TECHNOLOGY READINESS LEVEL (TRL) - 2023

IEA Technology Collaboration Programme
Advanced Fuel Cells

TECHNOLOGY DETAILS

Technology: **Hydrogen fuel cell electric vehicle**

Value chain: Rail
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: **8**
The TRL at the beginning of 2023 is still 8, even if several commercial orders have been purchased in several countries. TRL is expected to achieve the status of “TRL 9 – Commercial operation in relevant environment" at the beginning of 2024.

TECHNOLOGY DESCRIPTION

A hydrogen fuel cell system generates electric power to run an electric motor, providing tractive energy. This technology represents an alternative to diesel for trains running on non-electrified tracks.

Hybrid battery and fuel cell configurations for rail are essential for increasing performance and range. Hybridized fuel cell trains can accommodate cargo up to 5,000 tonnes, travel at velocities of up to 180 km/h and attain a range of up to 700 km. Hydrogen-powered rail vehicles can operate for more than 18 hours without replenishing and can be refuelled in less than 20 minutes. However, when Fuel Cell technology is implemented without structural alterations to the body, it can cause issues such as lower passenger capacity or limited driving performance. Additionally, bi-mode trains can run solely on electricity from the catenary while also using Fuel Cell technology for non-electrified areas of the network Battery-powered trains suffer also from reduced range and increased idleness for recharging and are only appropriate for a limited number of routes. Hydrogen locomotives, on the other hand, have a promisingly low total cost of operation (TCO). A TCO analysis (https://rail-research.europa.eu/wp-content/uploads/2019/05/Study-on-the-use-of-fuel-cells-and-hydrogen-in-the-railway-environment_final.pdf) demonstrates that hydrogen-powered trains are less expensive than diesel and catenary electrification when the following conditions are met: the price of diesel reaches 1.35 euros per liter and the electricity price is less than 50 euros per megawatt-hour. There is no compromise in performance, and hydrogen-powered railroads are as versatile and adaptable as diesel-powered locomotives with comparable range. They are capable of meeting the needs of rail transport just as well as diesel trains.

KEY COUNTRIES

Germany, Japan, Korea, Italy, France, Spain, China, Canada, United States, Netherlands.

DEPLOYMENT TARGETS

HydrogenEurope targets 10% of trains sold for non-electrified railways to be powered by hydrogen fuel cells by 2030 (Source: http://www.hydrogeneurope.eu/sites/default/files/2018-10/Public_HE%20Tech%20Roadmaps_full%20pack_0.pdf)

Spain:
- Development of two hydrogen train lines running on 2030
https://www.miteco.gob.es/es/ministerio/planes-estrategias/hidrogeno/h2executivesummary_tcm30-513831.pdf

PROTOTYPE OR DEMONSTRATION PLANS, DEDICATED INVESTMENTS, LEADING INITIATIVES

* Europe leads in this area, having introduced fuel cell drivetrains in the rail sector, and having successfully deployed large scale infrastructure and formulated regulations that allow the use of hydrogen on railways

http://www.hydrogeneurope.eu/sites/default/files/2018-10/Public_HE%20Tech%20Roadmaps_full%20pack_0.pdf

* Alstom is running two hydrogen fuel cell trains on a short route in Germany and is now testing one hydrogen fuel cell train in Netherlands (https://www.alstom.com/press-releases-news/2020/9/trial-runs-alstoms-hydrogen-train-netherlands-deemed-officially) and one in Austria (https://www.h2-view.com/story/alstom-hydrogen-train-now-operational-in-austria/). Sweden has just started operating one exemplar of Alstom's hydrogen train (https://www.railway-technology.com/news/alstoms-coradia-ilint/).Besides, France and Italy have placed an order to Alstom to deliver respectively 12 and 6 hydrogen FCEV trains in 2023. Taunus region in Germany (Frankfort area) has ordered 27 hydrogen FCEV trains for 2022 (http://www.alstom.com/press-releases-news/2019/5/rmvs-subsidiary-fahma-orders-worlds-largest-fleet-fuel-cell-trains)

* Canada and US have also launched demonstration projects http://www.metrolinx.com/en/greaterregion/projects/hydrail.aspx and http://www.railwaygazette.com/traction-and-rolling-stock/us-hydrogen-train-contract-awarded/55124.article

* The UK (https://www.bbc.com/news/av/business-54350046), Korea (https://www.koreatechtoday.com/korea-railroad-research-institute-makes-eco-friendly-hydrogen-train-that-runs-372-mile-600km-on-a-single-charge/), Japan (https://www.asahi.com/ajw/articles/13796033), China (https://www.globaltimes.cn/page/202101/1214215.shtml) and Spain (https://fuelcellsworks.com/news/spain-talgos-hydrogen-train-will-be-ready-in-2023/?utm_source=FuelCellsWorks+Newsletter&utm_campaign=3a7ba6cc2e-NEWSLETTER_ISSUE_20&utm_medium=email&utm_term=0_b0517d6085-3a7ba6cc2e-406702557&mc_cid=3a7ba6cc2e&mc_eid=da4624d261) are planning or have just launched FCEV train trials with other technology developers.

* In addition, a fuel cell tram has started operating in Foshan (China) during 2019 and China is exploring further possibilities for H2-fueled rail.

COST REDUCTION TARGETS

A H2 drivetrain for a train is less than 150% diesel in capital costs (see http://www.hydrogeneurope.eu/sites/default/files/2018-10/Public_HE%20Tech%20Roadmaps_full%20pack_0.pdf).

Under low hydrogen costs, the operating costs of a hydrogen fuel cell train could be lower than for diesel one.

Other cost reduction targets include:

- Storage system optimization and CAPEX reduction: from 1,0000 €/kg H2 to 300 €/kg H2 in 2030, and Gravimetric capacity from 5 to 6% in 2030

- Fuel cell durability: up to 30,000 hours in 2030

- Hydrogen consumption: from 0.12 kgH2/100km/ton to 0.08 kg H2/100km/ton in 2030

- FC stack cost down to 50 €/kW in 2030

- Platinum loading at 0.3 g/kW in 2030

RELEVANT PARAMETERS

Energy density	1.0 W/cm2 when operating at 0.675 V
Fuel cell efficiency (%)	50-55 (Stack Efficiency)
Cost (€)	100 €/kW (for the Fuel Cell Stack)
Platinum loading	0.4 g/kW
Durability	15,000 hours (2020 - State of the Art)

Based on expert input:

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