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# On the future contribution of fuel cell vehicles to low carbon heavy-duty road transport

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## Executive Summary

Electrification of road transport offers strong reduction in tail pipe $CO_2$ emissions. Full electrification with battery electric vehicles is emerging as the most promising option for passenger cars, but the situation is less clear for heavy-duty trucks. Battery electric trucks (BET) and Fuel cell electric trucks (FCET) are presently under discussion to play a major role in low-carbon road freight transport. Here, I argue that FCET might play only a very minor if any role at all, based on a technical and economical comparison for important use cases of heavy-duty vehicles.

## 1 Introduction

Despite rising electric vehicles sales shares, transport in general but also road transport are still dominated by fossil fuels usage. Globally, transport is responsible for about one quarter of energy related green house gas (GHG) emissions and the largest share of the transport GHG emissions comes from road transport with about 72% [1]. Yet, the Paris Agreement implies a limited global GHG emission budget requires climate neutrality globally in a few decades [2, 3]. The limited overall carbon budget leads to a limited emission budget for all sectors and transport has to become climate neutral within just a few decades [2, 4]. Urgent action is needed as Paris compatible carbon budgets are small and stock turnover in road transport is slow [2, 5].

Luckily, technologies that offer low carbon road transport are already commercially available or under development. These technologies include the direct use of electricity in battery electric and plug-in hybrid vehicles (BEV and PHEV) with stationary or dynamical charging, fuel cell electric vehicles (FCEV), bio fuels and synthetic renewable fuels. These options are in different stages of commercialization and development for passenger cars, as well as light, medium, and heavy-duty vehicles. The role of each in a future sustainable road transport system is still under debate [1, 6].

## 2 Background

The now dominant alternative fuel in passenger vehicles is electricity. There are about fifteen million BEV and PHEV on the road globally at the beginning of 2022 [1 and extrapolating sales data https://www.ev-volumes.com/] with about one third PHEV. Newly sold BEV now have ranges of 300 km. PHEV combine a battery and electric motor with a tank (usually gasoline) and a combustion engine which is intended for propulsion when the battery is empty or energy demand very high, e.g. from driving at very high speeds. Basically all manufacturers now offer BEV or PHEV with more than 350 models available globally.

FCEV store the energy for propulsion in hydrogen that is then converted to electricity in a fuel cell and input for an electric motor for propulsion. At the beginning of 2021 there were about 25,000 fuel cell cars in stock globally, i.e. about 400 times less than BEV and PHEV. More than 90 % of fuel cell vehicles are in four countries only, Korea, the US, China, and Japan. Currently, only two passenger fuel cell car models available from global manufacturers as some other manufacturers stopped commercial fuel cell car production.

BEV and PHEV get their electricity from charging via the grid. For users without home charging option and for long-distance travel, charging at publicly accessible chargers is essential. In 2020, about 1.3 million public chargers were in operation globally, with about one quarter fast chargers (at least 22 kW power) [1]. More recently, charge point operators have started to construct high power fast chargers with more than 150 kW, typically up to 300 kW (with more than 800 charge points at 300 kW in operation in Europe already). Compared to electricity that is also available at home, FCEV need hydrogen refueling stations. About 540 hydrogen stations are in operation globally. Biofuels and synthetic fuels from electricity can be blended with conventional fuel and the existing infrastructure for conventional liquid fuels used. Note, however, that combustion engines could need modification to operate with very high shares of bio fuels or synthetic fuels. Problematic about synthetic fuels is mainly the non-existing large scale production capacity of renewable synthetic fuels. As planning and construction of such production capacities takes several years, the available amount of renewable liquid fuels will not be able to make a significant contribution to the required fast GHG emission reduction in road transport.

Zero emission vehicles are still in a much earlier market phase in trucks than in passenger cars, lacking about ten years behind. There are about 30,000 battery electric trucks (BET) in stock globally [1], more than 90 % thereof in China. Fuel cell electric trucks (FCET) are only operated in test trials (from one manufacturer) and not commercially available so far. There is currently no dedicated infrastructure for zero emission trucks. The large batteries of trucks require higher charging power for a full recharge when compared to passenger cars and existing fast chargers can be used for BET if the size of the parking is sufficient for a truck. FCET and fuel cell cars currently use gaseous hydrogen compressed to 350 bar at the existing hydrogen refueling stations.

# 3 Results

Current developments in vehicle and infrastructure technology but also industry announcements for low carbon fuels in transport differ between passenger cars and trucks. The transition to battery electric vehicles in cars is already ongoing at fast pace internationally with very little room left for fuel cell cars. Several major manufacturers have announced to focus mainly on battery electric vehicles (e.g. GM 2021, Volkswagen 2021, and Scania 2021). When BEV had very limited range of under 150 km and charging took a few hours, there was an important and large market segment for fuel cell vehicles: long-distance travel. The higher energy density of compressed hydrogen – when compared to battery electric vehicles – and fast refueling within a few minutes were ideal for frequent long-distance trips. Yet, new BEV already offer over 400 km real world range and the newest generation uses 800 Volt batteries allowing to charge 200 km of range in about 15 min. With further growing ranges and a growing network of high power fast chargers, the new battery electric vehicles easily allow also frequent long-distance travel and as FCEV are still hardly commercially available that market segment is lost for hydrogen. In addition, PHEV are still an attractive offer during the transition to only BEV, for those who want to drive short distance electrically and use conventional fuels for long-distance driving, despite their limited electric driving share [3].

Stimulated by ambitious $CO_2$ reduction targets also for heavy-duty vehicles [2], many manufacturers have announced new electric truck models, even up to 40 t of gross vehicle weight (GVW). Over 100 models are announced globally for medium freight trucks (3.5 – 12 t GVW) and over 50 models for heavy freight (>12 t GVW) [1]. These trucks will be basically the first generation battery electric trucks

(BET) and are announced with ranges 250 km in medium freight and 300 – 350 km range in heavy freight trucks [1]. Figure 1 shows the range of directly feasible applications for the first generation of BET [7, 8].

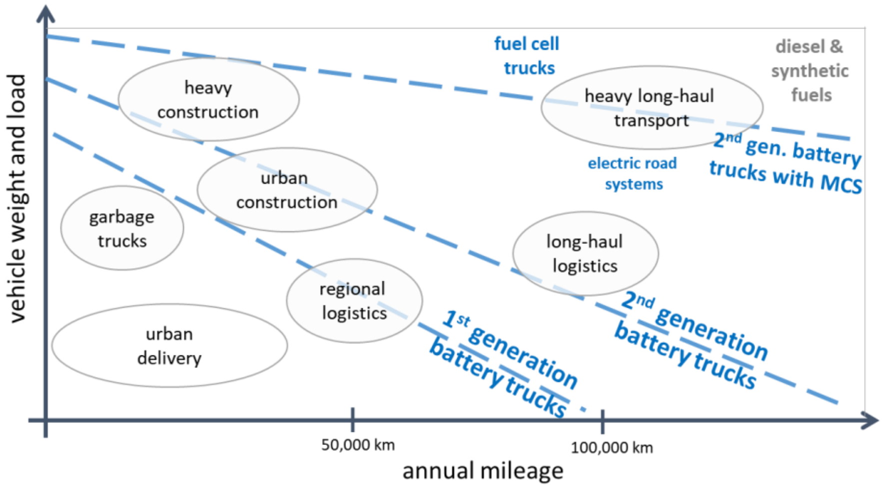


Figure 1: Freight segments and potential applications for zero emission trucks.

The current BET generation with 250 – 350 km range easily allows urban delivery with limited vehicle weight and load as well as annual distances of up to 50,000 km, i.e. a mean of 170 km per day on 300 driving days. The current challenge for BET are long-haul logistics operation with an average of 100,000 km per year and transport of very heavy goods which implies high energy consumption per km. This is the use case often discussed for hydrogen trucks. Several truck manufacturers as well as fuel cell and infrastructure providers have joined forces and announced a target of 100,000 fuel cell trucks on European roads by 2030, but this appears very unlikely when contrasted to the same companies' announcements of commercial series FCET production start earliest in 2027. By that time, the second generation BET will already be commercially available and in operation. All major truck manufacturers have announced more battery electric truck models for the coming years with significant market diffusion targets, including 20 – 60 % zero emission truck sales, mainly BET, in 2030 in Europe [9] and ZEV truck mandates of similar ambition in California.

Despite the future reduction in battery costs and energy density, long-haul operation with some-times more than 500 km per day poses a challenge for heavy BET. Yet, driving regulation allow only 4.5 hours of driving followed by a compulsory resting time of at least 45 min. Within 4.5 hours a heavy truck would make up to 400 km such that real world ranges of about 450 km would fully suffice if high power fast charging for BET was widely available. Charging 400 km in 45 min for a heavy trucks means about 800 kW charging power. The currently existing fast charging standard CCS allows up to 350 kW and a new Megawatt Charging System (MCS) standard is un-der development. It will allow over 2 MW charging and specifications are expected for the end of 2022 and final standard in 2023. Truck manufacturers are strongly pushing for the fast construction of such a megawatt charger network in Europe and have published potential locations for fast chargers [10] and the three biggest are forming a joint venture for the networks construction [11]. At the same time, a draft infrastructure proposal in Europe demands high power chargers every 50 km along the main highway network [12]. Such a network of megawatt chargers along main corridors enables long haul BET and would strongly reduce road freight emissions and energy consumption in Europe and the US [5, 13]. At the same time, electric road systems are being tested on public roads in Europe and could also support long-distance BET operation with charging on major highways and no need to charge during rest times [5].

# 4 Conclusion

The window of opportunity for a relevant market share for hydrogen cars is as good as closed since long-distance driving can well be done with new long-ranged BEV and high power fast charging within 20 min. For trucks, operating costs are more important than for cars, making the use case for FCET even smaller. If truck manufacturers do not start mass production of FCET very quickly to reduce costs, FCET will never succeed in low carbon road transport.

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# Presenter Biography

Patrick Plötz studied Physics in Greifswald, St. Petersburg and Göttingen. Doctorate degree in Theoretical Physics from the University of Heidelberg. Since 2011 researcher in the Competence Center Energy Technology and Energy Systems. Since March 2020 Coordinator of Business Unit Energy Economy. Since 2020 private lecturer at the Karlsruhe Institute of Technology (KIT).