The role of hydrogen in decarbonizing the heavy-duty vehicle sector in Europe

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ICCT works to decarbonize the transport sector

Our mission: Improve the environmental performance of all modes of motor transport, to address air pollution and climate change.

Runaway climate change is the greatest existential threat facing our planet. To limit emissions to 1.5º C, the ICCT is committed to meeting the challenge of decarbonizing the global transportation sector by mid-century in partnership with governments in major markets around the world.

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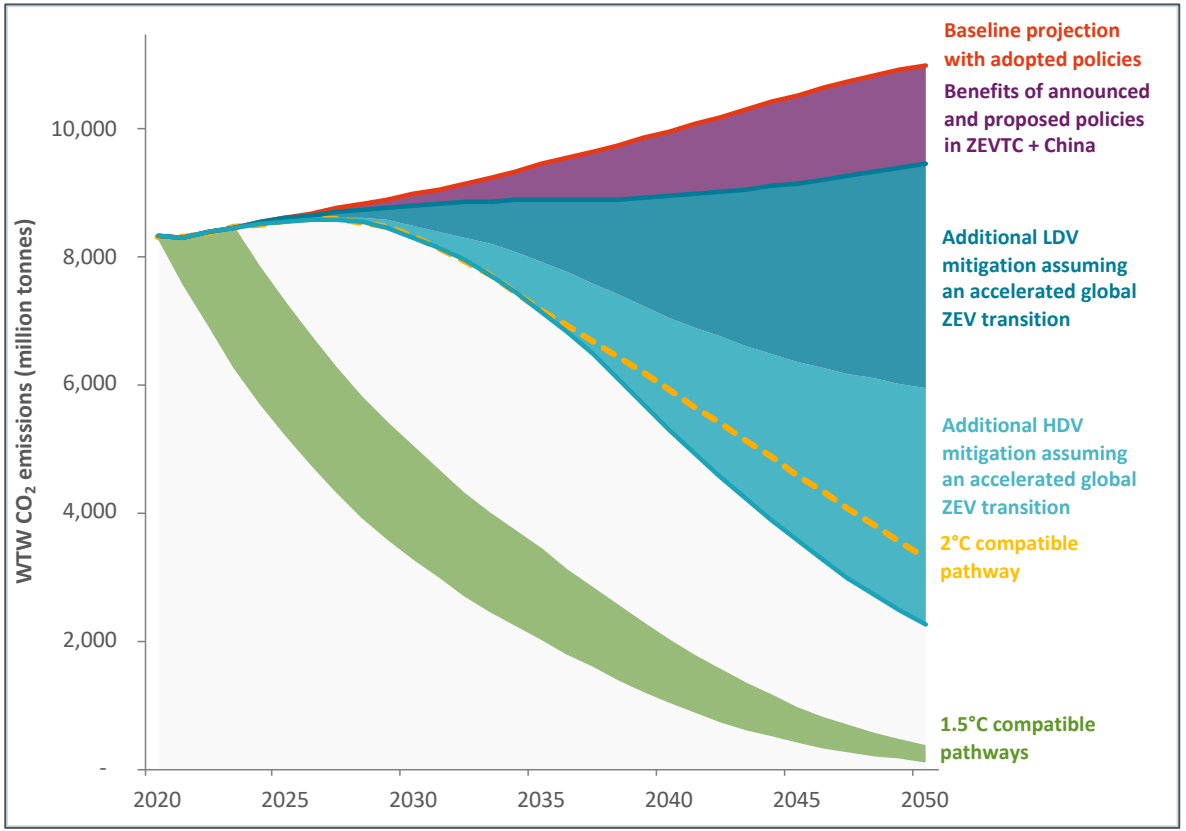
Paris Agreement aligned CO_2 pathway is possible with accelerated global ZEV transition

- Accelerated ZEV transition reduces CO_2 emissions 73% by 2050
- HDVs account for cumulative CO_2 reductions of 47.5 billion tonnes
- Paris Agreement's well below 2°C compatibility achieved under the scenario
- HD ZEV transition will have significant global health benefits



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Outline

- Technology analysis
- Economic analysis (Total cost of ownership)
- Conclusions

Technology analysis of fuel cell trucks in Europe

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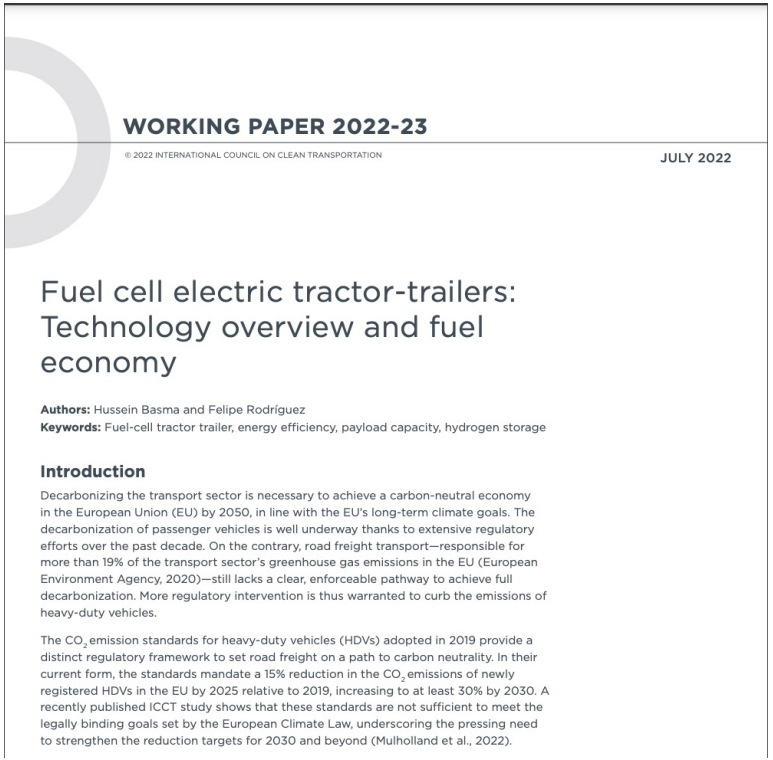
Scope and objectives

- Quantify key **operational metrics**:
  - Fuel economy
  - Driving range
  - Hydrogen storage capacity
  - Payload capacity

- Compare **energy efficiency** between different powertrain technologies



WORKING PAPER 2022-23

JULY 2022

Fuel cell electric tractor-trailers: Technology overview and fuel economy

Authors: Hussein Basma and Felipe Rodríguez

Keywords: Fuel-cell tractor trailer, energy efficiency, payload capacity, hydrogen storage

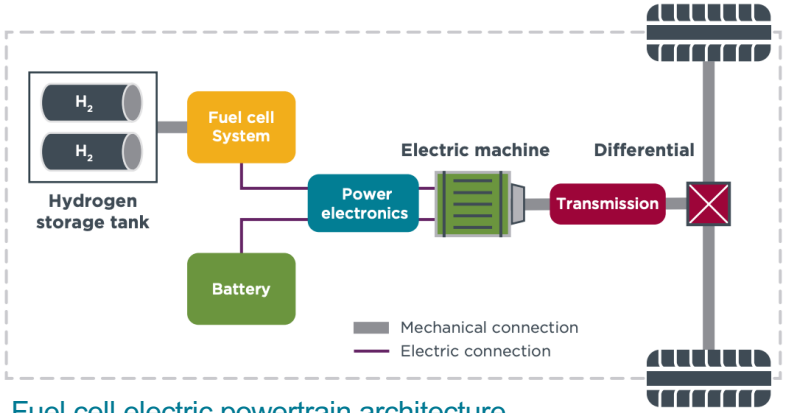
Introduction

Decarbonizing the transport sector is necessary to achieve a carbon-neutral economy in the European Union (EU) by 2050, in line with the EU's long-term climate goals. The decarbonization of passenger vehicles is well underway thanks to extensive regulatory efforts over the past decade. On the contrary, road freight transport—responsible for more than 19% of the transport sector's greenhouse gas emissions in the EU (European Environment Agency, 2020)—still lacks a clear, enforceable pathway to achieve full decarbonization. More regulatory intervention is thus warranted to curb the emissions of heavy-duty vehicles.

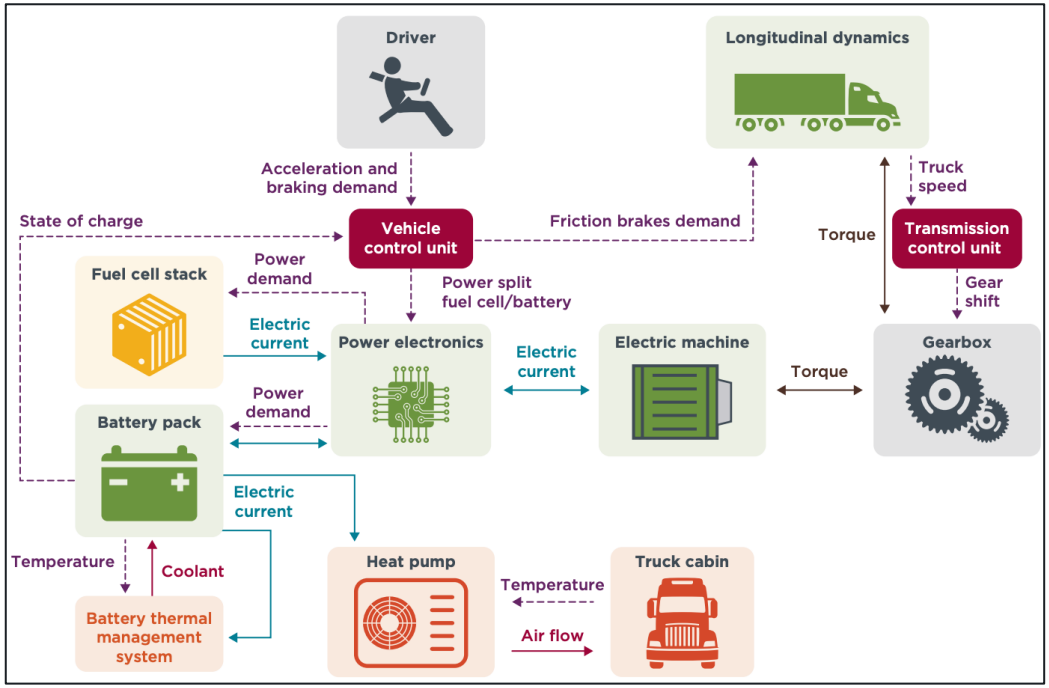
The CO_2 emission standards for heavy-duty vehicles (HDVs) adopted in 2019 provide a distinct regulatory framework to set road freight on a path to carbon neutrality. In their current form, the standards mandate a 15% reduction in the CO_2 emissions of newly registered HDVs in the EU by 2025 relative to 2019, increasing to at least 30% by 2030. A recently published ICCT study shows that these standards are not sufficient to meet the legally binding goals set by the European Climate Law, underscoring the pressing need to strengthen the reduction targets for 2030 and beyond (Mulholland et al., 2022).

https://theicct.org/publication/fuel-cell-tractor-trailer-tech-fuel-jul22/

Comprehensive vehicle energy consumption modeling



Fuel cell electric powertrain architecture



Schematic of the truck energy consumption model

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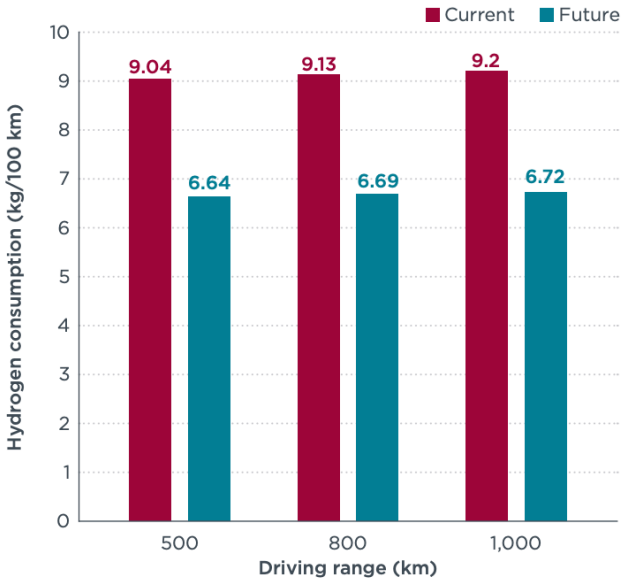
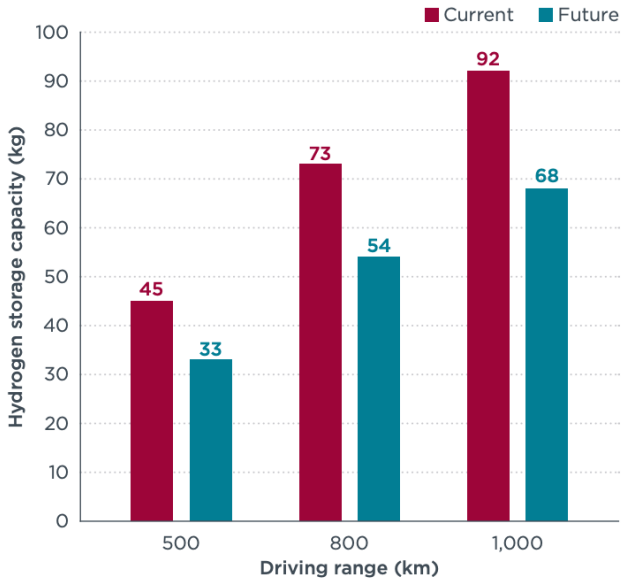
Fuel economy and required H_2 storage capacity

- Tractor-trailers' hydrogen fuel consumption ~ 9 kg/100 km today.
- Potentially decreasing to ~ 6.6 kg/100km by 2030 with the expected improvement in truck road load technologies, material light-weighting, drivetrain and fuel cell efficiencies.
- 45 kg usable H_2 storage is needed to cover 500 km today.
- > 90 kg usable H_2 storage to cover 1,000 km.





VECTO long-haul cycle - payload of 19,300 kg - 15°C ambient

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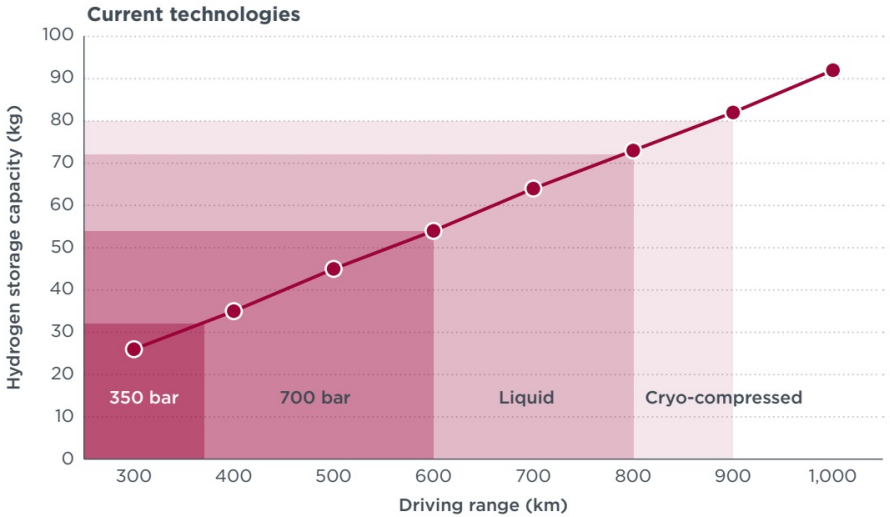
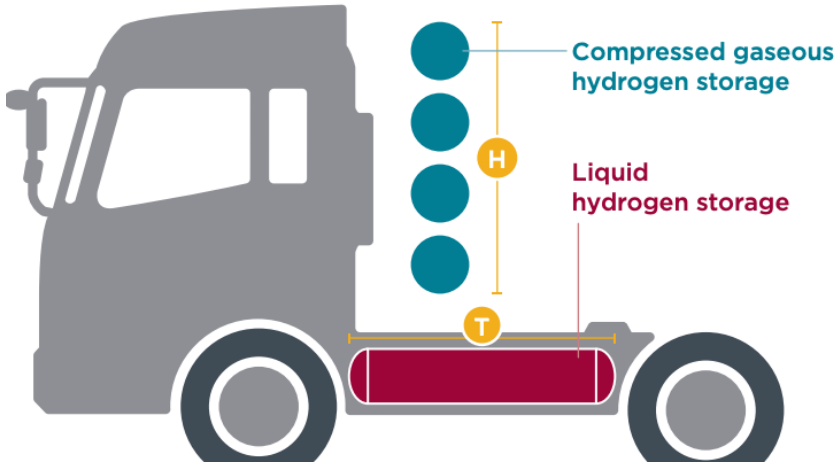
H_2 storage volume constraints and driving range



Maximum achievable driving range for different hydrogen storage technologies considering onboard volume constraints for hydrogen storage



Schematic of hydrogen storage system design (for illustration purposes only).

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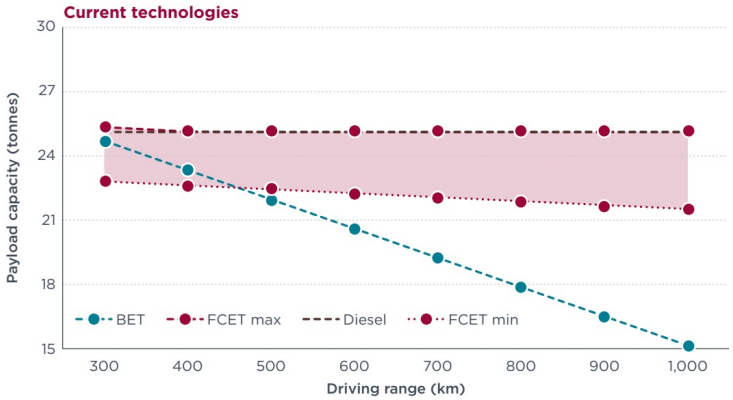
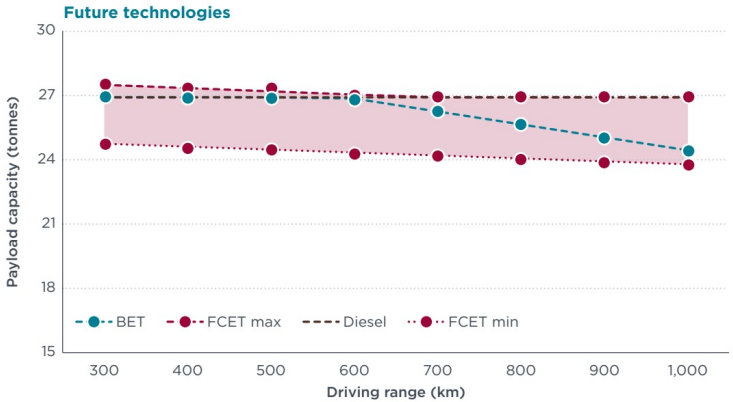
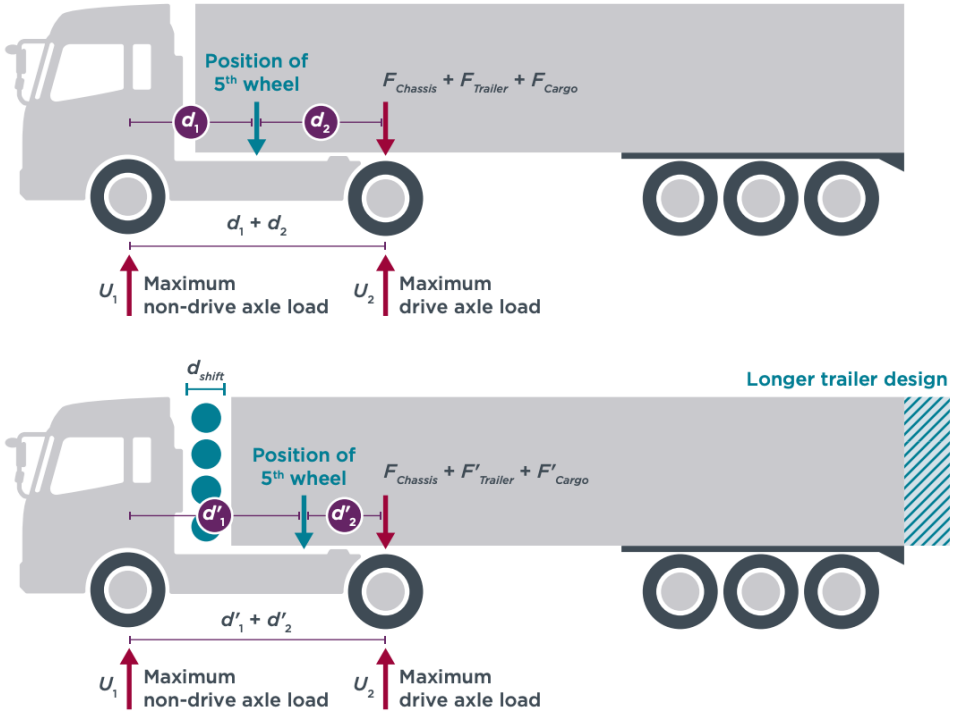
Payload capacity of zero-emission trucks



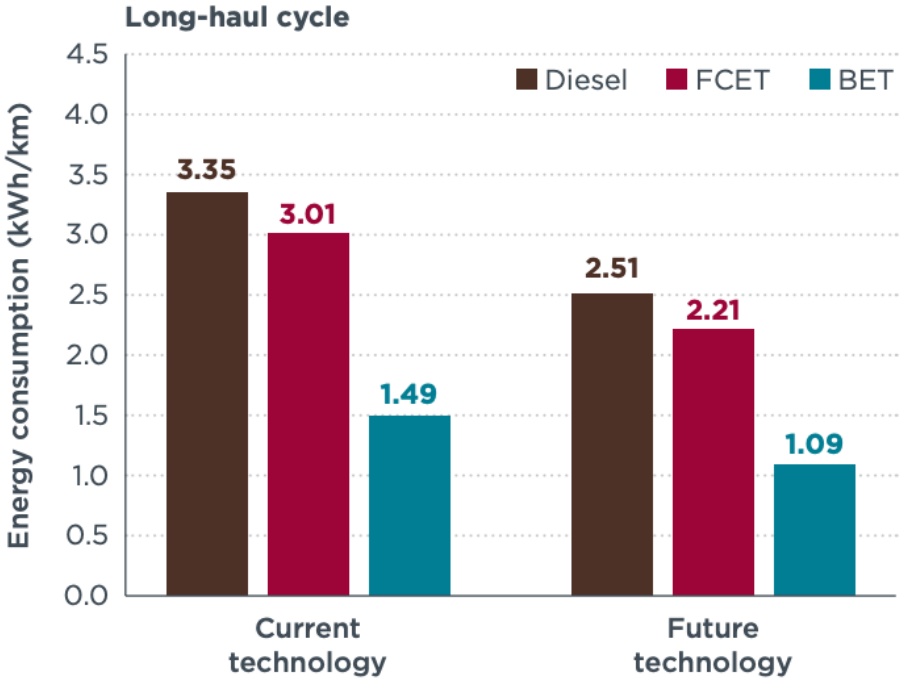




Schematic of hydrogen storage system design (for illustration purposes only). 10

Energy efficiency of zero-emission trucks

- FCETs are 10% to 12% more energy efficient than diesel trucks at the tank-to-wheel level.
- battery-electric trucks remain the most efficient powertrain technology.
  - ~ 50% more efficient than FCETs
  - ~ 60% more efficient than diesel
- Truck energy efficiency drives the total cost of operation and the total life-cycle greenhouse gas and pollutant emissions.



VECTO long-haul cycle - payload of 19,300 kg - 15°C ambient

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Total cost of ownership of fuel cell trucks in Europe

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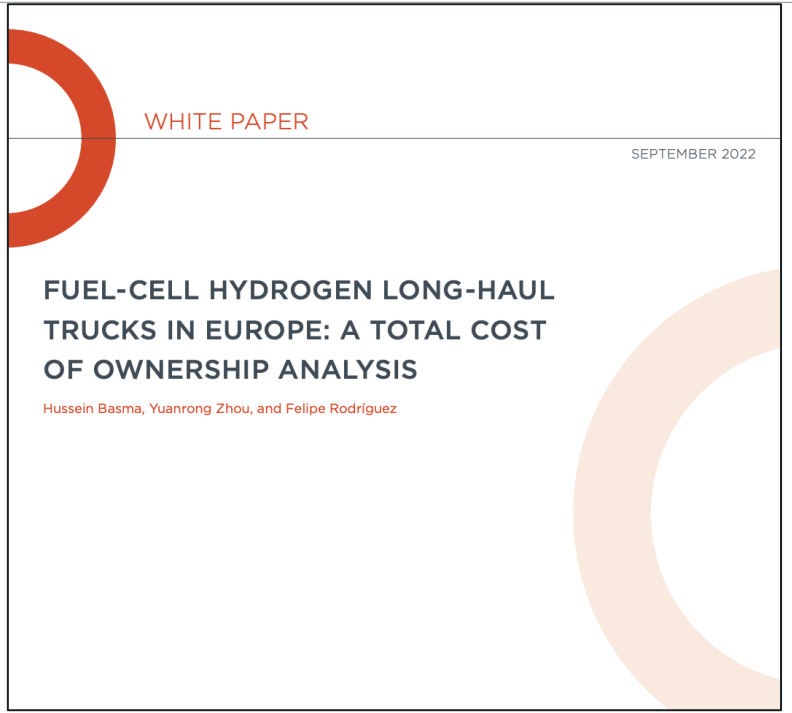
Scope and objectives

- Quantify and compare the **TCO** of fuel cell and diesel **long-haul tractor trailers** in 7 European countries.

- Assess the impact of **policy measures** on the TCO parity year of fuel cell and diesel trucks



https://theicct.org/publication/eu-hvs-fuels-evs-fuel-cell-hdvs-europe-sep22/

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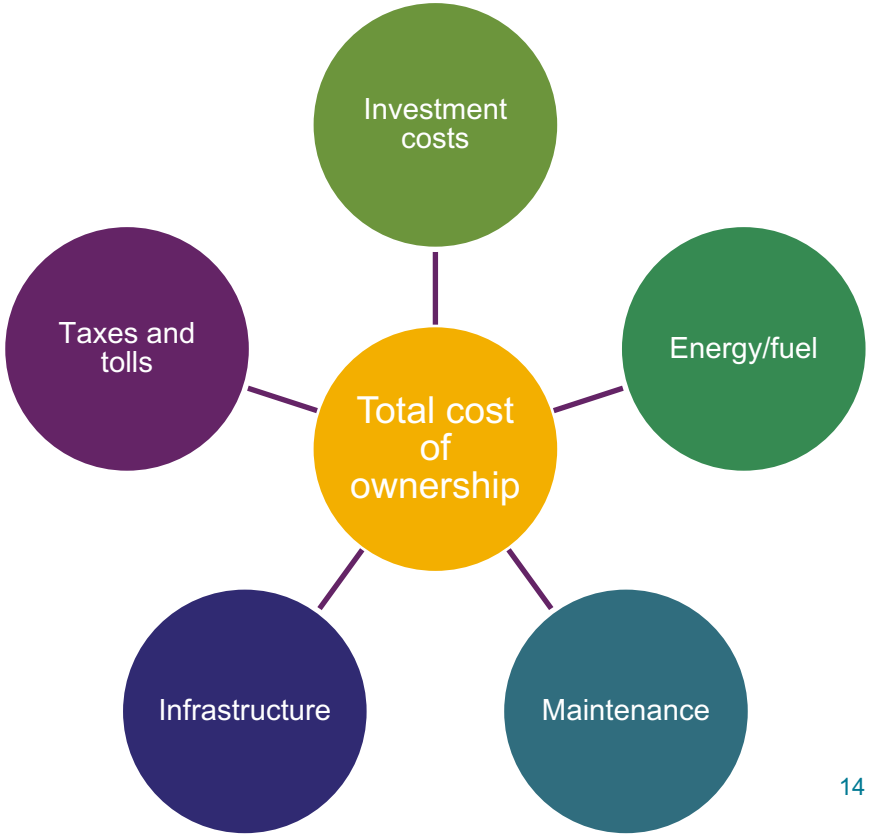
What about the economic viability of fuel cell trucks?

The economic viability of fuel cell trucks will be a key factor in driving their market demand

How does their total cost of ownership of compare to that of their diesel counterparts?

Focus is on trucks operating in long-haul as this will be the most promising application for FCETs.



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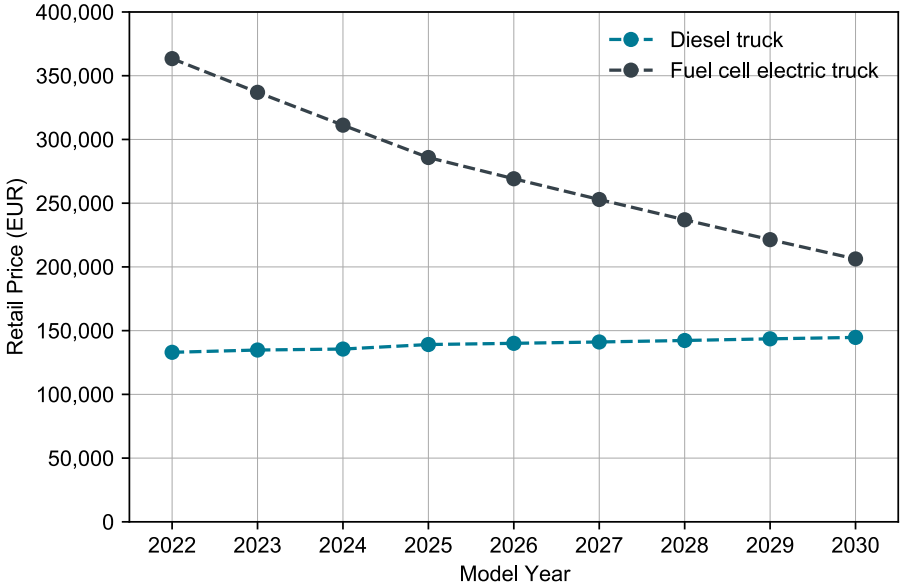
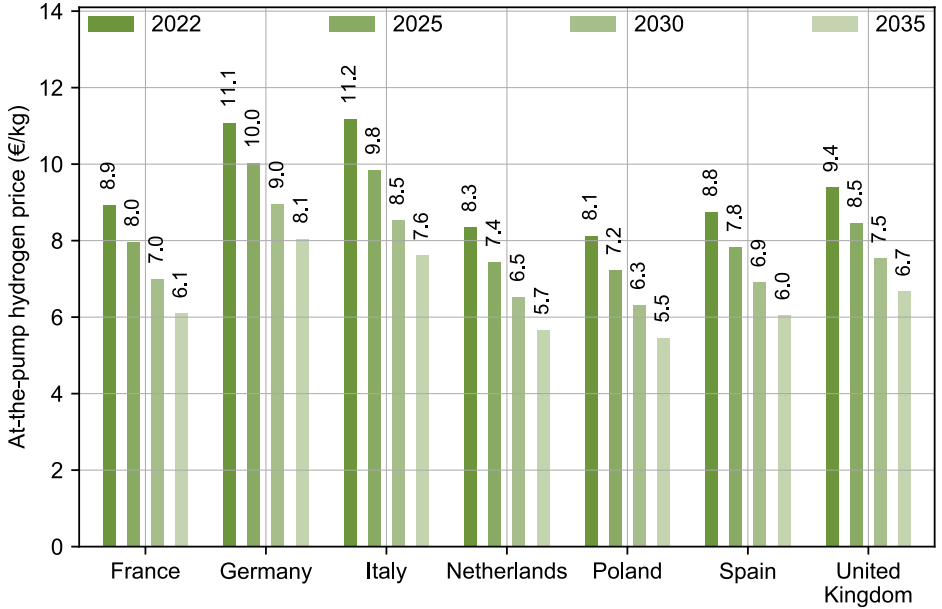
Truck retail price estimation and green H2 price at the pump



Retail price evolution of fuel cell and diesel trucks



Green H2 price at the pump between 2022 and 2035. Decentralized production

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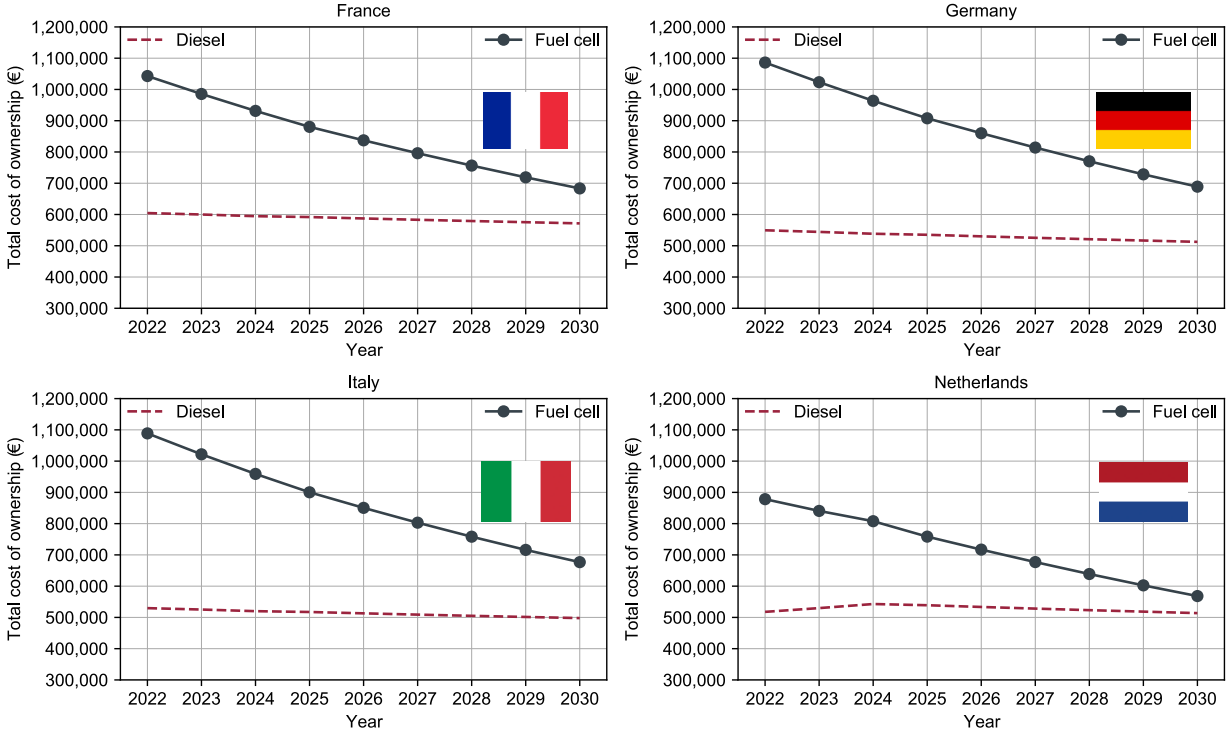
TCO of fuel cell trucks will be significantly higher than diesel trucks by 2030

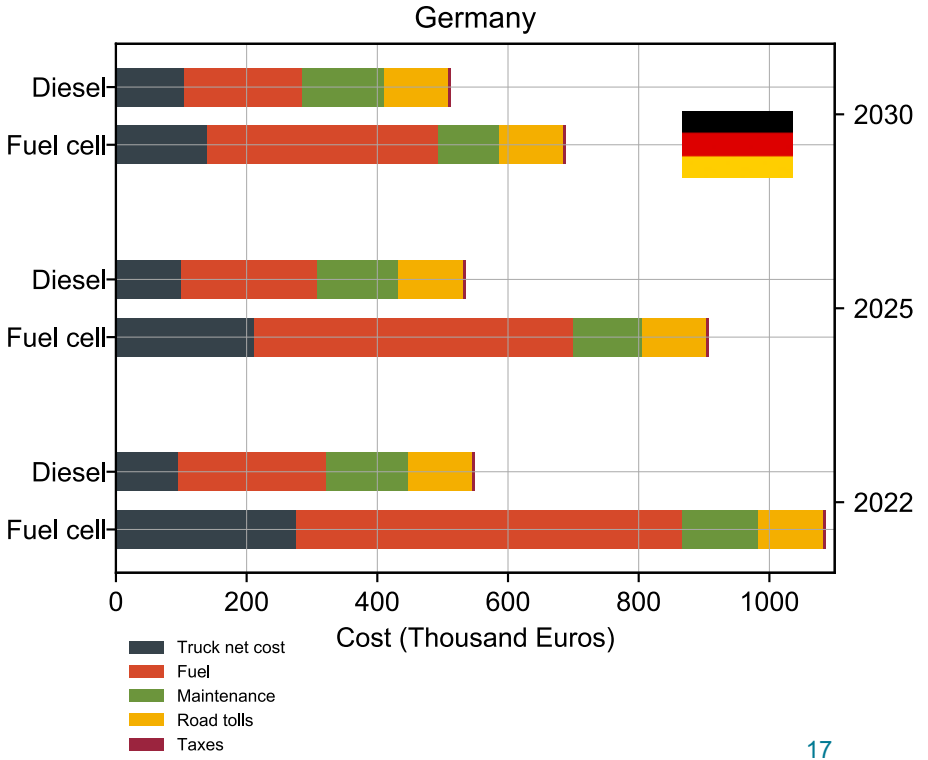
- The TCO of FCETs decreases significantly until 2030.
- Reduction in the FCET retail price (~ €350k today down to ~ €200k by 2030).
- Reduction in hydrogen fuel price between (8-11 €/kg in 2022 compared to 5-8 €/kg in 2035).
- Improvement in the FCET energy efficiency (~ 27% reduction in fuel consumption)



5-year TCO of fuel cell and diesel trucks

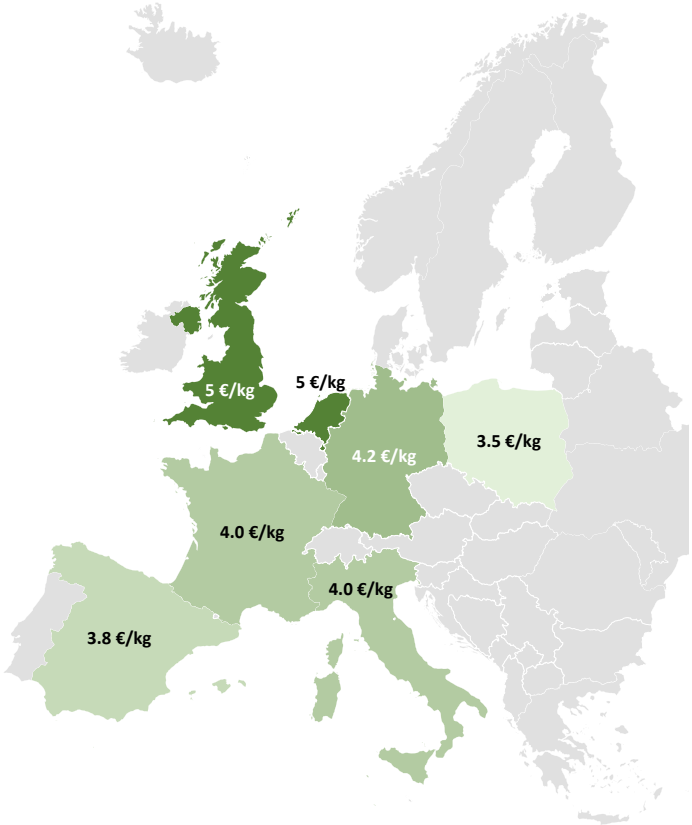
The price of hydrogen fuel is the primary driver of the TCO

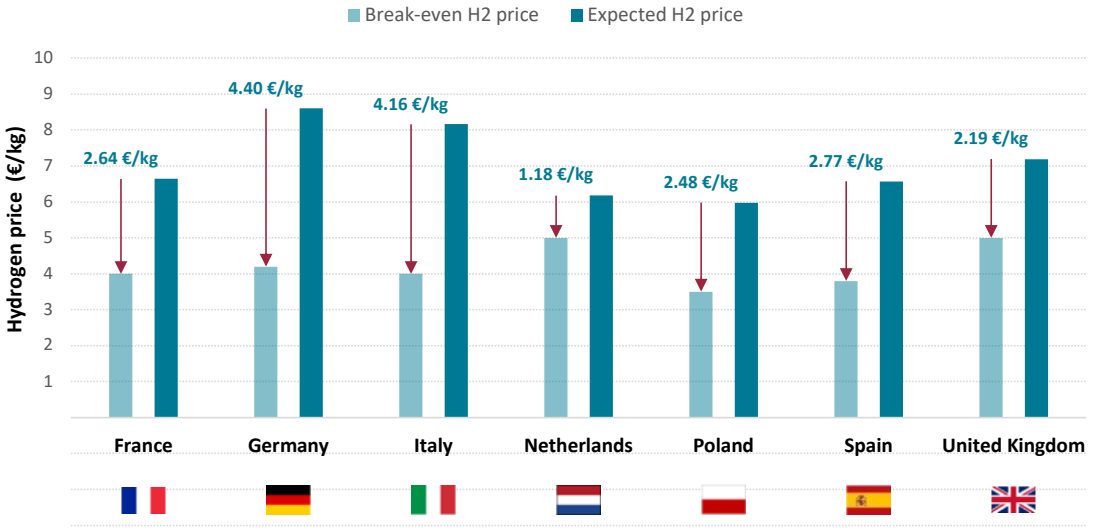
- The fuel costs of FCETs are expected to be three times higher than those of an equivalent diesel truck today.
- These will decrease by 2030 and become 1.8 times higher.
- The retail price of FCETs and diesel trucks are expected to be within the same range by 2030, making fuel costs the main TCO driver then.



TCO breakdown in Germany

Break-even H2 price at the pump and needed subsidies

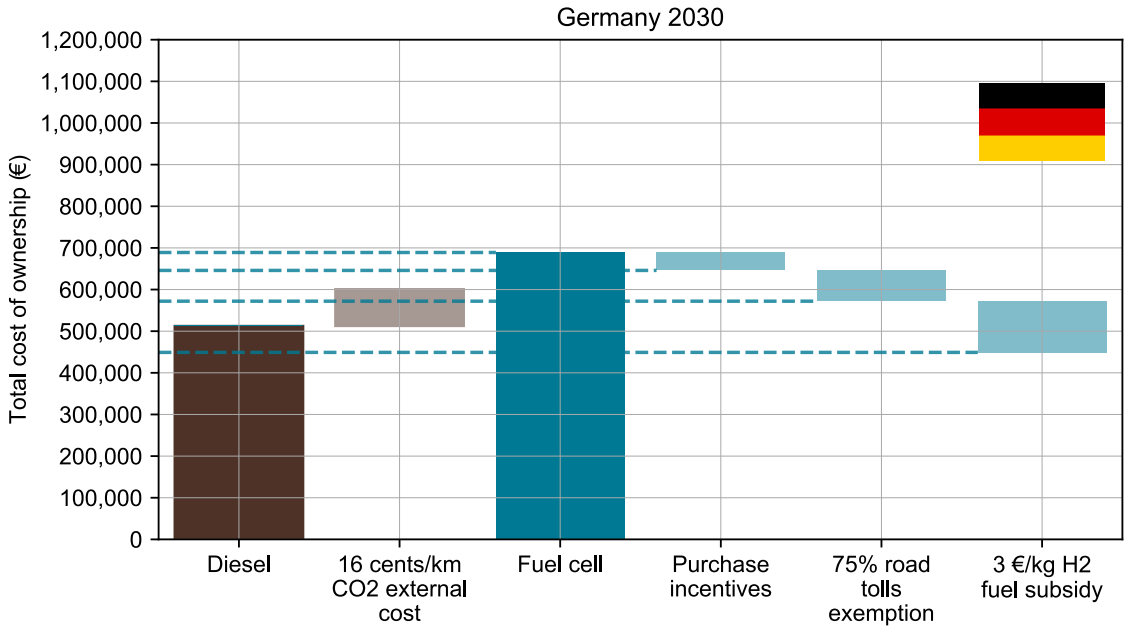




Green H2 price at the pump by 2030 and the required break-even price

Impact of policy measures

- A combination of several policy measures will be needed for FCETs to reach a lower TCO relative to diesel trucks
- The most influential policy implication is the hydrogen fuel subsidy at 3 €/kg as it reduces the FCET TCO by almost €150,000.
- Price differential purchase subsidies have a secondary impact on TCO as the operational expenses are the main TCO driver for FCETs.



Impact of policy measures on the fuel cell and diesel trucks TCO.

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Conclusions

Takeaways (1/2)

- Fuel cell tractor-trailers consume ~ 9 kg H2/100 km today, potentially decreasing to 6.6 kg H2/100km by 2030.
- Liquid hydrogen is a more suitable onboard storage technology for applications with very high driving ranges reaching 1,000 km and limited access to refueling stations.
- Fuel cell tractor-trailers are 10% to 12% more energy efficient than diesel trucks, while battery electric trucks remain the most efficient powertrain.
- Fuel cell tractor trucks show a similar payload in comparison to their diesel counterparts but axle load constraints may reduce their payload capacity.

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Takeaways (2/2)

- Fuel cell long-haul trucks would need significant policy support to reach TCO parity with diesel trucks by the end of the decade.
- The price of hydrogen fuel is the primary driver of the economic viability of fuel-cell electric trucks.
- A break-even hydrogen price of around 3-5 €/kg is needed for fuel-cell electric trucks to reach TCO parity with their diesel counterparts by 2030
- Hydrogen fuel subsidies would likely be necessary to make fuel cell electric trucks financially viable for truck operators at least until 2035.

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Questions

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