REALHYFC

RELIABLE DURABLE HIGH POWER HYDROGEN FUELED PEM FUEL CELL STACK



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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).







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	by the project	larget 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	€ E



