Institute of Transport Economics
Norwegian Centre for Transport Research

Summary

360 degree analysis of the potential for zero-emission vehicles

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This report analyses the potential and the prerequisites for reaching the National Transport Plans targets of only selling zero-emission passenger cars, small light commercial vehicles (Vans) and city buses in 2025, large vans in 2030 and that 50% of new trucks and 75% of new long distance buses shall be zero-emission by 2030. The passenger car target for 2025 is demanding due to the wide variation in user needs and preferences. Strong measures will be required to meet the goal. The goals for city buses and small light commercial vehicles can potentially be attainable with the right policy instruments. The technology development seems to converge with user needs the coming years. Also the 2030 heavy light commercial vehicle target seems within reach as this segment lags the small light commercial vehicle development by about 5 years. The 2030 truck and bus targets are much more uncertain as no commercial offerings are in place for these demanding sectors. Hydrogen may play a key role for long distance heavy duty applications.

Introduction

Users need vehicles that can be used to solve transport tasks efficiently, reliably and comfortably. To address this need, a vehicle and transport culture has been developed over 100 years based on internal combustion engines (ICE) that use fossil fuel as a source of energy. As part of a green transition, zero emission vehicles are now being introduced to replace those powered by ICE. The aim of these is to continue to provide the transport services that the community needs, whilst reducing greenhouse gas (GHG) emissions and local air pollution.

Battery electric technology is currently the most mature zero emission technology in use, relying primarily on lithium-ion batteries (LIB). Many battery electric vehicles have been introduced into the electric vehicle fleet already, and further transitioning to electro-mobility will lead to a continued rapid growth. Norway is a leading nation in the drive to electromobility with ambitious zero-emission vehicle targets set in the Norwegian National Transport Plan (NTP) (Norwegian Department for Transport 2017); by 2025, all new passenger cars, light vans and city buses are planned to be zero emission vehicles. Additionally, by 2030 all new heavier vans, 75 % of long-distance buses and 50 % of new trucks are planned to be zero-emission vehicles.

This report, commissioned by the Ministry of Climate and Environment, aims to document the current LIB based electric vehicle (EV) fleets and illustrate from various angles how far the introduction of zero emission vehicles can come towards targets in 2025 and 2030 for key vehicle segments. These segments include i)passenger cars, ii) light commercial vehicles (vans), iii) public transport (buses) and iiii) heavy duty vehicles. This was carried out by studying and analyzing the individual elements that need to be in place for the goals to be achieved, as presented in figure S1. As illustrated on the figure, these elements include technology and cost development, supply and demand for zero-emission vehicles, and driving forces and instruments.

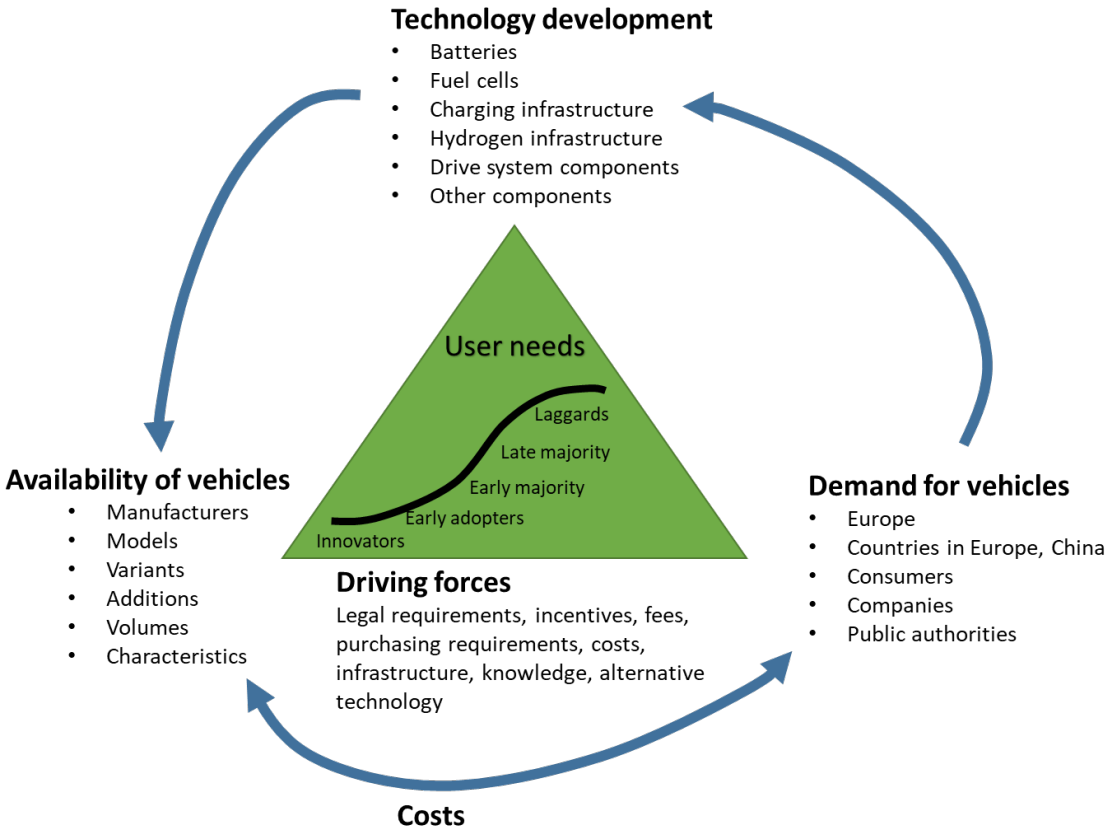

Figure S1: Elements that affect the ability to reach the zero emission vehicle targets in the Norwegian National Transport Plan (NTP).

Background

Battery electric vehicles have thrived in the Norwegian market. Going forward from 2020-2025, and again on until 2030, it is expected that there will be further great upheaval in the vehicle market. The share of new battery electric passenger vehicle sales passed 40 % in 2019, with another 13 % comprised of plug-in hybrids, meaning a total of 55 % of passenger vehicles have the opportunity to be powered from grid electricity. Sales in the van segment are not as high, with the market share for electric vans at approximately 6 % in 2019. The year 2019 also marks a breakthrough year for electric buses, with over 420 electric buses planned for Norwegian cities in 2020 and 199 on the read at the end of 2019. The first demonstration projects with electric trucks have also started.

But it is in the passenger car market that the major changes have taken place; in the year 2009 fewer than 200 new electric cars were registered, but ten years later in 2019 more than 65000 electric vehicles were registered. This is largely due to incentive use (which is more powerful than in the van market), with exemptions from value added tax (VAT), one-off sales tax and traffic insurance tax, reduced benefit taxation and some additional local benefits. In addition, usage characteristics have proven compatible with many user patterns, especially with a little support from fast chargers along longer trips. Electric passenger cars have become so favorable to buy and use that they have emerged despite the range and charging speed restrictions (which are particularly relevant in winter). The purchase price is lower or about the same as for petrol and diesel vehicles and the annual costs are significantly lower.

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For vans, the policy scope has been a little too limited, the VAT exemption has no effect and the one-off tax exemption is a minor advantage because diesel vans have lower one-off fees than passenger cars. Annual costs are on par or lower than for diesel vehicles, but the overall user experience and economics have not been favourable enough to date. The bus market is driven by tenders, which means that development can proceed rapidly when the technology is mature enough for ordinary route usage in Norwegian cities, and economics are acceptable. For trucks, there are so few pilot projects that the cost side is little known and more knowledge is needed on how to develop this market.

Whilst complementary to battery electric technology - hydrogen fuel cell vehicles are now considered less relevant within cities, although various test projects are underway. This technology is considered more relevant for long-range vehicles.

Methodology

A wide range of approaches, and different methods of analysis was used, to assess i) key drivers for the market and ii) whether the NTP objectives are achievable. Existing research and other knowledge was summarized through literature and document analyzes. In addition, separate calculations were made with models that calculate disaggregated purchase prices and annual costs (TØI-TCO), a similar model for freight transport, and a model for bus costs. Previous use of a stocks-flow cohort model was also summarised, in which various outcomes of policy changes were analyzed for the passenger car market. Furthermore, the effects of regulations and directives in the European Union (EU) were assessed together with other driving forces that may affect the vehicle market.

Key drivers

Research shows that the main driver for electrification of the transport sector is the international climate and environmental focus, which in turn has made the EU adopt stringent requirements for new vehicle CO_2 emission limits, as shown in figure S2. In addition, China and California have also adopted demands for the sale of increasing shares of electric vehicles in the future. New technology, primarily the development of Lithium battery technology, has made such demands possible.

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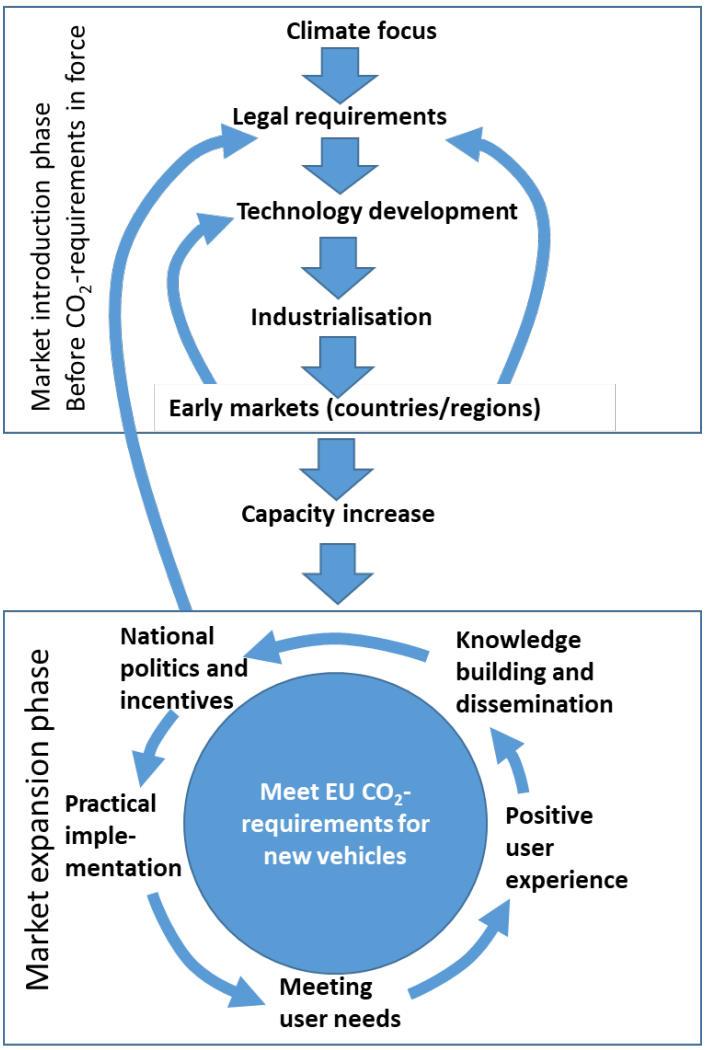

Figure S2: The dynamics that the EU's requirements for new vehicle CO_2 emission limits create in the zero emission vehicles markets.

This has led to a rapid and comprehensive technological development, and the beginning of European electromobility industrialization. Electric vehicles have been sold and tested in early markets such as Norway where strong incentives have meant that the technology has become more competitive with conventional vehicles at an earlier date than in other countries. From 2020, EU requirements for passenger vehicles will have full effect with heavy fines if the targets are not met. Thus, the market is in an expansion phase where electric vehicles are becoming standard products with most vehicle manufacturers. Where the vehicles end up, and how many will be sold beyond the EU minimum requirements, depends on how effective countries are in becoming organized for users to ensure positive experiences, and how they disseminate knowledge in society.

In Europe, the EU is thus the major electromobility driver with the requirement to reduce the average CO_2 emissions from new passenger vehicles, vans and trucks. Requirements by 2025 and 2030 are so stringent that electrification of all or part of the model range is inevitable. If manufacturers do not meet the requirements, then fines are so large that completing the requirement is a better option. China has similarly stringent requirements for quota shares with zero emissions vehicles. The EU requirements trigger the development of electric vehicles to a large extent. It is estimated that globally vehicle manufacturers will invest € 300 billion in electrification over the coming years, of which approx. 45 % will be invested in China. This means that there is also a corresponding

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industrialization and development of battery technology. Thus, investment decisions are made and development costs are to be regarded as depreciated costs when production starts. In a situation where one has to produce in order to meet legal requirements, this cost may not entirely be passed on to purchasers of electric vehicles.

The regulatory requirements will mean that (in the passenger car market) approximately 1.9 million electric vehicles and 0.9 million plug-in hybrid vehicles must be sold in 2025, and 4.3 million and 2.2 million respectively in 2030, in order for the CO_2 requirement to be achieved. The actual number may be higher, depending on how far down the emissions from Internal Combustion Engine vehicles may come. In the light commercial vehicle market, 0.26 and 0.64 million electric vans will probably need to be sold in 2025 and 2030, respectively. Trucks are sold in smaller volumes, which means that the CO_2 requirement could lead to sales of 16000-28000 zero-emission trucks sold in Europe in 2025 and 32000-60000 in 2030. For city buses there are as of yet no corresponding CO_2 requirements, but the EU requirements for public procurement of buses will provide a solid boost for battery electric city buses and should ensure a minimum sales of 20-40 per cent of the city buses sold. Hydrogen is particularly interesting for truck operation over longer distances. Hydrogen has low priority among passenger car and light commercial vehicles manufacturers (with a couple exceptions). It therefore seems unlikely that hydrogen vehicles will have a major role in meeting CO_2 requirements in these vehicle segments. The same goes for city buses.

The development is also expected to be driven in the future by (partially) new stakeholders, including manufacturers such as Tesla, Nikola and various Chinese manufacturers who seek new opportunities in Europe. Additionally, charging infrastructure is being developed and partly operated by new stakeholders, and increasingly also by gas station companies. National policy controls not only the volume of sales in a country, but also which countries are prioritized by vehicle manufacturers when new models are launched.

Barriers to the technology, as shown in figure S3, include technology limitations, lack of knowledge, lack of consensus on charging solutions, existing transport habits, and infrastructure that is not yet fully integrated with the rapid development of the fleet, and which is not capable of handling large variations in transport volume throughout the year. This competes against a system that has been optimized for over 100 years powered by ICE. Barriers are reduced over time with better technology and with increasing knowledge through use, and with an increase in the number of demanding customers.

Other trends such as population growth and the growing number of elderly people in Norway will probably not reduce the demand for transport by vehicles until 2030. Automation of vehicles is likely to take a long time to establish (in a sound manner) for Norwegian winter traffic conditions, and is not expected to limit the demand for electric vehicles up to 2030. In fact, the effect may even be the opposite, i.e. that during the drive towards automation the vehicles are made safer and more comfortable to drive, but still require a driver, which will contribute to increased sales of electric vehicles and vehicles in general, and thus increased traffic. It is also considered unlikely that trends such as micro-mobility or vehicle sharing in the foreseeable future will reduce vehicle purchases significantly the coming 10 years.

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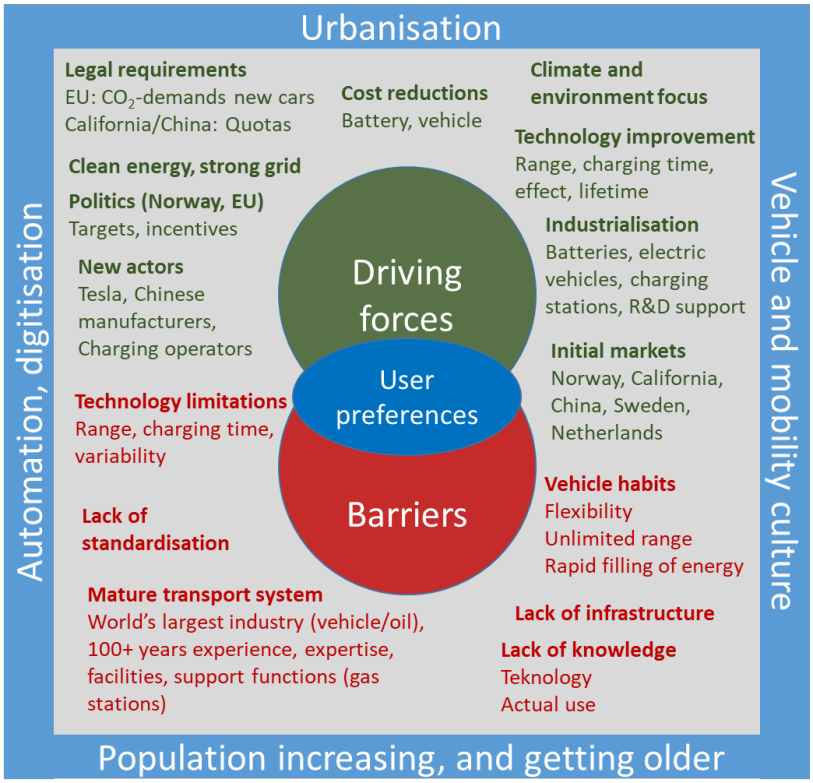

Figure S3: Drivers and barriers to a market dominated by zero emission vehicles.

Passenger car segment

The passenger car market is facing a major upheaval. A large number of electric vehicles and plug-in hybrid models will be launched in the period 2019-2022, and existing models will be renewed and get longer range. This upheaval will make it easier for the automotive industry to meet the requirements for average CO_2 emission targets of new vehicles in the EU, which are strengthened towards 2025 and 2030, and to meet quota requirements for the sale of electric vehicles in China. The investment in electric vehicles is greater than the investment in plug-in hybrid vehicles. Within the passenger vehicle market, a continuous price and model range will be developed from the smallest and cheapest electric vehicles to the largest and most expensive luxury vehicles. More users will thus be able to find vehicles with suitable range to meet their transport needs at a cost they can afford, but there may be some flexibility limitations. Vehicles launched the coming years will also be able to recharge faster.

The purchase price of compact size electric vehicles has, thanks to the tax exemptions, matched petrol and diesel vehicles since approx. 2015 with small batteries, and from 2019 with large batteries. Annual costs became compatible as early as 2012, which has resulted in the rapid market expansion from that year. From 2023 to 2025, electric vehicles are expected to become a socially economically profitable climate measure in Norway.

Van segment

In the van segment, the market for electric variants has been slow. It is expected to improve in 2020, but it will not be until 2021 that the major upheaval is expected. A

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majority of small van models are then expected to have a battery-electric variant that can meet the needs of most van users. Electric vans have not yet achieved cost parity upon purchase price, as mentioned, since there are fewer incentives available than for passenger cars. Purchase price parity is expected to be achieved in 2022-2023, but in terms of annual costs, electric vans have been compatible for the last 2-3 years. By 2021, producer costs are expected to have fallen so much that electric vans can become socio-economically viable.

Bus segment

Most bus manufacturers already have (or are about to launch) battery-electric powered city buses of all sizes. These buses are tailored to local operating conditions in terms of battery size, range, heating and cooling, and charging solutions, and route patterns are adapted to enable full route usage. As a result, there are no longer any major technical or accessibility barriers to increased use of battery electric city buses. The annual costs (as of 2019) are higher than for corresponding ICE vehicles, but are expected to fall rapidly towards 2025 where electric buses can become cost competitive. This is given that the battery lasts the life of the tender the bus is used in, or that a battery warranty can be provided within a cost corresponding to the savings in annual maintenance compared to diesel operation. Battery life uncertainty can be eliminated through such maintenance agreements with bus suppliers. It is not yet possible to know more about battery lifetime before buses are in normal operation under Norwegian conditions.

The city bus segment is controlled through tenders where the requirements for buses can be specified so that battery electric buses becomes the preferred option.

Long-haul buses are more uncertain and the assessments are the same as for long-haul trucks.

Truck segment

Trucks are at the very beginning of a market introduction and will gradually come into series production from 2020-2022. It is an open question whether hydrogen or battery-electric solutions are the optimal alternatives for long-distance driving, while for urban logistics and other applications in the city, battery-electric solutions are expected to be the major player due to the low cost of electricity, and because many of these vehicles return to the depot every day where they can be recharged.

As yet, there is very little experience in practical operation, meaning that there is high uncertainty about the cost of batteries and the complete battery electric truck, as well as the lifetime of the batteries. There is also great uncertainty about the cost of hydrogen solutions and operation. It is therefore not possible to conclude wether or not the 2030 target can be met.

Summary of target progress

The goals in NTP for the introduction of zero-emission vehicles are five and ten years ahead, respectively. Therefore some vehicle models for sale in 2019 will still be for sale in 2025. Most of the models launched in 2020-2021 will still be on sale in 2025, possibly with a minor mid-life update. This means that much is already known about vehicle models that will be on sale in 2025, and it is easier to assess resulting progress towards 2025 targets than for those in 2030. In 2025, according to NTP targets, only zero-emission passenger

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vehicles, vans and city buses will be sold. By 2030, all major vans will also have to be zero emissions, along with 50 % of trucks and 75 % of long-haul buses. The analysis of whether the objectives can be achieved is summarized in Table S.1. To summarise - some NTP goals are achievable whilst others are more challenging.

Table 1: Summary of the possibilities for achieving the zero emission targets for vehicles in the Norwegian National Transport Plan (NTP).

NTP target	Ability to reach target	Effort needs
Only sell zero emission passenger cars from 2025	Some areas of the passenger vehicle market are challenging, making full voluntary compliance of the target costly. Nonetheless, production costs are reducing and much innovation is happening from vehicle manufacturers. There will be a large number of new models on the market from 2020-2022, but some buyer groups have extra demanding vehicle use, others have little to gain from buying an electric vehicle and some have other major barriers. In particularly cold areas, large range reduction will suppress the market even though the vehicles have higher range. The target will be easier to achieve if long-range plug-in hybrid vehicles have a place in the strategy, e.g. that for instance 20% of the target can be such vehicles.	Good incentives are still needed, along with better charging infrastructure, to achieve this goal. Charging infrastructure in particular needs to be improved in cities where people do not have their own parking, and there must be better solutions for financing fast chargers that enable long journeys. A major challenge will be vacation periods when roads are overcrowded
Only sell small zero-emission vans from 2025	The goal may be possible with the costs and characteristics of the battery electric vans that are coming on the market now. The supply of electric vans is increasing significantly, making the range more compatible with required applications. There may be challenges in areas where less information is available about the use, and in particularly cold areas due to range reduction. The segment is cost-sensitive and need reliable, flexible transport.	This goal requires more powerful means to achieve it. The most important electric vehicle incentive, VAT exemption, has no effect in this segment. Enova support from 2019 is good. Dissemination of knowledge in the sector will be essential.
Only sell large zero-emission vans from 2030	The technology may be good enough for the goal to be achieved, but in 2019-2020, large vans are not available in the market that will allow target attainment (too short range). However, since the goal is 10 years ahead and large vans are lagging approximately five years behind small vans in terms of market development, the goal can possibly be reached if the manufacturers develop large vans with long range in good time.	This goal requires more powerful means to achieve it. The most important electric vehicle incentive, VAT exemption, has no effect in this segment. Enova support from 2019 is good. Knowledge dissemination between companies will be essential.
Only sell large zero-emission city buses from 2025	The goal may be achievable. There is good availability of battery electric buses in the market and they are tailored to local conditions according to battery size and charging capacity. 2019 costs are higher than for diesel bus operations, and there are some significant infrastructure investments, but by 2025 costs may have fallen to a level compatible with diesel buses. 5-10% more buses may be needed on busy routes due to charging needs, which can lead to increased costs compared to diesel operation. This segment may potentially be the first to be fully electrified in Norway.	Requires active use of environmental requirements in public tenders. This is decentralized to Norwegian counties. National guidelines should be considered. All buses can be replaced within approx. 10 years by tenders. Knowledge dissemination on practical operations between counties / operators is essential, e.g. in user forums.
Sell 75% zero-emission long-distance buses from 2030	The long-distance buses can theoretically be electrified, requiring large batteries and fast charging, or use of hydrogen. There is only one electric bus available in the market (short range) and none with hydrogen. For buses in fixed routes, charging or hydrogen infrastructure can be established to varying degrees of complexity. Tour buses are the most challenging. They can run anywhere and must have a basic infrastructure for filling hydrogen / recharging the batteries that covers much of Norway.	In this area, technology and product development are primarily needed. There are no suitable products on the market, and thus no basis for national planning of policies, incentives or infrastructure.
Sell 50% zero-emission trucks from 2030	Theoretically, trucks can be electrified for many applications, or use hydrogen as an alternative. The market is in an initial phase with little information available on how this will in practice work in Norwegian conditions. There were no electric or hydrogen trucks in regular sales in 2019, only some rebuilds from diesel operation. By 2020-2022, large truck manufacturers and new companies such as Tesla and Nikola will offer series-produced battery electric trucks (and a hydrogen truck from Nikola and one from Hyundai). Market price and technical characteristics are unknown. In cities and other places where trucks are used locally, battery-powered solutions can work. This is a very limited part of the truck market. Much technology and product development will take place from 2020 to 2030, and the EU's requirements for average CO_2 emissions from new trucks will lead to the industrialization of electric and hydrogen trucks. It is too early to say whether this, together with an effective policy with good incentives, can achieve the goal.	Systematic collection and dissemination of knowledge about how this works in practice for Norwegian companies, and the economy of using electric trucks, will be essential to increase the likelihood of the goal being achieved. A rights-based system to support purchasing is likely to be needed to achieve a wider and faster rollout. More research is needed on how a nationwide heavy-duty vehicle charging and hydrogen infrastructure should look, how it can be established, and how transboundary transport could take place.

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