

TECHNOLOGY DETAILS

Technology: **Hydrogen fuel cell electric vehicle**
Sub-technology: **Solid Oxide**

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

TRL 2023: 7

According to IEA criteria, the TRL of this technology in 2021 was: 7

TECHNOLOGY DESCRIPTION

Solid Oxide Fuel Cells (SOFC) run at very high temperature (500-1000 degrees Celsius).

This fuel cell has low sensitivity to impurities, thus being able to run with hydrogen, methanol, LNG and diesel. It has a high cost (compared to other fuel cell technologies for maritime applications), can have medium size and has a moderate lifetime. Typical efficiency is 60% and this can be optimised to 85% with heat recovery (source: <http://www.dnvgl.com/maritime/publications/alternative-fuel-assessment-download.html>).

SOFC finds use as a propulsion component in hybrid designs; it operates at high temperatures (about 1000 °C), with sluggish power-setting fluctuations yet achieving great efficiency and enabling cogenerative systems. Due to these factors, SOFCs may act as the main propulsion system in transportation applications requiring high-power, often in hybrid setups with traditional propulsion systems. Large-scale applications, such ships and yachts, may use SOFCs as their main energy source if their sizes are more than 50 kW. Cogeneration applications, which provide electrical and thermal energy in SOFC-based systems, may also be assessed. Potential input fuels include hydrogen, natural gas, and/or diesel. A hybrid system made up of batteries and/or gas turbines is necessary for the SOFC sluggish load shifts.

SOFC can run with methanol, LNG and diesel but in that case external reformer (STR, ATR or POX) has to be used. Also LOHC can be used in marine applications as hydrogen storage.

KEY COUNTRIES

Norway, Denmark, Finland, Korea, Germany, USA and UK

DEPLOYMENT TARGETS

* The International Energy Agency (IEA) forecasts that biofuels, ammonia and hydrogen meet more than 80% of shipping's fuel needs by 2070.

<https://www.iea.org/reports/energy-technology-perspectives-2020>

* In the beginning few MWs class APU will be utilized and used in marine applications but 100% SOFC powered ships are quite far away in future.

PROTOTYPE OR DEMONSTRATION PLANS, DEDICATED INVESTMENTS, LEADING INITIATIVES

- SOFC development by Thyssenkrupp and Sunfire:
- MS Forester cargo ship, in the framework of E4Ships SchIBZ project has received a Diesel fuelled SOFC <http://www.sunfire.de/en/company/news/detail/sunfire-supplies-thyssenkrupp-marine-systems-with-50-kw-sofc-20>
- Bloom Energy and Samsung Heavy Industries Team Up to Build Ships Powered by Solid Oxide Fuel Cells <http://www.bloomenergy.com/newsroom/press-releases/bloom-energy-and-samsung-heavy-industries-team-up>
- Samsung announced new SOFC ship. <https://www.rivieramm.com/news-content-hub/fuel-cell-powered-Ing-carrier-breakthrough-for-samsung-66405>
- Shell-led consortium to explore Solid Oxide Fuel Cell technology use in shipping sector. <https://www.shell.com/business-customers/marine/news-and-media-releases/news-and-media-2022/shell-led-consortium-to-explore-solid-oxide-fuel-cell-technology-use-in-shipping-sector.html>
- ShipFC The ShipFC Project Will Demonstrate That Long-Range Zero-Emission Voyages with High Power on Larger Ships Is Possible. <https://shipfc.eu/about/>
- CORDIS Nautical Integrated Hybrid Energy System for Long-Haul Cruise Ships. Horizon 2020, 2020, 1–11. <https://nautilus-project.eu/news/why-the-sofc-module-is-tested-on-the-inclination-pod>
- SOFC4MARITIME. <https://www.zerocarbonshipping.com/projects/solid-oxide-fuel-cell-sofc-4-maritime/>
- FuelSOME. <https://cordis.europa.eu/project/id/101069828>

COST REDUCTION TARGETS

- Ships have had SOFC demonstrations with a 20–50 kW capacity. Scaling up is crucial.
- FC power rating, from 0.5 MW to 10 MW in 2030
- Maritime fuel cell system lifetime: up to 80,000 hours in 2030
- Warm start time down to 2 min in 2030
- improvements to FC stack design, diagnosis, and monitoring processes (looking at novel measurement / sensor devices for this purpose as well);
- improvements to testing procedures, including faster stress tests, for measuring the performance and longevity of FC stacks in marine conditions;
- Multi-modular connected stack;
- FC stacks' total system performance has to be improved in order to fulfill the demands of naval and marine end users while also increasing availability and longevity.
- Cost target for SOFC systems is 1400 €/kW. Currently cost is double or triple comparing to this.

RELEVANT PARAMETERS

Temperature (°C)	600 - 850
Efficiency (kWh/kg)	11.6 – 21.45
System cost (€/MW)	1,000,000 – 2,000,000
Cell lifetime (h)	20,000 – 25,000
Temperature resistance materials	600 - 1000

Based on expert input:

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