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Hydrogen & Fuel Cell Technologies in Heavy Goods Vehicles

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- What is hydrogen?
- Powertrain technologies
- How is it used? Is it safe?
- The market for hydrogen and fuel cells for heavy duty vehicles

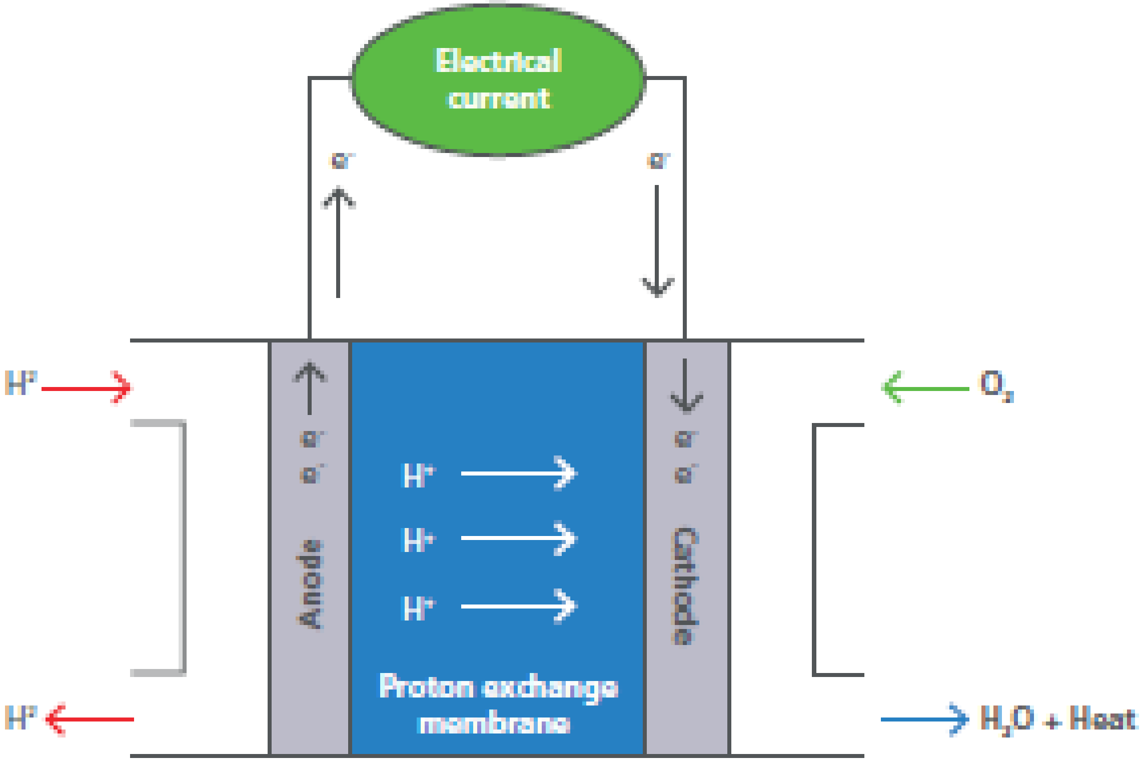
What is Hydrogen?

- Characteristics
- Feedstocks
- Production processes
- Energy security / flexibility
- WTW GHG Emissions

Hydrogen Technologies for road haulage

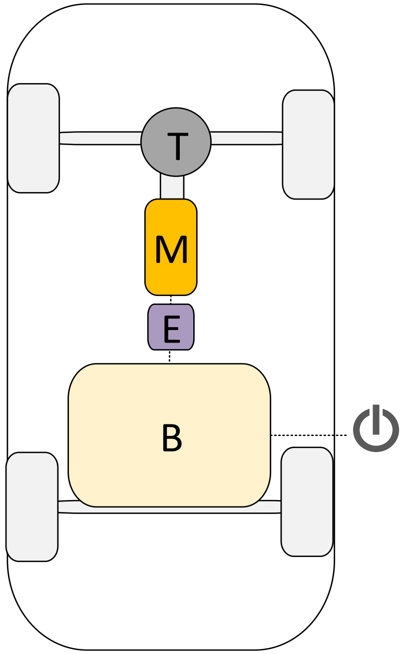
- Dual fuel / bi-fuel / retrofitting
- Internal combustion engines
- Fuel cells (PEMFC / SOFC)
- Auxiliary Power Units

Source: AVL.com

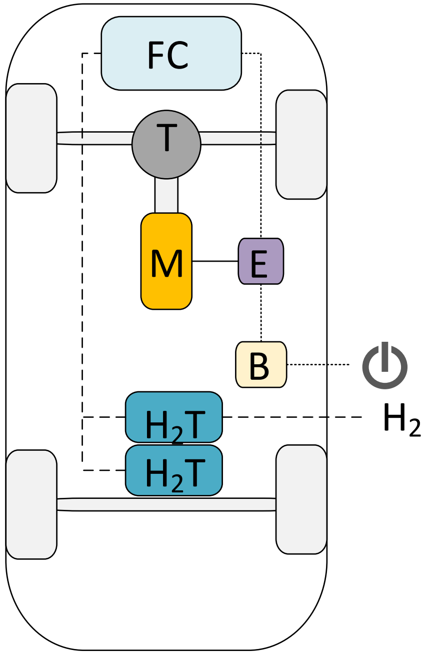


Source: Steinberger-Wilckens, R., Dodds, P.E., Kurban, Z., Velazquez Abad, A., and Radcliffe, J. (Eds.) (2017) The role of hydrogen and fuel cells in delivering energy security for the UK. H2FC Supergen, London, UK.

Comparison between BE and FC powertrains



Schema of a BEV. Components: B-battery, E-electronic controllers, M-electric motor, T-Transmission



Schema of a FCEV. Components: B-battery, E-electronic controllers, M-electric motor, T-Transmission, H2T-hydrogen tank, FC-fuel cell.

Source: Velazquez Abad A, 2017. *Techno-economic Comparison between Battery and Fuel Cell Electric Vehicles*, in *Southampton Business School*. University of Southampton: Southampton.

Practicalities of using Hydrogen

- Hydrogen safety:
  - The typical of compressed or liquefied fuels. In FC hydrogen is compressed @ 35/70 MPa or liquefied @ -253°C
  - Accidents / hydrogen tanks
  - Restricted routes / tunnels
- Refueling
  - Detours for refueling and a lack of refueling infrastructure
  - Alternatively, expensive investment on private filling stations and need to meet different safety standards than incumbent technology
- Lower maintenance (for FC vehicles only)

Benefits / limitations of FC HDVs

Benefits	Challenges
Similar refueling time to conventional HDV	Lack of infrastructure
Similar range to conventional HDV	Total cost of ownership (while achieving economies of scale) tend to be higher except in niche applications
Zero AQ emissions at the point of use	Limited offer
Some pathways yield very low WTW GHG emissions	Lack of policy instruments compared to BEV
Lower noise levels than conventional HDV	More safety checks than a conventional HDV
Wider benefits for the energy system (energy security and flexibility)	
Low wear / potential higher value second hand market	
High powertrain efficiency (up to 60%)	
High power density	
Lower operating temperature / good at cold-starts	

Comparative Performance of Drivetrains

		ICE	FCEV	BEV
Lower is better	Current Capital Cost	$	$ $ $	$ $
	Fuel cost	$ $	$ $ $	$
	Maintenance costs	$ $ $	$	$
	Infrastructure needs	$	$ $ $	$ $
	Emissions	● ● ●	●	●
Higher is better	Efficiency	*	* *	* * *
	Range	* * *	* * *	*
	Refuelling speed	* * *	* * *	*
	Lifetime	* * *	* * *	* *
	Acceleration	* *	* * *	* * *

Source: Staffell, I., Scamman, D., Abad, A. V., Balcombe, P., Dodds, P. E.,... Ward, K. R. (2018, February 21). The role and status of hydrogen and fuel cells across the global energy system. Retrieved from engrxiv.org/rzm4g

Current Status

- Current availability of hydrogen in commercial HD vehicles:
  - Dual Fuel vehicles (ULEMCO)
  - Hybrids (Symbio range extenders)
  - Class 6: UPS
  - Fuel Cells semi-articulated vehicles Class 8 (Toyota Project Portal, Kenworth T680, Scania 27t, Nikola 1 - in development)
  - Buses (JIVE / JIVE 2)
  - Refuse trucks (DAF CF75FA Nederlands)
  - Emergency vehicles
  - Auxiliary power units (SOFC AVL EU FP7 project, Eberspächer, OWI)

Current Status

Country	Fuel Cell Vehicles	Refuelling stations	Forklift Trucks
Japan	1,800 cars	90	21
Germany	467 cars, 14 buses	33	16
China	60 cars, 50 buses	5	N/A
US	2,750 cars, 33 buses	39 public 70 total	11,600
South Korea	100 cars	11	N/A
UK	42 cars, 18 buses	14	2

Source: Staffell, I., Scamman, D., Abad, A. V., Balcombe, P., Dodds, P. E.,... Ward, K. R. (2018, February 21). The role and status of hydrogen and fuel cells across the global energy system. Retrieved from engrxiv.org/rzm4g

Funding Worldwide

Country	Fuel Cell Vehicles	Refuelling
Japan	$147m	$61m
Germany	$4,000 / vehicle	$466m
China	$1,700 / kW (up to $57,000 / vehicle)	$1.1m / unit
US	Up to $13,000 / vehicle	30% of cost (up to $30,000) (California $100 M up to 2023)
South Korea	$5.4m (up to $31,000 / vehicle)	
UK	$33m (60% of cost for refuelling)	

Source: Staffell, I., Scamman, D., Abad, A. V., Balcombe, P., Dodds, P. E.,... Ward, K. R. (2018, February 21). The role and status of hydrogen and fuel cells across the global energy system. Retrieved from engrxiv.org/rzm4g

Infrastructure

Map European refuelling stations in operation

Source: h2stations.org

Map European planned refuelling stations

Future / Conclusions

- Trends: Hydrogen is likely to play a role in heavier and longer distance transport
- Cost parity: With economies of scale, FC vehicles will reach parity with BEV by 2030 and become cheaper than ICE by 2050
- Fact: So far H2FC powertrains are the only zero air quality and GHG emissions powertrain (at the point of use) that can provide enough power and range for heavier vehicles, with short refuelling time
- The cost of infrastructure is a challenge

References / Endnotes

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Any Questions?

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