TECHNOLOGY READINESS LEVEL (TRL) - 2023

IEA Technology Collaboration Programme
Advanced Fuel Cells

TECHNOLOGY DETAILS

Technology: **Hydrogen fuel cell electric vehicle**
Sub-technology: **Urban transit bus**

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

TRL 2023: 9

According to IEA criteria, the TRL of this technology in 2021 was: **9**

TECHNOLOGY DESCRIPTION

Hydrogen fuel cell electric vehicles (FCEVs) convert the chemical energy of hydrogen and air into electric power. FCEVs for bus applications offer advantages to the incumbent and alternative technologies, including long-range, sizing (FCEV have much smaller batteries than battery electric vehicles – at least by a factor of 10 –) fast refueling, ability to address longer and more power-demanding routes, and zero tail-pipe emissions (they only emit water). By exploiting the higher gravimetric energy density of hydrogen, FCEVs can offer a higher range than BEVs. However, their continuing deployment faces multiple technical and economic challenges, including safety of hydrogen handling (refuelling, residual leakage), 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).

FCEV buses have been widely and successfully demonstrated in Asia, Europe and North America. Further cost reductions in fuel cell technology and in hydrogen fuel will expand markets. Costs of the fuel cell stack and system are expected to decline significantly with economies of scale achieved with fuel cell adoption in other applications such for medium -and heavy-duty trucks.

KEY COUNTRIES

Japan, China, Korea, Europe, USA, Canada.

PROTOTYPE OR DEMONSTRATION PLANS, DEDICATED INVESTMENTS, LEADING INITIATIVES

There are widespread demonstration and deployment efforts in Asia, Europe and North America.

'China has the majority of FCEV buses and truck projects, with fleets in 2020 of around 5 300 FCEV buses (GEVO 2021).

DEPLOYMENT TARGETS

By 2030:

- 95,000 fuel cell trucks on European roads (2% of total stock).
- 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)
  https://www.clean-hydrogen.europa.eu/system/files/2019-02/Hydrogen%2520Roadmap%2520Europe_Report.pdf
- Korea announced plans to deploy 40,000 FCEV buses by 2040.
  https://reglobal.co/hydrogen-fleet-in-south-korea-push-to-deploy-40000-fuel-cell-buses-by-2040/#:~:text=In%20March%202022%2C%20the%20Ministry%20of%20Environment%20announced,to%20supply%20700%20hydrogen%20buses%20first%20by%202024

COST REDUCTION TARGETS

- **In the US:**
  $600,000 (bus cost)
  $200,000 (fuel cell power plant cost)
  $ 50,000)hydrogen storage cost)
  https://www.hydrogen.energy.gov/docs/hydrogenprogramlibraries/pdfs/12012_fuel_cell_bus_targets.pdf

- **In Europe:**
  In FCH-JU2 Multi-Annual plan addendum have targets (for 2030) of 40 Euro/kW for FC system for cars and 600 Euro/kW for buses, with total FC bus traget of 500,000 Euro - see www.clean-hydrogen.europa.eu/system/files/2018-06/MAWP%2520final%2520version_endorsed%2520GB%252015062018%2520%2528ID%25203712421%2529.pdf

  < EUR 40,000 for complete system (fuel cell + tank) for buses
  www.clean-hydrogen.europa.eu/system/files/2018-06/MAWP%2520final%2520version_endorsed%2520GB%252015062018%2520%2528ID%25203712421%2529.pdf

RELEVANT PARAMETERS

Energy density	4.0- 4.5 kW/L for the FC stack
Fuel cell efficiency (%)	8 miles per gallon diesel equivalent
Cost (€)	200,000 $
Platinum loading	0.40 mg Pt/cm2
Durability	18,000 h (at 20% voltage degradation)

Based on expert input:

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