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Zero-emission vehicles and zones in Nordic cities

Promotion, instruments and effects

Anders Roth, Jenny von Bahr, Henrik Kloo, Tomas Wisell

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Author: Anders Roth, Jenny von Bahr, Henrik Kloo, Tomas Wisell
Reviewer: Mats-Ola Larsson
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IVL Swedish Environmental Research Institute Ltd.
P.O Box 210 60, S-100 31 Stockholm, Sweden
Phone +46-(0)10-7886500 // www.ivl.se

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Summary

This study has been commissioned by the Swedish Energy Agency. It has been financed by the Nordic Council of Ministers and has been carried out under the project *Sustainable Nordic cities with a focus on climate-smart mobility*.

The foremost purpose of this study has been to provide recommendations to Nordic cities about how zero-emission vehicles can be promoted in harmony with social and environmental constraints, as well as economically sustainable mobility and accessibility considerations.

Data collection and analysis have been carried out via a review of relevant literature. In addition, interviews with representatives, researchers and experts were held in all the Nordic countries. This included visits to three key Nordic cities and a workshop with experts.

Our results indicate that the Nordic countries should avoid using tax revenue to subsidize the ownership and utilization of zero-emission cars on too large a scale or over too long a period. Policies designed to promote travel by public transport and bicycles may be adversely affected if these subsidies favour car ownership and driving becomes more economically advantageous.

Sometime during the next years, when electric vehicle introduction has reached between 70 - 90 per cent of new car sales in a Nordic country, there are good reasons to base the national vehicle taxation on kilometres driven rather than on fuel consumption. This tax can, for example, be designed to counteract congestion in cities.

Generally, to ramp up the number of zero-emission vehicles, cities should utilize their various formal and informal roles as authorities, procurers and facilitators.

The Nordic cities should be given greater legislative possibilities to reward the use of zero-emission vehicles. This legislation may include the possibility of introducing some form of environmental zone or levying traffic fees in urban areas, and also the ability to set vehicle categories in zero-emission zones that are governed by local rules. The ability to regulate the level of traffic fees, and reserve dedicated parking spaces for carpool use are important also.

Cities are advised to put together packages deploying a raft of instruments that mutually reinforce one another. As a basic package, most cities should work with improved conditions for zero-emission vehicles as charging and / or tank infrastructure, requirements for zero-emission vehicles in public procurement of vehicles and services, complementary measures that increase the supply and attractiveness of alternatives to the car, as well as measures that promote sustainable mobility and urban development independent of vehicle technology.

It is also important that improved charging capabilities for zero-emission vehicles go hand in hand with an environmentally friendly parking policy. Increased demand for zero-emission vehicle charging points will then be a good reason to review the city´s parking policy.

Under the right conditions ambitious cities can implement a more comprehensive policy package with a combination of various forms of zero emission zones or fee systems. Zones and fee systems can be designed to take conventional vehicles off the roads altogether, or at the very least make them more expensive to use. To fully implement these measures, cities must have a high proportion of zero-emission vehicles in the fleet as well as strengthening possibilities for residents to move around freely without having to own a car.

In the choice between zone and fee systems, the latter is preferred due to lower adjustment costs and a lesser impact on accessibility for large groups of road users than that inflicted by the introduction of zones.

Overall, the assessment is that cities can play an essential role in the transition to a climate-neutral transport sector. As climate goals are tightened, it will also become increasingly important that cities, countries and the EU speed up their ambitions and actions.

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1 Mission

Sweden took over the presidency of the Nordic Council of Ministers in 2018. In line with this role, the Swedish Energy Agency has implemented the "*Sustainable Nordic cities with a focus on climate smart mobility*" project. The aim of the project is to contribute to a sustainable urban development by supporting the transition to fossil free and sustainable transportation in Nordic cities and their surrounding regions.

IVL Swedish Environmental Institute has produced this report on behalf of the Swedish Energy Agency under the umbrella of this project. The most important reason to encouraging zero-emission vehicles is to reduce the climate impact of road traffic. Our task has therefore been to recommend ways of increasing the share of zero-emission vehicles in urban areas by different types of instruments and incentives. This will take place at the same time as climate-smart mobility is facilitated and reinforced. Hence, the study does not assume that all current vehicles should be replaced by zero-emission vehicles or that all transports and trips should be carried out by these. On the contrary, the starting point has been that walking, cycling and public transport needs to take market shares from both today´s car traffic and tomorrow´s electrified vehicle fleet.

The Nordics is a pioneering region in the field of electric mobility. The top-three market shares for new sales of plug-in electric vehicles are found here (Norway, Iceland and Sweden) and the region has one of the highest ratios of plug-in electric vehicles per capita in the world (IEA, 2020).

The study examines the role zero-emission vehicles (see definition in chapter 3) can play in sustainable urban development and identifies and recommends complementary instruments and measures such as increased investment in public transport, bicycle infrastructure and carpools. The purpose of the complementary measures is to promote climate-smart mobility together with increased accessibility as well as ensuring a development that is socially and economically sustainable. The study seeks to clarify the opportunities that are available and showcases good examples that will enable cities in the Nordic region to learn from and inspire one another.

Our efforts have a clear climate focus. However, we have also commented on how the introduction of zero-emission zones is a way to both increase the share of zero-emission vehicles and to improve the environment and quality of life by reducing local emissions. The study examines what this means for a city and its residents and how different forms of zero-emission zones or fee systems can be designed to promote sustainable mobility. It also explores the complementary instruments and measures required to achieve this. Finally, other issues deal with the social distributional effects of changed accessibility that different policy instruments may give rise to.

2 Method

The project consists of three main parts:

- A review of the literature
- Interviews, expert panels and city study visits
- Compilation and analysis

Our work has focused on the Nordic countries and addresses a Nordic context in which the main focus is on cities working successfully at a local level in an interaction with national policies. Experience shows that cities can implement local initiatives, but that local government and legislative assemblies need support. Examples from cities and the recommendations for countries have therefore been related to the national level.

A survey was carried out that provides an overview of the Nordic cities in terms of current policy instruments and incentives for increasing the overall number of zero-emission vehicles. Some examples from other European cities were also examined to find state-of-the-art examples. A study of the literature was conducted to unearth relevant research and facts. This was made to evaluate current knowledge about existing and, in some cases, possible future policy instruments.

Within the project, 15 in-depth interviews were conducted with representatives from cities and municipalities, research institutions and private organisations, these included representatives from all of the five Nordic countries. The interview questions focused on the main issues addressed by the project and were tailored to fit different actors depending on their roles. The interviews mainly addressed the following issues:

- The definition of a zero-emission vehicle
- Various environmental zones and their effects
- Opinions as to the efficacy of various instruments such as vehicle taxes, fuel taxes, subsidies, traffic regulations, public procurement etc.
- Implemented measures
- Organization of work with zero-emission vehicles
- Barriers to implementing measures
- Parking and charging of vehicles
- Collaboration between actors and levels in society
- Views as to the “best” instruments and key actors
- How to design sustainable instruments (especially zones)
- Other issues (own work, success factors, vehicle issues etc.)

Three city study visits were also carried out during the project. Meetings were held with representatives of cities and municipalities working on relevant issues. During these visits, questions similar to those posed in the above-mentioned interviews were asked. A few site visits also took place. The following Nordic cities were visited:

- Uppsala, Kommunledningskontoret Ekologisk hållbarhet (Municipality Executive office- Ecological sustainability), Sweden
- Aarhus, Teknik og Miljø (Technology and environment), Denmark
- Oslo, Bymiljøetaten (Agency for Urban Environment), Norway

Within the framework of the project, a panel of experts, project associates and officials from Swedish authorities were invited to attend a workshop. Participants shared their views on the instruments that were identified for the promotion of zero-emission vehicles, and these were based on different evaluation categories (environmental aspects, sustainable mobility, socio-economic and distributional effects).

Evaluation aspects

The project has analysed the varying environmental aspects of measures deployed to increase the share of zero-emission vehicles. As mentioned in chapter 2, the foremost reason for promoting zero-emission vehicles is to reduce the climate impact of road traffic. But there may also be significant effects on air quality and noise pollution. These and other relevant aspects have been included in the analyses.

The effects of different policy measures regarding socio-economy, distributional effects, accessibility and effects on local transports have also to some extent been evaluated. These analyses have been based on reviews of the literature and input from interviewees and experts. However, few relevant studies of socio-economy and distributional effects of various measures have been carried out.

Synthesis

Experiences emerging during work with the literature, interviews and analyses of various policy instruments have been summarized in brief surveys. Subsequently, a number of recommendations have been made for medium-sized and large cities in the Nordic region, based on the effects that can be expected if various measures are introduced locally. These recommendations underscore the fact that this can be done with the specific aim of ramping up the use of zero-emission vehicles at local levels. A number of possible policy packages enumerate the ways in which different measures can be combined for greater effect and to reduce unwanted side effects. The policy packages should be seen as examples of how different measures can be combined to reinforce one another and which measures have the most impact in a city of typical Nordic size. Recommendations are also given as to how cities should act based on local conditions. The recommendations are underpinned by knowledge garnered on how measures can interact in synergy and how different categories of residents, travellers and organizations may be affected.

3 Defining zero-emission vehicles

The definition of zero-emission vehicles varies between the Nordic countries. The term is used in different contexts and largely depends on the purpose for which it is used. This report does not take a position on the most suitable definition. This should always be determined by local conditions; it is also desirable that cities have the same definition in each country. The report assumes that zero-emission vehicles are primarily those that can be driven without contributing to exhaust emissions, i.e. battery electric vehicles, fuel cell electric vehicles and plug-in hybrid electric vehicles. There are also examples of Nordic countries and cities that include certain vehicles powered by renewable fuels as zero-emission vehicles.

A zero-emission vehicle may also be an electric bicycle or an electric scooter. However, the definition here is based on motor vehicles, as the measures studied focus on increasing the proportion of these vehicles. Measures that reward cycling are instead addressed through descriptions of complementary measures for the promotion of sustainable mobility in general.

In all the Nordic countries and cities studied, fully electric vehicles are considered zero-emission vehicles. This is regardless of whether they are powered by batteries or hydrogen fuel cells, and independent of how the energy carriers are produced. Here, the definition is determined by the fact that vehicles powered by hydrogen are electric driven and lack combustion engine.

Buses and trucks using plug-in hybrid technology are often regarded as zero-emission vehicles as these can travel a predetermined distance on a fixed loop without deploying the internal combustion engine. They are considered to operate emission-free in urban areas and municipalities also could have the possibility to develop systems to secure a high share of electrified propulsion. On the other hand, passenger cars utilising plug-in hybrid technology have a limited electric drive range and driving patterns usually determine when the car runs on electricity. As an option, the electric drive both can be selected as well as turned off by the user when traversing a built-up area. With current technology, this means that municipalities are unable to regulate the areas in which passenger cars using plug-in hybrid technology are exclusively powered by electricity. In a municipal perspective these vehicles cannot therefore be regarded as zero-emission.

As emissions from vehicles engines decrease, emissions of wear particles from tires and road surfaces will assume greater importance. The health and socio-economic aspect impact of these emissions has been re-evaluated in recent years (Trafikverket, 2020). It is therefore possible that future definitions of zero-emission vehicles will also include wear particles in the assessment.

Many Nordic cities have launched local initiatives to reduce the climate impact of traffic. This may, for example, be a matter of encouraging liquid fuel vehicles to use fuels with low climate impact, such as biogas, ethanol or renewable diesel. When it comes to climate impact, vehicles using this type of technology can also be regarded as zero-emission vehicles (provided that production only gives rise to low levels of greenhouse gases, something which is actually being done in some municipalities). This should be regarded as a reciprocal system of vehicles, fuel and climate impact in a life cycle perspective that

can be designated as a zero-emission solution. In many municipalities biogas occupies a special position as biofuel, as it is considered to have a particularly low climate impact and can be produced locally.

A certain perspective may be relevant for the countries that are part of the EU and also for Norway and Iceland. These countries are governed by the emissions trading system. This means that increased demand for electricity in a marginal perspective will not have an excessive climate impact because emissions trading sets a maximum allowable emission level that is gradually being reduced.

In the Nordic countries, there are also special tax levels and subsidies to stimulate the use of vehicles without local emissions or those that use renewable fuels. The special rules for these types of vehicles and fuels can also be seen as a form of definition of zero-emission vehicles.

With regard to international definitions, the EU definition of zero-emission vehicles in the Clean Vehicles Directive is of interest. The extended rules mandated in Clean Vehicle Directive II enter into force in 2021 (EU Clean vehicle directive, 2019). The requirements state that Member States must set certain environmental requirements for the public procurement of vehicles, public transport and certain transport services. This means that a certain percentage of the procurement must be zero-emission vehicles. The directive is to be adopted as law in member states. The directive defines zero-emission vehicles as follows:

- Passenger cars may emit a maximum of 50 grams carbon dioxide per kilometre and must comply with certain requirements regarding nitrogen oxides and particles. In 2026, these requirements will be tightened, and vehicles may no longer emit emissions of any kind. This implies they must be electrically powered.
- Heavy vehicles must be powered by hydrogen, battery electric operation including plug-in hybrids, methane, biofuels, synthetic diesel or liquified petroleum gas (LPG). A special group are designated as zero-emission vehicles, i.e., fuel cell vehicles and fully electric vehicles.

Appendix 1-9 describes more in detail how the concept of zero-emission vehicles is applied in the various Nordic countries.

4 Currently deployed instruments in the Nordic countries and cities

This chapter describes instruments and measures with a focus on what countries and cities in the Nordic region are doing to increase the introduction rate of zero-emission vehicles. The term *city* refers both to geographical area but also to the municipal administrative level when it is a question of legislation and the disposal of various measures.

European vehicle regulations

The Nordic countries and cities that are part of the EU must follow the rules and decisions made by this organization. The single most important measure to accelerate the introduction of zero-emission vehicles is probably the EU legislation regarding carbon dioxide emissions from new cars (European Commission, 2020). From 2020 to 2021, these requirements imply that new cars sold by a vehicle manufacturer must on average emit less than 95 grams of carbon dioxide per km. The threshold limit value is related to the weight of the car and in addition bonuses (super credits) are given for vehicles whose carbon dioxide emissions are less than 50 grams of carbon dioxide per km, i.e., for plug in electric vehicles and fuel cell vehicles. In 2025, car manufacturers are required to ensure that carbon dioxide emissions from new cars are 5 per cent below the 2021 level and by 2030, emissions from that year's crop of new sold cars should be 37,5 per cent lower. The regulations are a strong incentive to encourage the sale of electric vehicles and plug-in hybrids across Europe. Targets have also been set for heavy vehicles (European Commission, 2020).

Policy instruments at national level

At the national level, it is mainly by addressing various taxes that it is possible to influence new car sales. Table 1 below shows the most important national measures deployed in the Nordic countries. Several of the measures are aimed at making it cheaper to buy a zero-emission vehicle, such as introducing grants to purchase of certain vehicle types, eliminating or reducing registration tax or reducing or removing VAT. In recent years, subsidies have also been introduced in some countries to stimulate the purchase of buses and trucks. Incentives targeting heavy trucks are particularly important because the introduction of this type of zero-emission vehicles is slower than that of passenger cars and buses (see also Chapter 8).

Other national measures aim to reduce the cost of owning and driving zero-emission vehicles. Here the most common instrument among the Nordic countries is to reduce the annual vehicle tax or impose dissimilar tax levels on different vehicle types. Several countries also have implemented support systems designed to promote investment in the charging infrastructure. A more detailed description of national vehicle taxes can be found in Appendix 4.

Measure	Nordic country
Reduced annual vehicle tax for zero-emission vehicles	Denmark, Finland, Iceland, Norway, Sweden
Carbon dioxide differentiated annual vehicle tax	Iceland, Sweden
Purchase bonus/subsidy for zero-emission vehicles and low-emission vehicles	Finland, Sweden
Registration tax exemption	Iceland, Norway
Registration tax reduction	Finland
VAT exemption	Iceland, Norway
Reduced company car tax for zero-emission vehicles and low-emission vehicles	Norway, Sweden
Preferential treatment of zero-emission vehicles for taxi licenses	Denmark
Reduced ferry fees	Norway
Support schemes/ public support for charging stations	Norway, Finland, Iceland, Sweden
Electric bus grants	Norway
Electric truck grants	Norway, Sweden

Table 1: Policy measures at national level in the Nordic countries by 2020

In addition to influencing the sale of vehicles with tax rules, the national level can reward the sale and use of zero-emission vehicles by giving municipalities the legal right to implement various local measures, such as the introduction of environmental zones or environmental tolls.

The instruments in Table 1 all focus on subsidizing the purchase and use of motorized zero-emission vehicles. Such measures are important components in national strategies to accelerate the introduction of zero-emission vehicles. However, when it comes to national transport policies a broader focus on sustainability is needed, rather than a narrow focus on the sale of motorized vehicles only. Taxes and support measures should be designed in ways that also stimulate a high proportion of sustainable means of travel and transport. An example of this is the Swedish electric bicycle subsidy (see example below). This type of grant does not have the same side-effects as ownership subsidies of zero-emission cars and have been shown to reduce car driving (Fyhri A, 2020). Measures that contribute to ramping up ownership or use of passenger cars tend to contribute to increased congestion and may compete with public transport services as well as biking and walking.

Example: The e-bike subsidy in Sweden

Between September 2017 and September 2018, the Swedish government ran a subsidy scheme (known as the e-bike subsidy, but which also included other light electric vehicles) to support the purchase of electric bicycles, mopeds, motorcycles and outboard engines. The purpose of the subsidy was to facilitate a climate-friendly transport alternative and to contribute to increased accessibility and public health. Private individuals were able to receive compensation for 25 per cent of the purchase price up to SEK 10,000. In total, approximately 90,000 people utilized the subsidy to buy an electric bicycle. (Naturvårdsverket, 2019)

An evaluation carried out by the Swedish Environmental Protection Agency, showed that use of e-bikes among those who benefited from the subsidy replaced about half of the trips that would otherwise have been made by car. The data was largely relying on actual observations but is still considered to give an indication that support for the introduction of e-bikes has shown the potential to take market shares from cars, and not just generate new bicycle journeys or siphon off journeys from public transport. Even a transition from public transport to biking can often be seen as positive from an environmental point of view because it frees up public transport capacity that may attract new users. The study does not answer the question of whether the subsidy affected the sale of electric bikes or whether it just brought forward purchases that would have taken place anyway (Naturvårdsverket, 2019).

Policy instruments at city level

Table 2 below shows a number of local measures in place in the Nordic cities. The most common of these are the provision of charging infrastructure on public land in urban areas and procurement demands for municipal vehicle fleet and procurement requirements for municipal vehicles. On the other hand, few cities are currently able or willing to establish zero-emission zones or introduce a traffic fee system that would lead to an increased number of zero-emission vehicles on the roads. In Sweden, legislation to make zero-emission zone measures possible for municipalities has been put in place, but no Swedish city has yet decided on an introduction. When it comes to the imposition of traffic fees, only Norway has a legislation that allows cities to differentiate and reward zero-emission vehicles.

Some Norwegian cities allow passenger cars that meet zero emission criteria access to bus lanes. However, it is uncertain whether cities in the rest of the Nordic region will be permitted to follow Norway's example.

Linking taxi licensing to zero-emission vehicles is a measure that may be subject to both national and local regulations.

A more detailed description of local measures can be found in Appendix 1-3 and 5-9.

Example: taxi incentives in Nordic countries

The City of Oslo has launched an initiative that proposes that only zero emission-vehicles (battery electric or hydrogen powered) be granted taxi licenses in the future. This to take effect by 2022. This has been made possible through national legislation that permits cities to impose these kind of environmental requirements (Portvik, 2019).

Denmark has proposed national legislation stipulating that only zero-emission vehicles will be granted new taxi licenses. This to be in force by 2025. The most significant short-term measure is that 300 out of a total of 500 new taxi licenses awarded nationally in 2019 and 2020 were set aside for zero-emission vehicles. Zero-emission taxis will also be given priority at public transport ranks. (Eltis, 2019) (Taxi intelligence, 2019).

The Swedish initiative "Nollzon" (zero zone) has focused on taxi companies operating in large cities. The companies using taxi services cooperating with Nollzon want to increase the demand for electric taxis by allowing employees to automatically prioritize electric vehicles when ordering a taxi. Nollzon includes only battery electric or hydrogen vehicles. In 2019, 1228 companies were associated to the project. (Nollzon, 2019)

The temporary pollution emergency ban is only applicable in two Norwegian cities. It has been included here as an example, despite the fact that its stated purpose is to alleviate high nitrogen dioxide levels by banning the use of high emission diesel vehicles on days when unfavourable local conditions are peaking. The reason for this is that the effect of this measure was not only that diesel cars became less attractive. Also, sales of zero-emission vehicles increased.

Measure	Vehicle types*	Denmark	Finland	Iceland	Norway	Sweden
Zero-emission zone	PC, LCV, HGV, bus	Not legal	Not legal	Not legal	Not legal	Legal framework but not implemented
Environmentally differentiated traffic fees (road tolls or congestion charges)	PC, HGV, Bus	Not legal	Not legal	Not legal	Seven cities	Not legal
Reduced parking fees for zero-emission vehicles	PC	København	Helsinki	Reykjavík	Oslo, others	Not legal
Access to bus-lane for zero-emission vehicles	PC	–	–	–	Oslo, others	Not legal
Provision of public charging infrastructure	PC	Most larger cities	Most larger cities	Most larger cities	Most larger cities	Most larger cities
Procurement for municipal fleet of zero-emission vehicles	PC, LCV, (HGV), bus	København, others	Helsinki	–	Oslo, Trondheim, others	Stockholm, Göteborg, others
Dedicated parking spots for zero-emission vehicles	PC	København	–	–	–	–
Taxi license – zero-emission vehicle-demand	PC	København (partly)	–	–	Oslo (2020-)	–
Pollution emergency, temporary bans or diesel bans	PC, LCV HGV	–	–	–	Oslo, Bergen	–

Table 2: Policy measures at municipal or city level in the Nordic countries.
** PC = passenger car, LCV = light commercial vehicle, HGV = heavy goods vehicle, – = Unclear legal status or not implemented.*

Traffic fees in form of road tolls have now been implemented in seven Norwegian cities and in Sweden congestion charges have been implemented in two cities (Fjellinjen AS, 2020), (Ferde AS, 2020), (Vegfinans AS, 2020) (Transportstyrelsen, 2020). In Norway, some cities have differentiated road tolls based on the vehicle emission class, and all cities have designated zero-emission vehicles as a separate category with a reduced or waived fee. The Norwegian Parliament has also decided that road toll projects must reduce charges by at least 50 per cent for zero-emissions vehicles.

Figure 1 below shows whether zero-emission vehicles have reduced or abolished fees. In Bergen, dissimilar zero-emission vehicles are treated differently. Hydrogen-powered vehicles pay no fee, while battery electric vehicles pay a small fee. When it comes to plug-

in hybrid electric vehicles, on the other hand, the fee is almost at the same level as for a conventional car (Ferde AS, 2020).

Figure 1: Traffic fees (road tolls and congestion charging) systems in the Nordic cities by 2020

5 Experiences gained from current policy instruments in Nordic cities

The project has gathered facts and experiences about different policy instruments used in the Nordic countries today, their effects and how they might contribute to the introduction of zero-emission vehicles. The results of literature searches, interviews, study visits and reference groups are set forth in Appendix 1-9. This chapter summarizes some of the experiences learned when implementing different policy instruments and which are described in the appendix.

The conclusions and recommendations presented in Chapter 6-8 are based, among other things, on experiences around the effect of various policy instruments presented in Appendix 1-9 and summarized below.

Heavy vehicle emission zones

Low emission zones are used in various Nordic cities to exclude older vehicles and thus improve air quality. The low emission zones in the Nordic region target heavy vehicles exclusively (see Appendix 1 and 3). Elsewhere in Europe some cities also exclude certain types of passenger cars (Urban Access Regulations in Europe, 2019).

However, at present there are no heavy vehicle zones in the Nordic region that only grant access to zero-emission vehicles. In Sweden, municipalities have since January 2020 been able to introduce zero-emission zones for both light and heavy vehicles (Government, 2018), but no municipality has yet done so.

Assessments of the efficacy of low emission zones for heavy vehicles in Göteborg, Sweden show that these zones have been effective in influencing the choice of vehicles among local commercial actors who purchase heavy vehicles (Göteborg stad, 2004). Vehicle owners who utilize these zones will adapt to local rules and replace vehicles if this is needed to be able to continue operating. If individual vehicle owners incur increased costs as a result of regulations in force, these costs will ultimately be paid by the transport buyers. Operations essentially continue on as before, and intra-city transports are not significantly impacted. From a socio-economic perspective, a possible elevation of transport costs can be justified if sufficiently large societal benefits are delivered, i.e. reduced health and environmental impact (Stockholm Stad, 2018).

Literature reviews undertaken by the project did not reveal any studies from a Nordic perspective on possible effects from zones where only zero-emission vehicles are allowed. This means that there are no research findings or assessments to build on. In the absence of relevant studies, cautious conclusions could instead be drawn from experiences gained from low-emission zones. It can be assumed that these largely hold true for zero-emission zones as well. A zero-emission zone targeting heavy vehicles might function in much the same way as a low-emission zone, provided that there is adequate forward planning and enough approved vehicles suitable for the activities at hand on the market when the zone is introduced, and enough public charging stations (and filling stations for biogas if this fuel is also approved). Users of heavy commercial vehicles will then adapt their vehicle

park to local regulations and pretty much continue operations as usual, provided that the demand for deliveries of goods and transport within the zone is unchanged.

Passenger car emission zones

At present, there is only one single low-emission zone for passenger cars existing in the Nordic region. It covers one street, Hornsgatan, in central Stockholm, Sweden and restricts access for light vehicles that do not fulfil Euro 5 (Stockholms Stad, 2020). In addition, studded tyres are not allowed at that street.

There are no zero-emission zones for passenger cars in the Nordic region at present. As mentioned above, Swedish municipalities have the right to introduce zero-emission zones that include passenger cars, but no municipality has yet done so.

With the exception of this one street in Stockholm, low-emission zones in Sweden only target commercial traffic, public transport and the like with heavy vehicles, carried out by professional actors. This type of regulation has no significant effect on vehicle driving patterns or accessibility to the zone for these categories of road users. In contrast, a low-emission zone that discriminates high-emitting passenger cars will curtail the ability of private individuals to access the area with their own vehicles. A zone that excludes old cars risks affecting low-income earners disproportionally more than high-income earners, who on average own newer cars and are also more capable of replacing these if necessary (WSP, 2010). The extent to which low-income car mobility might be affected by a low-emission zone, however, depends on the location of the proposed zone. Since there are no zones targeting passenger cars in the Nordic region (except the one street zone in Stockholm that can be detoured by most drivers), no conclusions can be drawn from any real cases in a Nordic context.

In Gothenburg, Sweden, the possible effects of a low emission zone for passenger cars in central parts of the city was investigated in a theoretical study. The projected zone was designed to exclude 15-20-year-old passenger cars in an attempt to reduce the levels of nitrogen oxides (Göteborg stad, 2004). The study indicated that with the designed zone, only a small proportion of low-income car owners living in the municipality would be affected. Most people with low income reside in the suburbs and rarely use a car to travel into the centre. A large proportion of their trips are made by public transport. However, the small proportion who need to drive to the city centre would be strongly impacted because they are less able buy new vehicles due to financial constraints. The effect of such a zone depends on where it is introduced, the type of activities carried out in it, age requirements for the cars involved and the socio-economic conditions prevailing in the municipality. The extent to which different socio-economic groups are affected also depends on the availability of alternative modes of travel such as public transport, walking, cycling, car rental, carpools and more. A newer study in Gothenburg, Sweden have shown that it is difficult to assess the effects of an environmental zone on travels and vehicle ownership (Göteborgs stad, 2020).

Due to a lack of sufficient data, the effects of introducing a local zero-emission zone for passenger cars are difficult to gauge. Theoretically the impact on accessibility in different income groups could be similar to those described in theoretical studies on low-emission

zones above. The socio-economic effects can be limited if a local zone is introduced on a small scale, with adequate forward planning, at a time when there is a sufficiently large supply of used cars in different classes that makes it possible for low-income earners to switch to an approved model. However, the effect of zones that exclude certain types passenger cars are assumed to be significant if they are big enough to affect a large number of people, and especially if limited accessibility by car not mitigated by other modes of transport. Therefore, the effect on mobility of a zero-emission zone for passenger cars is determined not only by the extent of the zone, but also by the standard of public transport and the possibility of introducing complementary measures as described in Chapter 7. A zero-emission zone impairs accessibility for households whose current means of transport is dependent on vehicles that will be prohibited, and who have not prioritized or can afford a switch to a zero-emission alternative. For non-car owners, however, there are mainly benefits since they can take advantage of, where appropriate, enhanced public transport and other complementary measures.

Monitoring compliance with the zoning regulations is important. Compliance in environmental zones is often carried out by the police. To facilitate this, cities may be able to deploy, among others, parking attendants to help with monitoring. In Sweden the Swedish Transport Agency has submitted a proposal along these lines to the government (Elo K, 2019).

Exemptions from zero-emission zone rules should primarily be based on national exemptions in order to avoid an excessive flora of local variants. Local variants can confuse users and generate extra work for cities. In this respect, Sweden has introduced general exemption categories that apply to vehicles whose drivers or passengers hold a parking permit for the disabled and for vehicles specially adapted for a disabled owner with societal financial support.

A more thorough review about environmental zones is found in Appendix 1.

Traffic fees

To date, two Nordic countries have implemented one or other form of traffic fees. Seven Norwegian cities have implemented road tolls, and two Swedish cities congestion charges (see Appendix 2 and 3). Both road tolls and congestion charges are systems where those who use a road under a certain period of time pay a fee. The fundamental difference between the systems is that road tolls are primarily intended to be used to finance the development of new roads or bridges, while congestion charges are primarily intended to control traffic flows and reduce congestion.

In Norway, however, several cities have started to design their road tolls to control traffic flows as well. In order to influence vehicle choice, tolls have also been environmentally differentiated so that zero-emission vehicles are exempt or charged a reduced fee (Bruvoll, 2020).

The Swedish congestion taxes serve a dual purpose. They were introduced partly to reduce congestion and emissions but were also intended to bolster investment in new roads and railways. As taxes, they are decided and controlled by the Swedish parliament. During the first years of congestion charges in Stockholm, zero-emission vehicles were

exempted to simultaneously stimulate the purchase of these vehicles. After a couple of years this discount was gradually phased out, and since 2012, zero-emission vehicles pay the same amount as other vehicles. However, there are some exceptions for buses, emergency vehicles, etc (Transportstyrelsen, 2020).

In Gothenburg, a congestion tax has been in use since 2013. There has not been any exemptions or reduced fees for zero-emission vehicles in Gothenburg.

Experiences and evaluations of road tolls in Norway and congestion charges in Sweden show that road fees can be powerful local tools that can be used not only to control traffic in certain streets or areas, limit traffic flows in a city or region, increase travel by public transport but also to stimulate an increased use of zero-emission vehicles (Trafikverket, 2016 b). The effect achieved depends on how the fees are designed and the types of vehicles that are subjected to fees.

When zero-emission passenger cars were exempted from congestion charges in Stockholm, the sales of zero-emission vehicles increased significantly (mostly vehicles driven by ethanol). But as an increasing proportion of cars were exempted, the traffic control effect was adversely impacted. This was the reason why the exemption was removed a few years down the line (Mannberg A, 2014). A government inquiry in Sweden, however, suggested that it might be possible to lower congestion charges for heavy zero-emission vehicles, since driving patterns of these vehicles are not affected by fees in the same way (SOU 2013:84, 2013). Here, lowering charges could accelerate a transition to zero-emission heavy vehicles without significantly impairing the traffic-controlling effect (Kågeson, 2019).

In Norway, too, discounts and exemptions for zero-emission passenger cars would appear to impair any traffic control effect or financing benefit, which were the foremost reasons for the introduction of road tolls in the first place. This is one reason why the city of Oslo has in recent years reduced discounts for zero-emission vehicles.

The socio-economic effects of introducing local road fees on car travel have been studied in Sweden (Eliasson, 2016), (Trafikverket, 2017). According to some studies, the effect depends on which road user groups pay the most and how the income derived from this source is used. Most of the fees are generally paid by people in the middle incomes and higher income brackets because these more often own cars and use them more than low-income earners. If revenues from road tolls are mainly used to invest in public transport, this means that resources are redistributed to people with lower incomes, as these travel more by public transport. If the revenue is instead used to strengthen the road network, the distribution profile will be different. Other aspects that affect the socio-economic effect of road tolls are the proportion of low-income earners who drive on toll roads and how high the tolls are.

The fee level can be set according to local air pollution levels and can be levied throughout the day to provide the greatest effect. In a fee system entirely based on exhaust emissions, the charge for zero-emission vehicles will be zero. But there may be reasons to also take into account congestion or other local factors as particulates from road wear that may result in the fee not being zero, but still lower for zero-emission vehicles than for vehicles with internal combustion engines.

Read more about traffic fees in Appendix 2.

Fees versus zones

Traffic fees are examples of powerful policy instruments that can be implemented to stimulate use of zero-emission vehicles locally. It is interesting to compare fee systems with zero-emission zones, another policy instrument that can be utilized for the same purpose. The big difference is that zones are mandatory. In a zone it is forbidden to use certain vehicles. In a fee-based system, it is still possible to use any type of vehicle, even if some users are forced to pay more. Fee-based systems are more flexible and still grant accessibility by car to all. This is most important for low-income earners who are less able to upgrade their vehicles and instead must pay more (Eliasson, 2016). For motorists who do not use the area on a daily basis this system is more flexible, and accessibility is not affected to the same extent as by a zone. However, the pace of introduction of zero-emission vehicles will be lower if all types of vehicles are permitted. The differences between the systems depend on how high fees are set and the way in which the systems are designed.

Parking benefits and access to bus lanes

Other local policy measures in Nordic cities seek to provide parking benefits for zero-emission vehicles or grant access to bus lanes. Several cities have offered free or subsidized charging of electric vehicles. Experience from these types of measures shows that they can be used to accelerate the introduction of zero-emission vehicles by making it more attractive to own and use them. Lower costs for parking and charging make it cheaper to own your own car. Being able to drive in bus lanes allows faster access when roads are choked, for example in the approaches to cities.

If costs for residential parking are reduced, this will lead to reduced car overheads, which will encourage car ownership. If the cost of parking at workplaces is reduced, this primarily impacts the choice of transport mode so that car travels are favoured at the expense of public transport and bicycles. A Norwegian study that unpack the relationship between the cost of parking and the choice of means of transport have shown that the proportion of travellers who choose to commute to work by car may vary from less than 20 per cent when it is difficult and expensive to park, to over 60 per cent when parking is cheap and available (Christiansen P. et al, 2015). Zero-emission vehicles can also be charged less at visitor parking in the central parts of cities. This favour the selection of these vehicles.

So, there is a risk that this type of policy instruments not only increases the share of zero-emission vehicles in a city, but also makes driving a car more attractive and thus reduces the number of people who travel by public transport, bike and move around on foot in cities (Hamilton C J och Thörn H B, 2013). It can create more congestion, intensify environmental impacts and require higher investments in road infrastructure, parking spaces, etc. If passenger cars are allowed access to bus lanes, there is also a risk that public transport will be adversely affected by cars taking up space or creating congestion. There may also be an increased risk of accidents at bus stops. This type of policy instrument can

therefore be considered suitable in an initial stage when strong incentives are needed to stimulate the purchase of certain vehicles.

Read more about access to bus lanes in Appendix 5 and about parking benefits in Appendix 6.

Expanded charging infrastructure

Public charging infrastructure is primarily developed by commercial actors. However, experience from the Nordic cities shows that municipalities can still play an important role by collaborating with electricity network companies and charging infrastructure suppliers to facilitate decision-making processes or by providing suitable space on municipal land. For example, the power supply must be able to cope with a changed charging infrastructure for the entire bus depot. A dialogue is also essential to facilitate building permit processes. Proactive measures taken at this juncture lessen the risk of bottlenecks.

Municipalities also have an important role as owners of municipal housing and offices. The need for charging facilities where residents park their cars will only increase over the next few decades. The ability to charge at home where the car is parked is the most important single measure to encourage residents to purchase electric cars or plug-in hybrids. It is important that the municipalities expand the charging infrastructure in such buildings. The pace of expansion should follow developments in the market.

Charging stations for passenger cars increase the likelihood that consumers will acquire an electric car – in the first place if they are located close to places where people live and in the second in close proximity to their workplaces. Fast charging points for passenger cars should instead be established alongside roads with high traffic flows and good accessibility, in the same way petrol stations are distributed. Cities should be careful about providing space for charging on public land that may be needed for other purposes.

Municipal procurement

Municipalities as well as regional actors have an important role to play in ramping up the use of zero-emission vehicles via procurement of transport services. The most common agreement areas in which public procurement can be important for the acquisition of zero-emission vehicles are public transport, waste transport, transport services and certain goods deliveries. Additional measures deployed by municipalities can be the selection of zero-emission vehicles for the municipal fleet and participation in various pilot projects and testbeds. In cases where public transport services are controlled by regional authorities, there has to be a cooperation between the municipalities and the regional level.

Requiring suppliers to commit to using zero-emission vehicles in public procurement can intensify the spread of such vehicles in the city, even if the scope of the measure is naturally limited to city and contracted vehicles. The measure can be directed at the vehicles that the city buys in or leases for its own operations, and the suppliers of certain services can be required to use zero-emission vehicles when carrying out contract work

for the city, for example, waste collection or travel services. These requirements must be tailored to fit the service being procured. In the first instance, it is feasible to insist on these in connection with certain transport services. Procurement requirements will also need to comply with the EU Clean Vehicle Directive as soon as this has been adopted nationally (EU Clean vehicle directive, 2019).

In the early stages of electrification, procurement requirements can play a major role in contributing to a growing market for certain company cars, light and heavy trucks as well as buses. Contract work and construction engines are also an important category and have considerable potential for electrification. As the degree of electrification increases on the passenger car side, it becomes more important for municipalities to concentrate on sectors where market forces are still weak, such as heavy trucks and construction engines. Of course, procurement requirements can still be levelled at the passenger car segment together with a stronger focus on trucks and working machinery.

In order to increase the proportion of zero-emission vehicles, procurement specifications must clearly stipulate the requirements which vehicle must meet to comply with an established definition. If the city wishes to encourage the use of electric vehicles and plug-in hybrids, it is seldom sufficient to require the use of fossil-free vehicles or transport services. The fossil free requirement can seemingly be fulfilled by simply using climate-efficient fuels such as biogas, ethanol, FAME or HVO. However, if the city just wants to prioritize the climate aspects in the procurement, this type of solution may be adequate. It may also be necessary to require that electric vehicles are charged with climate-neutral electricity and to specify how such a requirement can be met and followed up on.

Complementary measures as public transport and parking policy

If a city introduces a zero-emission zone or differentiated road tolls or fees, complementary measures are needed to maintain good accessibility for all travel modes. Complementary measures are those that make it easier for residents and those working in these areas to choose alternative travel modes to avoid zone restrictions or charges. The most important complementary measures are to strengthen public transport, cycling and walking.

The measures primarily apply to those groups that today rely on cars that do not fulfil environmental requirements and who cannot afford or are not contemplating the purchase of a zero-emission vehicle. Some belonging to this group will be reached by the complementary measures and may increasingly take to using public transport and bikes. To the extent that these means of transport take longer time compared with a car journey, this group will suffer travel time losses. For various reasons others in this group will be unable to take advantage of the complementary measures and will find their mobility curtailed. This group consists, for example, of households outside the city centre, people who have difficulty cycling or walking to public transport stops or accessing car sharing services (Göteborg stad, 2004).

Measures designed to mitigate the effect of restrictions, as public transport and bicycle, do not only encourages travel with these modes. They can also indirectly have other positive

effects, such as better access to public spaces, reduced congestion, better public health outcomes and a reduced consumption of fuel and materials for road vehicles.

In major cities, a smaller proportion of all car journeys probably originate in socio-economically weak outer areas. If such a city locates a zero-emission zone in a central part of the urban conurbation it affects those residents to a lesser extent as these groups are less motorized and usually use public transport to travel to the city centre (Göteborg stad, 2004). However, a high proportion of car journeys from peripheral areas may be affected by any restriction, as those living in these areas are often have older cars for economic reasons. Those living and active in the central parts are likely to be impacted to a much greater extent. Districts primarily affected by a centrally located zero-emission zone, and areas with many vehicles that would be forbidden access to this zone, should therefore be compensated by the creation of an adequate public transport system.

The management, access to and pricing of parking is one of the most important local instruments to control car traffic flows that a city has at its disposal. Hence it is vital that the city policy is designed to encourage sustainable travel, to enable the shared use of parking facilities, to ensure that visitor and commercial parking in central areas is prioritized over workplace parking, that street parking is not subsidized to the detriment of parking garages, that flexible parking capacity stimulated by carpools is made possible and that costs are decoupled from the rent of apartments and workplaces (Hult, Larsson, Roth, & Envall, 2019).

Read more about public supported charging infrastructure in Appendix 7, public procurement in Appendix 8 and other measures in Appendix 9.

6 Recommendations to the national level

The following recommendations in this chapter are based on findings in this study and are addressed to national parliaments and governments. They aim at possibilities at the national level that can facilitate and strengthen contributions at a local and municipal level.

The Nordic countries are recommended to only use tax revenues to promote zero-emission vehicles (ownership) in an introduction phase. It could be appropriate when the number of zero-emission vehicles are low and need support. But as the share of zero-emission cars grows, measures and instruments aimed at achieving a high share of travel by public transport, walking and bicycling in cities can be hampered, if these subsidies make car ownership and driving more economically advantageous. On the other hand, compensating, for example, a higher purchase price for zero-emission vehicles may be crucial during an introductory period. A recent research study has shown that stimuli in the form of bonus-malus systems are important for the continued growth of the zero-emission vehicle stock in Sweden (Hennlock M, 2019). The bonus-malus principle implies that subsidies for zero-emission vehicles are not borne by the tax collective but by buyers and owners of cars with higher climate impact. It is likely that similar conditions apply in Finland and Denmark, in which countries there are fewer zero-emission cars on the roads than there are in Sweden at present.

Sometime during the coming years, when electric car introduction has reached approximately 70 – 90 per cent of new car sales in a Nordic country, there are good reasons to base the national vehicle taxation on kilometres driven rather than on fuel consumption. For Norway, with almost a 60 per cent plug-in electric vehicle share of new car sale (see Chapter 8, table 4), the issue is highly relevant already today. Such a model will become increasingly relevant if the social costs of car traffic factored in years to come as tax revenues from the sale of fuel start to fall off as the proportion of electric cars in use increases. Taxes based on mileage and geography are more likely to take into account distributional policy effects, as levels can be varied based on environmental performance and where the car is used. This tax can, for example, be designed to counteract congestion in cities (Hennlock M, 2020).

Example: byveksavtal (urban growth agreements) in Norway

One example of a policy package is the Norwegian "byveksavtal", which is a system of combined city, regional and national level of agreements. A similar construct is also in place in Sweden where is called "stadsmiljöavtal", although the Norwegian agreements are more far-reaching. The agreement is signed between the state and the region or municipality. The state supports the financing of investments in major public transport systems, bicycle infrastructure etc., in return for local measures that increase sustainable mobility and possibly put a cap on car traffic. One goal of the Norwegian agreements is to halt the increase of car traffic in absolute terms (zero growth target). (Government of Norway, 2020)

The Nordic countries are also recommended to ensure that cities have legislative possibilities to reward the sale and use of zero-emission vehicles. This may include the possibility to introduce some form of environmental zone or levy charges in urban areas, deciding which vehicle categories should be covered by local rules in a zero-emission zone or being able to influence the level of traffic fees, and reserving dedicated parking

spaces for carpool cars. Today, regulations vary and not all municipalities are able to implement these types of measures across the entire Nordic area (see Chapter 4, Table 2).

7 Recommendations to the city level

This chapter sets forth a number of local policy instruments that have come up during the project, and have been considered to be possible to deploy in Nordic cities. These instruments and measures have been chosen on the basis of the likelihood they will increase the proportion of zero-emission vehicles and of being relevant for implementation in at least one city in a Nordic country. This kind of instruments are summarized above in Chapter 4, Table 2 and described in more detail in Appendix 1-9. All of the measures that are described here are not possible for introduction in all Nordic countries at present, due to differences in legislation.

This chapter focuses on the first six measures in Table 2 which deal with zero emission zones, environmental tax zones, parking discounts, access to bus lanes, support for public charging infrastructure and public procurement. In the next chapter (Chapter 8) a number of recommendations are given as to how cities can combine these six instruments in policy packages. It is recommended that cities should use both "the stick and the carrot" to promote the development of zero-emission vehicles (Givoni M, 2014). If only "carrot-incentives" such as subsidized parking are used, they can increase the usage of cars at the expense of public transport, and favour high income groups. On the other hand, a focus on just "stick-incentives" such as zones and fees, can affect accessibility or societal distribution adversely.

If Nordic cities are to be able to ramp up numbers of zero-emission vehicles, it is recommended to utilize a combination of their various formal and informal roles as authorities, procurers and facilitators. As a public authority, cities can regulate traffic and land use and control urban planning to promote zero-emission vehicles and space-saving mobility. As procurers, cities can accelerate the introduction of zero-emission vehicles in certain market segments and increase and strengthen the range of mobility services by deploying car and bicycle pools. In their role as facilitators, cities can gather, support and coordinate both private and public actors. Pilot projects and test arenas are examples where a city can facilitate activities that brings together different actors. This may apply, for example, to energy companies, the automotive industry and property owners.

Environmental zone for zero-emission vehicles

Introduction and design

A zone that only gives access to zero-emission vehicles is one of the most powerful local instruments and has the greatest potential for increasing the share of zero-emission vehicles. A ban on certain vehicles can entail major restrictions on the travel and transport of private individuals and companies. Thus, zero-emission zones are only suitable in cities that have ambitious objectives and are prepared to invest sufficient resources for information dissemination and complementary measures. Zero-emission zones are at first hand relevant for cities that already have a relatively high proportion of zero-emission vehicles. Zero-emission zones are mostly suitable in cities or parts of cities that have well-developed public transport and a good cycle path network.

A zero-emission zone does not need to span over a large geographical area but can be realized on a smaller scale, for example as an extension of existing car-free streets or areas already existing in some cities, like those in Aarhus, Denmark (see example box below). This means that a zero-emission zone only needs to include one or a few streets in order to influence selected vehicle groups. A larger zone, on the other hand, delivers a more significant impact but also affects larger parts of the population, which requires more planning and complementary measures. A recommendation for cities could be to start with a smaller zone that may be enlarged further on.

A zero-emission zone may focus on special vehicle categories as light commercial vehicles and heavy trucks in an industrial area adjacent to the city centre (Larsson M-O, 2020). This may make an introduction easier and could keep costs lower for road users. Even if the zone is relatively small, it can still have a significant impact, as the kind of vehicle owners that operate throughout the urban area may be compelled to replace their vehicles in order to gain access to the zone. Light trucks have been tested as a vehicle category in a zero-emission zone in Oslo. However, the regulation had to be withdrawn due to lack of legal support from the national government.

The introduction of a zero-emission zone for an entire district should be announced years in advance. This is necessary if all actors – municipalities, companies and households – are to have enough time to adapt to the new conditions. This reduces costs for users and makes it easier to garner support for the implementation. Amsterdam is an example of a city that has decided to introduce a zero-emission zone across the entire city in 2030 (see example box in Chapter 8, *Large zone*).

A prerequisite for banning certain types of vehicles in a zone is to make thorough analysis of the market availability of vehicles that will be permitted, as well as the access to charging facilities, filling stations etc. The zone should not be introduced until the market is able meet all transportation needs. However, the local market for zero-emission vehicles does not have to be quite as broad or economically competitive as that for conventional vehicles. The purpose of a zero-emission zone, in addition to the fulfilment of local environmental goals, is the ability to influence market development.

When plans are drawn up to introduce zero-emission zones, the city can also prepare for car-free areas as a complement, or as an alternative in smaller areas.

Effects

To mitigate effects on affected households, cities should at an early stage identify the groups most impacted by a zero-emission zone and develop an action plan with complementary measures (see below). It is vital that projected complementary measures are properly implemented and prioritized. The positive effects of the zero-emission zone that have been foreseen may otherwise fail to materialize, giving rise to accessibility problems that undermine the legitimacy of the zero-emission concept and reduce any societal benefit that might otherwise have accrued.

Households who own vehicles banned from entering the zones will be faced with the expenditure necessary for the purchase of a zero-emission vehicle. They may be forced to bring forward a planned vehicle purchase as the car they currently own plummets in value. Depending on the maturity of the market at the time of introduction, the purchase

price of a zero-emission vehicle may also be higher compared to that of traditional equivalent, while the secondary market is not yet fully developed. In the long run, prices for zero-emission vehicles are likely to be comparable with conventional cars in both the new car and second-hand markets.

Simultaneously, diminished car use will have positive effects on accessibility for other road user groups. If the number of cars in the city decreases, more street space can be freed up for public transport, walking and cycling. This can benefit groups lacking access to a car by giving them access to faster alternative means of transport and reducing accidents. This outcome means that the measures will benefit the most economically vulnerable households, as it is often these that lack access to a car. The groups that already own a zero-emission vehicle will also benefit.

The commercial use of passenger cars will not significantly affect driving patterns, provided that a smaller zone is introduced in such a way as to ensure that transport needs in the area can be satisfied with the zero-emission vehicle types available on the market at time of introduction. Business will go on as before and those organizations compelled to swap vehicles will do so in order to be able to continue with their operations. If additional costs arise due to this, it will ultimately be the end consumer who will pay more for services and goods that are affected. A special case, however, are business trips in employees' private cars. Employers will have to provide some form of company, rental or car sharing car for those employees whose cars do not meet requirements.

When a ban that targets a certain class of vehicles is implemented in a zone, reactions will be varied. As pointed out above, many road users will switch to zero-emission vehicles that meet the requirements, while others will use more public transport and or bicycles. Some trips will be opted out completely. However, a number of road users will detour around the zone, which could increase climate and environmental impacts in surrounding areas. This risk here is judged to be a lesser evil compared with the positive climate effects achieved by a ban. An indication of this could be seen when a congestion tax was introduced in Gothenburg in 2013 – passenger car traffic decreased in the toll zone but also fell in the region as a whole. The total traffic volume decreased by 2.5 per cent a few months after implementation (Västsvenska paketet, 2020).

Commercial transports are not affected by zero-emission zones to the same extent (Johansson T B, 2013). Provided that there are sufficient vehicles suitable for different segments available on the market and extensive charging or fuelling options exist or are projected, organizations and companies will be able to have the same access to an area even after restrictions have been introduced. For these users, it is natural to have a vehicle fleet that is fit-for-use and adapted to local regulations. The introduction of a zone may mean that some companies incur increased vehicle acquisition costs in a transitional phase, but this will be part of the cost of running a business that ultimately will be passed on to the consumers of the goods and services and transport-buying customers. Local commercial traffic may also need to adjust routes and operations to changed vehicle performance, charging capabilities etc.

Cities are recommended to initiate a dialogue with all concerned to give those affected time to adapt operations to the new conditions before the introduction of the zone. Besides heavy transports this could be taxi, rental car and delivery companies and others affected, to encourage them adapt services and offers to the new zero-emission zone in

good time. In this way a well-implemented introduction may contribute to behavioural change and leverage new business ideas that can lead to a new equilibrium in modes of transport.

Long-distance hauliers may find it more difficult to adapt their vehicle fleet to local regulations. If necessary, these problems can be handled with dispensations for vehicles that do not meet requirements.

Example: zero emission zone in Bergen, Norway

From 2025 there are plans to introduce a zero-emission zone for the municipality of Bergen for passenger cars, light commercial trucks and heavy vehicles. Only plug in electric vehicles, hydrogen vehicles or vehicles that are defined as fossil free should be given admission to the zone area. Complementary measures to support the transition are commuter parking, mobility areas with car rental and car sharing services, economical support systems for light commercial vehicles and reloading areas for city distribution and heavy trucks. **(**Bergen kommune, 2020)

Differentiated traffic fees

Introduction and design

Differentiated traffic fees is an instrument that has the potential to significantly ramp up the introduction of zero-emission vehicles. This is because it affects so many users in so many different groups. Fees for light vehicles are mainly recommended for cities or parts of cities that have a well-developed public transport and a good cycle path network.

A zone where the fees or charges for vehicle passages are based on environmental performance may span the whole city, or just parts of it. It could be recommended to start in a smaller scale. A limited environmental charging system should primarily be introduced in those parts of the city where the benefits of reduced air pollution and noise are greatest. An environmental fee system can advantageously include both passenger cars and heavy vehicles. In Oxford, UK, there are plans to introduce such a fee system that will initially span only a few streets (see example box in Chapter 8).

The design and introduction of the fees should be adapted to the level of ambition and the market supply of zero-emission vehicles within each category. It is also possible to implement different fee levels that are also based on the vehicle's euro class and emissions affecting health. For heavy vehicles, it is especially important from a health perspective to phase out vehicles that have poorer environmental performance than that set by Euro VI. Milan, Italy is an example of a city that uses a differentiated fee system (Eltis, 2020).

If a city has already introduced road tolls or congestion charges designed to be a source of revenue or to reduce congestion, the environmental tax may be baked into the same system “on top” of the toll or charge. Properly designed, the system may contribute not only to lower emissions and reduced congestion but also to increased use of public transport, bicycle and pedestrian traffic. If the system has a fiscal purpose, the design should be adapted accordingly (Bruvoll, 2020).

Traffic fees might be introduced for heavy vehicles exclusively in order to promote the introduction of zero-emission heavy vehicles. Truck traffic is just as price sensitive as passenger vehicle traffic, which implies that increased driving costs also will lead to reduced kilometres driven (Vägslitageskattekommittén, 2017). But as truck traffic makes up a smaller part of total vehicle traffic, negative effects on congestion and revenues from this measure will not be as great as for passenger vehicle traffic. It is then feasible to raise fees for trucks with internal combustion engines while simultaneously maintaining low rates for zero-emission trucks.

In order for differentiation to be possible, however, legislative changes may be needed in certain Nordic countries, and collaboration between a city and the governmental level is necessary. It is recommended that revenues from the fee system are used to bolster public transport or the bicycle infrastructure. Thus, the transition to sustainable travel will be accelerated.

Effects

A fee system has the possibility to deliver almost the same environmental effect as the bans enforced by a zone system. One important difference, however, is that a fee system imposes significantly lower costs on society and road users, as, for example, rare visitors can continue to gain access to the zone area provided that a fee is paid. The environmental and climate effect of the zone is determined by how high the fee is set. (Stockholm Stad, 2018). Therefore, a fee is recommended in favour of a zone system.

Initially, the measure will lead to fewer private individuals driving in the zone. This effect may diminish as the proportion of zero-emission vehicles increases in the passenger car fleet. Therefore, in connection with the initial traffic reduction, it may be strategic to convert some lanes and car parks into bus or bicycle lanes, as well as bicycle parking lots and bus stops. Such measures make it possible to have a more long-term transition towards reduced car travel by changing the way different areas of the city are used and increasing the proportion of sustainable travel modes.

If the restrictions target passenger cars, it will be important to introduce complementary measures for public transport, cycling and car sharing. An increased investment in shuttle car parks or Park and Ride adapted to the scope of the toll zone may also be needed.

For commercial traffic and business trips by car, the effect of this package will be approximately the same as that described for zone restrictions. Operators will adapt their vehicle purchases to the size of the fee, the cost of different vehicle types and the need to drive in the zone. Operations and driving patterns are not significantly affected. An important difference between a prohibition zone and a fee zone is that commercial transport and business trips that rarely drive in the latter will have continued access to the area without having to replace their cars. This instrument package is therefore more flexible and is likely to result in lower societal costs.

Example: differentiated roads tolls in Oslo, Norway

In Oslo, road fees are differentiated by time, vehicle type, fuel-technology and geographical categorization. There are three toll rings: the inner ring, the Oslo ring and the city ring. Diesel cars are charged at a slightly higher rate than petrol cars. The charge also covers a congestion fee that is higher in rush hours. Fully electric cars used to be exempted, but from June 2019 a new system is in place, electric vehicles are now charged approximately 30 per cent of the fee in rush hours and 20 per cent at other times (Fjellinjen AS, 2020).

Differentiated parking fees

Differentiated parking fees are primarily suitable for cities that have a low proportion of zero-emission vehicles, as a way to awaken interest and reduce running costs. This measure should only be applied for a limited period of time, as long as the number of zero-emission vehicles remains low. Otherwise it is likely that this measure will have an indirect effect on the choice of transport mode by increasing the car ownership. At present, this means that the measure may be relevant only for Danish and possibly also for Finnish cities.

It is worth noting that it can be politically difficult to withdraw a benefit once it has been established. Therefore, a recommendation is that the subsidy should be limited in time from start, and this message should be emphasized in all communications with the public. When a political decision is made to introduce this measure, a decision should also be made as to when it will be withdrawn (a particular date, a specific proportion of zero-emission vehicles, improved congestion management, etc.)

Parking subsidies for zero-emission vehicles have a negative distributional profile as they are primarily aimed at those who own and drive cars in central parts of the city and these are more likely to be residents from the higher income bracket (Trafikverket, 2011), (Innovativ parkering, 2020).

Parking fees do not significantly impact the commercial transport sector, as commercial vehicles are often in use throughout the day. However, other sectors, i.e., craftsmen and certain service industries that depend on cars and light trucks, utilize paid parking to a greater extent and for this reason are also affected by this type of incentive.

Access to public transport lanes

It is not recommended for cities to allow light zero-emission vehicles access to bus lanes. Access to bus lanes can be a powerful incentive to both buy and use a zero-emission vehicle. This is especially the case in congested areas where public transport lanes are often conspicuously empty. However, there is significant risk that car travel will be strengthened at the expense of public and other modes of transport, which in turn will adversely impact the environment as well as any accessibility and distributional effects. If the public or the business community are allowed to drive cars or light trucks in bus lanes, there will also be a direct negative effect on bus passability as the numbers of zero-emission vehicles on the roads increase.

A potential problem here is also that dispensations that allow zero-emission vehicles to access bus lanes may dial back compliance. Drivers of conventional passenger cars can also be tempted to use the bus lanes, and this means that steps must be taken to ensure that the instrument does not lose efficacy.

One possibility, however, might be to open the bus lanes for heavy zero-emission trucks. There are significantly fewer trucks on the road than passenger cars, so there is less risk of adversely impacting bus accessibility, and the need for instruments and incentives for heavy zero-emission trucks is greater than for passenger cars. The socio-economic benefit of constructing bus lanes could also be greater if these can be shared with certain trucks. This in turn could make it easier to justify the construction of new bus lanes. However, there are problems here that require trade-offs. Some bus lanes in a city may already be experiencing capacity problems, while other bus lanes might have spare capacity that could be utilized by heavy zero-emission traffic. This must be investigated prior to any introduction, and it must be clear to truck drivers which bus lanes are available, even for international hauliers unfamiliar with local conditions. This differs from offering taxi traffic access to certain bus lanes. Taxi drivers are mostly active in a local or regional area and find it easier to follow local rules and regulations.

Support for developing charging infrastructure and hydrogen filling stations

Cities generally have little control over the deployment of zero-emission vehicle charging points and filling stations. The initiative for these is normally taken by commercial operators. There are still things cities can do to support the development of this infrastructure. It is important that cities support this sort of expansion if investment in zero-emission vehicles is to work in practice.

The charging infrastructure

Cities are recommended to follow the following steps to implement support of a variety of different charging solutions:

1. Ensure that municipally owned housing and business premises have agreements with suppliers of charging services that can be offered to tenants.
2. Inventory the city´s parking spaces and provide a plan for delivering adequate charging services at these locations. Such services should primarily be operated and debited by commercial actors so that an upscaling can take place using working business models and free from dependency on local support measures.
3. Collaborate with private property owners and support their efforts to build a charging infrastructure and facilitate their administrative processes around building permits etc.

It is also recommended for cities to support the expansion of a charging infrastructure for buses and trucks. It is important to build up charging facilities at truck terminals, transhipment points and bus stations. A dialogue should be initiated with electricity

network owners and energy and public transport companies to ensure the expansion of the charging infrastructure proceeds smoothly.

Example: Charging infrastructure for light and heavy-duty vehicles in Region Västra Götaland

The RegionEl project focuses on stationary charging and aims to accelerate the introduction of light and heavy-duty vehicle electrification. This will be accomplished by scaling up from demo projects to major deployments. To facilitate charging four types of natural charging situations have been identified. These are at terminals, drop off locations and fast and slow roadside charging.

The driving forces behind the project are the gradually stricter EU carbon dioxide emissions regulations and the wish of the region establish itself as a test arena for electric transports. Another important factor is that both Volvo and Scania recently announced that by 2030 sales of fully electrified trucks will be increased to 30 – 50 per cent of total sales volume.

At start partners in the project consist of the vehicle industry and grid owners, as well as regional and local authorities. Research institutes are also involved. In a second phase more actors will be take part, i.e., transport buyers, logistics suppliers, hauliers, municipalities, grid operators and charge point operators (CPO). So although this is a regional project municipalities and cities will be important stakeholders as most transports either end or originate in a city. (Fossilfritt Sverige, 2020) (Lindholmen Science park, 2020)

Hydrogen tank infrastructure

Hydrogen-powered electric vehicles running on fuel cells may become a viable alternative in some regions and for certain vehicle categories. In cities where this is implemented, it should be leveraged by the deployment of hydrogen filling stations similar to the way cities today support and collaborate with the actors that provide filling stations for compressed natural gas (CNG) and liquefied biogas (LBG). Where applicable, cities may need to plan for the accessibility to hydrogen in the future and the tank infrastructure this will entail. Cities should in the first instance cooperate with commercial actors such as gas distributors, representatives of public transport companies and freight distributors. Cities should assist with planning issues related to the availability and provision of land required for infrastructure at strategic locations. Cities can also participate in pilot projects using their vehicles fleet as well when the tank infrastructure starts to come online.

Example: Charging stations in Reykjavik, Iceland

Reykjavík City has embarked upon three collaborative undertakings together with the Reykjavík Energy (utility company): a fund for charging stations at apartment houses, the setting up of charging stations at official buildings accessible for residents and setting up charging points for people who have to park on the street. In addition, Reykjavík City will establish charging stations at tourist spots around the country and at some hotels (Friðriksson, 2019).

Municipal procurement

Municipalities and cities are recommended to play a role as a forerunner and good example by modernizing its own vehicle fleet. As the vehicle fleet is replaced by zero-emission vehicles, facilities for charging municipal vehicles must be guaranteed. Several Nordic cities have set up targets for their own vehicle fleet. In Copenhagen, for example, the goal is to achieve 100 per cent zero-emission vehicles in the municipal passenger car fleet and for buses by 2025 (Isbrand, 2019).

Example: procurement requirements for electric work sites in Oslo, Norway

The city of Oslo has established a zero-emissions standard for working machinery in tender documents, based upon a dialogue with suppliers and the availability of zero-emission vehicles and machinery. Four kindergartens and two sports arenas are currently under construction in accordance with the new standard. This means that diesel driven machinery and equipment will be replaced with fossil-free alternatives when these become available. (Oslo Kommune, 2019)

Procurement measurements should be directed at the vehicles that the city buys in or leases for its own operations. The suppliers of certain services can be required to use zero-emission vehicles when carrying out contract work for the city, for example, waste collection or travel services.

City bus fleets in major Nordic cities have the potential to be almost fully electrified by 2030, if public transport procurers set the necessary procurement requirements over the next few years. The market for electric buses is now mature enough to satisfy the needs of city traffic. Close cooperation and good foresight must be established between public transport authorities, city planning offices and network owners to set aside land and electric power for the new depots and stops needed for charging the buses. These depots and charging stations need not mirror the needs depots have needed for the deployment of diesel buses, as have been done in the example presented below from Gothenburg.

Example: Electric bus procurement in Gothenburg, Sweden

With traffic start in December 2020, Western Sweden´s regional public transport company Västtrafik has procured 160 electric buses for service in Gothenburg and surrounding urban areas. This is the largest electric bus procurement carried out in Europe so far. Prior to the procurement, together with, inter alia, the City of Gothenburg extensive preparations have been made to secure land for the bus depots and electricity supplies to serve them. The procurement has also been facilitated via an "Electricity testbed demo project" which is based on a partnership between the municipality, public transport actors and authorities, the automotive industry, network owners and academia. (Västtrafik, 2020)

Cities may also specify zero-emission trucks when precuring services and goods where transport is a demonstrable part of the service. The level of ambition should be determined by a preparatory market analysis during which environmental, vehicle and procurement specialists collaborate. At this stage it is of particular interest for cities to accelerate the market introduction of distribution trucks if several different models are available.

Example: Low-carbon city distribution hub in Oslo, Norway

In this project in Norway, Oslo established the Oslo City Hub depot for the transhipment of goods. This depot will mainly be used for reloading goods from larger vehicles to smaller electric distribution ones, thus combining the introduction of zero-emission vehicles with higher transport efficiency. Some important lessons learned were that routines at the depot should be simple and flexible, that the facility should be located close to the city centre, and that support from the public sector was essential. (Ørving T., 2019)

It is crucial that procurement requirements are followed up properly, otherwise they will not be complied with as they often entail additional costs. Here Copenhagen sets an example. Its suppliers are compelled to document that they have achieved a certain proportion of zero-emission vehicles in their vehicle fleet. One method that has been used successfully by various cities is to earmark parts of the budget to cover the cost of deploying zero-emission vehicles. In this way, operators are not forced to choose between investments in zero-emission vehicles and their core activities.

This kind of public procurement affects a small percentage of business transports, although it can be an important forerunner and push the market forward. To the extent that the efforts of the municipality contribute to the expansion of public charging infrastructure or the supply of hydrogen fuel is ramped up, this package can also accelerate the pace of change in the overall business community.

Complementary measures to support sustainable mobility

Above, certain restrictions for conventional vehicles are described. If such measures are introduced, cities are strongly recommended to introduce complementary measures to mitigate the effects of zone restrictions or fee systems.

Public transport, cycling and walking

The most important complementary measures are to strengthen public transport, cycling and walking. Increased shuttle parking and Park and Ride solutions can also be important. Measures to strengthen public transport should focus both on the central parts of a city if the majority of those affected live and travel there, as well as on outlying areas to counteract socio-economic disparity. This must be done in cooperation with public transport authorities.

In addition to an increased funding of public transport and cycling, these modes of travel should also be prioritized at the expense of the car. This can mean that buses and bicycles are granted road space in the form of bus lanes and cycle paths – space that is currently used by passenger cars. In this way, the relative attractiveness of public transport can be improved by allocating more space in urban environments. A term often used here is the so-called travel time ratio, i.e., travel time for public transport or bicycle compared to that of a car. Surveys have shown a causation between reduced travel time quotas and increasing public transport utilization in medium-sized Swedish cities (Olausson Bob, 2019).

Example: Complementary measures together with congestion charges in Gothenburg, Sweden

When congestion charges were introduced in Gothenburg in 2013 this was done in combination with a number of other measures grouped together in a package, the so-called Västsvenska paketet (West Swedish package). New commuter trains were purchased, and commuter stations platforms extended to accommodate longer trains. Furthermore, approximately 60 kilometres of new bus lanes were built along access routes and in the centre of Gothenburg to prioritize buses over passenger car traffic. New shuttle car parks were also built in and outside Gothenburg to make room for 2,000 cars and a similar number of bicycles (Västsvenska paketet, 2020).

The city can also try to ensure good access to car sharing and support the market for renting or borrowing bicycles, electric scooters and electric cars.

Such measures are important to compensate for the reduced accessibility that certain groups may incur, and to ensure that all groups in society have good access to the restricted area. To facilitate accessibility for these groups, cities are recommended to support the establishment of, and provide attractive parking for, carpool cars with coverage throughout the current zero emission zone. For carpool cars to reach a broader group of customers, the access to attractive parking spaces in the neighbourhood of residential areas and workplaces is crucial (Larsson M.-O., 2018).

Carpools can also be promoted by cities purchasing pool cars for their own operations and allowing the public and businesses to use them, by public transport operators cooperating with car sharing actors, or by the city making it easier for market participants to gain access to parking for car sharing services. These carpool vehicles can then be used both inside and outside the zone.

Promoting bicycle riding could include bicycle hire schemes. To make them efficient they must be coordinated with public transport in terms of among other things location and payment systems. Rental bicycle systems can be purchased by the municipality.

Example: dedicated parking for carsharers in Oslo, Norway

The City of Oslo is planning to assign 600 parking spaces to car sharing services. It is estimated that there are around 2 000 car sharing cars in Oslo. The city will also reserve a minimum of 20 per cent of designated parking spaces for electric car sharing vehicles. Oslo will build a charging infrastructure for these parking spaces and only zero-emission car sharing vehicles will be allowed. (Portvik, 2019)

Public transport, bicycles and car sharing services are means of transport that together create a more attractive system than if measures stand alone (Givoni M, 2014). This applies not only to urban planning but also when a city designs complementary measures.

Example: Mobility as a service in Helsinki, Finland

Helsinki's vision is to grant equal access to all residents by 2025, whether they currently have access to a car or not. In a collaboration with Maas Global, the Whim app has been developed. The application allows users to travel from one point to another using a mix of transport modes.

The application, which is available in different versions with differing prices, allows booking trip with city bikes, taxi, electric scooters or rental car. In the simplest version, which costs 60 € a month, travelers are given access to the city´s public transport system, city bikes, 4 shorter taxi journeys (up to 5 km), a discount on rental cars and scooters while the premium service version, which has a monthly fee of about 500 € provides access to 80 shorter taxi rides, unlimited car rental and public transport throughout the region. There is also a "Whim to go" version, to book a trip, with different transport modes and debit each trip separately.

What makes Helsinki especially noteworthy is that in 2016 the Helsinki Regional Transport Authority (HSL) decided to provide open data both in the form of interfaces and data packages. (Karlsson I. C. M. et al, 2020)

Speed limitations and traffic restrictions

Some complementary measures can be recommended that focus on sustainable mobility and urban development independent of vehicle technology. Such local measures can for instance target the parking conditions, speed limitations, and other restrictions on vehicle traffic.

An important regulation that boosts biking, walking and urban development is to design and implement a low-speed traffic environment. 30 km / h is a suitable speed limit in many urban areas. At speeds less than 30 km / h, the relative attractiveness of walking, biking and public transport is improved compared to car travel (Wennberg H., Sundberg I., 2016). If the vehicles drive at lower speeds, the traffic area needed for motorized traffic can also be reduced.

Speed limitations can also be combined with the introduction of general traffic restrictions in central streets. The street design should encourage walking and biking, with the planned introduction of dedicated pedestrian and bicycle streets. To facilitate freight distribution, systems with a number of terminals and cargo bikes can be established and supported by the city (Behernds, 2020).

Example: Redesign central streets in Aarhus, Denmark

Measures taken to decrease the attractiveness of the car in the inner center is to reduce car parking and use the space for other purposes e.g. bike parking, social and green areas. This especially at street corners where sidewalks are expanded into the road space to reduce pedestrian crossing distances, they call these areas "dog ears". These measures also reduce the speed of cars, without reducing the set speed limits. Some streets are also being changed into pedestrian streets, inspired by e.g. summer pedestrian streets (*sommargågator)* in Sweden. Restaurants and cafés are interest in these kinds of areas along pedestrian streets but also in "dog ear" areas, however safety is an important factor to consider in the design. (Skou Nicolaisen, 2019)

Parking measures

As part of a package of complementary measures, cities are recommended to apply appropriate parking fees and parking regulations in affected areas to support sustainable travel, thus making sure that sustainable modes of transport are prioritized and given a competitive edge. Cities are also recommended to add a more long-term component to the mix of complementary measures by targeting the number of parking spaces planned for new construction. Public property owners and parking companies should strive to price parking so that tenants and others are compelled to pay the full cost for building, financing and maintaining parking places so that these costs are not subsidized by the all the residents or tenants community. The municipality can, for example, allow a property owner that plan for building new apartments to build a smaller number of parking spaces in exchange for facilitating mobility services to residents and businesses, collective deliveries of goods, purchasing public transport, etc. (Innovativ parkering, 2020).

Example: parking policy in Oslo, Norway

City of Oslo has a restrictive parking 'norm' that strives to reduce car ownership and car usage, regardless of whether a vehicle is fossil powered or zero-emission. The city also plans to abolish the minimum standard for establishing new parking lots currently in use when new apartments and workplaces are planned and built. This will lead to more market-orientated parking with higher prices for parking and reduced car ownership in combination with an increased number of mobility services. (Portvik, 2019)

Through environmentally controlled parking policies, public transport, cycle paths and measures to stimulate the growth of car sharing and solutions for sharing or renting bicycles and other means of transport - cities are recommended to strive to make it easier for residents to live and work in the city without having to own a car.

8 Policy package proposals for Nordic cities

The measures described in previous chapters have in this chapter been assembled into a proposal of five different policy packages (summarized in table 3 below). The policy packages have been given the following names, and they are presented further down in this chapter.

- Basic policy
- Selective zone
- Large zone
- Selective fees
- Comprehensive fees

The proposed policy packages laid out here are intended for medium-sized and larger Nordic cities. However, it makes no sense to set an exact limit on how big a city must be to qualify for the medium-sized label. To get an idea of how many Nordic cities could be included in this category, there are 46 cities in the Nordic region that are in the same order of magnitude as Kristiansand in Norway where they have introduced a fee system , i.e., around 60,000 inhabitants: 20 in Sweden, 10 in Finland, 8 in Norway, 7 in Denmark and one city (Reykjavik) in Iceland (Wikipedia, 2020).

The packages are suggested as a mix of measures that cities can put together. Experience suggests that several policy instruments that push in the same direction tend to reinforce one another and create a positive spiral (Givoni M, 2014). If, for example, charging infrastructure is poorly developed in apartment buildings, the impact of other measures will be limited.

To serve as some examples of state-of-the-art policy packages, this chapter provides an overview of packages similar to both *Selective fees* and *Large zone* packages that are being introduced in Oxford and Amsterdam.

One potential obstacle for introducing policy packages is that although the cost in the form of fees or restrictions may be obvious to individuals, the benefits are less so, or become apparent only when the package has been in operation over a longer period of time. If a policy package is to succeed, the purposes and the benefits it is expected to deliver must be communicated. It is also important to communicate the negative effects that may arise, and to be clear about what complementary measures are being taken to alleviate these.

Note that some of the measures presented here would require changes in current national legislation to make them legally possible across the entire Nordic region.

Each proposed policy package is described further below. First, an introduction of content and design aspects is given here.

Content in all policy packages

All packages contain measures designed to improve the charging or tank infrastructure as well as public procurement requirements. They also include complementary measures

targeting public transport, the bicycle infrastructure, support for car sharing services, parking and speed limitation measures. These kinds of measures are important prerequisites for a successful increase of the share of zero-emission vehicles, regardless of which policy instruments that being implemented in other respects.

Design of Selective zone and Large zone

The *Selective zone* (selective in size or type of vehicles) and *Large zone* policy packages are zones that ban vehicles that do not fulfil the local definition of zero-emission vehicles. These packages require significant complementary measures for private persons who can no longer use their passenger cars. This is also described in chapter 7.

Depending on the size and scope of different vehicle categories, the time perspective is essential if road users and companies are to have time to adapt to the regulations, for example by replacing vehicles. When introducing larger zones for passenger car, as in the Amsterdam example below, a 10-year forward planning projections may be appropriate. However, when introducing a smaller zone for just one vehicle category, a shorter time span is possible.

Design of Selective fee and Comprehensive fee

The policy packages with *Selective fees* and *Comprehensive fees* (or taxes) are based on levying environmental fees to benefit zero-emission vehicles throughout the day, possibly with additional fees that throttle traffic flow during those times when congestion is likely to occur. An environmental fee or tax offers rare users of the zone an opportunity to continue to use their vehicles in the zone for a more limited cost than to purchase another vehicle. Users that frequently traffic a zone area, however, will notice little difference between bans or fees, if the latter are designed in a way that delivers similar environmental effects as those achieved by a zero-emission zone. This means that rigorous complementary measures will be needed to complement these packages just as for the zone packages.

Policy packages that contain zones or environmental fees can be introduced in both medium-sized and large Nordic cities. However, these packages should be adapted to local conditions concerning congestion, air quality and public transport. Socio-economic effects must also be considered. For example, the proportion of single pensioner households and the numbers commuting to heavily built-up areas varies considerably between different Nordic cities.

It is also possible to plan for a policy package that contains a mix of zone and fee regulations. In cities with existing congestion charges or tolls, the introduction of a limited zero-emission zone as in the *Selective zone* package may be adequate. Such a restricted zone can be implemented only a smaller part of the toll system area, or only for a certain vehicle category such as light trucks where the city wants to speed up the transition to zero-emission vehicles.

Policy package, overview	Basic policy	Selective zone	Large zone	Selective fees	Compre-hensive fees
Zero-emission zones for certain types of vehicles or for certain districts		X			(X)
Zero-emission zone across the entire city for all types of vehicles			X		
Environmental charges for vehicle traffic in parts of the city and/or for certain types of vehicles				X	
Environmental charges for vehicle traffic in the entire city and for all types of vehicles					X
Improved charging and tank infrastructure for zero-emission vehicles	X	X	X	X	X
Requirements for zero-emission vehicles when procuring vehicles and services	X	X	X	X	X
Subsidized parking for zero-emission vehicles in an initial stage	X				
Complementary measures targeting public transport, bicycle infrastructure, expanded car sharing, bicycle hire, parking policy, speed limitations, coordinated goods distribution etc.	X	X	X	X	X

Table 3: Different types of policy packages.
(X) = Selective zone could be used in combination with comprehensive fees.

The Basic policy packages

A *Basic policy* package contains a number of actions to promote a higher share of zero-emission vehicles and sustainable transport modes. Such measures are recommended to all Nordic cities that have ambitions to speed up the transition to zero-emission vehicles by using local measures. This kind of measures can also be seen as a first step, before introducing zones or fees. A *Basic policy* package includes the following:

- Subsidized parking or similar incentives for zero emission vehicles in an initial stage, provided that the proportion of zero-emission vehicles is still low
- Support to the establishment and expansion of charging and / or tank infrastructure for zero-emission vehicles
- Requirements for zero-emission vehicles in municipal procurement of vehicles and services
- Complementary measures that increase the range and attractiveness of alternatives to car travel such as an extended public transport network,

a bicycle infrastructure, support for car sharing and reloading options for distribution traffic

- Complementary measures such as stricter parking policy, extended speed limitations or similar restrictions on vehicle traffic

A *Basic policy* package will allow cities to prepare the ground for a significant increase in the number of zero-emission vehicles. It will make it easier for inhabitants to own a zero-emission vehicle as there will be more filling and charging stations. Subsidized parking will make it cheaper for private individuals to use these cars on a daily basis (this is only relevant for Danish and possibly Finnish cities at present, where the share of zero-emission still is relatively low). Contractors will be compelled to switch to zero-emission vehicles if they want to continue serving the city. The city´s own fleet will be converted to zero-emission vehicles.

Improved zero-emission vehicle charging capabilities should go hand in hand with an eco-responsible parking strategy. This means, for example, that parking costs should not subsidize electric charging costs and that parking spaces with charging options should not be tied to individual cars, which limits the shared use of parking spaces. Instead, increased demand for charging points for zero-emission vehicles can be a good reason for an overarching review of city parking policies (Larsson, Holmqvist, & Roth, 2018).

Compared to other policy packages, the *Basic policy* package is less effective in encouraging the transition to zero-emission vehicles. However, the negative effects on accessibility for passenger cars are less, which makes it easier to gain acceptance for the package.

Commercial traffic is only marginally affected. Those primarily concerned are business community and the transport industry that supply goods and services to the municipality.

The Selective zone policy package

The most important element in a *Selective zone* policy package is the establishment of a zero-emission zone for certain types of vehicles or certain districts. Such a package would include the following instruments:

- Zero-emission zone for certain types of vehicles or certain districts
- Support to the establishment and expansion of charging and / or tank infrastructure for zero-emission vehicles (as in the *Basic policy* package)
- Requirements for zero-emission vehicles required in public procurement of vehicles and services (as in the *Basic policy* package)
- Complementary measures that increase the range and attractiveness of alternatives to car travel such as an extended public transport network, a bicycle infrastructure, support for car sharing and reloading options for distribution traffic (as in the *Basic policy* package)
- Complementary measures such as stricter parking policy, extended speed limitations or similar restrictions on vehicle traffic (as in the *Basic policy* package)

A *Selective zone* policy will increase the proportion of zero-emission vehicles more than a *Basic policy* package. It will have an impact on vehicle use in a municipality not only inside the zone, since it also will affect the share of zero-emission vehicles outside the zone. Consequently, it may also give rise to greater adjustment costs and it can impact accessibility for certain road user groups widely.

This kind of policy package is recommended for cities that are highly ambitious, have achieved a relatively high share of zero-emission vehicles, and where the opportunities for residents to travel without owning a car are relatively good. It may also be suitable for cities that are eager to cut emissions from heavy traffic and are willing to introduce zero-emission zones for these vehicles.

However, to be possible to introduce, such a package would need legal changes in most Nordic countries. As can be seen in Chapter 5, Table 2, up until now only Swedish cities can legally introduce zero-emission zones. The Swedish regulation prescribes similar regulations for light and heavy vehicles, so as things stand, Swedish cities must introduce a zero-emission zone both for passenger cars, buses and trucks.

To facilitate an introduction of a *Selective zone*, it will also be necessary to implement the measures recommended in the *Basic policy* package to support the roll out of filling stations and the charging infrastructure and requirements for zero-emission vehicles in public procurement.

See more about possible effects from different measures in chapter 7.

The Large zone policy package

A *Large zone* policy package contains similar regulations as the *Selective zone* above, but it spans a major part or the entire city. This would require cities to point out a target year at which the full transition to a zero-emission city shall be completed and initiate major policies in order to achieve this. The implementation should be carried out with forward planning spanning 5 - 10 years, and it can be done in stages.

This policy package consists of a far-reaching measure, the establishment of a zero-emission zone across the entire city in a certain year. The package recommends the following instruments:

- Zero-emission zones for the entire built up city and all vehicle types
- Support to the establishment and expansion of charging and / or tank infrastructure for zero-emission vehicles (as in the *Basic policy* package)
- Requirements for zero-emission vehicles required in public procurement of vehicles and services (as in the *Basic policy* package)
- Complementary measures that increase the range and attractiveness of alternatives to car travel such as an extended public transport network, a bicycle infrastructure, support for car sharing and reloading options for distribution traffic (as in the *Basic policy* package)

- Complementary measures such as stricter parking policy, extended speed limitations or similar restrictions on vehicle traffic (as in the *Basic policy* package)

A policy package that includes a large zero-emission zone is only recommended to cities that have ambitions to achieve major climate and health benefits and that wish to establish the city as a pioneer when it comes to zero emissions from traffic. It concerns cities that are highly motivated and have established a sound basis for introducing this measure in combination with all the needed complementary measures. Like the *Comprehensive fee* package below, this package is thought to deliver the greatest climate effect. This implies a high local share of zero-emission vehicles and extended possibilities to travel without privately owned cars.

Otherwise, the same conditions apply as for the *Selective zone* policy package above. If restrictions target passenger cars, it will be highly important to introduce complementary measures. It would also require legal changes in most of the Nordic countries.

This policy package leads more or less to a 100 per cent transition to zero-emission vehicles, although exceptions will probably be made for special circumstances. At the same time, this is the policy package that triggers the highest adjustment costs and that may affect accessibility and accessibility for large groups of road users, both negatively and positively.

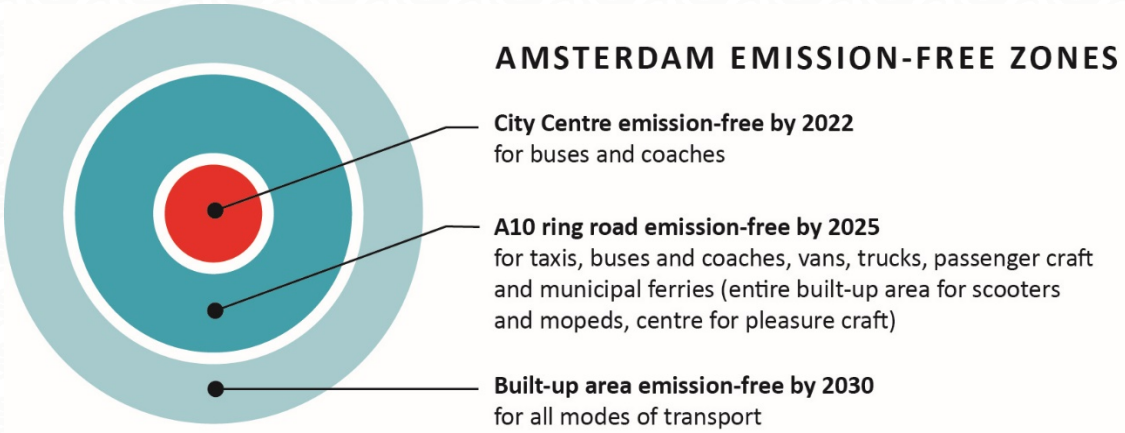
See more about possible effects from different measures in chapter 7.

Example: environmental zones in Amsterdam, the Netherlands

Objectives and implementation
The city of Amsterdam has adopted a vision to become "world capital of emission-free mobility" and a strategy has been developed – the Clean air action plan. The goal is to meet WHO standards for good air quality by 2030. These standards are stricter than those mandated by the EU. The planned measures, mainly a transition to electric vehicle transports, are also expected to reduce climate impact and make a positive contribution to noise reduction. In percentage terms, the estimated reduction will be 96% for nitrogen oxides, 52% for particles and 95% for carbon dioxide realized by reducing the number of kilometres driven using fossil fuels by 95%.

The strategy is based on a number of steps with different time aspects. The city currently has five environmental zones (low emission zones) in the centre. Diesel vehicles with an emission class below Euro 3 have earlier been prohibited and in a first step, these zones will be expanded, and requirements tightened to adhere to the Euro 4 standard in 2020.

In the continued strategy, the city has been divided into three zones: city centre (inside ring road S100), the area inside the outer ring road A10 and the entire urban area (built-up area). The main steps in the plan are summarized in three steps according to the figure below:



The main steps are supplemented with several actions that are gradually being increased. Requirements for higher emission classes are introduced as things progress as follows:

- 2020 Introduction of an environmental zone for Euro 4 diesel passenger cars and vans within the A10 ring road. Existing environmental zones intensified and expanded, except for scooters and mopeds.
- 2021 Ban on taxis running on green gas at clean taxi ranks.
- 2022 Centre is emission-free zone for buses and coaches (within the S100 south of the railway line). Environmental zone for (diesel) trucks tightened up to Euro 6.
- 2025 Environmental zone in built-up area for scooters and mopeds becomes emission-free. Emission-free zone for trucks and vans within the A10 ring road. Emission-free zone for taxis, buses and coaches within the A10 ring road. Pleasure craft emission-free in the city centre. Passenger craft and municipal ferries emission-free on Amsterdam's waterways. Built-up area an emission-free zone for all modalities.

Implementation strategy
Implementation targets four strategic areas; communication, stimulation, facilitation and regulation.

A high degree of acceptance is considered absolutely crucial to success and communication activities also make up a large part of the budget. Communications will consist in both informing about the reasons behind and goals of environmental requirements and initiating a dialogue with citizens. Illustrating with positive examples and good alternatives will be vital. It is apparent that not everyone will react positively to the planned restrictions and therefore great focus will be placed on maintaining an active dialogue. For example, opinion polls are projected, but in-depth dialogues on specific issues are also planned via digital media.

Incentive measures aim to make the alternatives more attractive. Planning includes measures such as scrapping premiums, diversified parking fees for electric vehicles and car sharing, dedicated reloading zones for electric freight transport and benefits for electric taxis. For commercial traffic, they point to measures such as environmental requirements in public procurement, own vehicles, benefits for taxis with zero-emission vehicles in agreements with hotels and parking and charging stations. Improvements for bicycles, pedestrian traffic are also included.

The facilitation part deals mainly with the demand-driven expansion of the charging infrastructure for various vehicle categories (passenger cars, taxis, delivery vehicles, buses, etc.). Today there are 3,000 charging points, but an expansion to between 16,000–23,000 is in the pipeline.

Socio-economic effects
Restrictions on passenger cars are expected to have the greatest socio-economic effect, as older cars will no longer be permitted in 2030. Informing the owners of older vehicles and initiating a dialogue with them at an early stage is seen as important, but it is also expected that the stimulus measures to be presented later on will mitigate these effects.

Synergy with other mobility activities and plans

Two other strategies and programmes for sustainable mobility have been initiated and are linked to the Clean Air Action plan and the environmental zones. These are the Amsterdam Low-Car City agenda and "Smart mobility".

The purpose of the Low-Car City agenda is to reduce car traffic, especially in the city centre, and simultaneously promote efficient traffic flows on and around the North Ring, by providing alternative modes of transport in the city centre. A cornerstone in this strategy is reducing the street parking places in the centre. 1,000 have already been removed and by 2025 another 7,000-10,000 places will follow suit. These areas are transformed into green areas, cycle paths or playgrounds. Parking fees in the central parts have also been increased from 5 to 7.50 € / hour. On several streets, obstacles have been set up to eliminate through traffic without completely obstructing essential traffic, i.e., taxis, delivery vehicles and emergency services, etc.

Alternatively, car sharing services are offered (e.g., the Car2Go app), other means of transport such as scooters and bicycles. There are currently 7,000 emission-free vehicles in the car-sharing programme, and these have also been provided with parking permits valid for multiple locations. To facilitate the use of the car sharing cars for longer journeys, discussions are underway to extend the validity of parking permits to other Dutch cities.

Smart mobility includes a data and digitization programme that aims to manage, analyse, predict and in the long run control real-time traffic flows in the city. As an example, a mobility lab that works with big data about parking (in garages, on streets and bicycle parking), the use of public transport, transport on Amsterdam´s sensitive quays and data from traffic lights, which show traffic intensity at different times. Crowd monitoring analyses showing the movement of people, and how close they are to another but without compromising personal integrity.
(City of Amsterdam, 2020) (Sustainable Amsterdam, 2020) (City of Amsterdam, 2020)

The Selective fees policy package

A *Selective fee* policy package contains measures that prescribe differentiated environmental fees that are based on local emissions in different parts of the city. The fee can apply to all types of vehicles or only to certain types of vehicles.

This kind of policy package is recommended to ambitious cities who want progress towards a transition to zero-emission vehicles rapidly and has similar ambitions as described for the *Selective zone* above. It can be recommended for cities planning to introduce a zero-emission zone across the entire city in the long run, but who want to start on a smaller scale. The package includes the following measures:

- Environmental fees and taxes for vehicle traffic in parts of the city and / or for certain vehicle types throughout the day. The system can be supplemented with a congestion charge during certain parts of the day.
- Support to the establishment and expansion of charging and / or tank infrastructure for zero-emission vehicles (as in the *Basic policy* package)
- Requirements for zero-emission vehicles required in the public procurement of vehicles and services (as in the *Basic policy* package)
- Complementary measures that increase the range and attractiveness of alternatives to car travel such as an extended public transport network, a bicycle infrastructure, support for car sharing and reloading options for distribution traffic (as in the *Basic policy* package)

- Complementary measures such as stricter parking policy, extended speed limitations or similar restrictions on vehicle traffic (as in the *Basic policy* package)

This kind of policy package provides a strong regulation of zero-emission vehicles and can cause high conversion costs for certain groups. At the same time, accessibility can be improved for some groups of private individuals but weakened for others (see the reasoning for *Selective zone* package above and text on Traffic fees, Chapter 5). An important difference from a prohibition zone, however, is that accessibility in practice is less affected by a fee zone. An owner of a vehicle that does not meet the requirements must purchase can still gain access to a toll zone by paying a fee.

At present, however, only Norwegian cities introduce environmental taxes legally. Such a package would need legal changes in the other Nordic countries.

The British city of Oxford with just over 150,000 inhabitants is an example of a medium-sized city that plans to introduce a policy package with fees as a major element. Starting in the central parts of the city, the authorities will launch an environmental tax system to reward the use of zero-emission vehicles and for gaining better air quality (see fact box below).

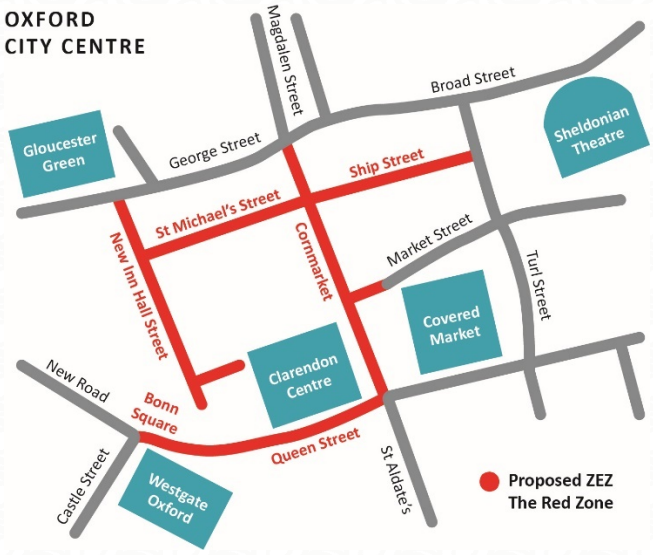
See more about possible effects from different measures in chapter 7.

Example: an environmental tax zone in Oxford, Great Britain

In an attempt to improve air quality, reduce noise pollution and climate impact, Oxford plans to introduce an environmental tax zone in the so-called "Redzone". This is a relatively small area consisting of a few streets clustered around the city centre (see illustration). This zone will serve as a pilot project prior to the introduction of a zero-emission zone across the entire city in 2035.

The decision is to implement this by introducing entrance fees for non-zero emission vehicles. Zero-emission vehicles in this instance are electric cars, plug-in hybrid cars and fuel cell cars. Vans and other commercial vehicles with low carbon emissions are also given a discount.

For all other vehicles a fee of £10 will be charged for access between 07.00 and 19.00 starting in the summer of 2021. The intention is to increase the fee to £20. As complementary measures residents and business owners in the area will be given a discount. Also, vehicles for the disabled and some other special vehicles will be exempt. Large vehicles that meet ultra-low vehicle emission requirements will also be allowed to enter the zone free of charge. From August 2030, several exemptions from the fee will be removed.



(Oxford City Council, 2020)

The Comprehensive fee policy package

The *Comprehensive fee* policy package is similar to *Selective fee* above, but it spans a major part or the entire city, and it includes all types of vehicles. It is similar to, but more extensive than, the *Large zone* policy package and is considered to deliver the greatest climate effect. The impact on road users inside and outside the toll area is also expected to be similar to that of the *Large zone* in many respects, but as mentioned in the *Selected fee* zone above, in contrary to a prohibition zone, accessibility is in practice less affected by a fee zone.

This policy package is recommended to ambitious cities wanting to achieve major climate and health benefits, and who wish to be at the cutting edge when it comes to the transition to zero-emission vehicles, but who want to avoid a zero-emission zone which would completely prohibit excluded vehicles from driving in the city.

The package includes the following measures:

- Environmental fees or taxes on all types of vehicles across the entire city throughout the day. The system can be supplemented with a congestion charge during certain hours.
- Support to the establishment and expansion of charging and / or tank infrastructure for zero-emission vehicles (as in the *Basic policy* package)
- Requirements for zero-emission vehicles in public procurement of vehicles and services (as in the *Basic policy* package)
- Complementary measures that increase the range and attractiveness of alternatives to car travel such as an extended public transport network, a bicycle infrastructure, support for car sharing and reloading options for distribution traffic (as in the *Basic policy* package)

Complementary measures such as stricter parking policy, extended speed limitations or similar restrictions on vehicle traffic (as in the *Basic policy* package)

The city of Amsterdam exemplifies a number of measures similar those in the *Comprehensive fee* (se example box in the section describing the *Large zone*).

See more about possible effects from different measures in chapter 7.

Adaptation to Nordic conditions and examples

These kind of policy packages must be adjusted to a number of local conditions. The size of the city is one of these, although the size is not as significant as might be imagined. The city of Oxford in the example above as it has around 150,000 inhabitants and is planning to implement an environmental tax zone (Oxford City Council, 2020). Several Norwegian cities with less than 100,000 inhabitants have existing fee systems.

In addition to city size, other factors are relevant such as local levels of air quality, accessibility for various road user groups, location of the city centre, industrial and residential areas and so forth. It is recommended to implement measures that target more than one issue simultaneously, such as climate combined with air quality. Other important factors when it comes to choosing measures and packages are how ambitious ambition levels and objectives that are possible to introduce and sustain in a local and political context.

The type of measures a city should select is also determined by local prerequisites for the vehicle fleet and the share of the zero-emission vehicles in the city and its surroundings. Table 4 below shows the market share of battery electric and plug-in hybrid passenger cars in the Nordic countries. The table also shows biogas vehicles, which play an important role in the efforts of some countries and cities to achieve a fossil-free transport.

PASSENGER CARS				
Country	**Type of vehicle**	**Market share new cars, %**	**Total 2020 ytd**	**Share of total car stock, 2020 ytd, %**
Denmark	Battery electric	2.2	20,028	0.77
	Plug-in hybrid	1.6	12,964	0.5
	Biogas*	0	0	0
	Total	3.8	**32,992** of 2,594,000	1.27
Finland	Battery electric	1.7	5,458	0.2
	Plug-in hybrid	4.8	21,544	0.8
	Biogas*	0.6	11,143	0.38
	Total	7.1	**38,145** of 2,696,000	1.41
Iceland	Battery electric	13.7	5 015	2.0
	Plug-in hybrid	11.3	8,538	3.4
	Biogas*	0.6	1,627	0.65
	Total	24.6	**15 180** of 250,000	6.07
Norway	Battery electric	43.9	286 239	10.6
	Plug-in hybrid	11.9	117,554	4.3
	Biogas*	0	0	0
	Total	55.8	403 793 of 2,700,000	15.0
Sweden	Battery electric	4.4	44,119	0.91
	Plug-in hybrid	7.0	106,138	2.18
	Biogas*	1.35	43,233	0.89
	Total	12.8	**193,490** of 4,871,000	3.97

*Table 4. Zero-emission passenger cars in the Nordic countries. Market share of new vehicle sales, total numbers and share of total stock May 2020 *Biogas (methane) includes both natural gas and biogas. (European Alternative Fuels Observatory, 2020) (Insideevs, 2020) (Danskelbilalliance, 2020) (Automotive information highway, 2020)*

In Norway, the share of new car sales taken by zero-emission vehicles exceeds 50 per cent and accounts for more than 15 per cent of the number of vehicles sold in 2020, with an even higher representation in the larger cities. This means that cities in Norway generally need to be more restrictive about subsidies to increase the share of electric vehicles, such as parking subsidies and exemptions from tolls, since this can cause conflicts with other local measures that aims to obtain a more environmentally sustainable transport system. Such subsidies are recommended to be reduced and phased out gradually, if they are not to have an increasingly negative impact on urban planning, congestion and accessibility for groups that cannot afford to purchase subsidized car types. Oslo has started to cut back on these kinds of subsidies, while at the same time deploying robust packages of

measures designed to limit car use similar to some of the complementary measures described in this report.

In Denmark, the share of zero-emission vehicle in new car sales was less than 5 per in 2020. In Danish cities, where electric vehicle introduction is still at an initial stage, it could still be a good idea to implement free or subsidized parking as a temporary measure that can then to be phased out as the introduction rate picks up. Aarhus is an example of a city that offers free parking for zero-emission vehicles at certain car parks. However, such a subsidy must be applied with caution so that an increased number of zero-emission vehicles in the coming years are not allowed to replace bicycles and public transport as means of transport. A way of handling this kind of risk is to set a volume cap on parking subsidies and similar incentives.

In Sweden, Uppsala is an example of a relatively large city with high ambitions for promoting traveling by public transport and bicycle. At the same time, sales of zero-emission vehicles have begun to pick up speed in Sweden and the share in new sales of rechargeable cars reached around 25 per cent in 2020. This means that Uppsala have no need to implement parking subsidies, which in this instance might have a negative impact on public transport accessibility and thus become an issue for road users lacking cars.

In addition to passenger cars, cities also need to focus on other vehicle categories such as buses, trucks and light transport vehicles. Tables 5 –7 below show the sales share and total number of zero-emission vehicles sold in these vehicle categories in the Nordic countries.

For buses, the rate of zero-emission vehicle new sale is relatively high in most countries, although the total number of buses is not yet that large. It also appears that methane and biogas is still a priority alternative for the public procurement of buses. This is especially true for Sweden and Norway. In 2020, Sweden also had by far the biggest biogas-fuelled bus fleet with over 2,000 vehicles.

BUSSES				
Country	**Type of vehicle**	**Market share new busses 2019, %**	**Total stock 2018**	**Share of total bus stock 2018, %**
Denmark	Battery electric	18.5	90	0.1
	Plug-in hybrid	0	0	0
	Biogas*	0	153	1.7
	Total	18.5	**243** of 8,982	1.8
Finland	Battery electric	6.5	25	0.2
	Plug-in hybrid	0	0	0
	Biogas*	2.9	37	0.3
	Total	9.4	**62** of 212,481	0.5
Iceland	Battery electric			
	Plug-in hybrid			
	Biogas*			
	Total	No data	No data	No data
Norway	Battery electric	6.8	47	0.3
	Plug-in hybrid	0	0	0
	Biogas*	8.1	813	5.2
	Total	14.9	**860** of 15,644	5.5
Sweden	Battery electric	7.4	100	0.7
	Plug-in hybrid	1.1	144	1.0
	Biogas*	21.5	2,516	17.5
	Total	28.0	**2,760** of 14,378	19.2

*Table 5. Zero emission busses in the Nordic countries. Market share in new vehicle sale, total numbers and share of total stock. *Biogas (methane) includes both natural gas and biogas. (ACEA, 2019) (ACEA, 2019)*

Conversion of the truck fleet proceeds at a much slower rate compared to that of buses, where the rapid development is largely driven by procurement of public transport buyers. In private sector, the price is the most important factor when the bigger transport buyers procure transport services, with the environment ranking second (Styhre, 2019). However, not only insufficient environmental ambitions from transport buyers matters. The limited supply of vehicles and charging or filling stations is also holding back the development. There is currently a very limited range of zero-emission trucks available on the market. The proportion of zero-emission vehicles in new vehicle sales in 2019 was only one or a few per thousand of total sale volumes. However, many analysts believe that the market for zero emission distribution trucks will increase significantly in coming years. Even in the truck segment, the sales of methane-fuelled vehicles are more significant in both Sweden and Norway. One conclusion that can be made here is that the pace of change in the truck segment needs ramping up and that Nordic countries and cities should increase their efforts by applying various instruments and incentives.

MEDIUM AND HEAVY TRUCKS				
Country	**Type of vehicle**	**Market share new trucks 2019, %**	**Total stock 2018**	**Share of total truck stock 2018, %**
Denmark	Battery electric	0.1	0	0
	Plug-in hybrid	0	0	0
	Biogas*	0.8	171	0.4
	Total	0.9	**171** of 42,741	0.4
Finland	Battery electric	0	0	0
	Plug-in hybrid	0.1	0	0
	Biogas*	1.7	96	0.1
	Total	1.8	**96** of 96,169	0.1
Iceland	Battery electric			
	Plug-in hybrid			
	Biogas*			
	Total	No data	No data	No data
Norway	Battery electric	0	0	0
	Plug-in hybrid	0	0	0
	Biogas*	1.7	222	0.4
	Total	1.7	222 of 55,661	0.4
Sweden	Battery electric	0	11*	0.01*
	Plug-in hybrid	0.1	28*	0.03*
	Biogas*	3.1	1 034*	1.23*
	Total	3.2	**1,073*** of 84,153*	1.27*

*Table 6. Zero-emission medium and heavy trucks in the Nordic countries. Market share in new vehicle sale, total numbers and share of total stock. *Biogas (methane) includes both natural gas and biogas. (ACEA, 2019) (Trafikanalys, 2020) (ACEA, 2020)*

Example: the port of Gothenburg will introduce charges to encourage truck and ship traffic to adopt fossil-free fuel

The Port of Gothenburg, together with AB Volvo, Scania, Stena Lina and the Swedish government, has initiated a project that aims to reduce carbon dioxide emissions by 70 per cent by 2030. Included in the emissions are those from the port´s own operations, but also emissions from both ships and truck traffic entering the port.

The Port of Gothenburg will establish the necessary infrastructure and access to alternative fossil-free fuels for heavy vehicles. AB Volvo and Scania will guarantee that there will be access to fossil-free heavy trucks. Stena Line, on the other hand, will guarantee that electric ships will be put into service with Gothenburg as base.

To stimulate the transition, a bonus / malus system regulating access to the port is planned. (Guthed, 2020)

Development of the light truck segment is more uneven in the Nordic countries, but in general it remains at a low level. Norway in particular has a higher share of zero-emission vehicles in new vehicle sales at about 5 per cent. In Sweden, more biogas-fuelled light commercial vehicles are sold than electric and plug-in hybrid ones. Even in this segment, targeted instruments are needed to increase demand and control. For example, cities should set requirements for zero-emission vehicles when procuring transport services. This which also will be compulsory in 2021 according to the Clean Vehicle Directive (EU Clean vehicle directive, 2019).

LIGHT COMMERCIAL VEHICLES				
Country	**Type of vehicle**	**Market share new vehicles 2019, %**	**Total stock 2018**	**Share of total car stock 2018, %**
Denmark	Battery electric	0.8	761	0.2
	Plug-in hybrid	1.4	1,521	0.4
	Biogas*	0	0	0
	Total	2.2	**2,282** of 380,350	0.6
Finland	Battery electric	0.4	2 279	0.7
	Plug-in hybrid	0.1	0	0
	Biogas*	0.4	1,302	0.4
	Total	0.9	**3,581** of 325,622	1.1
Iceland	Battery electric			
	Plug-in hybrid			
	Biogas*			
	Total	No data	No data	No data
Norway	Battery electric	5.3	5,547	1.1
	Plug-in hybrid	0	0	0
	Biogas*	0.1	504	0.1
	Total	5.4	6,051 of 504,361	1.2
Sweden	Battery electric	2.6	2,636	0.04
	Plug-in hybrid	0	0	0
	Biogas*	2.2	9,144	1.4
	Total	4.8	**11 808** of 656,052	1.8

*Table 7: Zero-emission light commercial vehicles in the Nordic countries. Market share in new vehicle sale, total numbers and share of total stock. *Biogas (methane) includes both natural gas and biogas. (ACEA, 2019) (Trafikanalys, 2020) (ACEA, 2019)*

Another effective tool to stimulate a higher share of zero-emission light commercial trucks would be to introduce a selective zero-emission zone for light commercial vehicles in a certain area. This is now being planned in Amsterdam. Oslo has tried to implement something similar but for legal reasons was forced to abandon the attempt. As mentioned above, such measures require legal adjustments in all Nordic countries.

A selective zero-emission zone for light commercial vehicles exclusively could serve several purposes. On the one hand, a transition to zero-emission vehicles is speeded up, but in addition, groupage and consolidation operations will be leveraged and more efficient goods handling reinforced. This is due to the current trend of more and more light transport vehicles together with increasing e-commerce and a customer preference for fast deliveries. These trends can cause problems for the coordinated delivery systems that have already been built up by the larger suppliers who, among other things, use heavy truck transports to be able to offer a high degree of groupage (Behernds, 2020). By increasing the environmental requirements for light transport vehicles that do not have the same opportunity for groupage, existing grouped flows in cities will be given a competitive advantage.

Cities can also further facilitate the use of coordinated delivery systems by providing space for smaller transhipment terminals. Carriers who want to utilize the micro-terminal as a transhipment point and depot, undertake to receive deliveries from third parties and include these in their own deliveries, these may be from small suppliers who cannot afford to buy new vehicles (Behernds, 2020).

9 Concluding remarks

One current issue is the extent to which local measures at city level play a role when it comes to increasing the proportion of zero-emission vehicles in relation to national and European actions. The European legal standards for emissions from new light and heavy vehicles sets a floor on the level of carbon dioxide emissions generated by the sale of new cars. In practice, these requirements become strongly governing for the sale of zero-emission vehicles within the EU. In addition, the European Clean Vehicle Directive (see Chapter 5) will have an impact on vehicle purchase in municipalities and other public actors. One interpretation of this may then be that national and local instruments only distribute a fixed number of zero-emission vehicles within the EU-market. The Swedish Bonus-malus system has been criticized in this regard for harmonizing poorly with EU rules, as according to economic theory, extra subsides are not necessary in a regulated EU-market. A national system that rewards increased sales of low-emission vehicles such as zero-emission vehicles can lead to car manufacturers instead selling more cars with higher emission levels in another member state (Konjunkturinstitutet, 2019).

In the short term, it may be true that city and national climate measures only redistribute emissions within levels set by the EU. But over time this is an overly static assessment of the way in which environmental policy is shaped between actors at local and national levels in interaction with the EU. One reason for this is that European cities have in recent years become actively involved in climate issues. Joining forces in different constellations and organizations with clear ambitions and proposals for action, local and regional ambitions and policy packages have had a pronounced influence on the EU´s efforts to among other things set goals and determine the funding of research and environmental projects.

This can be exemplified by *Viable Cities*, a collaboration between eight Swedish cities that have expressed ambitions to take a lead in testing and experimenting with ways of becoming climate neutral by 2030. These cities want to apply collective approach to the financing of climate investments and prepare for future EU programmes, especially those addressing climate change at city levels, for instance the "*EU Mission for Climate Neutral Cities*" (*Viable cities*, 2020-11-19). Another collaboration between cities which are focussing on climate is *The Covenant of Mayors for Climate & Energy*. This organization was launched in Europe in 2008 with the ambition of gathering local governments or cities desirous of both achieving and exceeding EU climate and energy targets. *The Covenant of Mayors* now has more than 100 member cities from the Nordic countries (Covenant of Mayors for Climate & Energy, Europe, 2020).

A further reason why the contributions and ambitions of cities are important could be that local initiatives provides an opportunity for companies, organizations and research institutions to utilize the city as a test arena or living lab. This is especially apparent when it comes to the introduction of zero-emission vehicles, where both old and new stakeholders need to cooperate if it shall be possible to accelerate the pace of introduction. An example of this, mentioned earlier in this report, is the Electricity project in Gothenburg, which has paved the way for the single largest procurement of electric buses in Europe.

Finally, the cost of measures taken to reduce the climate impact of traffic also needs to be assessed in the context of incidental benefits, such as those of health, reduced emissions and increased land values. According to a recent study, policy makers tend to focus overmuch on the costs of climate action in isolation, while additional benefits in terms of reduced climate change costs are commonly overlooked. This is highlighted as a clear obstacle hindering the implementation of the policies and measures required to meet climate goals (Karlsson, Alfredsson, & Westling, 2020).

All in all, this means that cities are judged to play a central role in the transition to a climate-neutral transport sector. As climate goals are tightened, it will become increasingly important for actors and stakeholders at all levels to ramp up their efforts.

Appendix – An introduction

During the project, facts were collected around policy instruments and measures that can be implemented in the Nordic countries to accelerate the introduction of zero-emission vehicles. These fact findings are listed in the following appendices.

The appendices provide a compilation of the information that emerged during the project´s interviews, study visits, literature searches, reference groups and the own analyses of the report authors.

Many of the conclusions and recommendations in the main report are based on the factual basis set forth in the appendices. The appendices consist of the following parts:

- Appendix 1. Environmental and zero-emission zones
- Appendix 2. Traffic fees
- Appendix 3. Summary of zones and fees in Nordic cities
- Appendix 4. Vehicle taxes
- Appendix 5. Access to bus lanes
- Appendix 6. Parking benefits
- Appendix 7. Public charging infrastructure
- Appendix 8. Public procurement
- Appendix 9. Other municipal measures
  - Zero-emission vehicles in the municipal fleet
  - Managing zero-emission vehicle targets
  - Cooperation with other actors
  - Pilot projects and testbeds
  - Promotion of zero-emission taxi vehicles

Appendix 1. Environmental zones and zero-emission zones

The map below presents an overview of cities with traffic restricted zones in the Nordic countries in 2019 (Urban Access Regulations in Europe, 2019). In appendix 3, there is also a figure with a summary of zones, tolls and congestion charges in Nordic cities.

Appendix 1, figure 1. Map over low emission zones in Nordic cities. Source: (Urban Access Regulations in Europe, 2019).

There are mainly five different types of environmental zones as follows:

- Low emission zone, for heavy-duty trucks
- Low emission zone, for light and heavy-duty vehicles

- Zero-emission zone
- Pollution emergency zones
- Studded tires restrictions zone

Improved air quality is the key driver behind environmental zones and can be achieved by designing the regulations in a way that targets certain characteristics of the vehicle, such as fuel type, engine type, vehicle weight or tire type. The environmental zone can also be designed with prudent geographical limitations in combination, possibly with certain time restrictions or for some vehicle types. The time period may be unvarying such as during certain periods on weekdays, or only activated when a certain situation arises.

The environmental zone's rules, geographical extent and total size relative to the entire urban area or in the absolute sense also give rise to some unintended side effects. How these side effects occur, is directly influenced by the zone rules design and geography, but also by external factors such as the city's structure, traffic system, population density, population income level and distribution etc. The side effects can be classed as positive, negative or neutral, depending on whether the starting point is environmental considerations, mobility/accessibility, socio- economy, social distributional effects, etc. and the judgement can be considered as more or less subjective.

Overview of Nordic countries

In Sweden, the legal framework comprises three different concepts that correspond to three different "classes" of environmental zones (Transportstyrelsen, 2019). Class 1 zones have been implemented in Sweden in different cities since 1996. Class 2 and 3 can be introduced from 2020 (Transportstyrelsen, 2019). Class 1 has restrictions for heavy duty vehicles. Class 2 has restrictions for heavy duty and light vehicles. Class 3 allows only zero-emission vehicles. Denmark has national regulations for environmental zones that implemented in four cities that are similar to the Swedish class 1. Norway has no environmental zones strictly speaking but has implemented environmentally differentiated road tolls in some cities. Finland has only a limited ban of buses and garbage trucks in Helsinki. Iceland has no such zones.

Researchers have identified several determining factors for the effectiveness of a low emission zone, with respect to change in the vehicle fleet composition. This depends on several key variables; (Transport & Environment, 2019):

- **Territory covered:** Size is an important factor because it determines the number of residents who will be directly impacted, and which parts of the vehicle fleet will be concerned.
- **Level of stringency:** More restrictive zones that only allow the cleanest vehicles into the city center are driving much of these results.
- **Enforcement of policies:** Proper enforcement and penalties are key issues; low emission zone infringements are reduced considerably when a city starts to fine people. Controlling foreign vehicles is equally important for effectiveness and public acceptance.

- **Exemptions granted to users:** Exemptions for certain groups or types of vehicles are important considerations but these should be granted carefully and follow a strict timeline.
- **Clarity and predictability of policies:** A clear and predictable schedule must be established and communicated to the public and tourists. Consulting stakeholders has also been identified as a key to the acceptance and effectiveness of a low emission zone. (Transport & Environment, 2019).

Low emission zones for heavy duty vehicles

Introduction and usage in the Nordic countries

A low emission zone for heavy duty vehicles is a defined geographical area within a city which regulate access for heavy duty vehicles with emission levels above a given threshold. It is used to exclude the most polluting heavy-duty vehicles from sensitive areas of the city in order to improve local air quality. The concept assumes that the emission control technology of vehicles, namely of regulated emissions such as nitrogen oxides and particulates, has significantly improved over time, mainly driven by technological advances and European emission standards. Older vehicles with lower than current Euro-emission standard, e.g. Euro IV, Euro V, generally emit significantly higher amounts of pollutants per km than vehicles that fulfil higher emission standards, e.g. Euro VI (Dieselnet, 2019). By banning the most polluting heavy-duty vehicles from sensitive inner-city areas, emission from heavy duty vehicles can thus be reduced while the restrictions only affect a limited number of vehicles.

A low emission zone class 1 for heavy-duty vehicles called Miljözon, was pioneered in Sweden and introduced in 1996. The measure is currently implemented in Stockholm, Göteborg, Malmö, Mölndal, Uppsala, Helsingborg, Lund and Umeå. The decision to introduce a low emission zone and in what geographical area is determined by the municipality. It generally covers central parts of cities; adjacent highways are not included.

The purpose of environmental zones is to improve the air quality in an area and the criteria that specify which vehicles may and may not drive within the zone are based primarily on the engine's Euro class. The municipality decides on the actual geographical area of the low emission zone, as well as on dispensations and certain exceptions. The legal framework is provided on a national level in Trafikförordningen (1998:1276). Euro V and EEV vehicles can be driven until 2020. For vehicles that fulfil Euro VI or better emission standards, there is currently no limitation for entering the low emission zone class 1 (Transportstyrelsen, 2019).

In Denmark, a low emission zone for heavy-duty vehicles was first introduced in 2008 and is called Miljøzon. The measure is currently implemented in København, Frederiksberg, Aalborg, Aarhus and Odense. The geographical area is decided by the municipality and is legally based on changes in the national environmental legislation introduced in 2006 (EcoSticker, 2019).

A vehicle must comply with Euro IV emission standards (or above) or have a certified particulate filter fitted if it is permitted to drive with the low emission zone. The Danish

government has under 2019 decided to update the demands for environmental zones. From July 2020, diesel powered heavy-duty buses and trucks need to be registered on October 1, 2009 or later to be allowed into the zones, from 2022 only vehicles registered on January 1, 2014 or later will be allowed. Alternatively, the vehicle can be retrofitted with a certified particulate filter. For distribution trucks, slightly less stringent rules are applied. Exemptions can be granted, but only temporarily (Miljøstyrelsen, 2019).

Norway has road tolls and in two cities, the road tolls are differentiated by emission class.

An introduction of low emission zone called "concept 1" for heavy trucks in Oslo was evaluated in 2016 (Kåstad Høiskar, Sundvor, & Vogt, 2016). This was intended to ban heavy trucks that not fulfil Euro VI. A vehicle not complying with the rules will pay a fee of 300 NOK/day. However, this concept has so far only been evaluated and not enforced.

In Finland, a low emission zone for heavy duty vehicles has been implemented in Helsinki since 2010 (Soot free for the climate, 2019). It applies to buses and garbage trucks. For buses, vehicles must comply to Euro III emission levels to be allowed to operate within the low emission zone, for garbage trucks to Euro V (Urban Access Regulations in Europe, 2019).

Iceland has no such current zone.

Effects on carbon dioxide emissions

To date, the introduction of low emission zones has not led to any measurable impact on traffic related emissions of carbon dioxide. This is understandable as the emission zones are introduced from an air quality perspective. A forward looking study on the future impact of different versions of low emission zones in the case of Göteborg indicated a minor *increase* of -emissions of carbon dioxide due to the introduction of a low emission zone for heavy duty vehicles given currently known emission reduction technology (Koucky & Partner, 2015).

In Norway, according to an evaluation of a theoretical low emission zone for heavy duty vehicles (concept 1, see above), concluded that the studied low emission zone would contribute to a reduction in carbon dioxide emissions of 2 per cent (Kåstad Høiskar, Sundvor, & Vogt, 2016).

Effects on air quality

The impact a low emission zone for heavy duty vehicles has on air quality depends directly on the contribution to pollution levels from the targeted vehicles. Subsequently, how the zone will influence the vehicle fleet composition towards cleaner vehicles, and potentially reduce the traffic volume. This will then further rely on several factors such as the size of the zone and how strict the limitations are. To have a significant effect on air quality, the targeted vehicle group needs to be a significant source of local pollution (Amundsen & Sundvor, 2018). Evaluation studies from Denmark and Sweden show that the zones have altered the composition of the vehicle fleet and hence reduced emission from the targeted vehicle groups.

The Stockholm a low emission zone has been in operation since 1996, and its impact was extensively reviewed in 2000. The levels of $PM_{0.2}$ (mass of particles < 0.2 μm) have been

estimated. These are some of the smallest particles that are of most concern to health. Since diesel particulate exhaust emissions are all $PM_{0.2}$, they are reduced by the low emission zone. The zone area reduced concentrations of $PM_{0.2}$ by 0.5- 9 per cent , if all vehicles had been fully compliant, the reduction would have been 0.5 - 12 per cent (SLB Analys, 2000).

A study over the impact of the Stockholm low emission zone from 2008 calculated that during 2007 levels of local emissions were reduced by 3-4 per cent for nitrogen oxides, 16-21 per cent for hydrocarbon with and 13-19 per cent for particles, due to changes in the vehicle fleet, compared to a reference fleet. Vehicles registered in the municipality of Stockholm were younger in general, compared to vehicles registered in Stockholm County. To what extent these reductions of emissions of heavy-duty vehicles contributed to reduced concentrations of pollutants on a street level was, however, not estimated (Trafikkontoret, Stockholm stad, 2008).

In a forward-looking study on the future impact of different versions of low emission zones in the case of Gothenburg, it is calculated that the current low emission zone in Göteborg (requiring Euro V until 2020, Euro VI from 2020) leads to the following reductions within the zone compared to a scenario without any regulation; nitrogen oxides: –28 per cent in 2020, –10 per cent 2025 and –4 per cent in 2030, compared to 2015. For particulate matter PM10, the corresponding figures are –2 per cent, –1 per cent and 0 per cent. The results clearly indicate that the low emission zone was responsible for the largest reductions in the immediate years after the introduction but that the effect compared to the impact of the naturally occurring upgrades of the vehicle fleet diminished rapidly over time. The findings further support the conclusion that the impact of a heavy-duty low emission zone on total traffic emissions is strongly dependent on the contribution of heavy-duty vehicles in certain emission categories (Koucky & Partner, 2015).

Street level concentrations are highly dependent of background levels, weather and wind conditions and other factors. This is supported by international studies, e.g., studies over the impact of a low emission zone for heavy-duty vehicles on ambient air pollution in Dutch cities that shows that it is difficult to link changes in local ambient air quality to the introduction of a low emission zone. An exception was the concentration of fine particles (PM2,5) where more significant reductions could be measured (Boogaard et al., 2012). Tightening of today's low emission zone class 1 greatly improves air quality if the traffic work is unchanged, and in Stockholm the fleet becomes cleaner which means both the European and Swedish Environmental quality standard for nitrogen dioxide will be achieved by 2022 (Stockholm Stad, 2018).

An evaluation of the impact of the Danish low emission zone on air quality at street level was carried out in 2011, using a combination of air quality measurements, dispersion modelling and registration of vehicle number plates. The results indicate that the low emission zone requirements have led to a reduction of 12 percent for fine particles (PM2,5) in relation to the street contribution and about 5 per cent in relation to the street concentrations at H.C. Andersens Boulevard in København during the period January 2, 2008 to December 15, 2010. Calculations of the impact of the low emission zones at selected streets in København, Aarhus, Odense and Aalborg in the same study show that the low emission zones reduced annual levels of $PM_{2.5}$ and PM_{10} slightly and NO_2 somewhat (Jensen, Ketzel, Nöjgaard, & Becker, 2011).

In Aarhus, the rules have not been updated for ten years (Euro IV was allowed from 2005). The zones will be updated with new regulations in 2020 and Euro V will then be required for heavy vehicles (and light trucks but Euro 4), and from 2022 Euro VI for heavy vehicles (and light trucks Euro 5). The new regulations that include both heavy vehicles and light trucks, will reduce the emissions of nitrogen oxides with 5 per cent and of particles with 25 per cent respectively in Aarhus (Svanborg & Nielsen, 2019).

In Oslo, concept 1 would result in a reduction in annual emissions of nitrogen oxides by approximately 9 per cent in 2018. The low emission zone would contribute to reducing the annual average concentration of nitrogen dioxide NO_2 by 5-10 per cent near traffic roads, and the number of people living in areas with annual mean values above the threshold would be halved (Kåstad Høiskar, Sundvor, & Vogt, 2016).

In summary, environmental zones for heavy-duty vehicles can have some, although limited impact on local air quality in cases where:

- Heavy-duty vehicle traffic is a significant source of local emissions and
- the regulations are strict enough to significantly reduce the proportion of the vehicles with low emission standard in the zone (currently below Euro VI)

The impact of the regulations is most significant in the beginning subsequent to introduction. Over time, the difference compared to the improvements that would occur naturally due to the renewal of the vehicle fleet, diminishes if the regulations are not gradually tightened.

Effects on mobility and accessibility

The city of Göteborg, Sweden, undertook a survey among hauliers and suppliers on their perception of low emission zones. It was fairly positive, with 21 percent of respondents giving the low emission zone a good overall rating, 28 percent fairly good, and only 20 percent a negative rating, despite the effect of the low emission zone on their business operations (Transportstyrelsen, 2019).

Socio-economy and distributional effects

The socio-economic impact of the low emission zone for heavy vehicles in Göteborg was evaluated in 2004. The study monetarized the estimated reduction of emissions and compared the benefits with costs of control, implementation and costs to vehicle owners, e.g., premature fleet renewal. The results showed that the measure had a positive socio-economic impact, if the emission reduction that was expected outside the zone also was included. However, the results of the study were highly dependent on the expected total reduction of emissions (in kg nitrogen oxides or particulates), the assumed negative monetary value of these emissions and the assumed costs for implementing the low emission zone (Göteborg stad, 2004).

Low-emission zones for light duty vehicles

A low emission zone for light duty vehicles is an area within a city to which all vehicles with emission levels above a given threshold are prohibited to enter. It is used to exclude the most polluting vehicles from sensitive areas of the city in an effort to improve local air

quality. Thresholds are usually set based on the emission categories of the vehicle (Euro-class) and compliance is controlled through registration data.

Presence in Nordic countries and Europe

The only Nordic country that currently has low emission zones for passenger cars is Sweden. On one street in central Stockholm, *Hornsgatan*, a low emission zone class 2 was introduced in January 1, 2020. The low emission zone is applicable to all cars, trucks and buses, including passenger cars, light buses and light trucks (Transportstyrelsen, 2019).

Low emission zones for light vehicles have been implemented in several other European countries, e.g., in Germany, Italy, The Netherlands and Portugal (Trafikanalys, 2015). Most commonly used are low emission zones in Germany where they currently have implemented in 58 cities (Umweltbundesamt , 2019).

The Swedish rules

To be entitled to drive within a Swedish low emission zone class 2, vehicles with both petrol and diesel engines must comply to emission class Euro 5 or higher. From July 1, 2022, requirements for cars with diesel engines will be raised to Euro 6. Exceptions can be made for vehicles used for certain specified services and purposes (Transportstyrelsen, 2019).

A study in Norway

A study was made in 2016 of an introduction of low emission zone for light duty vehicles in Oslo with two different concepts (called concept 2 and 3) which included diesel driven passenger cars (Kåstad Høiskar, Sundvor, & Vogt, 2016). A vehicle not complying with the rules would incur a fine. These concepts are just evaluated and not enforced.

- Concept 2: Bans heavy trucks below Euro VI and all diesel driven passenger cars and vans in *all of the Oslo Municipality*. Fee 300 NOK for heavy trucks and 25 NOK/day for light duty vehicles.
- Concept 3: Bans heavy trucks below Euro VI and all diesel driven passenger cars and vans *within the ring 3-area*. Fee 300 NOK for heavy trucks and 25 NOK/day for light duty vehicles.

Effects on climate gas emissions

A study on the potential impact of a low emission zone in Stockholm raises concerns that a wider introduction might lead to an increase of of carbon dioxide emissions due to a transition from diesel to petrol driven cars. This is mainly attributed to the feared misconception that the low emission zone prohibits all light diesel vehicles and that this could lead to a reduction in the sale of new diesel cars.

According to this study, complete transition from diesel to petrol in new car sales in Stockholm County alone would correspond to an increase of 5 percent of the carbon dioxide emissions from the transport sector, with an even greater predicted effect after 2030. A low emission zone could also affect the choice for new car buyers in the rest of Sweden, through expected decrease in resale values for used diesel cars, further increasing the negative climate effect. Therefore, the magnitude of the risk is dependent on how the communication of the rules for the low emission zone is managed (Stockholm Stad, 2018).

In contrast, a predictive study on the impact of low emission zones for light duty vehicles in Gothenburg (2015) indicates a reduction of (local) carbon dioxide emissions due to an accelerated renewal of the vehicle fleet and generally lower carbon dioxide emissions of newer vehicles. Within the low emission zone, reductions of 3-12 percent are predicted. However, on a larger scale far fewer reductions can be expected, since the replaced vehicles can be expected still be in use outside the low emission zone. In some areas they are expected to replace (even) older vehicles, thus contributing to an accelerated renewal of the total vehicle fleet (Koucky & Partner, 2015).

A study in Gothenburg (2010) evaluated different scenarios of introduction of a low emission zone for light vehicles. Emission reductions of carbon dioxide were predicted to occur in different scenarios with restrictions on diesel-powered cars. If petrol-driven cars are also covered by the same Euro-class, the reduction of carbon dioxide emissions was estimated to be around 2 percent (WSP, 2010).

In Norway, the evaluation of a low emission zone for light vehicle concept 2 and 3, see above, the low emission zone was predicted to contribute to a reduction in carbon dioxide emissions. Concept 2 showed a reduction of 5 percent, while Concept 3 should result in a reduction of 4 percent (Kåstad Høiskar, Sundvor, & Vogt, 2016).

To sum up, the impact of low emission zones for light duty vehicles on carbon dioxide emissions is uncertain. Some studies predict a slight increase of the emissions due to the replacement of diesel cars with petrol cars, while others indicate a slight reduction due to an accelerated renewal of the car fleet. This is mainly dependent on which vehicles will replace the cars no longer allowed into the low emission zone. If primarily diesel vehicles are replaced with petrol vehicles, the total carbon dioxide emissions could increase, especially if the low emission zone influences vehicle choice also outside the urban area. However, if the replacement consists of more fuel-efficient vehicles such as diesel cars that fulfil the emission criteria, electric or hybrid vehicles or highly efficient petrol cars, the carbon dioxide impact may be positive. The key factor seems to be whether the low emission zone is primarily perceived as a “diesel-ban” or whether it simply accelerates the renewal of the vehicle fleet.

Effects on air quality

Low emission zones that also include light duty vehicles are widely regarded as efficient tools to reduce local emission of traffic-related pollutants. During 2018, the Stockholm City Council carried out a special study to analyse the effects of several different possible designs of low emission zone class 2. According to the study, the expected impact in Stockholm is smaller than in cities with a large proportion of diesel cars. The measure is nevertheless considered to be one of the most powerful means of reducing emissions of exhaust particles and nitrogen oxides. However, the impact on particulates PM10 is considered to be insignificant (Stockholm Stad, 2018).

A predictive study was carried out in 2015 on the impact of a low emission zone for light duty vehicles in Gothenburg within the same boundaries as the current low emission zone for heavy duty vehicles. It indicated a reduction of 4-12 percent for nitrogen oxides and 1 percent for PM_{10} in 2020 (a reduction from the 2015 level of vehicle emissions), compared to the current low emission zone that only applies to heavy duty vehicles. For particulate emissions the impact was estimated to be a reduction of 10 percent for 2025, falling to 4 percent reduction by 2030. The impact of the new zone

compared to a scenario without it, will gradually be reduced over time, if regulations are not tightened, due to the general renewal of the vehicle fleet (Koucky & Partner, 2015).

Evaluations of the impact of low emission zones for light duty vehicles in German cities indicate that the measure has significantly contributed to the reduction of the most hazardous particle emissions (fine particles PM2,5) rather than to the reduction of bigger particles (PM10) or nitrogen oxides, even if the measure had a positive impact even on these emissions. However, since more than 90 percent of vehicles in Germany are allowed into the most strictly regulated low emission zone, it is concluded that the instrument in its current form no longer has any significant impact on air quality and that the criteria need to be tightened to allow further emission reduction (Umweltbundesamt , 2019).

In Norway, an evaluation has estimated that emissions of nitrogen oxides could be further reduced if a low emission zone also includes light diesel vehicles, within the Oslo municipality (concept 2) or within Ring 3 (concept 3) as described above. The same applies to annual mean values and the number of exposed persons. Concept 2 would give the best effect (Kåstad Høiskar, Sundvor, & Vogt, 2016).

To sum up, the low emission zones for light duty vehicles can have a significant impact on air quality, especially where the proportion of diesel vehicles is high. Existing studies indicate that the impact is most significant on emissions of exhaust-borne particle emissions but small on the total emissions of particulates (PM10). Also, the impact on Emissions of nitrogen oxides from transport is significant. The impact of the regulations is most significant in the beginning of its introduction. Over time, the difference compared to the improvements that would occur naturally due to the renewal of the vehicle fleet, diminish if the regulations are not gradually tightened.

Effects on mobility and accessibility

The simulation study of Norway from 2016 showed that traffic flow would decrease 1-3 percent for all of Oslo, depending on the chosen emission zone (Kåstad Høiskar, Sundvor, & Vogt, 2016).

The study in Gothenburg from 2010 showed that the proportion of old cars was highest in the low-income districts, while high-income districts had the lowest proportion of old vehicles. Thus, the low-income districts have a high proportion of vehicles that are potentially affected by a low emission zone. However, these do not necessarily have to operate in the low emission zone, since they mostly are located outside the city centre. The results showed that residents of the low-income districts seldom went by car to the low emission zones and would therefore be less affected. Instead, drivers living in the central (high-income) districts made the largest number of trips to a destination within the low emission zone (WSP, 2010).

Socio-economy and distributional effects

The costs of implementing a low emission zone for light duty vehicles, vary by municipality and the size the low emission zone. If the low emission zone only covers a small area, it can be easier for the municipality to run a more focused monitoring programme. However, the risk of a small low emission zone is that people choose to drive straight through without stopping or parking, and then the municipalities are not given the opportunity to monitor. If the low emission zone is a larger area, those who enter will

probably also stop or park more often and people who live or work in the zone, will to a greater extent choose to acquire vehicles that are permitted (Transportstyrelsen, 2019).

According to the study by the City of Stockholm, a Swedish low emission zone class 2 in the inner city will entail high socio-economic costs. Many residents will be adversely affected, while the benefits or profits are small. The socio-economic costs of a low emission zone class 2 in the entire inner city are estimated to be at least 10 times greater than the socio-economic benefits. For low emission zone class 2 on individual streets, the cost / benefit ratio is estimated to be around 12 (Hornsgatan), 18 (S: t Eriksgatan) and 25 (Sveavägen). Both cost and benefit calculations are subject to considerable uncertainty, but the study concluded that the cost to society is many times greater than the socio-economic benefits. The estimate does not include the potential costs for possible increases in climate emissions due to signal effects (increased petrol cars and reduced diesel cars). The costs for the vehicle owners' principally be due to the new low emission zone rules, vehicle replacements and new route choices (Stockholm Stad, 2018).

A low emission zone class 2 is estimated to exclude 150 million vehicle trips from Stockholm´s inner city in the period 2022-2030. The socio-economic losses in the entire inner city in the form of travel and transport bans are estimated to a total of SEK 10 billion during the same period. If an alternative method of calculation which involves dividing the prohibited vehicles into “frequent-riders” and “infrequent-riders”is used, a socio-economic loss of SEK 7 billion during the period could be expected. If low emission zone class 2 were to be introduced on individual streets, this would lead to adjustment costs for the vehicle owners for the prohibited vehicles of around SEK 120-240 million per street (Stockholm Stad, 2018).

The socio-economic calculations for a low emission zone class 2 assume full compliance. In the event of non-compliance, both adaptation costs for vehicle owners and health benefits will be lower, but the proportions between benefits and costs will be approximately the same (Stockholm Stad, 2018).

A low emission zone is widely considered to have negative distributional effects since the most affected (older) vehicles are generally owned by people with lower incomes than newer vehicles that fulfil the criteria of a low emission zone. According to the Stockholm study, 70 per cent of vehicles that would be banned in the low emission zone class 2 are owned by individuals. Owners of these older vehicles can be assumed to have lower incomes than owners of newer vehicles. Furthermore, the introduction of a low emission zone (class 2) could affect the secondhand vehicle market and thus redistribute wealth from owners of older vehicles to owners of newer. Owners of permitted vehicles would take over at least part of the street space previously used by prohibited vehicles. The owners of prohibited vehicles are thus affected partly by a reduction in the value of the vehicles and partly by either having to stop driving in the zone or having to replace their vehicle. On the other hand, the same effect will benefit buyers of secondhand vehicles living in regions that are not affected by the zone, profiting from lower prices. The introduction of a low emission zone therefore could have different distributional effects at a local and national level (Stockholm Stad, 2018).

In addition, companies are potentially affected by an introduction of a low emission zone class 2. If the zone is introduced at short notice, this might especially affect companies that have local transport activities. Smaller and local companies that use older light trucks are

more vulnerable to change and have limited opportunity to adapt by geographically redistributing their vehicle fleet. In addition, smaller companies may have less cash reserves, which are required for a changeover to permitted vehicles (Stockholm Stad, 2018).

The City of Copenhagen is not aware of any studies that evaluate socio-economic or distributional aspects of low emissions zones and they believe the accessibility and distributional effects should be relatively small. They recommend the national government to include passenger cars in the zones (Svanborg & Nielsen, 2019).

Zero-emission zones

A zero-emission zone is often defined as an area within a city which is restricted for all vehicles propelled solely by a combustion engine or using a combustion engine within the zone. It is used to exclude emitting vehicles to enter certain areas of the city to improve local air quality or promote climate friendly vehicles or technologies. But there are also definitions including vehicles using fuels with low climate impact.

Presence in Nordic countries

No zero-emission zone has yet been implemented in any Nordic country.
However, Sweden has passed regulations to allow cities to introduce close to a zero-emission zone, called low emission zone class 3, which will be similar to to a zero-emission zone. In low emission zone class 3 all battery electric cars and fuel cell vehicles are allowed, and light as well as heavy biogas vehicles if they apply Euro VI/6. Heavy duty plug-in hybrids may also run if the vehicle meets Euro VI emissions requirements. There are exemptions for certain vehicles (Transportstyrelsen, 2019).

Measures like establishing zero-emission zones and gradually expanding and these will then require new legislation in Denmark (Gudmundsson, 2019).

Recommendations from interviews

A mobility expert was interviewed and pointed out many possible complications with a restriction that would ban most existing passenger cars. A low emission zone levies a fee that is equal to the purchase cost of an electric vehicle. The difficulty here is that electric cars are expensive. Complementary measures such as improved public transport facilities especially for commuting to the zone are better than a zero-emission zone and could be implemented as an alternative. But a zero-emission zone has a negative impact on commuting and therefore it is especially important to compensate by providing good public transport. Congestion charges or tolls might be a more suitable way to promote the use of zero-emission vehicles (Brundell-Freij, 2019).

The political view in Aarhus on environmental zones is unclear, but a decision will soon be made as to whether existing zones are to be kept or not. However, it seems unlikely that politicians would regard environmental zones as a way of introducing zero-emission vehicles. Demands for these zones are being discussed in parliament, but so far earlier attempts to set up toll roads around Aarhus have been roundly rejected. Previously the municipality was permitted to remove the existing zones, but now the national government must decide on this. Vehicle owners who want exemption from environmental zone regulations must apply for a permit nationally, and municipalities cannot grant exemptions (Svanborg & Nielsen, 2019).

Other vehicle restrictions

In addition, there are other types of restrictions that can be applied or used as an alternative to environmental zones. For example, access can be restricted to certain hours of the day, for certain vehicles or trips, together with other specific circumstances, vehicle type, vehicle weight, type of trip (e.g., deliveries), resident or similar. These regulations are known as *Traffic Restrictions, Limited Traffic Zones, Access Restrictions, Permit Schemes* etc. Generally, pedestrian areas or parking schemes are not included in this category (Urban Access Regulations in Europe, 2019).

Temporary diesel ban

Some cities in Europe impose special emergency traffic restrictions in times of high pollution. These restrictions can for instance be a temporary ban on diesel-powered passenger cars, vans, buses and lorries that do not meet a certain euro-class. The city can also close certain municipal car parks.

Among the Nordic countries, only Oslo and Bergen in Norway use these kinds of restrictions. The City of Oslo can impose a temporary ban on diesel vehicles on days with a high level of pollution. Such a ban is introduced when there is a risk that the average hourly concentration of NO_2 exceeds 200 μg/m3 in a larger area for two days in a row or more. The ban must be communicated 24 hours before it is introduced and applies between 06 AM and 22 PM the inner city of Oslo (Stockholm Stad, 2018). The ban is initiated by the city of Oslo and is only valid on municipal roads (not state roads), and all roads inside the inner-city ring (Ring 2) and some inside the outer city ring (Ring 1). The diesel ban is not activated during nights (Oslo Kommune, 2016). The penalty is 1 500 NOK.

All diesel driven cars, light duty trucks, heavy duty trucks, and buses are prohibited with the following exceptions (Oslo kommune, 2019):

- Heavy Euro VI trucks
- Diesel plug-in hybrid electric cars with an electric range of at least 40 km
- Vehicles used for commercial purposes
- Disability and patient transports
- Emergency vehicles
- Vehicles used in public service or public transport
- Driving home from a ferry terminal and airport when the car was parked prior to the ban, or using a rental car when the rental agreement was made before the ban
- To or from a funeral service

As complementary measure for these days, buses and light rail in the county may be free of charge to make it easier to use public transport (Urban Access Regulations in Europe, 2019).

It is expected that the measure will result in a reduction of nitrogen oxides emissions of 20-25 percent compared to a normal situation concerning nitrogen oxides for the whole of

Oslo. However, it is difficult to estimate reductions in concentrations of nitrogen dioxide NO_2, as this depends on numerous factors such as local conditions, weather, etc. (Bymiljøetaten, 2016).

The costs to the public, business and road users are estimated to exceed benefits derived from reductions in environmental and health costs. In view of the consequences that the loss of trips of trade and services may have, and for employers and employees, one must consider that other means of transport can be an option (public transport, walking, cycling) (Bymiljøetaten, 2016).

Temporary ban odd-even license plate scheme

Increasing road tolls or introducing an odd and even license plate scheme can be implemented on days with risk for high pollution (contingency tolls) (Urban Access Regulations in Europe, 2019).

Icelandic municipalities are able to limit or temporarily ban vehicular traffic to reduce pollution levels from January 2020. The municipalities will be permitted to ban or limit traffic when air pollution levels are high or risk becoming high, particularly on dry winter days. Particulate pollution in the Reykjavík capital area has exceeded safe limits 14 times, and of nitrogen oxides three times during 2019 (Icelandic Review, 2019).

Bergen municipality has the option to enforce a temporary car ban when there are high levels of air pollution (nitrogen dioxide NO_2 or particulates PM). The ban is an odd-even traffic scheme which bans car from driving in the city depending on the last digit in their number plate and the date[1]. This is also valid for state roads and is combined with free public transport. Zero-emission vehicles and utility vehicles are exempted from the ban. The temporary ban is valid between 06 AM to 22 PM on weekdays. The odd-even number plate scheme has been used only on two days. This policy measure is used as an alternative to the temporary raised road tolls (Bergen Kommune, 2019).

In an evaluation of the impact of the odd-even traffic scheme in Bergen, toll passages decreased with 15-16 percent during the period when the odd-even scheme was enforced 2016, compared to the same period in 2015. This decrease is in the same level as previous experiences in 2010 when traffic was decreased by 14,5 percent (Bergen Kommune, 2016).

Temporary raised road tolls (not enforced)

Bergen is able to temporarily raise road tolls, five times the normal fee, on days with high levels of air pollution (nitrogen dioxide NO_2 or particulates PM). Zero-emission vehicles are *not* exempted from road tolls in general except in some areas. This measure is also valid for state roads and is combined with free public transport during the temporarily raised tolls (Bergen Kommune, 2019).

During periods of fivefold tolls, public transport will be free of charge. This will most likely increase the number of trips made using public transport and increase the cost, which should be financed by the road toll company (Bergen Kommune, 2016).

Compliance of zone restrictions

Evaluations of low emission zones often assume full compliance. There are significant gains to be made investing in measures to improve the level of compliance in low

emission zones. For example, the concentrations of nitrogen dioxide in Stockholm inner streets would be about 10 percent higher in a situation with full compliance (Stockholm Stad, 2018). In addition, increased compliance result in improved accessibility and better parking access in the low emission zone (Transportstyrelsen, 2019).

There have been further efforts in Stockholm to reduce the number of illegal vehicles that do not meet the emission standards in the low emission zone. Illegal vehicles are now less than 5 percent of the total entering the low emission zone and the contribution of emissions from illegal vehicles has been reduced (Urban Access Regulations in Europe, 2019).

A challenge for enforcing compliance in Sweden is that the driver is responsible, not the owner of the vehicle. In Sweden the only penalty legally possible is a monetary fine (Stockholm Stad, 2018), as there are no legal obstacles in Sweden to impose a penalty charge instead of punishment that the owner is obliged to pay. One prerequisite for this is that driving an unauthorized vehicle in a low emission zone is decriminalized. A review of examples of low emission zones in other countries in Europe, shows that penalties for the owner are the norm for low emission zone infringements (Amundsen & Sundvor, 2018). There seems to be no conflict with European criminal law principles (Stockholm Stad, 2018).

Currently it is only possible to monitor the vehicles in a low emission zone in Sweden when they are being driven and only the police have the authority to do this. If it also would be forbidden to stop or park in low emission zone in public places, monitoring could be done by the municipality. Since the municipalities have a self-interest in ensuring compliance in low emission zone, they would probably prioritize this surveillance. The existing parking monitoring system can be applied, and violations could be subject to a fine. However, these proposals may require changes to the law (Transportstyrelsen, 2019).

There is a clear correlation between the degree of traffic surveillance and the level of compliance. A similar outcome can be expected for future low emission zones that include light vehicles, even if the regulation largely affects another road user group. Costs may vary between different municipalities and the size of the low emission zone (Transportstyrelsen, 2019).

In the study, two other regulatory alternatives for compliance were considered, but were seen as "not realistic" (Transportstyrelsen, 2019);

- *Decal alternative*. The vehicle owner must have a decal on the front window stating that it is allowed in the low emission zone, which entails extra work and costs. It would be difficult to choose a specific decal for exceptions.
- *Monitoring by geofencing*. This is expected to take many years and only new vehicles can be monitored. This means that problems with poor air quality will probably be overplayed. The technology would most likely violate the EU-common basic rules on free movement of products and services.

Appendix 2. Traffic fees

Introduction

A congestion charge or road toll is an instrument applied to vehicles when entering an area that invokes a payment (Urban Access Regulations in Europe, 2019). The area is normally surveyed by cameras that register the vehicle identity, but some systems can also be accessed by manual payment.

The purposes of this instrument might be to finance infrastructure, reduce congestion or traffic in a city, or improve air quality and noise levels. The ways the pricing is differentiated may mirror the purpose of the schemes. The most common parameters for pricing are time periods, vehicle type (heavy/light), emission class (Euro) and fuel technology (for instance electric/other). If the price differentiation is with respect to time, it can be called "congestion" charging (toll or tax) since the target normally is to reduce the congestion in certain hours of the day. If the price differentiation is set with respect to fuel technology or emission class, the purpose is normally to improve air quality, noise or to promote a certain vehicle technology. Zero-emission vehicles can totally or partly be exempted from fees and serve as an incentive to promote their introduction.

In this report, the term *Road toll* is used for a system like that used in Norway, which is determined by the municipality. The term *Congestion charges* is used for a system like in Sweden, where the fee is a national tax and consequently decided by the national parliament, but in practice designed in collaboration with local governments, and the restricted area is decided locally. Table 1 below shows existing road tolls and congestion charges in Nordic countries. In appendix 3, there is also a figure with a summary of zones, tolls and congestion charges in Nordic cities.

Appendix 2, table 1. Table over cities in Norway and Sweden with road tolls or congestion charges. The table shows which parameters determine the fees charged.

Country / *City*	Fee parameters				
	Vehicle type	Time	Fuel/ Technology	Emission class	Geography
Norway					
Oslo	X	X	X	X	X
Bergen	X	X	X	X	
Trondheim	X	X	X		
Stavanger		X	x		
Tornsberg	X		X		
Haugesund	X		X		
Kristiansand	X	X	X		
Sweden					
Stockholm	X	X			
Göteborg	X	X			

Road tolls in Norway

The purpose of road tolls in Norway is to finance infrastructure such as bridges, tunnels etc. (Bisek, 2016). Multiple cities enforce the road tolls, but only a few have environmental differentiation of the fees, where the level of fee is determined by the vehicle's emissions. Hence those who pollute the most also pay the most at the toll point (Ferde, 2019). The cities of Oslo and Bergen have similar schemes, but these are designed differently (Fjellinjen, 2019).

In Oslo, the road tolls are differentiated by time, vehicle type, fuel-technology and geographical categorization. There are three toll rings: the inner ring, the Oslo ring and the city ring. Diesel cars are charged a slightly higher fee than petrol cars. The fee is also a congestion fee that is higher in rush hours. Zero-emission vehicles used to be exempted, but from June 2019 there is a new system, where they are charged approximately 30 percent of the fee in rush hours and 20 percent at other times (Fjellinjen, 2019). Bergen introduced differentiated road tolls in 2018 and costs vary with time and vehicle type, fuel type/technology and emission class. All vehicles are included with the exception of motorcycles, that only pay for the Atlanterhavstunnelen (a tunnel) and on ferries. Zero-emission vehicles were previously exempt, but this ceased in 2017 (Urban Access Regulations in Europe, 2019).

Although heavy zero-emission vehicles are exempt in both Oslo and Bergen, light zero-emission vehicles are not (Urban Access Regulations in Europe, 2019). Other exemptions in both Oslo and Bergen are; residents with registered parking cards, who can use the toll roads, bikes and pedestrians, service vehicles form Norwegian Public Roads Administration, hearses, public transport, emergency vehicles, drivers with reduced mobility (municipality-issued parking permit). The system is a cordon scheme, charges are incurred when crossing into the area, enforced with cameras at the entrance to the scheme through Automatic Number Plate Recognition.

Owners of battery electric cars pass toll road gates on the way to work twice as often as owners of conventional cars and plug-in hybrids. 63 percent of battery electric cars users pass toll gates, but the share has gone down since 2014 when 70 percent did (Figenbaum & Kolbenstvedt, 2016). Between 2016 and 2018 the value of exemption from road tolls increased 21 percent. The value of toll road exemption accounted for 65 percent (increased from 49 percent in 2016) of the total economic value of all local battery electric cars incentives in Norway and is ranked as the highest (Figenbaum, Erik; Nordbakke, Susanne, 2019).

Free or subsidized ferry passages in Norway

Norway has several car ferries where a fee is required for both passengers and vehicles. Electric vehicles travelled for free between 1997 and 2017, and had free fares on certain routes, but this was decided on a regional level. Passengers still paid for a passenger ticket. Starting in 2018, the EV fee is reduced with up to 50 percent and varies depending on the ferry route.

On average, owners of battery electric cars save 580 NOK per year on reduced ferry rates, whereas owners of plug-in hybrid electric cars spend 500 NOK and conventional cars owners 740 NOK. Owners of battery electric cars are given an average rebate of 50 percent

(Figenbaum & Kolbenstvedt, 2016). There is little correlation between the value of ferry incentives and the share of battery electric cars in the fleet. This means that this is not the most important incentive for a higher battery electric car share (Figenbaum & Kolbenstvedt, 2016). It can be estimated that between 2016 and 2018 the value of reduced ferry rates increased by 20 percent. The value of time saved of reduced ferry rates accounted for around 5 percent (increased from 4 percent in 2016) of the total economic value of all local battery electric car incentive in Norway (Figenbaum, Erik; Nordbakke, Susanne, 2019).

Congestion charges in Sweden

When congestion charges were introduced in Stockholm in 2005/06, an exemption was implemented for zero-emission vehicles. The exemption from congestion charges was made for cars that were defined as zero-emission vehicle according to a Swedish law that by that time included all car models that were fueled by methane, ethanol or electricity. From 2009, the exemption was no longer valid for new cars that was registered from that year and forward, and from 2012 the exemption for zero-emission vehicles was ended. From 2013, congestion charges are also introduced in Göteborg, the second biggest city in Sweden.

Effects of zero-emission vehicle fleet

The tax exemption was considered to be the most important way of encouraging Stockholmers to buy more zero-emission vehicles. The composition of the fleet changed faster in Stockholm than in the country as a whole. The proportion of zero-emission vehicles increased from 3 percent in 2006 to 12 percent in 2008 at the toll gates, while the proportion of zero-emission vehicles of passenger cars registered in Stockholm increased from 5 percent to 14 percent. (SLB Analys, 2008). Recent surveys in Norway show that the most important reason for people to choose electric vehicles is discounts on road tolls (Allt om elbil, 2019).

Norway has road tolls in six cities, but the differentiation in price for low emission vehicles is small and not enough to improve the traffic flow in rush hours. However, in Oslo as in Stockholm, it was realized that such an exemption had a very big impact and was considered a very important incentive in the early years of electric vehicle introduction (Portvik, 2019). Electric vehicles have been partly exempted in Norway and were an important part of the package for the promotion of zero-emission vehicles. A significant effect on zero-emission vehicles sales in smaller municipalities close by larger ones has been observed in Norway's peripheral municipalities (Sprei, 2019) (Fridstrøm, 2019).

The exemption of zero-emission vehicles from congestion charges or road toll might conflict with other objectives as this can increase congestion and stimulate car driving. In Göteborg this strategy is avoided, because the city does not want to support car use in general (Sprei, 2019). The zero-emission vehicles will contribute to congestion without paying. Still it seems to work for the conversion of the fleet (Brundell-Freij, 2019) (Fridstrøm, 2019).

Effects on climate gas emissions

Emissions of fossil carbon dioxide in the Stockholm inner city were estimated to have decreased by about 8 percent 2006-2008 when the congestion charge was introduced. For the whole of Stockholm city, the reduction was about 4 percent (SLB Analys, 2008).

Effects on air quality

The biggest differences are seen in fossil carbon dioxide emissions, carbon monoxide (CO) and hydrocarbons. The emissions decreased faster than they would have otherwise thanks to an increased number of zero-emission vehicles. In the inner city of Stockholm, emissions of hydrocarbons and carbon monoxide were reduced by about 1/3 between (2006-2008), due to less petrol and more diesel and ethanol use. Emissions of nitrogen oxides decreased less, 13 percent, since an increase in diesel counteracted the reduction of emissions. The concentration of nitrogen oxides lowered 10 percent and carbon monoxide lowered 15 percent. Particulate matter (PM10) is lowered 15-20 lower with tax (SLB Analys, 2008).

For the whole of Stockholm city, the reduction of air pollutions was less because the traffic in general has increased. The changes in vehicle fleet composition of the city has resulted in large emission reductions for hydrocarbons and carbon dioxide, whilst the emissions of nitrogen oxides have decreased by only 8 percent in 2006-2008 (SLB Analys, 2008).

Effects on mobility and accessibility

Stockholm carried out a congestion charge trial in January-July 2006 and introduced a full-scale system in January 2007. Traffic volume fell during periods of congestion charges (SLB Analys, 2008). Traffic in the inner city of Stockholm has continued to decline.

When the congestion charge in Stockholm´s inner city was raised (an increase of 4-10 SEK), and introduced on the "Essinge passage" thoroughfare (0 to 11-30 SEK), traffic decreased about 5 percent and mobility improved. The effect on travel time was small, only 1 minute shorter. It is therefore likely that the improvement is not really appreciated by individual road users, partly because travel times vary greatly between days. In most sections the mean travelling time decreased about 5-10 minutes. At severe congestion the travel time per day was reduced by an average of 40 minutes. The number of passenger cars owned by private individuals decreased in the inner city, while company cars increased slightly, and for the thoroughfare there was an even more apparent difference between private and company owned cars. These road user groups often have lower price sensitivity than private owners as the drivers does not pay themselves. Truck traffic has also increased on the thoroughfare and in the city center, which mirrors the increased accessibility there (Trafikverket, 2016).

Trafikverket (2017) carried out a study on a theoretical expansion of the congestion charges to also include the suburbs of Stockholm. The study concluded that it would have a major positive impact on accessibility in large parts of Stockholm County. Some other roads are also expected to show an increase in traffic, because a new congestion charge system would redistribute traffic flows. A large part of the congestion was

expected to disappear or cease altogether and the greatest improvements in mobility were expected on the main roads (Trafikverket, 2017).

A pre-study of the emission effects of differentiated road tolls in Bergen indicated that the decrease in road traffic would be 10-15 percent in the city area, and 2-4 percent in the central city (K. Høiskar, Sundvor, Johnsrud, W. Haug, & Solli, 2017).

Environmentally differentiated road tolls are the major component of Oslopakke 3, which contains a number of policy measures to stem the increase of traffic in Oslo. The "pakkes" are designed to stabilize the number of car journeys and contribute to an increased use of public transport, and to promote biking or walking. To achieve this, public transport coverage has been jacked up, financed with the revenue generated by toll fees (Bymiljøetaten, 2017). The impact of Oslopakke 3 on traffic volumes show a decrease by 4 percent by 2020 as compared to a reference scenario. The decrease is greater in the central areas, and lower in outer areas. This is the effect of the full Oslopakke and not only the road tolls. In the long term, traffic is expected to decrease by 2 percent overall and traffic flow at the road toll cordon is expected to decrease by 13 percent (COWI, 2017).

Socio-economy and distributional effects

In Norway, road tolls contribute to the public coffers, even with the electric vehicle exemption and the free road tolls are the most valuable of the local incentives (Figenbaum & Kolbenstvedt, 2016). About 50 percent of the public revenue from road tolls in Trondheim finances road infrastructure and 50 percent finances public transport, which improves accessibility for the public (Trondheim kommune, 2018).

Eliasson (2016) evaluated whether the Swedish congestion charge is "fair" seen from a citizen and consumer perspective, by asking people in three Nordic cities (Stockholm, Göteborg and Helsinki) how they would vote in a hypothetical referendum. Adaptation costs (changed behavior) make up a small part of the total welfare effect (socio-economic effect), while the value of travel time reduction is more important. The results suggested that the number of tolls paid generally gives an indication of the total welfare effect. The way in which the revenues are used largely determines their impact on equity (Eliasson, 2016).

In Stockholm, the number of those who pay a lot in tax is low. In Gothenburg, the charge per passage is lower than in Stockholm, but a larger share of the population pays high amounts (there are also more who pay nothing). The total payments relative to income fall with increasing income (Eliasson, 2016).

The main difference between socioeconomic groups is that in Gothenburg, households with children pay more tolls than those without children. In Stockholm, men pay more than women, even when income is taken into account and the difference is larger for middle income groups. Differences between age groups and education levels are very small, even though the "oldest" group (>75) pays a little less. The only social issue where there is a clear difference in opinion between income groups is equity. Views on equity and support for congestion pricing are however not correlated in any of the cities and attitudes are almost the same in all income groups (except the lowest). The negative attitudes accelerate under a monthly salary around SEK 30 000 (around median level) and the effect becomes more apparent among those with lower incomes. Attitudes affect a

theoretical voting for congestion charges in the same way in different income groups (Eliasson, 2016).

Benefits from the systems generally increase with higher income. Payment in absolute terms increases with income except in the highest income class. The relative distributional effects from both citizen and consumer perspectives are similar regardless of the income group. The total effect when adding the two perspectives together (consumer- negative effects, citizen- positive effects), is clearly positive, however the impression that higher income groups benefit more becomes even stronger (Eliasson, 2016).

Another conclusion is that exemptions from the systems may have unintended consequences for distributional effects. One example is the exemption for company cars in Sweden where the owner does not pay at all as the charge is considered an operational cost. Because of this effect, the congestion charges in Göteborg changes from being an almost neutral system from an equity perspective to a system where higher income groups clearly benefit more (Eliasson, 2016).

Changes to the Stockholm congestion charge systems have been evaluated by the Swedish Transport Administration (2017). To harmonize the thoroughfare tax level to the rest of the system would positively effect mobility at a very low price. Differentiating the levels of the congestion charges with respect to daily peak periods, driving directions and certain passages would have a positive effect on the mobility for seven months of the year and would increase public revenues. Widening the tax period to cover the early hours of the morning has a positive effect on mobility and is relatively cheap. Introducing a congestion charge on public holidays has only small positive effects on mobility and the public revenues are low. Increasing the maximum daily tax level may have some positive effects on mobility but there is risk that a high maximum rate, particularly in combination with other increases in congestion charge levels, can give rise to undesirable socio-economic effects for both private and commercial actors, especially for in areas that are located close to or are adjacent to the existing the inner-city zone boundaries. Extending the congestion charges to the inner-city streets can be justified since this should have relatively good mobility effects and boost public revenue, though increased congestion on certain roads may be an unintended side-effect. Finally, expanding the congestion charge system in the suburbs may have a major positive impact on accessibility in large parts of Stockholm County and the public revenues are considerable (Trafikverket, 2017).

In a study (Kristoffersson, Engelson, & Börjesson, 2017), the conflicting objective of congestion charges, namely the trade-off between equity and efficiency in the design of the Stockholm congestion charging, were analysed. Four scenarios were modelled, with different designs for the way the areas are cordoned (a cordon is the taxed area). The results show that the consumer surplus is higher for the two more complex schemes (differentiated cordon and four cordon), although the revenues are of the same magnitude. The systems differentiated cordon and four cordons generate a substantially larger social surplus than the simple cordon. The differentiated cordon design generates a 20 percent larger social surplus than the simple cordon scheme and the four cordons scheme 82 percent larger. The most efficient scheme design is thus clearly the four cordons scheme. Considering first the simple cordon, low-income inhabitants lose least, and high-income inhabitants lose most. The differentiated cordon generates positive consumer surplus for all groups, because the travel time gains are larger than in the simple cordon. The largest change in consumer surplus still accrues to low-income

inhabitants for the same reason as the simple cordon (Kristoffersson, Engelson, & Börjesson, 2017).

Recommendations from interviewed

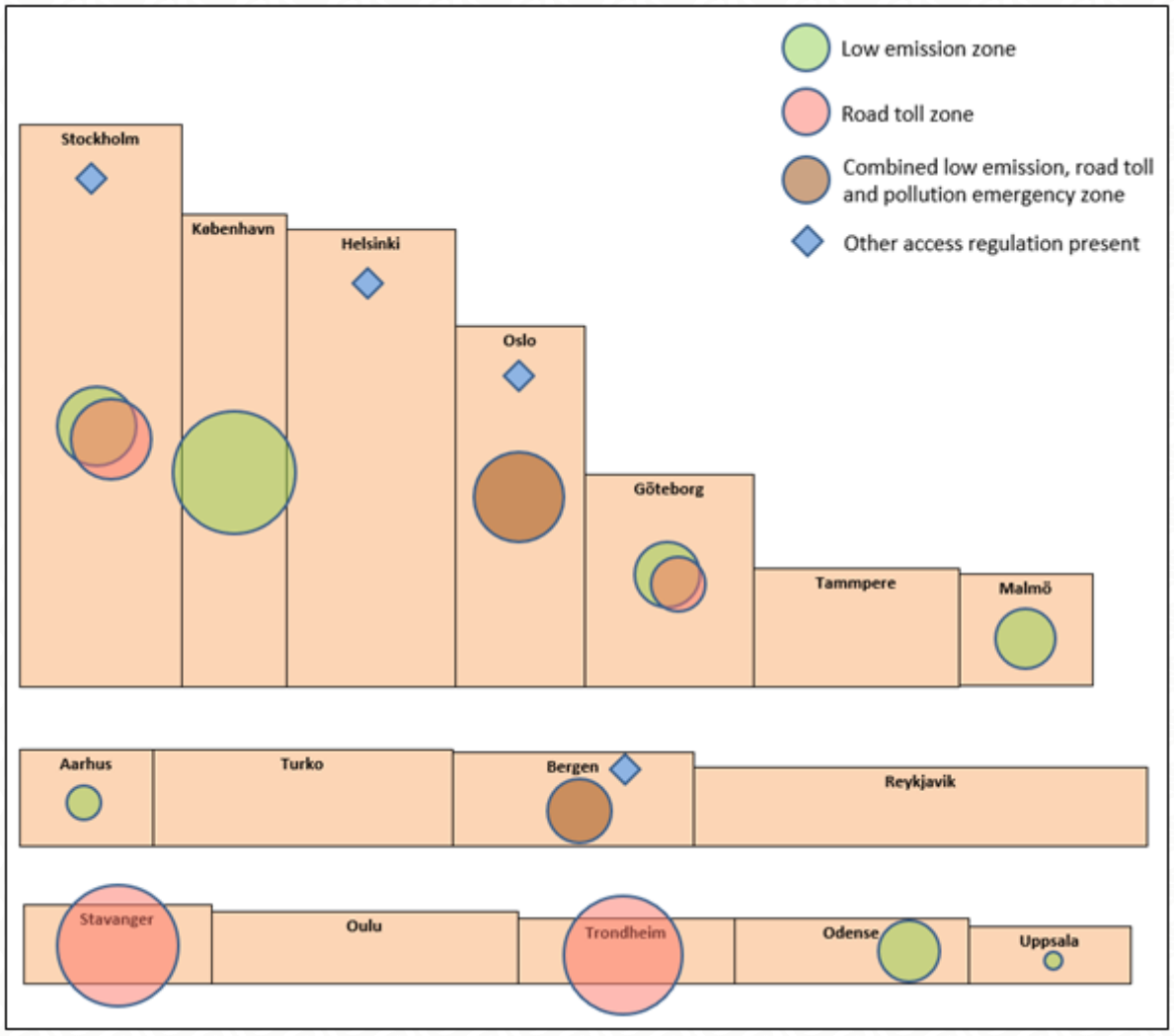
In Denmark, there are no congestion charges, and it is not considered an effective instrument as high congestion is rare. An environmental differentiated vehicle tax that treats zero-emission vehicles from fossil cars differently is regarded as better (Gudmundsson, 2019). The Aarhus Municipality is of the same opinion and they highlight the risk that such exemption can compete with other goals such as increasing public transport, cycling and walking (Nielsen, 2019).

Iceland´s research respondent considers tax exemptions for all eco-friendly technologies an effective tool, including exemption from congestion charges for zero-emission vehicles because it lowers costs and enhances public acceptance (Iceland has no congestion charges) (Davíðsdóttir, 2019).

Among members of the expert panel, a few recommended exemptions from road tolls for zero-emission vehicles. One proposal was that geofencing could be a tool to enforce compliance. Maybe the congestion charges surveillance cameras can be used for more purposes such as differentiating environmental zones with respect to other parameters. Others disagreed and find the charges an important measure for regulating car traffic.

Appendix 3. Summary of zones and fees in Nordic cities

The figure below shows the 16 most populated cities in the Nordic countries are sorted by population size. The rectangular area represents the urban area and the green circle shows the low emission zone, the red circle the road toll/congestion charge zone and the brown combined zones. The blue symbol shows when there is another environmentally based access regulation in force. The zone areas as well as the city's areas are all to the same scale, in order to enable a direct comparison.



Appendix 3, figure 1. Emission zones, road tolls and congestion charges in the 16 most populated cities in the Nordic countries sorted by population size (height).

Appendix 4. Vehicle taxes

Introduction

There are big differences in the national vehicle taxes between the Nordic countries. There are many regulations that often are complex and based on vehicle types, fuel types, uses, age, size, ownership and so on.

A complete overview of all existing vehicle taxes is outside the scope of this report. Instead we focus on the existing vehicle tax regulations. Nordic vehicle taxes can be divided into the following groups:

- Purchase tax
- Value Added Tax (VAT)
- Annual tax
- Vehicle licensing fee
- Bonus-malus
- Vehicle grants

There are examples from Nordic countries where most of the existing taxes to a lesser or greater extent are differentiated based on environmental performance, fuel or propulsion system.

Norwegian subsidies for passenger cars

Below is an overview of the economic incentives for private owners of battery driven electric cars in Norway.

- No purchase/import taxes (since 1990)
- Exemption from 25 percent VAT on purchase (since 2001)
- No annual road tax (since 1996)
- 50 percent reduced company car tax (2000-2018).
- Company car tax reduction of 40 percent (since 2018)
- Exemption from 25 percent VAT on leasing (since 2015)
- Fiscal compensation for the scrapping of fossil vans when converting to a zero-emission van (since 2018)

Norway has a registration tax for cars. The tax is based on the vehicle's carbon dioxide emissions, Emissions of nitrogen oxides, weight and engine power. Electric vehicles have been exempted from registration tax since 1990. Fuel cell electric vehicles are also exempted. The exemption evens out the difference in purchasing cost between an electric vehicle and a conventional car for the consumer and is financed by revenues from registration taxes on conventional cars. Hybrid cars have no general exemption from registration tax, but since the tax is less for low emitting cars, the tax level is generally

lower for hybrid cars. VAT of 25 percent is added to the purchase when buying a new car. Electric vehicles are exempted from VAT since 2001 (Nordic Energy Research, 2016).

The added value of the subsidies (VAT+ registration + low licensing fee) for the individual could equal half of the vehicle price in the first 4 years (Zsuzsa Lévay, Drossinos, & Thiel, 2017).

Cars in Norway were subject to an annual licensing fee although this was removed in 2017. The fee was lower for electric cars, but the difference was not significant. In 2017, electric vehicles paid an annual fee of 455 NOK and other cars generally paid a fee of 2820 NOK. The licensing fee was replaced in 2018 with a new fee, Trafikkforsikringsavgift, with no differentiation for EVs (Ystmark Bjerkan, E. Nørbech, & Elvsaas Nordtømme, 2016).

Table 1 below shows an example of how the Norwegian exemption from purchase tax and VAT affects the taxation when a private customer buys a new electric battery vehicle[2].

Appendix 4, table 1. Comparison of a cost differences when purchasing an electric car and a corresponding conventional model in Norway.

Incentive	Petrol /diesel	Battery electric	Example model
Purchase tax	59 000	0	Volkswagen Golf
VAT 25 percent	69 000	0	Nissan Leaf
Annual fee	2 820	455	Standard car
Surcharge incurred	250	50	Standard car

Socio-economic and distributional effects

The general picture from almost all interviewees in this project is that they consider differentiated vehicle and fuel taxes a good and efficient policy instrument for promoting zero-emission vehicles. However, several of the respondents' noted potential negative distributional effects, and evidenced concerns about how to use the public resources in the best way.

According to a Norwegian study, battery electric cars and plug-in hybrid electric cars are not equally purchased by all socioeconomic groups. Owners of battery electric cars typically live in larger households, have more children and are younger. They are more likely to have more than one car than owners of plug-in hybrid electric cars, and they have a longer distance to work. More battery electric car owners live in urban areas than owners of both plug-in hybrid electric cars and conventional cars. About two thirds of battery electric car owners live in detached houses and have in general good access to parking and charging on their own property. Battery electric cars are used more in total, and on weekdays, but less for vacations. They are charged mostly at home, partly at work and rarely elsewhere. Owners of battery electric cars manage everyday driving and very seldom changed travel plans due to of a perceived limitation of their car (Figenbaum & Kolbenstvedt, 2016).

However, according to another study, in 2018 battery electric cars owners were older and more were females compared to in 2016. Fewer were also active in the workforce and households were smaller. The adoption of battery electric cars is moving up on the s-curve to the "early majority" of adopters (Figenbaum, Erik; Nordbakke, Susanne, 2019).

Recommendations from interviewed

Some researchers suggest that governments should be wary of purchase subsidies, and that it is important to consider "the whole value chain/system". Zero-emission vehicles have low operating costs but a high purchase cost (although the gap is shrinking constantly). So if purchases are subsidized, but it is still cheap to drive, there is a risk of an increase in traffic, which is problematic in other regards, even though the vehicles in question are zero-emission (Brundell-Freij, 2019), (Sprei, 2019).

In Uppsala, the interviewees consider that reducing the price of public transport is a way to increase its use. The municipality cannot influence the mileage cost of private cars, which is an is important to commuters. It would be useful if the municipality were better able to supervise the observance of the low emission zone would be (Sigurdsson, 2019).

Regarding heavy-duty vehicles, the representative from the truck manufacturer Volvo supported the idea of an electric truck grant. There has been national support for LNG and LBG trucks, and that environmental truck grant was very important for the hauliers to reduce the extra cost. There has also been national support for building production plants and distribution infrastructure. Additionally, in order to sell these trucks, there needs to be an adequate supply of biogas at filling stations. One possibility would be to shift from fuel-based taxation to distance-based tax, where taxes could be based on the type of powertrain and fuel used. Regarding charging infrastructure, quicker municipal processes for building permits would be appropriate. If the hauliers were given an extended environmental truck grant, they would take higher financial and operational risks. Introducing leasing models will also ameliorate haulier costs and attenuate risks associated with batteries, longevity etc. (Berger, 2019).

In Denmark and Iceland, there seems to be the same positive opinions around the issue. New technology requires governmental push (Gudmundsson, 2019), (Davíðsdóttir, 2019).

In Göteborg, the public transport company Västtrafik asks for an electric bus premium with enough financing to cover all the upcoming buses cities want to procure. Support to build depots would be a very important instrument in larger cities and should be included in national infrastructure plans, which then become the regional infrastructure plans. That would make financing easier (Björk, 2019). Electric bus grants are also recommended to a certain extent by the expert panel.

Vehicle tax relief (including VAT) is recommended to a certain extent by the expert panel. This obviously will result in a reduced environmental impact. But they considered it more difficult to assess the general effects of tax exemption on accessibility and socio-economically. This should be assessed on a case-by-case basis. These measures are considered important, especially if they are balanced within the system, type of bonus-malus rather than tax exemption. Bonus benefits mostly high-income groups and companies that buy new vehicles. It is important to emphasize that these measures will

only result in significant improvements over the long-term, as they only affect new sales and not the existing fleet.

Appendix 5. Access to bus lanes

Introduction

Zero-emission vehicles may have the right to drive in public transport lanes (bus) as an incentive for promotion, which increases their accessibility. The rule can be applied to a certain time period (for example rush hours) or with a certain criterion such a requirement of the number of persons in the car. Whether the zero-emission vehicles should have the legal right to drive in the bus lanes is a controversial issue since the bus lanes are primarily intended for public transport purposes, which risk being negatively affected and congested because of the zero-emission vehicles. This can also provoke negative reactions among other drivers such as jealousy or anger directed at those seen as privileged because can afford to buy a zero-emission vehicle.

Presence in Nordic countries

Battery electric cars have access to bus lanes in most Norwegian towns and cities. Regulations fall under the national regulation on traffic signs, which since 2005 allow electric cars in bus lanes, unless indicated by the municipality (local roads) or the Norwegian Road Administration (national roads).

Since 2015, access for battery electric cars to bus lanes in Oslo has required at least one passenger during rush hours. As of 2017, local governments in Norway can decide on incentives such as access to bus lanes and free municipal parking (Ecofys, 2018).

While implementing this type of local policy, it is important to avoid a modal shift from public buses to cars. In Norway, bus utilization is at its highest level ever (Nordic EV Outlook, 2018).

Effect on zero-emission vehicles promotion

The instrument that gives zero-emission vehicles access to bus lanes has only been tested in Norway and no other Nordic country has tried this, therefore there is a lack of experience in this regard and few sources in the literature. The incentive was evaluated to a certain extent in Oslo, Norway.

The incentive is deemed as very efficient in regions with large rush-hour delays in traffic flows. The disadvantage is that only a limited number of vehicles can use the bus lane before buses are delayed. Access to bus lanes is thought to have been a factor influencing electric vehicle sales in the Asker municipality outside Oslo, as commuters there face the largest rush hour delays in Norway, and may have been the most attractive user incentive in Oslo in 2013 (Figenbaum; Kolbenstvedt, 2013).

In Oslo there were significant increases between 2016 and 2018 of those who reported that this incentive was of “great/crucial” importance for buying a zero-emission vehicle. The greater importance of bus lanes is a puzzle as restrictions apply in an increasing number of locations due to the increase in the battery electric car fleets (Figenbaum, Erik; Nordbakke, Susanne, 2019). Other municipalities in Norway no longer impose that rule.

The instrument should be used in a flexible way and works well as an instrument to kickstart the market (Portvik, 2019).

Effects on mobility and accessibility

The incentive is often seen as conflicting with accessibility for public transport. As soon as electric vehicles stop being a niche market, this incentive must be modified (Myklebust, 2013). It is also for commuting that access to bus lanes has the highest value as these trips are carried out at peak travel times (Figenbaum, Erik; Nordbakke, Susanne, 2019).

Socio-economy and distributional effects

The average time saved in Norway by those driving in bus lanes is about 13 minutes per day, which may be expressed as a socio-economic value (in the rush hours) of around 60 NOK (280 /hour). Still, the share of BEV-users who drive in bus lanes has decreased over time (Figenbaum & Kolbenstvedt, 2016). Access to bus lanes for commuting has the highest value as these trips are carried out at peak travel times (Figenbaum, Erik; Nordbakke, Susanne, 2019).

The value of this instrument shifted substantially in many of the Oslo´s counties between 2016 and 2018 and lost most of its benefit due to the requirement for more than one person in the vehicle in the rush hour. Partial or full access to bus lanes (depending on local conditions) for battery electric car users is a benefit in time, which can be recalculated in monetary terms, landing at 1130 NOK in 2018. The value of time saved in bus lanes accounted for around 8 percent (down from 31 percent in 2016) of the total economic value of all local battery electric car incentives in Norway and is ranked as the third highest (road toll exemption accounted for 65 percent and free parking for 18 percent) (Figenbaum, Erik; Nordbakke, Susanne, 2019).

Recommendations from interviewed

The general recommendation from the expert panel was to refrain from using this instrument. It competes with public transport and thus counteracts environmental improvements. Accessibility is deemed to be adversely affected, and it seems to have a negative distributional effect. Individual participants in the reference group were more positive and one thought it might be good in an early phase. In Sweden, the overall opinion of this incentive from respondents is somewhat negative, influenced by wide acceptance of the principle that public transport using the lanes should not have to compete with other traffic. This may be a good idea when used in an early phase, carefully monitored and if the authorities are prepared to cancel it at short notice when the bus lanes start to get crowded (Sprei, 2019).

Negative reactions to this incentive include that it sends the wrong signals and supports car driving at the expense of public transport, bicycling and walking. The key question is how much lanes are utilized. If there is free capacity the measure may work out well, especially on some major routes on the outskirts of cities surrounding municipalities or on state highways (Sunnerstedt, 2019). From a Swedish perspective, (Brundell-Freij, 2019) suggests that the incentive should target zero-emission freight vehicles and similar vehicles such as distribution trucks, that and its use considered in certain sections where it

can be implemented without interfering with public transport. An advantage in this regard is that can quite easily be withdrawn (Brundell-Freij, 2019).

Nevertheless, problems may arise inside the city because buses and others drive at the same time (Berger, 2019). In Denmark few regard the instrument positively. The previous government opened up for shared bus lanes, but this has not been implemented. It is not likely to be effective because there are few bus lanes in Denmark, and it is feared the congestion this might lead to would disrupt public transport. It could also be difficult for the police to monitor (Gudmundsson, 2019). Isbrand (2019) believes that the zero-emission vehicles will block the lanes and delay public transport. Another risk is that non-compliant cars might indulge in copy-cat behavior and use the lanes illegally (Isbrand, 2019).

In Iceland there is also a negative attitude, the bus lanes should be kept free for public transport. However, the research respondent is positive to giving priority to all eco-friendly technologies, including zero-emission vehicles. They are competing with more dirty mature technologies but giving priority incentivizes increased investment, lowering costs and promoting public acceptance (Davíðsdóttir, 2019). The issue has also been discussed in Helsinki but has not been implemented as the city prioritizes public transport over private cars (Venho, 2019).

The distributional effects of this policy instrument were deemed to be negative by the expert panel.

Appendix 6. Parking benefits

Parking benefits can be used as an instrument to channel certain privileges to zero-emission vehicles. The privilege can be with respect to cost, the opportunity to refuel (basically charging), access or special rules such as time limits. Locally, or at city level, parking policies can be used to influence the choice of vehicle at the time of purchase. Parking benefits or benefits that lead to better availability can be used as incentives for choosing a zero-emission vehicle. Examples are local parking benefits such as free parking for zero-emission vehicles at municipal parking spaces (Koucky & Partner, 2015).

Presence in Nordic countries

Starting in 1999 in Norway, municipalities have had free parking for EVs. Since 2017, municipalities can decide to what extent they want to implement free parking, but there is an upper limit where municipalities cannot charge more than 50 percent of the fee levied on fossil fuel-cars (Figenbaum & Kolbenstvedt, 2016).

In Oslo, the Urban Environment Agency (Bymiljøetaten) is responsible for all municipal-owned parking spaces, and thus is more able to integrate the charging policy with the parking policy. Oslo municipality has a restrictive parking 'norm' which strives to reduce car-use, regardless of whether it is a question of fossil powered vehicles or zero-emission vehicles. There are currently some requirements for commercial and residential buildings outside the city centre, and the number of parking spaces allowed is determined by ease of access to public transport. At least 20 percent of the parking spaces must have access to a charging station, but other vehicles are allowed to park at these spaces as well (Portvik, 2019).

Effect on zero-emission vehicles promotion

A widely held opinion about free parking for zero-emission vehicles is that it may have a significant effect on the willingness to buy a zero-emission vehicle, however the instrument is not considered favorably due to several potential negative side effects.

The availability and pricing of car parks are other effective instruments for influencing the use of cars in urban areas. Parking measures are probably among the most effective means of control that cities possess. The effects of various parking measures on the choice of vehicle and car use are well documented in the literature. The availability and price of parking have a major impact on the transport choice and the effect of price measures can be assumed to be comparable to the effect of the congestion charges (Koucky & Partner, 2015).

Effects on mobility and accessibility

Parking measures can be implemented in all cities, regardless of size. An advantage is that parking measures do not exclude specific vehicles and that the effect can easily be adapted through, for example, time limits, supply changes or fees (Koucky & Partner, 2015).

Socio-economy and distributional effects

Parking benefits may be suitable for free-floating rental services and encourage them them to rent out electric vehicles, in which case they will have a positive socio-economic effect (Gudmundsson, 2019).

There is little correlation between the cost of parking and the share of battery electric cars in the fleet, and the incentive can thus be considered weak in Norway. This may not be the case in other countries, as it is a function of the general level of parking fees (Figenbaum & Kolbenstvedt, 2016).

In a study by Ecofys (2018), the direct costs of EV introduction instruments in Norway, e.g., subsidies, implementation costs and foregone revenues, e.g., from reduced taxes, were analyzed. Researchers have found that, in the case of Norway, exemptions from parking fees come with a comparatively high cost to the public purse (ca 50 NOK per kg of CARBON DIOXIDE). Most policy measures lead to a budget cost of NOK 30- to 40 per kg of carbon dioxide in 2020 (Ecofys, 2018).

However, compared to low emission zones and congestion charges, parking measures are in general simple and cheap to implement. Control and monitoring, however, will be costly for the city when the privileged vehicle type gains a larger market share, either due to reduced revenues or reduced accessibility (Koucky & Partner, 2015). The survey's primary objective was to provide information on why people buy plug-in electric cars, how they are used and the users' opinions about them. In addition, battery electric car owners and conventional car owners surveyed, provide a reference for the results. The respondents are representative of the fleet's geographical distribution and cover only privately-owned plug-in electric cars (whole Norway). They do not have free parking and may thus have to pay for parking when charging if the charging station is in an area where you must pay for parking.

On average, owners of battery electric cars in Norway save 2350 NOK per year on free parking, whereas owners of plug-in hybrid electric cars spent 1210 NOK and owners of conventional cars spent 1530 NOK in 2016 (Figenbaum & Kolbenstvedt, 2016). Free parking and time saved to find parking for battery electric car users can be recalculated as in monetary terms to a value of about 2540 NOK and 580 NOK respectively in 2018. The parking incentive accounted for around 22 percent (increased from 16 percent in 2016) of the total economic value of all local battery electric car incentives in Norway and is ranked as the second highest (road toll exemption accounted for 65 percent) (Figenbaum, Erik; Nordbakke, Susanne, 2019).

A challenge with powerful parking measures is that it can be difficult to get public support for the measures, especially in cities where there is no lack of parking space (Koucky & Partner, 2015).

Good examples

There were restrictions previously in Aarhus on how much they could subsidize the parking of EVs, but the rules have changed. The new parking policy focus on more short-term parking, always free lots, use simple systems, supporting green mobility and combine charging strategies for electric cars with parking measures. One purpose is to

transfer cars from the streets to parking facilities so only residents can park, and if they have electric vehicles. For companies, the monthly cost is free (Nielsen, 2019).

In Norway, there has been a change in the law that charging is required when parking at a charging point, with a time limit of maximum three hours (charging is not free) (Portvik, 2019).

Recommendations from interviewed

The expert panel does not recommend differentiated parking fees. This can have a negative impact on accessibility may adversely affect mobility and accessibility for other groups, but perceptions differed.

According to the research respondents in Sweden, free parking is considered as problematic and experiences from free parking for flexi-fuel vehicles in Sweden show some regulatory effect in the beginning but not later on and it also led to problems with more commuters and encouraged car use in general. Better would be to make it more expensive for conventional vehicles (Brundell-Freij, 2019), (Sprei, 2019). From the business side in Stockholm (Taxi Stockholm), accessibility is seen as most important, and this is adversely impacted by cars parked on the streets (Welander, 2019).

In Oslo, there are concerns about accessibility to free parking and the elderly and those who have difficulty walking but do not have disabled status are still challenged (Portvik, 2019).

In the City of København, there is free parking for all EVs from January 2020. Also, the resident permits for conventional cars will simultaneously become more costly and structured according the energy efficiency of the cars in question. The permits for conventional cars will cost between DKK 1,000 and DKK 4,000 from January 2020 (Isbrand, 2019).

In Aarhus, there are worries about the risk that it may disturb other goals such as the increased use of public transport, cycling and walking (Nielsen, 2019).

Especially interesting are the regulations for residential parking when building new areas. Oslo City would like to enforce a requirement that a minimum amount of parking spaces should be prepared for electric vehicle charging, but this is not possible today (Portvik, 2019). It is important to note that the indirect effects, the benefit to groups that gain better access, may be more difficult to understand, perceive or take into account.

Free parking for zero-emission vehicles was tested in Oslo. Parking spaces have been transformed for other urban uses. The total number of public parking lots has increased considerably but parking fees were raised in Oslo significantly in 2016, so the total income has increased even though BEV's park for free. All on-street parking has been removed from the city center, but parking garages are still in place. The introduction of residential parking permits was also very important (Portvik, 2019).

A research respondent in Norway thinks there should not be different rules, but still thinks it may have some impact on the willingness to buy a zero-emission vehicle. In any

case, the rules should not be different if the car is rented or privately owned, but free parking is among the less important incentives in Norway (Fridstrøm, 2019).

In Reykjavík and Iceland there is a positive attitude to free parking. There is free parking for zero-emission vehicles in the city centre (Friðriksson, 2019). In Helsinki there is a 50 percent discount on parking granted to "low-emission" vehicles on city-owned parking spaces. But the effect on zero-emission vehicles promotion and the incentives will be re-evaluated and changes may be expected soon (Venho, 2019). Reykjavík City supports charging stations on the streets and in parking houses. There are also free 90 min parking spaces in the city centre for zero-emission vehicles and plug-in hybrids (Friðriksson, 2019).

The vehicle strategy adopted by Stockholm addressed requirements in connection with transport services and mandated free parking for zero-emission vehicles. The latter has since been removed. However, some form of reduced parking fees for electric vehicles is seen as positive. Even bikes may start paying for themselves, there is now some increasing willingness to pay for electric and more expensive bicycles (Sunnerstedt, 2019).

Uppsala now works actively with parking availability as an instrument but rejects free parking for zero-emission vehicles (Sigurdsson, 2019). In Copenhagen differentiated parking fees have been implemented and from 2020 parking will be free for zero-emission vehicles (Gudmundsson, 2019).

In Aarhus a new parking strategy grants free parking to EVs. Parking spaces reserved for electric vans and closed parking on days with bad air quality (Nielsen, 2019).

Appendix 7. Public support of charging infrastructure

Presence in Nordic countries

Stockholm city is working actively with combinations of charging and parking. They offer street space where private actors can set up charging points at their own expense and install charging facilities in their own garages. They are also working with the "green parking index" which means that the city provides a construction company with reduced parking rates in exchange for the construction company providing positive mobility services (car sharing, bicycle pool, bicycle parking, electric scooters park). Also, if you have permission places you do not need to build visitor parking. But there is no increased taxation or any other such measure. On street parking and the cost of the electricity you use are paid for separately. It is not legally possible to reduce the price of on-street parking for electric vehicles. In Stockholm the city itself purchases EVs, and supports the charging infrastructure to help the employees charge their cars at work and let the municipal cars charge during the night where they stand (Sunnerstedt, 2019).

The Uppsala municipality has no charging or land use strategy but is in need of such according to an official, however there are general strategies in place at county level. The municipal parking company installs charging facilities in their own garage. Uppsala still does not offer other mobility services, but does provide mobility houses, a concept that combines parking for both cars and bicycles with other types of traffic and transport services. These will start to appear around in areas near to the town center and will include charging solutions (Sigurdsson, 2019).

The City of København has decided to reserve up to 1,000 parking spaces for EVs. Currently a little over 500 have been established. There is a demand from citizens for more charging facilities, since many of these are often occupied. For this reason, the Municipality has decided to implement time limited parking (3 hours) at 24 of the locations as a trial. A political decision has been made that all new municipal parking-houses will be include charging facilities However, new parking-houses are rarely established by the Municipality. The implementation of a new EU directive is currently under consideration at national level. Under the proposal it is obligatory to establish a charging infrastructure at parking spaces with room for more than 20 cars both in new and in existing buildings (Isbrand, 2019).

The parking strategy in Aarhus, described above, combines charging strategies for electric cars with parking measures. The strategy aims to charge for residential parking in a larger area than before and simplify payments and clarify zoning and pricing. One of the goals was to move parked cars off the streets and into parking facilities, so that only local residents that live close by can park there (Nielsen, 2019).

Further actions by Reykjavík City include setting up charging stations at tourist stops and at locations around the country as well as at selected hotels etc. The charging infrastructure is subsidized on Iceland, and the state pays about 30 percent of the cost of setting up charging stations on streets and in parking houses in the city centre (Friðriksson, 2019).

The city of Helsinki gives operators street space for charging electric vehicles on specified terms but provides no funding. There is a master plan for charging points, and a separate transport plan over all charging points, but these are not included in the city plans. Charging is considered as one of the biggest obstacles or aspects considered by potential EV buyers. For the time being there are about 50 public charging points for electric vehicles in Helsinki, and in 2020 another 60 will be built at public parking spaces (Venho, 2019).

Hydrogen filling stations in Denmark

Attempts have been made in Denmark to increase hydrogen-powered vehicles and fuel stations that will enable the use of these both locally and regionally. According to officials, hydrogen vehicles have received negative press since they are relatively expensive and are not generally popular (Nielsen, 2019).

Effect on zero-emission vehicles promotion

The research shows that access to charging has an effect as an incentive to increase zero-emission vehicle sales, but long-term charging in the city is less important than fast-charging along highways (Fridstrøm, 2019), (Sprei, 2019).

In Iceland, low access to charging creates a mental and physical barrier to the purchase of zero-emission vehicles. Lack of access to quick charging is one of the highest ranked reasons not to buy an EV (Davíðsdóttir, 2019).

The importance of charging stations is greater in areas where most people live in apartments, whilst in cities with a high degree of small houses, people can charge at home. Other researchers claim that charging infrastructure is not an important incentive and there seems to be no consensus of how important this incentive is for promotion of the zero-emission vehicles (Sprei, 2019), (Brundell-Freij, 2019).

At a regional level, it has been shown that the number of charging stations was the incentive with highest correlation with electric vehicle ownership in the population. At a municipal level, charging stations also correlate with EV ownership of company cars but not as much with electric vehicle shares for private cars. It is suggested that pricing incentives combined with access to charging stations may be the best policy to increase electric vehicle sales (Mersky, Frances, Samaras, & Qian, 2016).

A study in Sweden (Trosvik & Egnér, 2017) indicates that an increased number of public charging points causally increases the adoption rates of EVs. Differences in the expansion of the public charging infrastructure might explain why the adoption rate was faster in some municipalities and therefore seen as an effective instrument to increase the electric vehicle share. The effect was found to be greater in urban municipalities than in suburban and rural ones. Adjusting policy instruments to the specific characteristics of municipalities and making them visible to the public can increase the effectiveness of the instrument. In urban municipalities, public charging points should be placed close to the home as the main urban barrier is limited charging possibilities at home (Trosvik & Egnér, 2017).

There has only been limited research in Denmark on the provision of charging facilities at parking spaces as an incentive for zero-emission vehicles uptake, but there is no clear

result. The number of charging points per vehicle in Denmark is one of the highest, which indicates that it is not very important, since there are still rather few electric vehicles in Denmark (Gudmundsson, 2019).

Effects on mobility and accessibility

Public charging in Norway is considered as an important incentive especially for businesses. In Norway the country is rife with charging possibilities and this is not a major issue anymore. Sometimes there may be queues at charging stations due to the high number's electric vehicles on the roads today, but this is not considered a major problem. Public charging stations are easy to find easy via an app, map functionality in the electric vehicle and signage. It takes around 15-20 minutes to fast charge a battery (Haugneland, 2019).

In Oslo, there is are no regulations surrounding private property, meaning that incentives favoring electric vehicles through discounted prices are entirely up to the owner. A new norm has been proposed, which if enforced would do away with minimum requirements for commercial buildings, meaning no requirements for electric vehicle parking either. When parking spaces are built, there will be requirements for a higher proportion with charging stations and the possibility to add stations later (Kristiansen, 2019).

In Reykjavík City charging when parking is a very important incentive. Fast charging is still not fast enough and the possibility to charge normally is still considered more important. Public fast chargers will not make the purchase of an EV more feasible for people living in apartments with no charging facilities. Charging points in car parks although not on the street is considered adequate. Electricity could be free in p-houses but still cost on the streets, today there is no difference. The city is planning for 20 percent of the parking lots to have charging possibilities by 2025 (Friðriksson, 2019).

Socio-economical and distributional effects

According to interviewees, subsidizing the establishment of a charging infrastructure with the purpose of increasing the adoption of zero-emission vehicles is another controversial issue, since there are distribution aspects and a risk that the already wealthy are even more favored. There are doubts whether energy use at all should be subsidized since all energy production has environmental impacts and energy saving is a sustainability principle.

There are socio-economic aspects to consider when subsidizing public charging infrastructure. According to general research there is no point in subsidizing electricity in the Nordic countries because electricity is already cheap and the running costs for electric vehicles are very low. The main barrier for electric vehicles is the high purchase cost, not running costs. Regarding subsidizing charging infrastructure, views differ as to whether this is good or not. Some studies point out negative effects (Sprei, 2019). On the other hand, subsidizing public charging infrastructure may be needed to speed up and facilitate transition, but business models may be a difficult topic. Public charging infrastructure is more goodwill-creating but not important, because most people will charge at home at night. But in the cities, there are many cars that "live" on the streets and have no "natural" charging place. In Sweden, the cities installations are today financed via taxes (Brundell-

Freij, 2019). Public free fast charging should in any case not be free because then some strange effects may appear, such as people charging at strange times of the days or parking for an excessive length of time at fast charging stations (Sprei, 2019).

The business sector is of the opinion that those who drive most should be most heavily sanctioned. However, in the beginning subsidies are needed to kick-start the market although in the long term the market should be self-sustaining. Users should pay, not the taxpayers (Welander, 2019). Regarding public transport: if this can run entirely on electricity it will release large volumes of biofuels that can be used for other transports that are more difficult to carry out using zero-emission vehicles, so subsidies of public transport charging infrastructure (electric buses) is beneficial. This would be an appropriate instrument for increasing the attractiveness in certain areas close to public transport routes (so-called land value capture), and attractiveness is amplified if the public transport is clean and quiet (like electrified/ zero-emission). It is even better if zero-emission (electrified) public transport could be extended out to low-traffic areas to reduce air emission and noise, things that today stand in the way of development (by reducing other traffic). The process can go faster if you can get resources other than tax (Björk, 2019).

Regarding heavy trucks, the starting point is that every truck must be given a dedicated charging station where it stands and recharges overnight, but there is a need for some extra charging during the day as well. However, it is not necessary to subsidize the infrastructure and energy supplies. Regional transports (up to 300 km) will be able to manage with zero-emission trucks (BEV) without major payload losses. Of these transports, very few are limited by weight. With long distance transport (64 tons) battery trucks are assumed to be out of the question in the short / medium term. The automotive industry is still unsure if there will be plug-in hybrids, fuel cells, renewable fuels, or electric roads in the long run. In order to gain socio-economic relevance, the electric roads must be well used, to get enough traffic flow and maybe light cars must be included, and the busiest roads to be selected for electrification. Plug-in hybrids run on electricity in the city (and work as zero-emission vehicle) and on liquid fuel on the highways, but this is an expensive solution that requires two powertrains. The question is how much zero-emission operation is needed. In the Nordic countries most of transports go to terminals outside the city and then are reloaded and into smaller vans for shipment to their final destinations (Berger, 2019).

Taxi companies and many smaller companies do not usually have their own charging facilities in a central location and cannot park in the city, in contrast to a haulage company that normally disposes over its own charging facilities. The risk of congestion increases with more electric vehicles and Tesla´s private customers already want to exclude others from their charging stations. For example, a taxi company charges often, has many new electric vehicles in its fleet and is highly visible. Access to charging is crucial for businesses, and the charging infrastructure is at present discouraging the introduction of zero-emission vehicles, there is a need for charging points at every "hub". If fast charging can be guaranteed, taxi companies can increase the number of EVs (Welander, 2019).

From a private perspective, electricity is cheap, but subsidies of installation of home charging device may be effective. Charging has been free to the public until now, but that's just because it was more expensive to install a payment system than to supply the electricity. Now there should be a market for payment solutions, and this will make it

possible to build more stations. In the long run free electricity will not work (Haugneland, 2019).

In Oslo, free charging resulted in electric vehicles using the charging spaces to park (since they were free) and has disfavored charging lots that do not offer charging. There are many legal issues that should be implemented at a national level (Portvik, 2019).

In Reykjavík, electricity is still free for electric vehicle users at public charging points, but most people charge at home, so the effect of a subsidy is not as significant. Free charging is not yet available to most people as the charging stations are located in the city center. But with more new distributed charging stations the electricity must have a cost despite that fact that green electricity is extremely cheap in Iceland (Friðriksson, 2019).

Good examples

The City of Oslo is currently investigating if it is possible to assign 600 parking spaces to car sharing cars by 2020. It is estimated that there are around 2,000 car sharing cars in Oslo. The city will reserve a minimum of 20 percent of designated parking spaces for car sharing to EVs. Oslo will build charging infrastructure for these parking spaces and only sharing electric vehicles will be allowed to use them (Portvik, 2019).

A survey showed that the lack of charging infrastructure and thus charging points is an obstacle to driving electric cars for every second Swede. This can be addressed with new business models around sharing charging points. One of these is the "Elbnb" initiative launched by a car manufacturer, that allows anyone to share electricity with electric car drivers around the country. This means that all private charging points in the city can be used to charge vehicles at all hours of the day. This makes it easier for commuters to move in and out of the city (WSP, 2018).

Reykjavík City set up charging stations at street parking spaces and in p-houses with free electricity. Free parking for 90 minutes in the city center for battery electric cars and plug-in hybrid electric cars (if their emissions are below a certain amount of carbon dioxide per km). Reykjavík City also started three collaborative projects with the Reykjavík Energy utility company: 1) a fund for charging stations at multi-apartment houses, 2) setting up charging stations at official buildings that are accessible for city residents 3) setting up 20 charging points every year for the next three years for residents who have to park on street (Friðriksson, 2019).

The city is not working to implement charging in conjunction with parking or increased taxation solutions. Neither does Reykjavík offer any other mobility services. However, electric vehicle pools were discussed, but this was not implemented (Friðriksson, 2019).

In Gothenburg, Sweden, the parking company, the energy company and the housing companies owned by the municipality have developed a scheme to meet the increased demand for home charging without providing a fixed parking space. This is a necessary step if the City of Gothenburg is be able to facilitate the acquisition electric vehicles for residents (Trafikkontoret Göteborg Stad, 2016). Today Göteborg Energy company is addressing the integration of this issue (Göteborg Energi, 2019).

Recommendations from interviewees

From a business perspective, fast public charging is considered important for the willingness to buy electric vehicles. An example is the "double pass" for taxi drivers, the drivers must be able to charge at the streets in the city (at a reasonable price), and when the drivers change over from day pass to night pass, they cannot leave the car. Fast charging during the work hours is therefore essential. It is very expensive to have the driver standing and not working (Welander, Quality, sustainability and project manager, 2019). Public charging is also considered as an important incentive in Norway especially for private owners (Haugneland, 2019).

Regarding heavy vehicles, the establishment of charging infrastructure should combine the service for both heavy trucks and buses, maybe simultaneously at the same place. This cannot be done without first securing the need for all the buses, (that are running with a few minutes intervals in cities). There will be free capacity at nights for trucks when the buses stand still, but such a combination would need careful planning and trials before full scale implementation. For public acceptance, it is very important that the electrification of the public transport is trouble-free (Björk, 2019).

According to research respondents fast public charging is less important than access to home charging, but former is also needed if you want to electrify the fleet. So, a lot of public charging stations along the roads would not help if there is no possibility to charge at home. A measure in the cities could be large scale charging parks where you can leave your car overnight, but it must be simple to use these. Subsidies to charging infrastructure is considered less important and has very small impact compared to tax exemptions, the most important of which is the VAT exemption, both when purchasing and in day-to-day use (Fridstrøm, 2019).

In Denmark, lower electricity prices and lower electricity taxes would be a helpful measure. A tax free option to charge at the workplace would be worth considering, encouraging tax-free charging at work might leverage a positive result during a transition period and could limit the need for everyone to charge at home during peak hours of electricity demand (Gudmundsson, 2019). In Aarhus, politicians have adopted a charging strategy that aims to inspire, and mandate the appearance, placement and design of charging stations. The municipality cooperates with actors who establish public charging points but does not own its own equipment. It is not legal to park a non-electric vehicle at a parking lot with charging points and anyone doing this will be fined (Nielsen, 2019).

The expert panel considered public charging infrastructure and fuel stations important to some extent and these were deemed to have reduced environmental impacts. Accessibility can be adversely affected if charging stations are located inappropriately in urban environments. This instrument does matter but is not as important as other actions. Do not implement fast charging in cities where you do not want to attract car traffic. It is not suitable at street level, but and should preferably be installed at gas stations and similar places. Charging infrastructure (fast) along the main roads is recommended by the group. It is highlighted as an important measure for combating electric vehicle range anxiety and for influencing purchasing decisions. It does not give rise to any major negative distributional effects. It may also benefit the development in the country as a whole. It is significant, but not one of the most important measures that can be taken.

Appendix 8. Public procurement

Transport buyers can demand a climate smart approach to transport solutions. Public actors can impose procurement requirements on new technologies. Vehicle manufacturers, fuel manufacturers, electricity distributors and financiers need to develop new products, develop new business arrangements and collaborate with new players.

The main transport services where it is possible to include requirements for zero-emission vehicles in public procurement are the following:

- public transport
- waste transports
- taxi services, services for disabled etc
- deliverances of goods
- construction work.

Effect on zero-emission vehicles promotion

Researchers have a positive attitude towards using public procurement as an instrument because this can stimulate technology development in general. However, there have to be vehicles available that meet the specific requirements. Life cycle costs should be considered in the procurement specifications (lower operating costs for EVs). Creating a secondary market is also an important consequence (Brundell-Freij, 2019), (Sprei, 2019).

In Denmark, there is also a positive view, however public procured vehicles are still a small part of all the vehicles in the city, so it is much less effective than instruments that influence both private and company cars. To increase the efficiency of the requirements, the city should include private transport services (Gudmundsson, 2019). The requirements must be strict if a significant effect is to be achieved (Nielsen, 2019).

The findings of a research study in Sweden show that public procurement in municipalities increases the adoption rate of EVs. The hypothesis was that municipalities that use electric vehicles create a positive externality in terms of experience spill-overs to other citizens. This result suggests that public procurement of electric vehicles is an effective policy instrument and that local policy instruments should be differentiated to serve the particular characteristics of the municipalitiy and increase their effectiveness (Trosvik & Egnér, 2017).

Socio-economic and distributional effects

A representative from the taxi business emphasized that price determines the procurement. Environmental requirements must be followed up, otherwise the instrument is not effective. The costs can be distributed in society for new technology and an improved environment. Also transport buyers could change and prepare to finance the changeover (Welander, 2019).

København City is introducing rules regarding their own procurement in the city zone where suppliers will have to document that they have a certain proportion of zero-emission vehicles in their delivery fleet. A side effect could be that the vehicles become more expensive, but maybe not in the long run. There is a huge purchasing power in the municipality that make the instrument relevant (Gudmundsson, 2019).

In Aarhus, they initially received complaints from the suppliers about requirements that were too strict for procurement. Among other things, the Aarhus municipality is working with transferring some transports to bicycles and reviewing their own vehicle fleet, so they don't have lower internal requirements than on the procured services (Nielsen, 2019).

Examples from Nordic cities and recommendations from interviewed

The expert panel recommended public procurement as an effective tool and consider all aspects positive. The municipalities have control over the instrument, it is easy to implement and there is a high public acceptance. It is a good and straightforward instrument and is not technology driven but pushed forward by other means. It is important that procurement is followed up to secure compliance. Public procurement can also be used to send out signals to the public.

In Swedish cities, many activities are ongoing around this instrument and to bolster a positive attitude (Sunnerstedt, 2019) (Björk, 2019) (Sigurdsson, 2019). In Uppsala, the municipality is working toward fossil free procurement, as well as mobility management, transport distribution and priority groups, increased cycling etc. (Sigurdsson, 2019).

In Norway, like Sweden, they emphasize the general importance of the public sector in the Nordic countries and they use their power to push industry to deliver zero-emission vehicles. In Oslo City, the municipality's own vehicles will all be zero-emission vehicles or biofuels by 2020 (Portvik, 2019).

Oslo puts requirements on transport in public tenders. EU regulations for public tenders must be met, but one solution is to use "allocation requirements" instead of absolute requirements (Portvik, 2019). There is, though, a risk for low acceptance within businesses. The city has received complaints from suppliers concerning too many requirements (Nielsen, 2019).

In Reykjavík, public procurement is considered to be a very important instrument for the introduction of zero-emission vehicles and those used for services, waste collection etc. though in this case biogas powered vehicles approved as an option and defined as "zero-emission vehicles" (Friðriksson, 2019). New technologies require a governmental push to get into mass deployment (Davíðsdóttir, 2019).

In Helsinki, the procurement process is a big part of a strategy to increase the share of zero-emission vehicles and low-emission vehicles guidelines are applied to the city's own passenger vehicles. The greater Helsinki Metropolitan area has separate sets of environmental criteria for both light and heavy-duty transport services (Venho, 2019).

In Aarhus, the municipality sets requirements on all procured transport within the city including private companies (Nielsen, 2019). An alternative for smaller projects is

requirements to use cargo bikes which increases their efficiency. Aarhus city is working with transferring transports to bicycles and reviewing their own vehicle fleet, so they ensure they don't have lower requirements than on procured services (Nielsen, 2019).

Concerning construction and of road vehicles the cities of Stockholm, Göteborg and Malmö in Sweden use a common approach for public procurement for all contractors, including light and heavy road vehicles as well as non-road mobile machinery. The requirements are summarized in a mutual document (Trafikverket, Gemensamma miljökrav för entreprenader, 2018). These requirements are aimed at achieving environmental benefits in a cost-effective manner when implementing contracts. The requirements comprise fuel types, age, limits of carbon dioxide emissions, share of renewables in fuel and engine emission standards. At least 20 percent of the total energy use shall be electricity from renewable energy sources and/or sustainable high-mix and sustainable clean biofuels that are not subject to a reduction obligation (Trafikverket, Gemensamma miljökrav för entreprenader, 2018).

Through a special procurement strategy, the City of Oslo reduces climate gas emissions at construction sites and stimulates technological changes in the market. To reduce climate gas emissions at its construction sites, the City of Oslo is engaged in a dialogue with suppliers. Familiarity with the technology already available, enabled the city to set a zero-emissions standard in the tender documents, an even higher standard than initially expected. Four kindergartens and two sports arenas are currently under construction in accordance with the new standard. This means that diesel driven machinery and equipment are replaced by fossil free alternatives. Even though not all fully electrical machinery is available at the present time, the market is quickly adapting and developing new solutions. The lesson to be learned is that by setting standards, public developers can influence change in the market. Today, construction machinery accounts for 30 percent of Oslo's traffic emissions. In addition, heating/drying and traffic to and from the construction sites, are contributing both to local emissions as well as climate gas emissions. The goal of the City is to reduce climate gas emissions by 95 percent by 2030, and to slash the use of fossil fuels to zero by that same year. The City Council has adopted fossil free construction sites as minimum criteria in all its public procurement procedures from 2017. As a major developer and owner of buildings, the City of Oslo can significantly reduce city-wide emissions (Oslo Kommune, 2019).

The regional parliament and the public transport company (Västtrafik) imposes public procurement requirements on electrically powered refuse collection vehicles, buses and taxis. Västtrafik has targeted these issues in their current strategies (Västtrafik, 2018). The public company in the waste and recycling industry in West Sweden, Renova, has begun to introduce fully electric vehicles in Göteborg areas (Renova, 2019).

Appendix 9. Other municipal measures

Zero-emission vehicles in the municipal fleet

In Oslo, all municipal vehicles should be electric vehicles or use biofuels by 2020, and all public transport should be fossil free, in the year 2028 all vehicles should be electric (Portvik, 2019). There are still some vehicles (mainly light duty vans) that are not zero-emission, but there is a new date set for 2020. In addition, all municipal heavy goods vehicles and construction machinery should be zero-emission by 2020 (Oslo Kommune, 2018). Another example is Trondheim municipality that has decided that electric vehicles should be first choice when choosing a vehicle. They have also decided that the municipality should provide bikes and e-bikes for their employees to use when commuting to work. The impact on total emissions of a municipal electric vehicle fleet is small, but significant for emissions within the municipality (Trondheim kommune, 2018).

In Sweden, Stockholm City is unique as it focusses on zero-emission vehicles and has no specific goals but claims that in the future the town will mostly purchase EVs, gas powered and plug-in hybrids, but not hydrogen-powered cars. The current fleet is made up of mostly gas-powered cars (Sunnerstedt, 2019). Uppsala municipality aims to be fossil free by 2030, but zero-emission vehicles are not mentioned (Sigurdsson, 2019). The goal of Göteborg´s public transport company is to reach 90 percent reduction of carbon dioxide emissions in the years 2006 - 2035 (Björk, 2019). Taxi Stockholm´s goal is to have a fossil-free fleet by 2025, an ambition which includes biogas, but this goal is not described as "zero-emission". Hydrogen is clearly not included (Welander, 2019). In conclusion, Swedish actors have no zero-emission targets but set up instead climate targets, however those targets explicitly require a certain amount of electric vehicles to be achieved.

In the City of Copenhagen, the goal is 100 percent zero-emission vehicles in own fleet and public transport by 2025. Currently, the share of zero-emission vehicles in the city's own fleet of passenger cars is 85 percent (Isbrand, 2019). Aarhus City has a strategy to replace the municipal fleet with zero-emission vehicles and have as a goal to be fossil-free by 2030 (electric or hydrogen-powered). Biofuels are considered too expensive by the politicians and their tactic is therefore to await electrification (Nielsen, 2019).

Reykjavík City has a detailed plan around zero-emission vehicles introduction, with a target of reaching 35 percent by 2019, 70 per cent by 2021, 85 per cent by 2023 and "100 percent" by 2025, but biogas is considered "good enough" for waste collection trucks and these are considered "zero-emission vehicles" (Friðriksson, 2019).

In Finland, Helsinki City has a goal to become a carbon-neutral city by 2035, this will be achieved by promoting the use of EVs. The share of electric vehicles by 2035 should be 30 percent (which means that biofuels will have a dominant role). Goals and guidelines may be reassessed when the revised EU Clean Vehicle directive comes into force (Venho, 2019).

Managing zero-emission vehicle targets

In the city of Stockholm, Sweden, the politicians have overall responsibility for zero-emission vehicle strategies. Fleet manager officials and energy and-climate advisors are responsible for the vehicle management. Municipal administrations are responsible for the economical side of things, and municipal corporations and departments are responsible for the procurement of transport services. The vehicles strategy very clearly states, for example, that electric vehicles should be the first choice when new cars, vans or trucks are acquired (Sunnerstedt, 2019).

In the city of Uppsala, Sweden, the responsibility for municipal zero-emission vehicles is handled by a service function at the municipal management office. As this is not traditionally an issue for the traffic administration, but rather a climate matter, a change in mindset is needed for the required interdepartmental collaboration. The municipality do not receive extra funds for work with zero-emission vehicles issues (Sigurdsson, 2019).

The public transport company in Gothenburg, Sweden, (Västtrafik) has a portion of its budget earmarked the acquisition of electric buses (Björk, 2019).

In Oslo many policy measures are funded by either the government or the municipality.

In the City of København, a Technical and Environmental Committee is responsible for the political framework, and officials are responsible for implementing and working to achieve political goals. Everything must be approved by the politicians including financing of the measures deployed (Isbrand, 2019).

In Aarhus, the city considers that they have a clear picture of the strategy needed to become fossil free by 2030 and understand how this can be brought about. But the economic issues must compete with welfare costs and the politicians have been reluctant to allocate money for introduction of zero-emission vehicles (Nielsen, 2019).

In Reykjavík, the goals are set by politicians, but the responsibility is scattered and there is a lack of specific knowledge about electric vehicles. Every department is responsible for its own vehicles. Economy has not been as much of a problem as have other aspects. The municipality must handle zero-emission vehicle within its budget, but electric vehicles are cheaper to run so this is a minor problem. The procurement department is not responsible but is checking that "you do things in the proper manner" (Friðriksson, 2019).

Cooperation with other actors

In Sweden there are many collaborations between different actors about charging stations, fuel stations, grid owners, the municipality (different departments), different organizations such as biogas associations, electric cars associations etc.

When it comes to fuel supply and charging the Swedish Truck manufacturer AB Volvo and its competitors collaborate with a variety of actors. In addition, there are many ongoing collaborations with various energy companies. It is important to achieve interoperability[3] in finding, booking and paying, and working together

with regulating authorities, so that interoperability can be achieved between charging suppliers within the EU (Berger, 2019).

In Norway and Denmark, there are some collaborations within the charging infrastructure contractors, but little pro-active cooperation with the industry (Portvik, 2019) (Isbrand, 2019) (Nielsen, 2019). The Icelandic view is that there are presently too few collaborations ongoing (Friðriksson, 2019).

Pilot projects and test beds

The interviewees bring up a few pilot projects and testbeds that aim to promote the introduction of zero-emission vehicles. Stockholm has been involved in several projects, for instance the procurement of hydrogen powered buses, conversion of electric hybrids into chargeable vehicles, test drives in the city financed by research funding and evaluated by the academy. Göteborg public transport company participates in the *ElectriCity* research project along with AB Volvo. Electrified public transport is now being procured (Björk, 2019) (Electricity, 2019).

In Uppsala, the municipality works with freight transport and transports to construction sites via a center for construction logistics. The role of this centre is to reduce the impact of heavy transport to and from the sites, the consolidation of goods and to set procurement requirements for environmental and climate performance (Sigurdsson, 2019).

AB Volvo has major ongoing project in the US that test drives 30 tonne electric trucks with large batteries intended for regional distribution (< 300 km range) and from ports to logistics areas. These applications enable charging during the day (Berger, 2019).

The city of Oslo participates in the Oslo city hub, which is a low-carbon city distribution center established in May 2019. The centrally located new terminal will reduce emissions of carbon dioxide emissions from city goods distribution by 80 percent, using electric cars and e-bikes (Schenker, 2019). The operators' goal is that 80 percent of their distribution within ring road 3 in Oslo will be carried out using zero-emission vehicles by 2019, and Oslo City Hub will be important in achieving this goal. The project has been evaluated and some conclusions have been drawn (Ørving T., 2019).

Another Oslo project is the reservation of 600 parking spaces for car sharing, a trial with a Park-and-ride system and a testbed with a zero-emission building site. There are also many other tests underway and plans for mobility services such as bike and car sharing, e-scooters, city freight hubs, mobility houses etc. Public transport has expanded, modal shares have gone up and services have improved. At the moment, Oslo City is discussing with the National Traffic Authority how to clarify definitions around signage and regulations (Portvik, 2019).

The City of København has also been involved in a pilot mobility-as-a-service-solution (Maas), with the purpose of integrating different mobility solutions in the national travel planner app. Services provided by the Drive Now, Green Mobility and Bycyklen companies and others are available via this app. However, the project is now running without municipal involvement (Isbrand, 2019).

In Reykjavík, they reject the concept of pilots and instead focus on implementing charging stations and embrace the ”go for it” school of thought (Friðriksson, 2019).

Promotion of zero-emission taxi vehicles

Measures to promote zero-emission taxis are generally motivated by the fact that taxi vehicles are far more intensely used than average cars. Many of them are diesel-powered, and they often operate in inner city areas. Each vehicle therefore contributes more than other similar vehicles to city traffic emissions.

Taxi specific measures include:

- License requirements – emission constraints when licensing a vehicle as a taxi
- Taxi age limits
- Grants for the purchase of zero-emission taxis
- Taxi delicensing payments – special grants that are payed to delicense old, polluting taxi vehicles
- Dedicated charging points for taxi vehicles

Presence in Nordic countries

Taxi specific measures are to a certain extent implemented in the Nordic countries. A change in the Norwegian legislation regulating professional traffic now allows cities to require minimum emission standards for vehicles applying for a license for commercial taxi operation (Samferdselsdepartementet,2019, Lov om yrkestransport med motorvogn og fartøy (yrkestransportlova), §9). A transitional period of at least four years is mandated.

Denmark has introduced a national goal that will only allow zero-emission vehicles as new taxis. This to come into force by 2025. This objective, alongside a set of actions to support its achievement, was published by the Danish government in January 2019. The most significant short-term measure is that 300 out of the limited total of 500 new taxi licenses awarded nationally in 2019 and 2020 are set aside for zero-emission vehicle. Currently, taxi drivers owning zero-emission vehicles (electric or hydrogen-powered) are automatically guaranteed a taxi license. Furthermore, zero-emission- taxis will be given priority over those powered by fossil fuels at public transport ranks (Eltis, 2019) (Taxi intelligence, 2019).

In Sweden, several strategic locations – namely airports, have introduced environmental demands and preferential treatment for low emission taxi vehicles. Since 2012, only so called “green cars” (according to the definition for tax-benefits at that time) were granted contracts to operate at Göteborg-Landvetter airport, Sweden. Since 2016, zero-emission vehicles and biogas powered taxis are given preferential treatment in the taxi-queue system at the airport (Swedavia, 2019).

Effects on climate gas emissions and air quality

The impact on air quality is highly dependent on the relative contribution of taxi vehicles to total transport emissions but can be substantial in central areas. Annual savings of a zero-emission vehicle -taxi fleet in all of Oslo is estimated to be more than 20,000 tons of carbon dioxide emissions. The reductions are however not related to total traffic emissions and the total impact on air quality is therefore difficult to assess. Note that this

assessment is based on the assumption that zero-emission vehicles have zero contribution to climate emissions and therefore the assessment probably overestimates the positive climate impact of the measure. The impact on air pollution emissions in Oslo has also been estimated. The report shows considerable reduction possibilities for nitrogen oxides (reduction with 52 tonnes annually compared to 2015) and particulate matter (Bymiljøetaten, 2017).

In London, taxi vehicles are estimated to contribute 25 percent of all transport related nitrogen oxides emissions in central London (Transport for London, 2019). This is probably an exceptionally high contribution, but nevertheless shows that taxi vehicle emissions can be substantial.

Socio-economic and distributional effects

An assessment of the economic impact for taxi operators of zero-emission vehicles demands concluded that a transition to zero-emission vehicles for taxis by 2022 in Norway will not affect profitability of taxi operators in a negative way. A prerequisite for this finding is that transport capacity is not affected negatively by infrastructure, e.g., the availability of charging stations. Note that this conclusion is based on the current, generous tax-reductions for zero-emission vehicles in Norway (Bymiljøetaten, 2017).

The measures are not expected to influence taxi fares and is therefore not considered to have any real impact on taxi customers (Bymiljøetaten, 2017).

Good examples

Based on changes in legislation, the City of Oslo has proposed that only zero-emission vehicles (battery electric or hydrogen powered) will be granted taxi licenses by 2022. Taxis have not been subsidized, but the municipality and the taxi companies have devised a common strategy. This has been possible through a national legislation where cities may impose this kind of environmental requirement (Portvik, 2019). As a step to reach this goal, a suggestion is that zero-emission vehicles must be used for taxis with a capacity of maximum nine persons. Transports of disabled people are excluded. The suggested requirement is put on the taxi permit holder to ensure that taxis are zero-emission vehicles (Bymiljøetaten, 2016). This demand is currently under hearing and planned to be fully implemented by 2022 (Oslo Kommune, 2019) There have also been investments in wireless taxi charging (Portvik, 2019).

Taxi specific measures are heavily implemented in London that can showcase a whole series of taxi-specific measures: Payments for delicensing older taxis, age limits for taxi vehicles and a requirement for zero-emission capability (minimum 30 miles zero-emission range) for taxis presented for licensing for the first time (Transport for London, 2019).

According to one interviewee, national Norwegian regulations could be amended so that taxis can drive in car free areas. This would simplify matters for people that have difficulties getting about or walking long distances, but who are not eligible to receive a disabled parking permit (Portvik, 2019).

Zero zone taxi initiative

The *Nollzon* project (in English "Zero zone") initiative focusses on taxi companies in large cities. Nollzon is a non-profit association. Companies cooperating within Nollzon want to increase demand for electric vehicles and superchargers by allowing employees to

prioritize electric vehicles when they order a taxi. When a company registers its address, every cab order automatically prioritizes an electric vehicle. Nollzon deals only with fully electric powered vehicles running on batteries or hydrogen. Currently (2019), 1228 companies have joined Nollzon. A majority are situated in the Stockholm-region (Nollzon, 2019).

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IVL Swedish Environmental Research Institute Ltd.
P.O. Box 210 60 // S-100 31 Stockholm // Sweden
Phone +46-(0)10-7886500 // www.ivl.se