TECHNOLOGY READINESS LEVEL (TRL) - 2023

IEA Technology Collaboration Programme
Advanced Fuel Cells

TECHNOLOGY DETAILS

Technology: **Hydrogen fuel cell electric vehicle**
Sub-technology: **Truck**

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

TRL 2023: 7 - 9

According to IEA criteria, the TRL of this technology in 2021 was: **7-8**
According to AFC TCP annual data collection results, the number of deployed medium duty fuel cell trucks reached 3871 units and heavy-duty fuel cell trucks reached 3321 units as of end of 2022. With these numbers, the TRL has changed from demonstration (7-8) to early adoption (9). The solution is commercially available with many OEMs selling fuel cell trucks, especially in China. Yet, evolutionary improvements are required so that the technology stays competitive. Already today, there are several examples where the fuel cell trucks have a better TCO than their diesel counterparts.

TECHNOLOGY DESCRIPTION

The hydrogen fuel cell electric vehicles (FCEVs) convert the chemical energy of hydrogen and air into electricity. FCEV are hybrid vehicles, as they are hydrogen dominant and only use a small battery compared to battery electric vehicles (at least by a factor of 10). By exploiting the higher gravimetric energy density of hydrogen, FCEVs can offer a higher range than BEVs, including long-range, fast refuelling, and zero tail-pipe emissions (they only emit water). However, their continuing deployment faces multiple technical and economic challenges, including safety of hydrogen handling (refuelling, residual leakage), lack of sufficient refuelling infrastructure, on-board hydrogen storage (see the dedicated entry below) and the high cost of the fuel cell stack (the electrochemical reaction inside the stack requires a proton exchange membrane (PEM) coated with a platinum-based catalyst, a costly material) and system. Costs of the fuel cell stack and system are expected to decline significantly with economies of scale.

For FCEVs to be competitive with other powertrain technologies, hydrogen must be delivered to hydrogen refuelling stations at prices that bring per kilometre costs into the same range as conventional ICEs, or of battery electric vehicles powered by grid electricity. This will require further cost reductions in technologies for low- and zero-carbon hydrogen production technologies (e.g., SMR with CCS, renewable electricity generation such as wind and solar coupled to electrolysers), as well as in hydrogen transmission and distribution networks and in hydrogen refueling stations (HRS). Fuel cells needs also to meet the high durability (e.g., 25,000-hour lifetimes) and performance requirements for trucks.

KEY COUNTRIES

Japan, Korea, Germany, United States, Sweden, China and Switzerland.

PROTOTYPE OR DEMONSTRATION PLANS, DEDICATED INVESTMENTS, LEADING INITIATIVES

* The first-of-a-kind commercial hydrogen fuel cell truck developed by Hyundai has obtained 1600 orders for Swiss market http://www.reuters.com/article/us-hyundai-hydrogen-trucks/powered-by-hydrogen-hyundais-trucks-aim-to-conquer-the-swiss-alps-idUSKCN20M0Z9

* Daimler, Fuso, Hyundai, Fuso, Toyota, Scania, Volkswagen, and PSA are developing FCEV trucks, ranging from prototypes to commercial models. The Arizona-based truck start-up Nikola has managed to secure substantial funding and many pre-orders for its Class 8-trucks. Scania has recently delivered class 7 FCEV trucks to Norway. Hyundai Motor and H2 Energy aim to provide 1 000 fuel cell electric trucks to the Swiss market by 2023. Scania, Daimler, and California-based Nikola also have models at various stages between prototype and customer trials. FedEx and UPS are trialling fuel cell range-extender Class 6 delivery vehicles, and in Europe, the h2Share project is demonstrating several heavy trucks over 12 t.

* In 2021, 796 fuel cell heavy-duty trucks in China were delivered by 10 different OEMS:

1) Nanjing Golden Dragon Bus Co., Ltd.2) Feichi Technology 3) Suzhou Golden Dragon/Higer 4) Chengdu Dayun Automobile Co. Ltd. (CDDY) 5) SAIC HONGYAN Company 6) Jiangling heavy truck 7) Wanxiang Auto 8) SAIC MAXUS 9) Dongfeng Motor Corporation 10) Beijing Tianlutong Technology Co. Ltd..

* Quantron received an order to deliver 500 Class 8 fuel cell trucks to TMP Logistics, US, by 2024. (https://fuelcellsworks.com/news/quantron-us-receives-order-for-500-class-8-hydrogen-fuel-cell-powered-trucks/)

* Robert Bosch GmbH guarantee 20,000 h lifetime at @216 kW for their fuel cell power module with 108 kW power (twinbox, 216 kW).

DEPLOYMENT TARGETS

By 2025: Switzerland: 1600 fuel cell trucks

By 2028: France: 800-2000 Fuel cell buses and trucks

By 2030:

* Worldwide: 500,000 trucks powered by hydrogen by 2030 (2030 milestones from Hydrogen - Scaling Up report from Hydrogen Council, 2017). 2050 target of Hydrogen Council: 5 million trucks (30% market share).

* Europe: A total 45,000 trucks and buses in 2030 and 450,000 in 2040 (Milestones from the ambitious scenario of Hydrogen Roadmap Europe from 2019)

* Spain: 5000-7500 light and heavy fuel cell trucks, Italy: 200,000 fuel cell trucks.

* An order of magnitude of 10,000 new fuel cell truck sales per annum (c. 7% of annual sales)

* 5 million light-duty FCEVs operating by 2030 (1.5% of total stock)

* 750,000 new fuel cell LDV sales per annum (c. 5% of annual sales)

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

Source: An overview of several sources from Samsun, R.C.; Rex, M.; Antoni, L.; Stolten, D. Deployment of Fuel Cell Vehicles and Hydrogen Refueling Station Infrastructure: A Global Overview and Perspectives. Energies 2022, 15, 4975. https://doi.org/10.3390/en15144975

COST REDUCTION TARGETS

- In the US:
  USD 80/kW for heavy-duty trucks by 2030 and USD 60/kW (ultimate for 2050) in the US.
  USD 30/kW for passenger cars
  (US DOE, 2019: http://www.energy.gov/sites/prod/files/2019/06/f63/fcto-satyapal-overview-for-ecs-meeting-2019-05-27.pdf), with revision for durability emerging from the DOE's latest end-of-year review:
  http://www.energy.gov/sites/prod/files/2019/06/f63/fcto-satyapal-overview-for-ecs-meeting-2019-05-27.pdf (slides 28-30)
- In Europe:
  FC module CAPEX:
  State of art (2020): EUR 1500 / kW
  Targets:
  < EUR 480 / kW (2024); < EUR 100 / kW (2030)
  FC stack cost:
  State of art (2020): > EUR 100 / kW
  Targets:
  < EUR 75 / kW (2024); < EUR 50 / kW (2030)
  (https://www.clean-hydrogen.europa.eu/knowledge-management/strategy-map-and-key-performance-indicators/clean-hydrogen-ju-sria-key-performance-indicators-kpis_en)

RELEVANT PARAMETERS

Energy density	840 mW/cm^2 @peak power
Fuel cell efficiency (%)	US DOE Targets: 68% (2030), 72% (2050).
Cost (€)	US DOE Targets: FC System USD 80/kW (2030), USD 60/kW (2050).
Platinum loading	0.4 mg/ Pt/cm^2
Durability	US DOE Targets: FC System 25,000 h (2030), 30,000 h (2050)

Based on expert input:

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