Institute of Transport Economics
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Summary

Technological maturity level and market introduction timeline of zero-emission heavy-duty vehicles

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While phasing in of battery-electric passenger cars and buses speeds up in Norway, this does not apply to battery-electric vans and trucks. Differences in the phase-in progress are partly due to differences in the framework conditions, and the differences in the incentives to offset the economic additional costs associated with zero-emission solutions. In addition, this review shows that the technological maturity level for large vans and lorries has come much shorter than for passenger cars, small vans and buses. A start of serial production of battery-electric alternatives is expected in the coming years also for heavier vans and lorries. Hydrogen fuel cell technology is less mature than battery-electric alternatives, but also here buses are more mature and nearer serial production than freight vehicles are.

This document summarizes a review of the technological maturity level and expected market introduction for battery-electric and hydrogen-fuel cell technology for vans, buses and trucks, and associated charging and filling infrastructure.

Battery electric HDVs

A battery electric vehicle (BEV) uses chemical energy stored in rechargeable battery packs as a source for electricity used for propulsion in electric motors and motor controllers, instead of using fuels in an internal combustion engine (ICE).

In 2015, nearly all the electric buses in use globally were to be found in China. Since 2013 small European pilot projects involving 1-2 electric buses, have grown into larger pilots where entire bus lines are utilizing electric buses (ZeEUS report 2016) in more than 40 cities. These pilots include different models of electric buses and charging options, where both fast charging and over-night charging systems are tested out. Ruter, a public transport service provider in Norway, have 6 electric buses operating in their network (from November 2017) in Oslo and have recently issued operator contracts that will lead to the delivery of another 70 electric buses in 2019 (Ruter 2018). According to findings in ZeEUS, *serial* ***production of electric buses could reach maturity already in 2018-2020.*** However, this only applies to city buses, while coaches do not currently have a battery-electric alternative. Others have indicated that electric buses and their infrastructure should reach technological and economical ***maturity for*** *serial* ***production by 2020-2025*** (Hagman et al. 2017; Bloomberg 2018).

Although the electric bus market is near an economic maturity level, it is far from the case for goods vehicles. There are still only small electric vans that are serial produced, but this is about to change, and both serial produced large vans and trucks will soon come on the market. Until now, pilot tests with battery electric trucks have been limited to vehicles originally fitted with an ICE, that are refitted with a battery electric drivetrain. There are at least two companies in Europe, offering such services, Emoss in the Netherland and the French company PVI (Power Vehicle Innovation) which is owned by Renault.

Goods distribution services in cities operate in similar conditions as buses and can potentially be electrified with similar technology, motor and battery sizes. For trucks, that have a less predictable transport pattern over the day, it is more important with bigger batteries and longer range. Transport costs will increase when the cargo or passenger capacity is reduced and the time to fill energy into the vehicle increase compared to operating a diesel truck or bus, since more vehicles (and drivers) are needed to fulfil the same transportation tasks. Therefore, these parameters have a strong impact on the economics of freight and public transport using BEVs.

Postal companies have been some of the first to acquire battery electric vans in Europe. BEVs are suitable for postal deliveries because daily routes are usually fixed. For HDVs the early stage segments that can be electrified are most likely to be found within waste management, grocery trade and city logistics. Public tenders can help to phase-in BEVs within these segments.

Although the energy density in batteries have increased in the recent years, BEVs are often heavier than similar vehicles with ICE, which usually results in a reduced passenger or cargo capacity. The driving range of the vehicles is also a limiting factor, and there is a trade-off between the cargo/passenger capacity, driving range (battery size) and charge time. Battery packs are therefore tailored to specific bus routes based on charging potential at the end stops.

Different kinds of batteries are used, but it seems like lithium ion batteries is the most common battery type used for HDVs in Europe. In China lithium iron phosphate batteries, a variant of Li-Ion batteries, are commonly used in buses. Iveco's battery electric mini-buses use Sodium-$NiCl_2$ batteries, a battery type which is supposed to perform better during colder temperatures, as the battery chemistry operates at some 270°C.

Some operators are worried about the durability of batteries. In China a reduction of battery capacity after 3-5 years of bus usage has been reported (Shengyang Sun 2018). The battery electric buses on today's market typically have a battery warranty of four to up to ten years (Bloomberg 2018), the same as for the charging systems. The Lithium-Titanate-Oxide Li-Ion variant (LTO) have a warranty of up to 15,000 charging cycles, but the life expectancy of the batteries is about 18,000 full recharge cycles (Linkker 2017).

Three main options exist for recharging battery electric city buses; depot charging overnight, opportunity fast charging during the day at stops, and dynamic charging while driving (conductive as used by trolleybuses, or inductive buried in the road surface which is under development). In reality, combinations of these may be used.

Fuel cells HDVs

A fuel cell electric vehicle (FCEV) is an electric vehicle using compressed hydrogen as its fuel source. The fuel cell vehicle will most often also include small batteries to boost the acceleration, capture braking energy, and act as a power buffer. These batteries can, but need not, be externally rechargeable.

In Europe 82 fuel cell buses are being tested out in different pilot projects (CHIC 2017). The testing of a further 200-300 fuel cell buses in Europe in 2018-2020 is already being planned for by the EU projects Jive 1 and 2 and other projects (FCH Joint Undertaking 2017; FCH Joint Undertaking 2018). Ruter, Oslo, will be a partner in Jive2.

According to CHIC (2017) the availability of both buses and infrastructure needs to be improved further to give confidence to initiate further hydrogen fuel cell bus operations. This includes technical improvements, improved capabilities of suppliers and maintenance facilities, improved availability of spare parts, and reduced response and repair times when trouble arises.

As for BEVs, fuel cell vans and trucks are lagging behind the bus development. There are few concrete plans for *serial* production of this type of vehicle among European companies. Scania, in cooperation with the Norwegian wholesaler company Asko, is preparing five delivery trucks for fuel cell technology, which will be used in the Trondheim area from the late autumn of 2018.

Lack of hydrogen refuelling infrastructure, together with the higher current cost levels for hydrogen vehicles, are barriers to phasing-in this type of vehicle. This is a reason why Asko also established its own hydrogen production plant within their terminal area outside Trondheim. Hydrogen is produced by a solar systems on the warehouse roof and, will in addition to the trucks, also supply hydrogen-powered fork-lift trucks used inside the warehouse.

The pilots in the US experienced some of the same problems as in Europe: poor availability of spare parts, high maintenance costs for a relatively small number of vehicles, and competition with other zero emission technologies.