TECHNOLOGY READINESS LEVEL (TRL) - 2023

IEA Technology Collaboration Programme
Advanced Fuel Cells

TECHNOLOGY DETAILS

Technology: **Hydrogen fuel cell electric vehicle**
Sub-technology: **Proton Exchange Membrane**

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

TRL 2023: 8

According to IEA criteria, the TRL of this technology in 2021 was: **7**
TRL has increased since several first demonstrative commercial applications have been released.

TECHNOLOGY DESCRIPTION

This type of vessels is operated by a hydrogen fuel cell. Due to limited power output, this technology is likely to be used preferably for small and medium vessels, as currently proved by the on-going demonstrations.

Different fuel-cell types exist, and their names reflect the materials used in the electrolyte membrane.

DNV GL evaluated 7 fuel-cell technologies and concluded that the following are the most promising for maritime applications (source: http://www.dnvgl.com/maritime/publications/alternative-fuel-assessment-download.html).

According to the study from DNV-GL, Proton exchange membrane (PEM) fuel cell is considered a mature technology. Its operating temperature is 50-100 degrees Celsius and has a typical efficiency of is 50-60% and a moderate lifetime. It has medium sensitivity to impurity, thus requiring hydrogen as a fuel, and a low cost (compared to other fuel cell technologies for maritime applications).

Manufacturing compact fuel cells with high power densities is quite challenging. Thus, this technology is likely to be used preferably for small and medium vessels.

KEY COUNTRIES

Norway, U.S., South Korea, England, Denmark

Geographically, most of the fuel cell market is in Asia, Europe, and North America.

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.

Vertically integrated companies Nedstack, Powercell, and Ballard are among the leading marine PEMFC suppliers. Corvus Energy is another notable competitor with plans to release its first FC product using Toyota-sourced fuel cells within the next few years.

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 majority of orders in the midterm will utilize PEMFC technology and remain in inland and coastal sectors (due to hydrogen's volumetric limitations). However, the market is still in its infancy, and the IDTechEx report predicts that by the end of 2022, a total of 6MW will have been delivered to vessels.

PROTOTYPE OR DEMONSTRATION PLANS, DEDICATED INVESTMENTS, LEADING INITIATIVES

* FCS Alsterwasser 5-year lake demonstration project (GER) (Source: http://ec.europa.eu/environment/life/project/Projects/index.cfm?fuseaction=home.showFile&rep=file&fil=Zemships_Brochure_EN.pdf)

* Hyseas III project (UK)

* Ballard & ABB have a joint demonstration projects for a hydrogen FC tugboat http://www.electrive.com/2019/05/23/ballard-abb-developing-fc-tugboat/

* Norwegian Public Roads Administration has initiated a development project aiming to have the first hybrid H2 fuel cell ferry in commercial operation in 2021 http://www.dnvgl.com/expert-story/maritime-impact/Power-ahead-with-hydrogen-ferries.html

* Water-Go-Round has been launched. https://watergoround.com/

* ABB is working on a megawatt-scale hydrogen fuel cell to power the auxiliaries of a container ship https://newatlas.com/marine/hydrogen-ships-fuel-cell-marine-abb/

* VINCI Energies are developing a prototype of fuel cell 25-meters ferry that should become operative in 2020. Two 1 MW fuel cells will be installed http://www.vinci-energies.com/en/our-news/newscenter/renewable-energies-and-a-hydrogen-fuel-cell-to-power-a-ferry/

* Horizon2020 funded FLAGSHIP project aims at demonstrating the technical feasibility of hydrogen fuel cell as powertrain on two ships: a utility vessel on river and a passenger and car ferry. A total of 1.2 MW of on-board fuel cells will be installed https://cordis.europa.eu/project/id/826215

* The project of FC ship including fuel supply system was announced in Japan. https://global.kawasaki.com/en/corp/newsroom/news/detail/?f=20200901_6686

Among the largest orders are PowerCell's 3.2MW PEMFC system, and Nedstack's 2MW PEMFC orders for the H-Tug and Ulstein OSV.

Maranda Project: 2 PowerCell commercial stack-based 82.5 kW modules fueled by 350 bar compressed hydrogen.

HyShip: Vessel powered by green liquid hydrogen via 3 MW-PEMFC and 1 MWh battery system.

RiverCell: Inland passenger ship powered by 2 PEMFC modules (90 kW), three diesel generators, and two battery packs

TecBIA: 2 × 71 kW ProtonMotor PEMFC, 150 kWh of battery packs

HFC Marine: 200 kW PEMFC system, hybridized

Pa-X-ell 2: 2 MW PEMFC, for a ship in Denmark

H2PORTS: 70 kW PEMFC system, , hybridized

COST REDUCTION TARGETS

None.

RELEVANT PARAMETERS

Energy density	1,5 kW/kg
Fuel cell efficiency (%)	43.5 - 55
Cost (€)	2000 €/kW
Platinum loading	0,5 g/kW
Durability	20,000

Based on expert input:

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