Summary

Green Trucking?

Technology status, costs, user experiences

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The EU's CO_2 requirements for vehicles drive the rapid technological development in zero-emission vehicles of all types and have created a growing market. This has come the furthest for battery-electric passenger cars, followed by vans and city buses. Towards 2025, trucks will follow. Costs will be reduced and in 2025, battery-electric trucks will be the cheapest alternative to diesel, and will probably be favoured by the users where it is practically possible to use them, especially in cities. The first user experiences with the latest generation of series-produced battery-electric trucks are positive. At longer distances, both hydrogen, liquid biogas and biodiesel can be alternatives.

Market and technology status

The most important driver for the technological development of vans, trucks and buses are EU requirements and directives related to the reduction of CO_2 emissions from new vehicles for 2025 and 2030, and requirements for the environmental performance of buses and other vehicles purchased by the public sector. These legal requirements have led to major investments in the development and industrialization of battery-electric vehicles for commercial transport. Hydrogen vehicles lag behind in this development process, but an increasing number of manufacturers work on solutions ready for the market towards 2030.

Vans

All van models supplied by traditional manufacturers are now also available in battery-electric versions. In addition, electric vans from Chinese manufacturers are sold on the Norwegian market. This may lead to the range of electric vehicle models becoming wider than diesel models in the van segment. Newly launched battery-electric vans are available in similar configurations as diesel models. The vast majority of small and medium-sized vans also now have tow-bars, although in some cases with a lower maximum weight allowance than diesel models. Except for the largest vans, driving ranges up to 200 km are available, also when used in winter. Further, fast charging technology has been established, and vans can use the same fast chargers as passenger cars.

One manufacturer is developing and offers a hydrogen-based range extender for its battery-electric vans, while another may soon supply a rechargeable hybrid hydrogen van model.

City buses

For city buses, extensive technical developments have taken place and battery-electric solutions are now available from several manufacturers and in all size classes, function classes (Class I and Class II), and different combinations of battery and charging solutions. Buses with large batteries intended for depot charging, buses with small batteries for flash charging with pantographs at stops, and intermediate solutions with buses with medium-sized batteries that can be charged with a pantograph in different locations. This enables adaptation to a variety of local routes in Norwegian cities. Bus manufacturers offer consulting services for dimensioning of both buses and charging systems. Technically, there are few challenges associated with electrification of buses, but route adaptations may be required in order to allow sufficient charging during daytime, especially in winter. A particular challenge for city buses is the amount of energy needed for heating the passenger area in winter, combined with frequent door opening at stops. As for vans, there will soon be a wider range of electric buses available on the market because several Chinese manufacturers sell battery-electric buses in Europe, but no diesel buses.

VDL is developing and will start production of a completely new bus type from 2021, with batteries placed in the buses' floor and with lower energy consumption for heating than other buses. A number of hydrogen buses have been developed and tested in various cities in Europe and several manufacturers can also supply such buses to the market. The ongoing rapid development of battery-electric city buses implies that hydrogen technology will likely be most relevant in other use segments, such as regional buses.

Trucks for local and regional distribution transport

All of the major established truck manufacturers are bringing series-produced battery-electric trucks to market in 2021-2022. So far, this has first and foremost been in the 16-27t truck segment and with batteries of 165-400 kWh. These first series-produced trucks are optimized for urban and regional distribution, waste management and construction activities and have driving ranges of between 100-300 km, depending on load, season, driving conditions etc. From 2022, trucks over 27t with batteries of 400-540 kWh will also be available. Manufacturers report that payloads will be the same as for similar diesel models, but in some cases the payload may be somewhat reduced, a factor which most operators do not consider critical.

Several Chinese vehicle manufacturers are rapidly entering the Norwegian passenger car market and are already present in the van and bus markets. It is therefore likely that more battery-electric trucks will become available in the Norwegian market by 2025 and 2030, while also established manufacturers will have to launch electric trucks to meet the EU's CO_2 requirements. Market availability of electric trucks in the market is therefore expected to increase rapidly towards 2025.

Trucks for long-haul transport

Also for long-haul transport, electric trucks are under development. Tesla is working on a battery-electric semi-trailer which they claim will have a range of 475-800 km (Tesla Norway 2019), while Nikola is working on both hydrogen and battery-electric long-haul trucks and has entered into a collaboration with heavy truck manufacturer Iveco (Iveco 2019). Traditional manufacturers are also developing heavy electric trucks and commercializing these to meet the 2025 and 2030 requirements of the EU directive on truck CO_2 emissions.

Volvo, Scania, Mercedes and DAF also have such trucks under development and for sale (deliveries from 2022). Mercedes and Volvo will start series production of heavy trucks in 2021/2022. Volvo will deliver trucks with up to 44t total weight, batteries of 540 kWh and a real range of 300 km even under demanding driving conditions.

VanHool has developed and put into production a long-distance bus with a 676 kWh battery and range of over 300 km. This bus illustrates that there is a potential for electrification of trucks used on longer distances even given today's technology. Iveco and Nikola's electric truck will have batteries of more than 700 kWh.

Technological development

Electric and hydrogen truck technology are under rapid development. Trucks are used more intensively than passenger cars and vans, run longer and with heavier average loads. Development of robust batteries and fuel cells is therefore essential if these are to last throughout the truck's technical lifetime. Using batteries or fuel cells developed for passenger cars that only need approx. 5,000 hours of service life is not necessarily sufficient for trucks that are operated 10,000-20,000 hours in their lifetime. This entails that batteries and fuel cells for trucks can be somewhat more expensive than for passenger cars and that market development will be slower. Simultaneously, there are also indications that batteries for passenger cars and trucks can become very similar, with reports of strongly improved life times for passenger car batteries and record low costs for electric bus batteries. When passenger car batteries are used in heavy duty vehicles, costs per kWh can nevertheless be higher, because somewhat more of the battery capacity in trucks (vs. passenger cars) is reserved to yield a guaranteed mileage or remaining range for a fully charged battery up to a given year (for passenger cars and vans this is usually until the 8th year).

Hydrogen truck adoption is expected to take place in a somewhat longer run, with most manufacturers suggesting market introduction towards the late 2020s. Hyundai has a hydrogen truck in production, but in very limited volumes, and does not envisage large-scale production until after 2025. In the next few years, hydrogen trucks can be used for demonstration projects, so that real user experiences can also be established for this technology.

Biodiesel and biogas

Vehicles

Many heavy duty vehicles are constructed such that biodiesel can be used in the same drivetrain as regular diesel, but biogas and natural gas require dedicated drivetrains. Gas vehicles are in series production and are available in most vehicle segments, but for the time being there is only a limited number of gas vehicles in Norway. By the end of 2020, around 800 buses, 500 vans and 500 lorries were running on gas in Norway. This constitutes only 5 percent of the bus and 0.5 percent of the Norwegian truck fleet respectively. The number of vehicles using liquid biogas (LBG) is currently limited. Around 50 Norwegian trucks are adapted for LBG use, but the supply of this type of vehicle is increasing. LBG vehicles have longer driving ranges than compressed gas (CBG) vehicles, and are therefore better suited for long-distance transport. CBG vehicles, with their more limited driving range, are therefore more in competition with battery-electric trucks for local and regional use.

Except for long-distance transport, where the largest gas engine on the market is somewhat smaller than engines typically used in diesel vehicles, the performance for gas vehicles is nearly similar to diesel vehicles. At the same time, end users report a real additional fuel consumption of 5-20%. Tractor units stand out as a particularly suitable segment for biogas because battery-electric operation is currently unsuitable for this segment, while hydrogen operation is expensive and immature.

Filling stations in Norway

Most Norwegian filling stations offering 100% liquid biofuels are located close to main transport routes. In addition, companies such as Posten/Bring and ASKO have their own filling stations. For biogas, Norway counts just over 30 filling stations in 2021. The majority of these allow filling of compressed biogas, while liquid biogas is currently only available at four stations. Construction of several additional filling stations has been announced, and also the EUs AFI Directive (Directive 2014/94/EU on the deployment of alternative fuels infrastructure) and assessments made in the Klimakur 2030 report indicate that construction of additional filling stations is needed.

Production and use of biogas and biodiesel

Today, the most important market for the use of biogas as a fuel in Norway, is the bus market. Norway's production of biogas, and biogas upgraded to fuel quality, is relatively limited compared to e.g. Sweden and Denmark. This applies especially to liquid biogas. For the short term, there are several concrete plans for developing LBG production capacity, and a production potential identified for 2030 entails biogas production of approximately four times the 2018 level. Today, the most commonly used raw materials for biogas production are food waste and sewage sludge, which are also the cheapest inputs. By also utilizing other raw materials, the production potential, but also production costs, can increase. Furthermore, both shipping and storage of LBG are cost-driving. Barriers associated with increased production of fuel-quality biogas in Norway, uncertain access to raw materials and lack of a market for cost-driving bio-residue are other potential barriers to increased adoption.

Current turnover requirements (requiring a certain percentage of fuels sold to be bio-based) and requirements for increased shares of advanced biofuels entail a much greater need for biofuels, and several firms have announced plans for constructing biofuel production facilities based on timber as raw material.

Challenges and opportunities for the use of biofuels

Biogas sold in Norway is currently not subject to the EUs sustainability criteria, but this is something that has to be considered if biogas is to be included in turnover requirements or similar schemes. Other challenges are that the number of filling stations for biogas and pure biodiesel are limited, that the fuels are more costly and that biogas vehicles are more expensive than diesel trucks. In addition, framework conditions and objectives are unclear on several points, in addition to practical barriers. Further, the availability of biogas and advanced biodiesel is more limited in some periods than others.

From July 2020, Norway introduced levies on all liquid biofuels that can be used in petrol and diesel engines. This has made liquid biofuels a less attractive alternative. Another factor potentially reducing biofuel attractiveness is uncertainty about whether liquid biofuels or biogas can be used towards meeting EU requirements for emission reductions from heavy-duty vehicles for 2025 and 2030.

It is likely that Norwegian guidelines for public procurement soon will recommend advantageous treatment of zero-emission and biogas solutions, but not of biodiesel and bioethanol solutions, which are considered sufficiently regulated through turnover requirements.

Transport costs for different propulsion technologies

Trucks

Total ownership costs calculated for different propulsion technologies presented in this report are based on a three-axle truck and for each of the years 2020, 2025 and 2030. Costs are standardized with a diesel truck as the reference (= 100) in each of the years.

Table S.1. Total costs of ownership for 2020, 2025 and 2030, relative to a truck with internal combustion energy running on diesel. Based on three-axled truck (27t max. allowed total weight).

	2020	2025	2030
Diesel	100	100	100
FAME (advanced, UCOME)	105	107	110
HVO (advanced, type A)	112	115	117
BEV	134	103	91
FCEV	186	148	121
Biogas, liquid (LBG)	118	116	114
Biogas, compressed (CBG)	112	110	109
Hybrid (HEV)	112	113	112
Hybrid, plug-in (PHEV)	114	113	112

Today, total costs of ownership when using FAME or HVO are higher than under diesel operation, and cost differences are expected to increase into the future. This is driven by (relative) price forecasts for these fuels and current Norwegian tax policy. Biogas also yields higher costs of ownership than diesel operation due to somewhat higher energy and capital costs. In the longer run, biogas operation is expected to become somewhat more competitive due to reduced vehicle prices and potentially better residual values/a larger second-hand market. Battery electric propulsion will by 2025 be the cheapest alternative to diesel and by 2030 the cheapest option overall. This may have implications on the willingness to invest in the other alternatives. The table however shows that battery-electric operation today is clearly more expensive than diesel operation, even with an ENOVA subsidy covering 40% of the difference in vehicle investment costs.

Savings on amongst others energy costs and road toll expenses for battery-electric operation are currently not enough to recover higher capital costs. The costs of a battery-electric truck are expected to decrease in the future, but will still not be fully cost competitive versus diesel in 2025, even including the ENOVA subsidy. From 2030, the battery-electric alternative is expected to be the cheapest solution if the ENOVA subsidy is unchanged. However, these calculations are subject to large uncertainties. This applies particularly to investment costs for electric vehicles, which are high initially because manufacturers have had high development costs. The hydrogen-electric alternative (FCEV) is estimated to currently have ownership costs about twice as high as diesel vehicles (including ENOVA subsidy) and approx. 50% and 20% higher ownership costs in 2025 and 2030, respectively, although calculations for hydrogen-electric vehicles are particularly uncertain. The hybrid-electric alternatives also have higher ownership costs compared to diesel vehicles, as savings on fuel costs are insufficient to recover their higher investment costs.

Because the total costs of ownership in our calculations depend on the assumptions used, we also calculated cost effects of changing assumptions on annual mileage, residual values and depreciation period respectively. These calculations indicate that the competitiveness of vehicles with higher investment costs but lower energy costs than diesel trucks are sensitive to annual mileage. Shorter mileages reduce competitiveness, while longer mileages improve competitiveness. Risks associated with uncertain residual values can be compensated by longer time perspectives on investing in new technology and by the public sector offering various forms of support to the early users of new truck technology.

User experiences from the first series-produced battery-electric trucks

TØI previously interviewed some of the first Norwegian users of battery-electric trucks to collect real-world user experiences. At that time, battery-electric trucks were generally all rebuilt from diesel to electric drivetrain by independent converters, but from the summer of 2020, the first series-produced battery-electric trucks from major truck manufacturers have started arriving in Norway. Although this has given a boost to their adoption, there were still only 74 Norwegian-registered battery-electric trucks as of August 2021, mainly used by major actors and in the Greater Oslo area.

For the present work, we interviewed five of the first Norwegian firms that operate series-produced battery-electric trucks (three distributors and two contractors), in addition to a vehicle supplier and the Norwegian Public Roads Administration. In total, the firms operate 28 series-produced battery-electric trucks from several large truck manufacturers, both 2- and 3-axled distribution trucks and 3-axled construction trucks with a distribution truck chassis. The objective of the interviews was to gain insights into relevant experiences regarding further vehicle adoption, e.g. regarding purchasing, charging, use vs. diesel vehicles, incentives, challenges, and what would be necessary to achieve larger scale electrification to achieve the National Public Transport Plan's target of 50% of new trucks being zero-emission by 2030.

Drivers behind choosing battery-electric trucks

Early users state that investments in battery-electric trucks have largely been strategic and important drivers have been the firms' own climate and environmental objectives, in addition to passionate key staff. For construction firms, the environmental weighting in public tenders, especially from the City of Oslo, has been a very important driver. Distributors report increasing demand for greener transports, but with limited willingness to pay by customers.

Choice of vehicle manufacturer and investment cost premium vs. diesel

The firms' choice of vehicle model and supplier was largely steered by availability (with choice alternatives until recently being few and delivery times long), with a preference for well-known suppliers. Price was considered, but not a decisive factor due to investments being largely strategic.

Small and larger battery-electric distribution trucks are stated to have been 2-2.6 times and 3-4.6 times more expensive than similar diesel trucks, and battery-electric construction vehicles 3-3.5 times more expensive, respectively. Prices have gone down somewhat between 1st and 2nd generation series-production. Due to high investment costs and uncertainty about residual values, the firms interviewed often employ longer depreciation periods for battery-electric trucks than conventional vehicles or plan to use them longer. All firms received ENOVA subsidies for part of the additional investment costs (vs. a similar diesel vehicle). This is stated to be very important, even though there have been several challenges due to ENOVA's requirements and the design of the grant scheme.

Use patterns for battery-electric vs. diesel trucks

Both distributors and contractors made operational adjustments for the phase-in of their battery-electric trucks. In some cases, relatively small changes were sufficient, while in other cases, larger parts of operations were reorganized, although not all changes would strictly speaking have been necessary. Distributors mainly use their battery-electric trucks for urban distribution. Here, the battery-electric trucks approach one-on-one replacements of diesel vehicles, especially after the establishment of fast charging at depots, which allows an increase in the number of shifts and attainable annual mileages.

Use flexibility is somewhat limited due to the inability to drive with trailer and on longer routes. Bergen is stated to have more demanding topography and geographical surroundings, so that achieving fully electric city distribution will take longer than in Oslo, where separate city terminals have been established from which electric distribution transports are organized.

For construction trucks, usage patterns for diesel vehicles varies much, making direct comparisons difficult. The battery-electric construction vehicles are mainly used for light construction work during the day in the inner city of Oslo and between construction sites and disposal sites in Oslo. Usage patterns have been somewhat adapted to increased use of local disposal sites because this fits well with the procurement policies of the municipality of Oslo.

Experiences from use

Generally, energy consumption of the battery-electric trucks is reported to be low, yielding large energy and potentially also cost savings. Both energy consumption and driving range can vary much, depending on various factors, although wintertime reductions in driving range have generally been limited. In practice, the range of battery-electric trucks lies somewhat below the manufacturer-specified range, but much closer than some of the firms previously experienced with battery-electric vans. Newer generations of battery-electric trucks have also shown noticeable efficiency improvements and better driving ranges. Other than some individual cases, the firms have not experienced major technical problems, although experiences with training, service and maintenance, and the pricing of this, are mixed. Drivers are generally satisfied with the vehicles' performance and report an improved working environment.

Even though the weight of batteries negatively affects the vehicles' payload, this is not considered a major problem in practice because capacity limitations for distribution transport are usually set by volume, while construction activities in the inner city are time-consuming, so that construction trucks often drive before they are filled up to capacity. However, the placement of batteries can yield challenges with regard to axle load, space/placement on 3-axled vehicles and uneven construction site grounds.

Charging

The distributors mainly started with nighttime depot charging, but also want to be able to use more fast charging during daytime, although concrete charging strategies differ. The construction firms also use nighttime charging, in addition to several fast charging solutions during the day. While depot charging infrastructure is relatively inexpensive and electricity costs are low, fast charger infrastructure is expensive. A major barrier reported by all firms is that ENOVA subsidies are only given to chargers that are made publicly available. In addition, the establishment of fast chargers may require additional costly investments such as grid upgrades. External fast charging, however, is considered expensive and entails costs for charging time, detours, waiting in queues, etc. Investments in battery-electric vehicles and the availability of charging solutions are therefore described as a "chicken-and-egg-problem", because the competitiveness and profitability of the vehicle depends on how optimally the vehicle can be used. In this regard, it is pointed out that infrastructure construction is going too slowly.

Incentives and framework conditions

All firms point out the importance of stable, predictable and long-term framework conditions. For the time being, subsidies for battery-electric vehicles are considered very important for investments in zero-emission vehicles to be considered, while much better schemes for charging infrastructure are called for. In particular, it is noted that maintaining road toll advantages is critical for battery-electric vehicles to compete with other technologies. Further feedback suggests that should road toll advantages also be introduced for biogas vehicles, this could lead to a transition to these at the expense of battery-electric solutions.

Other (existing or potential) incentives brought up by the firms are access to public transport lanes, zero/low emission zones, low noise zones and dedicated loading/unloading zones for zero emission vehicles. Such incentives allow more (time) efficient use and improve the competitiveness of zero-emission vehicles. At the same time, it can be discussed whether hybrid trucks or biogas vehicles should receive any of these advantages.

Electrification potential and other propulsion technologies

Distributors are generally positive about the potential for electrifying their fleets. Much of local distribution can already be carried out with battery-electric trucks and fast charging and relatively small driving range improvements will enable battery-electric operation also for large shares of their regional transports. In addition to range restrictions, there are barriers associated with the (lacking) availability of vans and trucks in some vehicle classes, lack of four-wheel-drive and tow-bar, and some vehicle models not supporting fast charging. The construction firms report a need for improved driving ranges, vehicles with more than 3 axles and for vehicles with tow-bar, so that more disposal sites become practically reachable. On a general note, the vehicle manufacturer states that developments are moving quickly and that larger technological developments are expected in the future. It is also expected that costs can become significantly lower once much of the large development costs has been recovered.

Of other technologies, liquid biogas is considered the most promising alternative to battery-electric operation on heavy trucks. For urban use cases, biogas is competing with battery-electric propulsion. As battery-electric solutions becomes a cheaper option, biogas can gradually be squeezed out of urban areas, while liquid biogas can have applications in long-distance heavy transport. Biodiesel has become less competitive after a Norwegian levy was introduced, so that owners of diesel vehicles have started returning to (fossil) diesel operation. This illustrates a dilemma, where large emission reductions (due to the use of biofuels) can be zeroed out quickly when framework conditions change. Hydrogen is not considered a realistic alternative by the interviewed truck operators in the short to medium term.

Hurdalsplattformen (the new Norwegian Governments political platform) puts an increased focus on biobased fuels and targets tax reductions to stimulate increased use of Norwegian made biofuels. It is uncertain what the final policy will be as the Government does not have the majority in the Parliament behind it. The EU is currently revising the Alternative Fuels Infrastructure Directive and has proposed a stronger regulation with clearer targets for refueling and charging stations. The final ruling will likely not be ready until 2022.