TECHNOLOGY DETAILS

Technology: **Hydrogen fuel cell electric vehicle**
Sub-technology: **High temperature proton exchange membrane**

Value chain: Shipping
Sub-sector or technology: Vehicle/aircraft/vessel and components
Sector: Transport
Demand/Supply/Infrastructure: Demand

TRL $_{2023}$: 6

According to IEA criteria, the TRL of this technology in 2021 was: **6**

TECHNOLOGY DESCRIPTION

High Temperature Proton Exchange Membrane Fuel Cells (HT-PEMFC), rely mainly on the use of phosphoric acid-based membranes. HT-PEMFCs operate in the 150-250C range and, due to the higher temperature, have low sensitivity to fuel, impurities. This allows them to run with LNG, methanol, diesel as primary fuels after an external reforming stage, as well as directly with hydrogen. The higher temperature also allows for better catalyst performance and better system heat rejection. HT-PEMFCs have demonstrated stack efficiencies of 50-60% slightly higher than a PEM FC. Moreover, the High temperature PEMFC is less susceptible to CO and sulphur toxicity and does not require a water management system compared to the PEMFC, but has a lower power density and cannot be started from cold. They have comparable, if not lower cost, to other fuel cell technologies for maritime applications. Their modular design allows for building blocks at the kW level (eg. 50kW modules) that can be compiled for MW-scale systems. Remaining challenges include lifetime and relatively lower performance to other fuel cell technologies. http://www.dnvgl.com/maritime/publications/alternative-fuel-assessment-download.html).

Due to limited power output, this technology is likely to be used preferably for small and medium vessels, as currently proved by the ongoing demonstrations.

COST REDUCTION TARGETS

Stack optimisation for higher performance, durability, and reliability, including game-changing concepts on fundamental components and new methods for monitoring stack and system health.

Developing low-cost ideas and enhancing manufacturability and recyclability (processes, automation, quality control instruments, in-line and end-of-line diagnostics).

Various fuels that can be converted to hydrogen-rich gas in a reformer (such as methanol, ethanol, propanol, bio-butanol, bio-glycerol, methane, ethane, propane, butane, OME, gasoline, and ammonia) can be used.

HT-PEMFCs are one type of prospective energy device due to their fast reaction kinetics (high energy efficiency), high tolerance to fuel/air impurities, uncomplicated plate design, and improved heat and water management.

HT-PEMFC stacks face potential corrosion, mechanical failure of bipolar plates (BPPs), and degradation of the catalyst/catalyst support, catalyst layer (CL), and proton exchange membrane (PEM) at high-temperature, as well as inadequate heating strategies to achieve and maintain high operating temperature.

The U.S. Department of Energy and Lawrence Berkeley National Laboratory reported in 2014 that the HT-PEMFC stack cost at low production volumes (10 kW, 100 systems per year) is approximately 840 $/kW, whereas at high production volumes (100 kW, 50 000 systems per year), the HT-PEMFC stack cost is approximately 360 $/kW.

KEY COUNTRIES

Germany, Norway, USA

PROTOTYPE OR DEMONSTRATION PLANS, DEDICATED INVESTMENTS, LEADING INITIATIVES

High Temperature fuel cells are being developed and tested:

- Project MF Vågen, Norway, including a 12kW HT-PEM for small port commuter ferry http://www.emsa.europa.eu/emsa-homepage/2-news-a-press-centre/news/2921-emsa-study-on-the-use-of-fuel-cells-in-shipping.html
- HT-PEMFCs are demonstrated in the RicerCell projectT. he project is dedicated to the design and development of a fuel cell hybrid system for inland vessels. https://www.advent.energy/2021/12/20/rivercell-consortium-announces-successful-demonstration-of-advent-serene-fuel-cells-to-the-maritime-sector/
- In the Pa-X-ell project, a 90 kW methanol-fueled high-temperature proton exchange membrane fuel cell (HT-PEMFC) system with a reformer is deployed as an auxiliary power unit on a passenger vessel in addition to its conventional energy supply.
- Using metal hydride as a source of hydrogen, a 12 kW HTPEMFC has been installed on the MF Vgen passenger vessel.
- RiverCell 250 kW Methanol
- MF Vågen 12 kW H2
- RiverCell ELEKTRA 3 × 100 kW H2

DEPLOYMENT TARGETS

The International Maritime Organization (IMO) aims to reduce the total annual GHG emissions by at least 50 percent by 2050 compared to 2008, while pursuing efforts to eliminate them entirely.

The average system size per vessel has risen to over 1MW, per the project database tracked by IDTechEx in "“Fuel Cell Boats & Ships 2023-2033: PEMFC, SOFC, Hydrogen, Ammonia, LNG“. Few large systems in inland cargo vessels, workboats, offshore support vessels (OSVs), tugs, cruise ships, and ferries currently dominate the market.

IDTechEx anticipates that the market is still in its infancy, and the IDTechEx report predicts that by the end of 2022, a total of 6MW of fuel cells will have been delivered to vessels.

RELEVANT PARAMETERS

Hydrogen purity (%)	Reformate gas with hydrogen concentration of 50 - 75 %
CO concentration (%)	Up to 3% (30,000ppm) CO
Star-up time (h)	Approx. 15 min.
Temperature (ºC)	120 – 250
Efficiency (kWh/kg)	18 – 19 kWh/kg
System cost (€/MW)	~$1500/kW (100 kW system at 1,000 units per year)
Cell lifetime (h)	17,000 (MEA)
Temperature resistance materials	140 – 240

Based on expert input:

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