH, MAINZER VERKEHRSGESELLSCHAFT MBH, GELDERLAND, ERM FRANCE, ERM FRANCE, REBELGROUP ADVISORY BV, ESWE VERKEHRSGESELLSCHAFT MBH, LATVIJAS UDENRAZA ASOCIACIJA, VERKEHRS-VERBUND MAINZ-WIESBADEN GESELLSCHAFT MIT BESCHRANKTER HAFTUNG, REGIONALVERKEHR KOLN GMBH, EUE APS, DUNDEE CITY COUNCIL, WEST MIDLANDS TRAVEL LIMITED, SASA SPA AG SOCIETA AUTOBUS SERVIZID'AREA SPA, HERNING KOMMUNE, WSW MOBIL GMBH, RIGAS SATIKSME SIA, TRENTINO TRASPORTI SPA, EE ENERGY ENGINEERS GMBH, SPHERA SOLUTIONS GMBH, hySOLUTIONS GmbH, ABERDEEN CITY COUNCIL*, SUEDTIROLER TRANSPORTSTRUKTUREN AG, HyCologne - Wasserstoff Region Rheinland e.V., LONDON BUS SERVICES LIMITED, ELEMENT ENERGY LIMITED, PLANET PLANUNGSGRUPPE ENERGIE UND TECHNIK GBR, BIRMINGHAM CITY COUNCIL, FONDAZIONE BRUNO KESSLER, UNION INTERNATIONALE DES TRANSPORTS PUBLICS, HYDROGEN EUROPE |

http://www.fuelcellbuses.eu

### PROJECT AND GENERAL OBJECTIVES

JIVE exists to assist the commercialisation of fuel cell buses (FCBs) as a zero-emission public transport option across Europe. The project aims to address the current high ownership cost of FCBs relative to conventionally powered buses and the lack of hydrogen-refuelling infrastructure across Europe by supporting the deployment of 131 FCBs in seven locations - Aberdeen (UK), Birmingham (UK), Cologne (DE), Gelderland (NL), London (UK), South Tyrol (IT), and Wuppertal (DE). Combined with its sister project, JIVE 2, nearly 300 fuel cell buses will be deployed at sixteen sites by 2025 - the largest deployment in Europe to date.

### NON-QUANTITATIVE OBJECTIVES

- JIVE aims to demonstrate the suitability and provide experience of FCBs for wider roll-out. Through the publication of project deliverables, such as a best practice and commercialisation report, information flows to interested observer parties have been established.
- JIVE 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 continuation of the momentum for FCB uptake in Europe beyond the project.
- JIVE aims to deliver positive environmental impacts by operating FCBs for extended periods. As per the project's objective, all buses deployed thus far in the project are replacing diesel technology. This means that the buses will lead to $CO_2$ abatement and will not simply operate as a 'visible extra'.


### PROGRESS, MAIN ACHIEVEMENTS AND RESULTS

The project closed in June 2024 with the following key achievements:

- Deployment of 131 fuel cell buses operational across seven sites in four countries.
- Total travel distance for buses deployed in JIVE of 10 703 187 kms, with average travel distance per bus of 30 070 km/year, until June 2024.
- Reduction in average bus price within the project since 2018 (across JIVE and JIVE 2) and in comparison with other projects.
- Achievement of technical improvements, including a reduction in fuel consumption well below the target (9 kg $H_2$/100 km), consistently high FCB availability, and long daily travel distances.

- Significant experience has been gained by operators in the integration and management of large fleets of hydrogen buses.
- Expansion of hydrogen infrastructure in the partner regions, alongside stimulation of future growth of the hydrogen refuelling station network and of FCB fleets.
- Successful large-scale dissemination activities promoting the project and hydrogen technology across Europe and around the world, e.g. FCB Roadshow.

## FUTURE STEPS AND PLANS

- Operations of the JIVE buses will continue post-project.
- Continued expansion of FCB fleets for several sites.


## 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 | > 44 000 | 30 070 km/year/bus (all years included) / 33 168 km/year/bus excludes 2024 (data available only until June 2023). | |
| | Operating hours per fuel cell system | hours/bus | > 20 000 | 7 244 | |
| | Efficiency | % | > 42 | - | |
| | Availability | % | > 90 | 83.6 | |
| | Specific fuel consumption | kg/100km/bus | < 9.0 | 7.6 | ✓ |
| | Vehicle CAPEX | € | < 650 000 | - | |
| | Vehicle OPEX | € | max. 100% more than diesel bus OPEX | - | |
| | Mean time (distance) between failures (MDBF) | km/bus | > 2 500 | 24 174 | |

# JIVE 2

## JOINT INITIATIVE FOR HYDROGEN VEHICLES ACROSS EUROPE 2

| | |
|---|---|
| Project ID | 779563 |
| PRR 2025 | 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 | ELEMENT ENERGY, ZEROBUS OU, ERM FRANCE, ERM FRANCE, TRANSDEV OCCITANIE OUEST, HYPORT, OBCINA SOSTANJ, ENGIE ENERGIE SERVICES, CA DE L'AUXERROIS, CONNEXXION VLOOT BV, RHEINSCHE BAHNGESSELLSCHAFT AKTIENGESELLSCHAFT, SOCIETE PUBLIQUE LOCALE D'EXPLOITATION DES TRANSPORTS PUBLICS ET DES SERVICES A LA MOBILITE DE L'AGGLOMERATION PALOISE, STRAETO BS, TWYNSTRA GUDDE MOBILITEIT and INFRASTRUCTUUR BV, OPENBAAR LICHAAM OV-BUREAU GRONINGEN EN DRENTHE, PAU BEARN PYRENEES MOBILITES, LANDSTINGET GAVLEBORG, REBELGROUP ADVISORY BV, REGIONALVERKEHR KOLN GMBH, DUNDEE CITY COUNCIL, CONNEXXION OPENBAAR VERVOER NV, MESSER SE and CO. KGAA, WSW MOBIL GMBH, RIGAS PASVALDIBAS SABIEDRIBA AR IEROBEZOTU ATBILDIBU RIGAS SATIKSME, MESTNA OBCINA VELENJE, KOLDING KOMMUNE, EE ENERGY ENGINEERS GMBH, TRANSPORTS DE BARCELONA SA, SPHERA SOLUTIONS GMBH, BRIGHTON and HOVE BUS AND COACH COMPANY LIMITED, RUTER AS, Provincie Zuid-Holland, PETROGAL SA, VATGAS SVERIGE IDEELL FORENING, ELEMENT ENERGY LIMITED, NOORD-BRABANT PROVINCIE, UNION INTERNATIONALE DES TRANSPORTS PUBLICS, HYDROGEN EUROPE |

https://www.fuelcellbuses.eu/

### PROJECT AND GENERAL OBJECTIVES

The JIVE 2 project aims to deploy 160 fuel cell buses (FCBs) in eleven locations - Auxerre (FR), Barcelona (ES), Brighton/Crawley (UK), Cologne (DE), Emmen (NL), Groningen (NL), Jelgava (LV), Pau (FR), South Holland (NL), Toulouse (FR), Wuppertal (DE). Combined with its sister project, JIVE 2, nearly 300 fuel cell buses will be deployed at sixteen sites by 2025 - the largest deployment in Europe to date.

### NON-QUANTITATIVE OBJECTIVES

- JIVE 2 aims to demonstrate the suitability and provide experience of FCBs for wider roll-out. Through the publication of project deliverables, such as a best practice and commercialisation report, information flows to interested observer parties have been established.
- 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 continuation of the momentum for FCB uptake in Europe continues beyond the project.
- JIVE 2 aims to deliver positive environmental impacts by operating FCBs for extended periods. As per the project's objective, all buses deployed thus far in the project are replacing diesel technology. This means that the buses will lead to $CO_2$ abatement and will not simply operate as a 'visible extra'.

### PROGRESS, MAIN ACHIEVEMENTS AND RESULTS

- To date, all 160 buses have been ordered.
- To date, 150 buses have been delivered and 124 are operational.
- 12 599 637 km travelled by the buses deployed through JIVE 2.
- Average travel distance per bus of 38 521 km/year/ bus until December 2024. Excluding 2020, the average travel distance was 44 925 km/year/bus.
- One site has been operating its FCBs for over three years.
- One site (Jelgava) has joined as a demonstration site following the successful completion of one of the FCB Roadshows under the project's "Stimulating Further Demand".




Clean Hydrogen Partnership

Co-funded by the European Union

- Expansion of hydrogen infrastructure in the partner regions, alongside stimulation of future growth of the hydrogen refuelling station network and FCB fleets.
- Successful large-scale dissemination activities promoting the project and hydrogen technology across Europe and around the world (FCB Roadshows, participation in conferences and events - such as the Hydrogen Week, November 18-22 at Brussels Expo, participation in public dissemination events such as Hydrogen Solutions for European Cities: Learnings from JIVE II and REVIVE for Future Buses and Trucks workshop in Novembers 2024).

## FUTURE STEPS AND PLANS

- Continued operation of the buses until the end of the project.
- Final buses enter operation: Brighton/Crawley and Jelgava.
- Final dissemination activities such as the 4th and final roadshow in the Nordic countries, specifically Sweden and Finland.
- Project knowledge will be preserved through a digital archive, speaker briefs for consortium members and a short video showcasing 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 | 38 521 km/year/bus project to date (all years) / 44 925 km/year/bus project to date, excludes 2024 (data only available until June 2023) | |
| | Operating hours per fuel cell system | hours/bus | > 20 000 | 10 367 | |
| | Availability | % | >90 | 83.6 | |
| | Efficiency | % | > 42 | - | |
| | Specific fuel consumption | kg/100km/bus | < 9.0 | 7.4 | ✓ |
| | Vehicle CAPEX | € | <625 000 | - | |
| | Vehicle OPEX | € | max. 100% more than diesel bus OPEX | - | |
| | Mean time (distance) between failures (MDBF) | km/bus | > 3 500 | 24 913 | |

# MEASURED

## ADVANCED MEAS ENSURING HIGH EFFICIENCY HDV

| | |
|---|---|
| Project ID | 101101420 |
| PRR 2025 | 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 | AVL-AST NAPREDNE SIMULACIJSKE TEHNOLOGIJE DOO, HONEYWELL INTERNATIONAL SRO, UNIVERSITAT POLITECNICA DE VALENCIA, UNIVERZA V LJUBLJANI, AVL LIST GMBH, UNIVERSITY OF STUTTGART, TECHNISCHE UNIVERSITAET GRAZ |

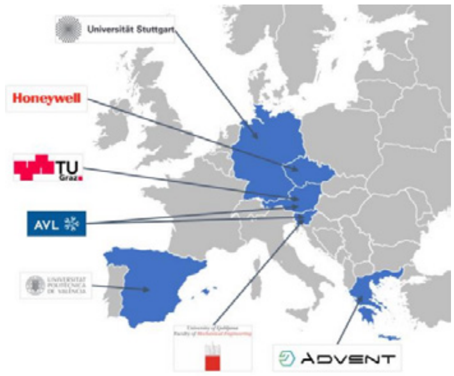
https://measured-horizon.eu/

### 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, operating above 160 °C, featuring minimal phosphoric acid uptake and a stable porous ionomer microstructure, combined with novel platinum-based catalysts. The MEA will be integrated in a short stack and its performance will be evaluated according to the project's key performance indicators. In parallel, fuel cell stack integration will be validated under heavy-duty vehicles 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 simulation tools, carry out testing-, harmonisation- and standardisation-related activities. Finally, MeasureD will execute an environmental assessment of the fuel cell manufacturing process, targeting 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

**Deliverable (hereinafter D) 1.8**: Requirements and key performance indicators for the polymer membranes for high-temperature fuel cells for aerospace applications from Honeywell.

**D 4.1**: Requirements of heavy-duty fuel cell electric vehicles' system architecture, performance lifetime and components' sizing and characterisation from AVL.

**D 6.1.** Project logo and visual identity 6 from Advent.



Clean Hydrogen Partnership
Co-funded by the European Union

**D 6.2.** Website and social media presence from Advent.

**D 6.3.** Measured newsletter from Advent.

**D 6.4.** Measured promotional material from Advent.

**D 6.5.** Plan for communication, dissemination and exploitation from Advent.

**D 7.1.** Project management handbook from Advent.

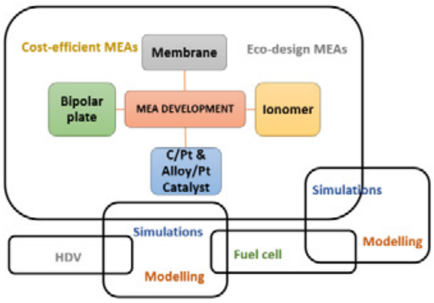
**D 7.2.** Quality management plan from Advent.

**D 7.3.** Risk management plan from Advent.

**D 7.4.** Data management plan from Advent.

### FUTURE STEPS AND PLANS

- Technical development of the MEA (both membrane and electrode) and the single cell assembly through experiments and testing methodologies to optimise performance.
- Digital models to simulate the characteristics of project innovations.
- Progress of vehicle-level simulations enabling assessment of the overall performance and integration of novel technologies within the context of larger systems.
- Environmental and economic assessments, to gauge the impact, recyclability, and manufacturing costs associated with project advancements.
- Communication, dissemination, and exploitation strategies to ensure effective outreach and maximise the impact of project advancements.
- Project management activities, ensuring effective and efficient project progress.




### PROJECT TARGETS

| Target source | Parameter | Unit | Target | Target achieved? |
|---|---|---|---|---|
| **Project's own objectives** | Fuel Cell stack cost | €/kW | < 75 | |

# MORELIFE

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

| | |
|---|---|
| **Project ID** | 101007170 |
| **PRR 2025** | 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** | EKPO FUEL CELL TECHNOLOGIES GMBH, MEBIUS, RAZISKOVALNO RAZVOJNA DEJAVNOST, ZASTOPANJE IN TRGOVINA, DOO, NEDSTACK FUEL CELL TECHNOLOGY BV, UNIVERZA V LJUBLJANI, TECHNISCHE UNIVERSITEIT EINDHOVEN, TECHNISCHE UNIVERSITAET MUENCHEN |

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 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 material have been created.
- A third generation of novel catalyst material has been developed with promising first results of rotating disc electrode investigations.
- Post-mortem analysis on aged state-of-the-art material has been performed in order to improve mechanistic degradation models created in this project.

### FUTURE STEPS AND PLANS

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



Clean Hydrogen Partnership
Co-funded by the European Union

# NIMPHEA

## NEXT GENERATION OF IMPROVED HIGH TEMPERATURE MEMBRANE ELECTRODE ASSEMBLY FOR AVIATION

NIMPHEA
Next-generation MEA for aviation

| | |
|---|---|
| **Project ID** | 101101407 |
| **PRR 2025** | Pillar 3 - $H_2$ End Uses - Transport |
| **Call Topic** | HORIZON-JTI-CLEANH$_2$-2022-03-08 |
| **Project Total Costs** | 4 942 898.75 |
| **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** | ADVANCED ENERGY TECHNOLOGIES AE EREUNAS and ANAPTYXIS YLIKON and PROIONTON ANANEOSIMON PIGON ENERGEIAS and SYNAFON SYMVOULEFTIKON YPIRESION, UNIVERSITE DE STRASBOURG, Fundacion IMDEA Energia, SAFRAN SA, FRAUNHOFER GESELLSCHAFT ZUR FORDERUNG DER ANGEWANDTEN FORSCHUNG EV, COMMISSARIAT A L ENERGIE ATOMIQUE ET AUX ENERGIES ALTERNATIVES, CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE CNRS |

https://www.nimphea.eu/

### PROJECT AND GENERAL OBJECTIVES

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

### NON-QUANTITATIVE OBJECTIVES

- Design the concept of the new-generation disruptive MEA operating above 120°C and develop its components.
- Upscale the small-scale MEA with a view to prepare for manufacturing and future integration at fuel cell stack level.
- Validate and demonstrate the performances 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 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/cm² | 0.75 | 0.13 (160°C, 0.75V) | | 0.1 W/cm² (160°C, 0.65V) | 2024 |
| | Power density (optimal conditions) | W/cm² | 1.25 | 0.3 (180°C, 0.5V) | | 0.29 W/cm² (180°C, 0.5V) | 2024 |
| | Degradation rate | µV/h | 3-5 | - | | N/A | N/A |
| | Membrane uniformity (thickness) | % | ± 7 | - | | | |
| | GDE uniformity (PGM variation) | % | ± 5 | 1.7 | | | |

# PEMTASTIC

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

PEMTASTIC

| | |
|---|---|
| **Project ID** | 101101433 |
| **PRR 2025** | 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 - 31-01-2026 |
| **Coordinator Beneficiary** | DEUTSCHES ZENTRUM FUR LUFT - UND RAUMFAHRT EV, DE |
| **Beneficiaries** | SYMBIO FRANCE, IMERYS GRAPHITE and CARBON BELGIUM, CHEMOURS FRANCE SAS, CHEMOURS BELGIUM, THE CHEMOURS COMPANY FC, LLC, HERAEUS DEUTSCHLAND GMBH and CO KG, IMERYS GRAPHITE and CARBON SWITZERLAND SA, IRD FUEL CELLS A/S, ZURCHER HOCHSCHULE FUR ANGEWANDTE WISSENSCHAFTEN, COMMISSARIAT A L ENERGIE ATOMIQUE ET AUX ENERGIES ALTERNATIVES |

https://pemtastic-project.eu/

### PROJECT AND GENERAL OBJECTIVES

PEMTASTIC aims to tackle the key technical challenges to increase durability of membrane electrode assemblies (MEAs) for heavy-duty applications. These challenges are approached with 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 temperature (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 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.
- Development of a multiscale modelling approach to predict cell performance and degradation processes from the mesoscale to the single-cell level, improving understanding of which characterisations are needed or available to parametrise the models.
- Implementation, validation and revision of new testing protocols into test benches ensuring reproducibility among testing partners.
- Durability tests up to 1 500 hours using PEMTATIC heavy-duty load cycle along with in-situ and ex-situ characterisation.
- Sensitivity study on Gen0 and Gen1 MEAs and ongoing stressor tests.
- Use of innovative materials from IMERYS, Herae-

Clean Hydrogen Partnership

Co-funded by the European Union

PEMTASTIC

us and Chemours to design the first generation PEMTASTIC MEA.

- Identification of promising materials the second generation PEMTASTIC MEA.
- Very good visibility of PEMTASTIC achieved (website, LinkedIn, workshops, fairs).

## FUTURE STEPS AND PLANS

- Finalise tests on the first generation PEMTASTIC MEA.
- Assembly of the second generation PEMTASTIC MEA.
- Improvement of degradation model using experimental results of the first-generation MEA.
- Demonstration that model outcomes can guide the MEA development to improve MEA performance and durability.
- Disseminate project results in conferences and journals.

## 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. Stable prototype membrane used with 2.5-fold higher AST durability. 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 mgcm-2. | | 0.4 | 2020 |
| | Power density | W cm-2 | 1.2@0.65 V | Adjustment of I/C ratio to optimise performance. In differential conditions Gen1 exhibits power of 1.2 Wcm-2 at 650 mV and Pt loading of 0.3 mg cm-2. | | 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 allow identification of degradation at targeted temperature. | | N/A | N/A |



Clean Hydrogen Partnership
Co-funded by the European Union

# REALHYFC

## RELIABLE DURABLE HIGH POWER HYDROGEN FUELED PEM FUEL CELL STACK

RealHyFC

| | |
|---|---|
| **Project ID** | 101111904 |
| **PRR 2025** | 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 - 31-05-2026 |
| **Coordinator Beneficiary** | COMMISSARIAT A L ENERGIE ATOMIQUE ET AUX ENERGIES ALTERNATIVES, FR |
| **Beneficiaries** | UNITED MOTION IDEAS, DYNERGIE, Powercell Sweden AB, IRD FUEL CELLS A/S, ZENTRUM FUR SONNENENERGIE- UND WASSERSTOFF-FORSCHUNG BADEN-WURTTEMBERG, UNIVERZA V LJUBLJANI, AVL LIST GMBH, DEUTSCHES ZENTRUM FUR LUFT - UND RAUMFAHRT EV |

https://realhyfc-project.eu/

### PROJECT AND GENERAL OBJECTIVES

RealHyFC has targets in efficiency, reliability and durability for proton exchange membrane fuel cells (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 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 the local degradation of stack components and better controlling the stack operations to hinder conditions promoting reversible or irreversible losses are the selected predominant means to improve stacks lifetime. Meanwhile, to enable heavy-duty-vehicle specific improvements aiming at 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 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 on hydrogen for heavy-duty applications in all relevant scopes (industries, regulatory bodies, policy makers, citizens).



Clean Hydrogen Partnership

Co-funded by the European Union

RealHyFC

## PROGRESS, MAIN ACHIEVEMENTS AND RESULTS

- Definition and manufacturing of reference metallic stacks for PEMFC and for a new graphite composite stack.
- Definition of a project-specific MEA for all the stack platforms identified for the investigations and technical solutions developments: Commercial Design Metal (CDM), Open Design Metal (ODM) and Open Design Carbon (ODC).
- Definition of test protocols for the quantification of performance and durability testing including a heavy-duty cycle.
- Two metallic stack platforms showed similar performance and good reproducibility in tests conducted at three partners.
- Confirmation of appropriate level of performance of the newly tested open-design, compared to the state-of-the-art design providing confidence in the database to be used for further developments.
- The heterogeneities within the stacks have been studied with simulations and measurements on the ODM stack. The catalyst degradation modelling framework was extended to accommodate bimetallic nanoparticles, and a model reduction strategy was introduced to optimise simulation performance. The metal BPP corrosion model was enhanced, enabling more accurate predictions. Multiple machine learning techniques were implemented to estimate remaining useful life and state of health. Reduced order models have been created to improve computational efficiency in energy management systems. A spatially resolved operational condition observer was developed to provide real-time insights. Advanced models and test systems were utilised to simulate real-world conditions, integrating virtual sensors and digital twin models for real-time operational condition assessments.
- An open graphite-composite design was devised for optimal BPPs, offering the best achievable comparability to the open metal design. This graphite composite open design will enable direct valuable comparison between metal and graphite composite technology. Furthermore, this reference carbon composite design will form the basis for the development of an optimised stack featuring improved BoS components and BPPs to enhance homogeneity and durability.
- Increased understanding of inhomogeneity issues is achieved through significant progress on characterisation of mechanical component properties and modelling of constraints within large stacks.
- Communication and dissemination activities, through social media, as well as a first successful workshop dedicated to industry stakeholders, have raised awareness around the hydrogen market and PEMFC developments realised through RealHyFC.
- Active synergies with sister projects allowed to pave the way towards the common objective of supporting future industrial empowerment of RealHyFC results.

## FUTURE STEPS AND PLANS

- Additional tests on available CDM, ODM and ODC short-stacks with selected protocols and test program: performance, sensitivity, durability.
- Ex-situ analyses on pristine and MEA samples, aged in the project stacks, and of metal bipolar plates from available other sources, for determination and understanding of mechanisms and for validation of the performance and degradation models related to the stack core materials.
- Model and algorithms validation based on RealHyFC stack performance data.
- Continuation of model implementation to develop control algorithms for monitoring operational conditions, state of health, and remaining useful life.
- Continuation of developments for optimisation of control and energy management system, based on a representative description of the application conditions and usage profile.
- Continuation of developments on the open design carbon bipolar plates and stacks.
- Validation of simulations of heterogeneity in the open-design stack by coupling cell performance models with mechanical constraint models.
- Further dissemination and communication actions are foreseen with more scientific publications, continuous website updates, posts on LinkedIn about RealHyFC and the hydrogen market, and the organisation of the second project workshop (due by the end of 2025).

## 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 | 50 | ⚙ |

# REVIVE

## REFUSE VEHICLE INNOVATION AND VALIDATION IN EUROPE

| | |
|---|---|
| Project ID | 779589 |
| PRR 2025 | Pillar 3 - $H_2$ End Uses - Transport |
| Call Topic | FCH-01-7-2017 |
| Project Total Costs | 9 760 023.65 |
| Clean $H_2$ JU Max. Contribution | 4 993 851.00 |
| Project Period | 01-01-2018 - 31-12-2024 |
| Coordinator Beneficiary | TRACTEBEL ENGINEERING S.A., BE |
| Beneficiaries | ERM FRANCE, GEMEENTE GRONINGEN, ERM FRANCE, GEMEENTE NOORDENVELD, ENGIE IMPACT BELGIUM, GEMEENTE GRONINGEN, SAVER NV, PREZERO NEDERLAND HOLDING BV, AZIENDA SERVIZI MUNICIPALIZZATI DI MERANO SPA, SEAB SERVIZI ENERGIA AMBIENTE BOLZANO SPA, SWISS HYDROGEN SA, RENOVA AKTIEBOLAG, E-TRUCKS EUROPE, ENVIRONMENTAL RESOURCES MANAGEMENT LIMITED, GEMEENTE BREDA, SYMBIO, STAD ANTWERPEN,WATERSTOFNET VZW, Powercell Sweden AB, ELEMENT ENERGY LIMITED, Proton Motor Fuel Cell GmbH, GEMEENTE AMSTERDAM, COMMISSARIAT A L ENERGIE ATOMIQUE ET AUX ENERGIES ALTERNATIVES |

https://h2revive.eu/

### PROJECT AND GENERAL OBJECTIVES

REVIVE will significantly advance the state of development of fuel cell bin lorries by integrating fuel cell power trains into eleven vehicles and deploying them at eight sites across Europe. The project will deliver substantial technical progress by integrating fuel cell systems from four major suppliers and by developing effective hardware and control strategies to meet highly demanding refuse truck duty cycles., All trucks are in operation.

### NON-QUANTITATIVE OBJECTIVES

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

### PROGRESS, MAIN ACHIEVEMENTS AND RESULTS

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

### FUTURE STEPS AND PLANS

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

### PROJECT SRIA TARGETS

| Target source | Parameter | Unit | Target | Achieved to date by the project | Target achieved? | SoA result achieved to date (by others) |
|---|---|---|---|---|---|---|
| Project's own objectives | FC Power | kW | >40 | 45 | ✓ | 90 |
| | Tank-to-wheel efficiency | % | 50 | 55 | | N/A |



Clean Hydrogen Partnership
Co-funded by the European Union

# RH$_2$IWER

## RENEWABLE HYDROGEN FOR INLAND WATERWAY EMISSION REDUCTION

| | |
|---|---|
| **Project ID** | 101101358 |
| **PRR 2025** | 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** | MTS DUISBURG GMBH, H2BOAT SRL, VERENIGDE TANKREDERIJ B.V., SOGESTION, AIR LIQUIDE BV, FUTURE PROOF SHIPPING BV, L'AIR LIQUIDE BELGE, DFDS AS, STICHTING PROJECTEN BINNENVAART, Compagnie Fluviale de Transport, THEO POUW BV, BALLARD POWER SYSTEMS EUROPE AS, NEDSTACK FUEL CELL TECHNOLOGY BV, L AIR LIQUIDE SA, UNIVERSITA DEGLI STUDI DI GENOVA |

http://rh2iwer.eu/

### PROJECT AND GENERAL OBJECTIVES

RH$_2$IWER 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$_2$IWER 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$_2$IWER will create a basis on which the shipping industry can significantly reduce its environmental footprint and remove emissions from its entire fleet in the future.

### NON-QUANTITATIVE OBJECTIVES

- 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$_2$IWER partners have been working to develop the demonstration vessels' general design as well as the business cases. Partners have also started to work on standardised fuel cell and hydrogen storage containers in order to alleviate the risks for shipowners in the future when adopting these technologies.

### FUTURE STEPS AND PLANS

Moving forward in the project, the hydrogen and fuel cell systems on board of the vessels will be designed in more detail and 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** | $H_2$andFC vessels demonstrated | Number | 6 | |
| | Maritime FCH lifetime | hours | 40 000 | |
| | Safety, PNR/RCS workshops | Number/ year | 1 | ✓ |

# SH$_2$APED

## STORAGE OF HYDROGEN: ALTERNATIVE PRESSURE ENCLOSURE DEVELOPMENT

| | |
|---|---|
| **Project ID** | 101007182 |
| **PRR 2025** | Pillar 3 - $H_2$ End Uses - Transport |
| **Call Topic** | FCH-01-1-2020 |
| **Project Total Costs** | 1 993 550.00 |
| **Clean $H_2$ JU Max. Contribution** | 1 993 550.00 |
| **Project Period** | 01-01-2021 - 30-09-2024 |
| **Coordinator Beneficiary** | PLASTIC OMNIUM NEW ENERGIES, FR |
| **Beneficiaries** | MISAL SRL, OPTIMUM CPV, OMB SALERI SPA, PLASTIC OMNIUM ADVANCED INNOVATION AND RESEARCH, BUNDESANSTALT FUER MATERIALFORSCHUNG UND -PRUEFUNG, UNIVERSITY OF ULSTER |

https://sh2aped.eu/

### PROJECT AND GENERAL OBJECTIVES

The goal of the SH$_2$APED project is to develop and test, at technology readiness level 4, a conformable and cost-effective hydrogen 70 MPa hydrogen storage system with increased efficiency and exceptional safety performance.

### NON-QUANTITATIVE OBJECTIVES

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

### PROGRESS, MAIN ACHIEVEMENTS AND RESULTS

The project has achieved significant technical advancements, such as:

- Integration of fiber optic sensors in composite pressure vessels.
- Improved safety design of 70 MPa hydrogen storage system.
- Advanced computational fluid dynamics modeling.
- Development of a conformable hydrogen storage system with microleaks-no-burst technology.
- Improved manifold design for hydrogen tanks.
- Enhanced manufacturing processes, ex. blow modeling technology for liners.

### 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 | $H_2$ storage volume for estimated design space | % | > 45 | 42 | | 41 | 2021 |
| | Cost for tank system | €/kg $H_2$ | 400 | >850 | | DOE target | 2022 |
| | Low-cost process for liner | 1M | 1M | 3M | | N/A | 2021 |
| | Burst pressure (R134) | MPa | > 157.5 | 170 | | 157 | 2022 |
| | Hydraulic Pressure Cycle test 87,5MPa, 20C | - | 22 000 | > 22 000 | ✓ | | |
| | Gravimetric efficiency | % | > 5.7 | 6.10 | | N/A | N/A |
| | Permeation | $cm^3/h/l$ at 55°C | < 46 | < 46 | | | |



Clean Hydrogen Partnership

Co-funded by the European Union

# SHIPFC

## PILOTING MULTI MW AMMONIA SHIP FUEL CELLS

| | |
|---|---|
| **Project ID** | 875156 |
| **PRR 2025** | Pillar 3 - $H_2$ End Uses - Transport |
| **Call Topic** | FCH-01-2-2019 |
| **Project Total Costs** | 13 179 056.25 |
| **Clean $H_2$ JU Max. Contribution** | 9 975 477.50 |
| **Project Period** | 01-01-2020 - 31-12-2025 |
| **Coordinator Beneficiary** | MARITIME CLEANTECH, NO |
| **Beneficiaries** | YARA CLEAN AMMONIA NORGE AS, ALMA CLEAN POWER AS, EIDESVIK SHIPPING AS, Wärtsilä Gas Solutions Norway AS, SUSTAINABLE ENERGY AS, NORTH SEA SHIPPING AS, STAR BULK SHIP MANAGEMENT CO. (CYPRUS) LTD, WARTSILA NORWAY AS, CAPITAL-EXECUTIVE SHIP MANAGEMENT CORP, PERSEE, CLARA VENTURE LABS AS, EQUINOR ENERGY AS, Yara International ASA,UNIVERSITY OF STRATHCLYDE, NATIONAL CENTER FOR SCIENTIFIC RESEARCH "DEMOKRITOS", FRAUNHOFER GESELLSCHAFT ZUR FORDERUNG DER ANGEWANDTEN FORSCHUNG EV |

http://shipfc.eu

### PROJECT AND GENERAL OBJECTIVES

ShipFC's main mission is to prove and demonstrate the case for large-scale zero-emission shipping through developing, piloting and replicating a modular 2 MW fuel cell technology using ammonia as fuel. The project will also prove the case for large-scale, zero-emission fuel infrastructure through a realistic business model. Currently, the fuel cells are being scaled up and going through laboratory testing.

### NON-QUANTITATIVE OBJECTIVES

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

### PROGRESS, MAIN ACHIEVEMENTS AND RESULTS

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

### FUTURE STEPS AND PLANS

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

### PROJECT TARGETS

| Target source | Parameter | Unit | Target | Achieved to date by the project | Target achieved? |
|---|---|---|---|---|---|
| **Project's own objectives** | GHG reduction by use of ammonia Fuel | % | 70 | - | |
| | Ammonia SOFC system Power | MW | 2 | 6 kW | |

# STASHH

## STANDARD-SIZED HEAVY-DUTY HYDROGEN

| | |
|---|---|
| **Project ID** | 101005934 |
| **PRR 2025** | 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** | FEV SOFTWARE AND TESTING SOLUTIONS GMBH, PLASTIC OMNIUM NEW ENERGIES WELS GMBH, VDL SPECIAL VEHICLES BV, DAMEN RESEARCH DEVELOPMENT and INNOVATION BV, FREUDENBERG FUEL CELL E POWER SYSTEMS GMBH, DAMEN GLOBAL SUPPORT BV, VDL ENERGY SYSTEMS, PLASTIC OMNIUM NEW ENERGIES WELS GMBH, FUTURE PROOF SHIPPING BV, HYSTER-YALE ITALIA SPA, FCP FUEL CELL POWERTRAIN GMBH, VDL ENABLING TRANSPORT SOLUTIONS BV, HYUNDAI MOTOR EUROPE TECHNICAL CENTER GMBH, HYDROGENICS GMBH, FREUDENBERG FST GMBH,AKTIEBOLAGET VOLVO PENTA, SYMBIO,SCHEEPSWERF DAMEN GORINCHEM BV,INTELLIGENT ENERGY LIMITED, VOLVO CONSTRUCTION EQUIPMENT A+B, WATERSTOFNET VZW, BALLARD POWER SYSTEMS EUROPE AS, SOLARIS BUS and COACH SPOLKA Z OGRANICZONA ODPOWIEDZIALNOSCIA, Proton Motor Fuel Cell GmbH, TOYOTA MOTOR EUROPE NV, CETENA SPA CENTRO PER GLI STUDI DI TECNICA NAVALE, NEDSTACK FUEL CELL TECHNOLOGY BV, FEV EUROPE GMBH, ALSTOM TRANSPORT SA, AVL LIST GMBH, VOLVO TECHNOLOGY AB, NEDERLANDSE ORGANISATIE VOOR TOEGEPAST NATUURWETENSCHAPPELIJK ONDERZOEK TNO, COMMISSARIAT A L ENERGIE ATOMIQUE ET AUX ENERGIES ALTERNATIVES |

https://stashh.eu

### PROJECT AND GENERAL OBJECTIVES

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