Electric heavy-duty trucks - Policy Outlook

Planned and implemented policies to support battery electric heavy-duty vehicles in Sweden, Austria, Germany, the Netherlands, UK and California (US)

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Preface

This study is funded by REEL and E-Charge which are Swedish national initiatives to accelerate the transition to an electrified heavy-duty transport sector. Within REEL, around 60 regional electrified logistic flows are established, driven and evaluated. E-Charge gathers 14 actors that in collaboration develop, test and demonstrate battery electric long-haul trucks. Both projects receive co-funding from the Strategic Vehicle Research and Innovation program (FFI) through Vinnova, the Swedish Energy Agency and the Swedish Transport Administration.

Executive summary

The transport sector accounted for 37% of global CO_2 emissions from end-use sectors in 2021. For the transport- and road freight sector to contribute to emissions reduction targets while still meeting the foreseen increase in transport demands, decarbonization will play a key role.

This study focus on battery-electric heavy-duty trucks and the objective is to provide an overview of policy instruments, planned or implemented, that support the introduction of such trucks in Austria, Germany, the Netherlands, Sweden, UK and California (US). This study also aims to identify policy design that could be interesting to further investigate in a Swedish context.

Although the number of trucks is still very low, all countries have implemented various policy instruments to support an increasing electrification of the freight sector. In general, all countries seem to have a similar approach when implementing such policy instruments although there are also interesting differences that could be used for inspiration when designing new policies.

The most common economic policy instrument is investment subsidies for vehicles as well as infrastructure. It can be noted that the size of the subsidy varies between different countries which could reflect different market conditions or different ambition from policy makers. Either way, since market conditions change rapidly, not least due to a technical development, it is important that policy makers have access to updated TCO calculations to make sure that investment subsidies are on the required level.

In addition to the size of the subsidy, there are also some differences in the practical implementation. In the EU, it is required that the buyer of the truck apply for a subsidy in competition with others. California and the UK on the other hand use a voucher system that does not require an application from the truck buyer. In addition to investment subsidies for vehicles, most countries have also implemented subsidies for charging infrastructure. In this matter, Sweden stands out with several subsidies for infrastructure that does not require investments in trucks at the same time. Although this is a more flexible solution for market actors, the application system applied in Sweden and other EU countries seems to require more administration and uncertainties for the company that like to invest compared to the voucher system applied in the UK and California. It would therefore be interesting to further analyse if such a system could be implemented under EU state aid regulations.

It is also common to use administrative policy instruments to create incentives for low or zero emission trucks including but not limited to battery-electric heavy duty trucks. The fit for 55 package in the EU includes for instance CO2 emission standards that currently requires manufacturer to reduce emissions from new trucks with an overtime increasing percentage as compared to 2019 levels.

A similar but maybe more direct approach can be found in California where authorities have implemented both push and pull instruments aiming at manufacturers as well as private fleet owners. These instruments create an obligation for manufacturers to sell and for fleet owners to buy and thus ensuring a minimum share of zero emission trucks operated in California.

In Sweden it is probably necessary do follow EU regulation when it comes to requirements on manufacturers. However, it could be interesting to analyse possibilities and challenges with a system that makes it mandatory for large fleet owners to buy or operate a minimum number of zero-emission trucks.

Another kind of policy instrument that is or will be implemented in several countries are zero emission zones. This instrument allows policy makers to push for zero emission trucks where they give the highest benefits from a society perspective. Several countries are also working with different road toll systems on high-ways or zones in cities where conventional trucks are not forbidden but must pay a fee that is higher than the fee for zero-emission trucks. Thus, policy makers can create an incentive for zero-emission trucks without banning conventional trucks. In Sweden, there are no zero-emission zones, road tolls or any other similar system that affect the operation cost of an electric truck compared to conventional trucks. Since such policy instruments make it possible to target measures to areas where electric vehicles have the highest benefits it could be beneficial to further analyse the pros and cons with such policy instruments in a Swedish context.

Acronyms & Abbreviations

EV	Electric Vehicle
GHG	Greenhouse Gas
HDV	Heavy-Duty Vehicle
LDV	Light-Duty Vehicle
N1	EU vehicle classification – small commercial vehicles designed for carriage of goods, weighing less than 3.5 tons
N2	EU vehicle classification – Commercial vehicles that weigh more than 3.5 tons, but not more than 12 tons
N3	EU vehicle classification – Commercial vehicles that weigh more than 12 tons
TCO	Total cost of Ownership
Tkm	Ton-km
ZEV	Zero-Emission Vehicle – A vehicle that does not emit emissions from the tailpipe

1 Introduction

The transport sector accounted for 37% of total CO_2 emissions from end-use sectors globally in 2021 [1]. Medium and heavy-duty trucks are responsible for 9% of global emissions or 23% of total emissions from the transport sector [2, 3]. In the European Union, medium and heavy-duty trucks contributed with approximately 7% of total GHG emissions in 2021 and 38% of emissions from the road transport sector [4]. The demand for both passenger and freight transport are expected to increase rapidly during the coming years, with volumes of road freight estimated to increase by approximately 1% per year up until 2050 – forecasting a 8% increase in CO_2 emissions from the sector given current policy and regulatory actions [4].

For the transport- and road freight sector to contribute to global emissions reduction targets while still meeting the increasing transport demands, decarbonization will play a key role. Many heavy-duty vehicle manufacturers have set ambitious goals to put increasing numbers of zero-emission vehicles on the rapidly growing market. Combined these goals indicate that 40% of all sales in 2030 will be a battery-electric or fuel-cell vehicle [4]. Sales of zero-emission trucks are gaining increasing market share in North America, Europe, and China. IEA estimated the current global stock of electric trucks to 66,000 – representing 0.3% of new registrations in 2021, and 0.1% of the total fleet [2]. Projections from IEA further forecasts a continued increase in these numbers during the coming years, with the global number of electric medium- and heavy-duty trucks expected to be between 280,000-340,000 in 2025 considering existing and announced policies [5].

There are, however, many technical, operational and financial challenges to overcome in the transition to a zero-emission road freight sector. These challenges might be reduced by technical and economic development, but also by creating and implementing adequate policy frameworks [6]. Policy action can help to catalyse industry and allocate costs of transitioning to different segments of society so that they remain bearable. Since many vehicle manufacturers act on a global market and countries that wants to decarbonize their transport sector could face similar challenges, the construction and implementation of policy instruments can benefit from considering examples and lessons learned from several different countries.

1.1 Objective, method and delimitations

The objective of this study is to provide an overview of policy instruments supporting the introduction of battery-electric heavy-duty trucks that are planned or already implemented in some selected countries. This study also aims to identify policy design that could be interesting to further investigate in a Swedish context.

The study is limited to Sweden, Austria, Germany, the Netherlands, UK and California (US) and policies exclusively aimed to support hydrogen fuel cell vehicles or electric road systems are out of scope and not considered here.

Policies presented in the country overview have been identified mainly through a review of documents and sources available online in English. Thus, there could be relevant policies or details that were not identified in the reviewed material. Further, although briefly mentioned, this study does not focus on information policies and R&D policies.

1.2 Choice of countries

The countries included in this study were selected based on discussions with members of REEL's reference group. All countries included are recognized to be progressive when it comes to policy and legislation to support the uptake of battery-electric heavy-duty vehicles. As the study aims to identify and discuss policy design that could be interesting to further investigate in a Swedish context, it was considered important to include countries with leading policy practices that could act as inspiration and guidance for Swedish policy development. Austria and the Netherlands were selected as they are determined to be fairly similar to Sweden in terms of population- and vehicle fleet sizes. However, both countries are more densely populated which implies different types of challenges to the heavy-duty transport sector, especially in urban environments. Germany was selected as the country represents a large EU economy, with a renowned automotive manufacturing industry. As Sweden is also home to leading vehicle manufacturers, German policy principles and applications could be relevant in a Swedish context as well.

Further, it was considered important to look outside of the EU. As a former EU member, UK is an interesting case. UK's policy and legislative landscape has in the past been greatly influenced by the EU, but the country has since its exit from EU been free to implement any measures without being restricted by EU legislation. California was also considered an interesting case to investigate as the state is renowned for advancing in its politics to support zero-emission mobility as well as home to some leading heavy-duty vehicle manufacturing and assembling industries.

2 Use of policy instruments in the transport sector

A policy instrument can be described as a tool used by governing authorities to influence different actors in a direction that is beneficial to achieve certain political goals and/or agendas. Properly designed policy instruments are believed to be crucial to overcome barriers in the early stages of road freight electrification [4].

To influence the development and operation of the transport sector, there is a wide range of policy instruments available – internationally as well as on national levels. Policy instruments can take many forms – it can be e.g. environmental standards, economic incentives to correct resource allocation failures, education, R&D, laws, or monitoring mechanisms [7]. In general, several types of policy instruments from different categories can be used in combination to achieve desired results – this combination of measures is often referred to as a policy mix.

This chapter provides an overview of different categories of policy: administrative-, financial- and information policies. Those categories further act as a framework in Chapter 3 to present policy findings in each of the studied countries. Further, this chapter provides some examples of policy instruments commonly used to diffuse innovation in the transport sector.

2.1 Administrative policy instruments

Administrative policy instruments include mainly regulations, law, standards, directives, monitoring, and voluntary agreements. Administrative policy relies on regulation – permissions, prohibitions, standard setting and enforcement, as opposed to financial incentives [8].

Through its design, regulatory measures are designed to force individuals and organizations to act in a certain way in order to not risk facing negative consequences. Regulatory measures are appropriate to address activities with potentially serious risks of impacts for the economy, the environment or individuals and where legal certainty and enforcement backed by legal sanctions are necessary. It could also be the only available option if "softer", self-regulatory approaches have already been tried and failed [9].

One example of an administrative policy instrument used to support zero-emission vehicle technologies is zero-emission zones. Zero-emission zones are areas where only zero-emission vehicles, pedestrians and cyclists are granted unrestricted access. Other vehicles are either prohibited from entering or permitted to enter upon a fee [10]. Zero emission zones provide a means for cities to pilot innovations in urban transport and mobility, increase the use of zero-emission vehicles, and prioritize walking, cycling and public transport. Zero-emission zones are also used to achieve local air quality improvements and other benefits such as lower noise levels [10].

In general, zero-emission zoning is a policy option implemented by cities and municipalities. Some types of zones need enabling legislation from the state [11]. As zero-emission zones will directly affect stakeholders in cities, public acceptance plays a significant role in successful implementation. Hence, public communication and involving stakeholders in the policy-making process is important [12].

Another example of binding legal rules used to specify the behaviour of actors in the transport system is sales- and purchase requirements. The costs of transitioning to zero-emission trucks can be high initially due to i.e., poor economies of scale and technological immaturity [6]. Economic incentives and cost reductions can be used to help overcome financial constraints and spur supply – but the effects of financial support on production level tend to be unpredictable [6]. Sales requirements can be used to achieve certainty of supply at a price that the market will bear. The purpose of sales requirements is to guarantee sufficient market supply and to put shift the incremental cost of bringing supply to the market on the producers rather than the consumers. Sales requirements for ZEV already exists on vehicle producers in California, China and the EU [6].

Further, sales requirements are often paired with purchase requirements. In early stages of market adoption for ZEV, the upfront investment cost as well as TCO is high. Instruments such as direct purchase requirements on fleets, bans on diesel vehicles, and CO_2 emission standards can all be used to forcefully affect demand [6]. The combination of sales- and purchase requirements on ZETs has for example been used in California through the Advanced Clean Truck rule (sales requirement) and the Advanced Clean Fleet rule (purchase requirement).

Another example of an administrative policy instrument is regulation on tailpipe CO_2 emission standards. Such regulation has been implemented in the EU for passenger cars and trucks, and there are ongoing discussions to implement standards for heavy-duty vehicles as well [13]. EU:s tailpipe CO_2 emission standards regulates the average CO_2 emissions that are allowed from manufacturer's fleets of newly registered vehicles. The regulation sets out mandatory monitoring and reporting requirements to ensure compliance with the regulations [13].

2.2 Financial incentives and economic instruments

Economic policy instruments are designed to adjust prices of goods and services in order to change society's behaviours towards desired policy objectives. There is a wide range of economic instruments available – including traditional fiscal instruments such as subsidies, grants, taxes, charges/fees and fiscal transfers. Tradable permits such as pollution permits are also a type of economic policy instrument.

Economic policy instruments aim to make it financially easier or more difficult for actors to perform certain actions. In this way, economic instruments differ from command- and control measures as they do not per se force the actors to act in a certain way. Instruments such as subsidies, tax credits and investment aids are frequently used by governments to stimulate diffusion of new (less GHG-emitting) technologies. Charges and taxes can also be applied in a governing purpose, to be applied only to those who use a service or behave in a certain way, e.g. noise- or pollution fees.

There are several types of economic policy instruments that can be used to promote deployment of electric trucks. Many of those have already been seen used to spur the uptake of electric passenger cars, charging infrastructure and battery industries. The measures are primarily different types of purchase subsidies, grants and tax rebates – designed to reduce the price gap with conventional vehicles [14]. Other examples are tradable permits where rights to exploit resources can be exchanged through a fee or a controlled permit market [15]. One such example is the EU Emissions Trading System (ETS) for GHG emission rights trading.

2.3 Information policies

Information policies are sometimes called public disclosure requirements. This type of policy instrument aims to increase knowledge to change attitudes and/or guide actors to make better-informed choices. Information policies can take the form of i.e., information campaigns, education, or consulting services.

Information policies further carry the potential to improve effectiveness of other types of policies. They are often used in combination with regulatory or financial instruments, as a complement or with the purpose to increase acceptance of these other types of instruments. Information policies also play an important role in communicating the general direction of the politics/public sector, and hence make it possible for actors to adjust their operations to fit long-term, established goals in society [16].

2.4 R&D

Research and development (R&D) activities are carried out in the public sector as well as in private businesses and can play a major role in deciding on the direction of development in a certain sector. Support for research and development in the transport sector generally aims to guide R&D activities in a direction that achieve the sector's climate targets. Hence, one of the most common forms of R&D instruments in the transport sector is to give financial support to research within prioritized areas, such as renewable fuels and electrified vehicles.

R&D instruments are an important practice to achieve long-term results. R&D instruments can influence which areas that are prioritized in research and innovation, which over the course affects which solutions and technologies that are available on the market. New technologies and innovations being available can also make it easier for actors in the market to choose more sustainable options.

3 EU policies and regulations

The EU law is a system of rules operating within the member states of the European Union. Every action taken by the EU is founded on treaties of every member country. The treaties have been approved voluntarily and democratically and acts as a binding agreement between all EU member countries. The treaties are the cornerstone of EU law and are known as primary law. The body of law that is based on the principles and objectives of the treaties are known as secondary law and includes regulations, directives, decisions, recommendations, and opinions [17].

EU regulations are legal acts that apply uniformly to all EU countries as soon as they enter into force, without any need to be transposed into each county's national law. EU directives require membership countries to achieve a certain result but leave each country free to choose how to do so. However, all countries must adopt measures to achieve the objectives set by the directive and incorporate them into national law. The measures must be communicated to the European Commission by national authorities [17]. This chapter gives an overview of EU regulations and policy in the transport and climate sectors that directly or indirectly affect the implementation of electric trucks in the EU. These policies and regulations act as a base for applied national policy and regulations in the studied EU-countries which are described in further detail in chapter 4.

3.1 European Green Deal

As a part of its commitment to the international Paris Agreement, the EU has pledged to achieve climate neutrality by 2050. The European Green deal, which was launched by the EU commission in 2019, is a package of proposed policy instruments and actions that will ensure EU's fulfilment of the 2050 climate neutrality goal [18]. As a part of the European Green Deal, the EU Commission proposed the first European Climate Law in March 4, 2020 [19]. The European Union's climate law includes the targets set in the European Green Deal [20]. The European climate law, which came into force in July 2021, states that the economy and society of the EU should be climate neutral by 2050. As an intermediate target, net greenhouse gas (GHG) emissions should be reduced by at least 55% by 2030 compared to 1990s levels [18, 21]. There are no targets for specific sectors but the European Commission states that the transportation sector must reduce GHG emissions with 90% until 2050 for the EU to reach its goal of climate neutrality [22].

3.2 Fit for 55

Fit for 55 is a legislative package published by the European Commission in July 2021. Fit for 55 contains a set of proposals to revise climate, energy, and transport-related legislation to align current EU laws with the ambitions set in the European Green Deal and the targets stated in the climate law [18, 23]. The proposed revisions related to transport includes:

- The EU emissions tradingsystem (EU ETS)
- The renewable energy directive
- The energy tax directive CO_2 emission standards for cars and vans
- Deployment of alternative fuels infrastructure

The EU emissions trading system (EU ETS): The EU ETS is an emissions trading system where a cap is set on GHG emissions from companies in certain sectors. These emission rights are bought or given to the companies and can be traded between the actors included in the system. The European Council has agreed to create a new emissions trading system (ETS2) which will include heating of buildings and the road transport sectors. The new system will complement the existing system covering emissions from energy and industry and will apply to distributors that supply all types of fossil fuels for consumption in the road and transport sectors [24]. Further, it is suggested that issuing of new emission rights should gradually decrease to completely stop by 2043 [25].

The Renewable Energy Directive: The Fit for 55 package includes a proposal for a revision of the Renewable Energy Directive. The proposal is to increase the current EU target of at least 32% of renewable energy sources in the overall energy mix to at least 40% by 2030. The proposal further includes sectorial sub-targets and measures across sectors, with a special focus on transport, buildings and industry [23]. The sub-targets for the transport sector states inter alia that each member state shall reduce its transport sector's GHG intensity with at least 13% by 2030 compared to baseline levels [26]. This obligation puts requirements to increase the share of renewable fuels and renewable electricity supplied to the transport sector.

The energy tax directive: The revision of the energy tax directive aims to align the taxation of energy products and electricity with EU's current energy and climate policies. The energy taxation can help encouraging a transition to cleaner energy and a greener industry [23]. The revised directive will mainly focus on the following two areas: the structure of tax rates, and to broaden the taxable base. The revision of the structure of tax rates implies that the most polluting fuels, i.e. coal, oil, and gas, will be taxed higher. Broadening the taxable base means that more products will be taxable, and that some of the current tax exemptions and reductions will be removed [27]. For example, it is proposed that aviation and maritime fuels

will become subject to taxation. There will also be no distinction in taxation between commercial and non-commercial use of fuels and electricity [27].

CO_2 emission standards for cars and vans: The Fit for 55 package includes a proposal to revise the CO_2 emission standards for new cars and vans. The proposed regulation increases CO_2 emission reduction targets for 2030 and sets a new target of 100% emission reduction for 2035. In practice, this means that from 2035 it will no longer be possible to place cars or vans with an internal combustion engine on the EU market [23]. The proposal is currently (November 2022) pending formal adoption [28]. There have not yet been any revisions of emission standards for heavy-duty vehicles or trucks, but the ICCT and the European Clean Trucking Alliance states that a revision of heavy-duty CO_2 emission standards are planned for November 2022 [4]. Current heavy-duty CO_2 emission standards were adopted in 2019 and only require manufacturers to reduce emissions of new trucks and buses with 15% in 2025 and 30% in 2030 and onwards, relative to 2019 levels [4]. The proposed revision includes targets for 2035 and 2040 and is expected to extend its scope to buses as well [29].

Deployment of Alternative Fuels Infrastructure: In June 2022, EU member states agreed on the Commission's proposal for the revision of existing directive aiming to accelerate the deployment of infrastructure for recharging or refuelling vehicles with alternative fuels. With the alternative fuels infrastructure regulation (AFIR) proposal, the European Commission sets concrete targets for deploying such infrastructure in the EU. The proposal further includes a repeal of the directive and replacing it with a regulation – to ensure "swift and coherent development" of the infrastructure across the EU [30].

For road transport, AFIR proposes that there should be an electric charging station at least every 60 km on main roads. For passenger cars, this goal should be reached by the end of 2025 and for heavy-duty vehicles by the end of 2030. The number of charging stations should grow with the number of registered electric cars and vans. Further, the new regulation states that there should be at least one charging station for heavy vehicles (over 3,5 tons) in each "safe and secure parking area" by the end of 2030, and that there should be charging stations in urban areas [31]. All new charging stations must allow ad-hoc charging and accept electronic payment [31].

3.3 Sustainable and Smart Mobility Strategy

The European climate law, although legally binding, is on a general level and does not specify how the set targets should be reached. The European Green Deal consists of several policy packages, covering different policy areas and regulations for various disciplines of society. Policies addressing transport and mobility are gathered in the "Sustainable and Smart Mobility Strategy." The strategy calls for a 90% reduction of GHG emissions in transport by 2050, for EU to reach climate neutrality [18].

3.4 CO_2 emission standards for heavy-duty vehicles

The EU-regulation 2019/1242 sets CO_2 emission standards and monitoring mechanisms for heavy-duty vehicles [32]. Levels of CO_2 emissions are determined through a procedure regulated through Directive EC 595/2009. The emissions data are then reported and monitored through regulation 2018/956. As earlier mentioned, the ICCT and the European Clean Trucking Alliance states that a revision of heavy-duty CO_2 emission standards are planned for November 2022 [4].

The system is based on compliance – and manufacturers not meeting the targets will pay emission credits or emission debts. Exceeding the allowed CO2 emissions required paying up to 4250 EUR/gCO_2/tkm [32].

To incentivize early uptake of zero- and low-emission trucks, EU has introduced a super-credits system applying from 2019 to 2024 [33]. The super-credit system sets CO_2 emissions reduction targets for heavy-duty vehicles for 2025 and 2030. For the reporting period of 2025-2030, average specific CO_2 emissions of heavy-duty vehicles should be reduced by 15% compared to 2019 levels. From 2030 and onwards, the target is to reduce CO_2 emissions by 30% compared to 2019 levels [32]. The super-credit system implies that before 2025, all zero- and low emission heavy-duty vehicles should be counted multiple times when determining the average specific CO_2 emissions of a manufacturer [32]. A zero-emission heavy-duty vehicle shall be counted as two vehicles, meaning that they boost a lower average specific CO_2 emission value for the manufacturer and acts as an incentive mechanism for zero- and low-emission vehicles.

3.5 The Eurovignette Directive

In the EU, road charging is a choice to be made by each nation. However, if a member state decides to adopt charges on heavy-duty vehicles, they can follow the rules set out by Directive 1999/62/EC, known as the Eurovignette Directive. The directive provides a structure of minimum and maximum tax rates, as well as guidelines for member states to cooperate and set up a common system for road user charges [34]. Eurovignette is such a common system that was imposed as a result of the Directive 1999/62/EC.

The Eurovignette system is based on electronic vignettes (a type of time-based ticket fee) for heavy-duty vehicles for the use of certain infrastructure. When the system was introduced in 1995, it was adopted in the Netherlands, Luxembourg, Sweden, Denmark, Belgium and Germany. Germany and Belgium however replaced the Eurovignette system with their own national toll collecting systems in 2003 and 2016, respectively.

Table 1: Eurovignette tariffs (EUR), valid from 1/1 2022 until 31/12 2022]35]

Emission group	Annual tariff		Monthly tariff		Weekly tariff		Daily tariff	
Number of axles	1 – 3	≥ 4	1 – 3	≥ 4	1 – 3	≥ 4	1 – 3	≥ 4
Euro 6 or less polluting	750	1 250	75	125	20	33	12	12
Euro 5	796	1 327	79	132	21	35	12	12
Euro 4	842	1 404	84	140	22	37	12	12
Euro 3	926	1 543	92	154	24	41	12	12
Euro 2	1 065	1 776	106	177	28	47	12	12
Euro 1	1 223	2 042	122	204	32	54	12	12
Euro 0	1 407	2 359	140	231	37	62	12	12

In 2022, the European Parliament and the European Council presented an amendment of the Eurovignette Directive. The goal of the new Eurovignette Directive is to make road pricing fairer and more efficient, and to better reflect the "polluter-pays"-principles as a means to achieve a competitive and resource-efficient transport system [36]. The revised legislation is still awaiting final adoption by the European Council as of October 2022.

The main revision to the Eurovignette Directive is that the system of vignettes for heavy-duty vehicles will be phased out and replaced by distance-based tolls across the core trans-European network. The new system would start to apply to heavy-duty vehicle and buses in the end of 2023, and then be expanded to also cover passenger cars and vans by the end of 2027 [36]. Further, the current variation of charges according to Euro emission classes of the vehicles will be phased out and replaced by a scale of charges depending on the vehicle's CO_2 emission levels [36]. The amendment will hence benefit operators of zero-emission heavy-duty vehicles, as zero-emission vehicles will receive significant toll discounts [29].

3.6 State Aid Rules

Within the EU, state aid to individual companies is in general prohibited [37]. In some cases, it might however be motivated or even necessary for a well-functioning economy. IF member states wish to establish such policy instruments, EU state aid control requires prior notification of such measures, and they cannot be put in effect before the commission has decided if they are aloud or not [37].

There are also some cases where such notification is not necessary. These are de minimis aid that does not exceed 200 000 EUR over a 3-year period as well as aid granted under an aid scheme that has already been authorized by the Commission.

Finally, there are also the General Block Exemption Regulation (GBER) where specific categories of state aid are declared compatible with the EU Treaty and therefore not requiring notification [38].

In the latest version of GBER, aid for public accessible recharging infrastructure is listed as one of the exemptions. Member states can thus fund up to 100% of the investment cost in such infrastructure under certain conditions without notification to the commission [38]

4 Austria

In June 2022, Austria had almost 500 000 light-duty vehicles and 55 000 medium and heavy-duty vehicles in total [39]. As for electric vehicles, the country had 6 614 electric light-duty trucks and 66 electric heavy-duty trucks – corresponding to approximately 1.3% and 0.1% of the fleet, respectively [39, 40].

Austria recognizes E-mobility and renewable energy as integral parts to realize the Paris Agreement as well as national and EU-wide climate targets [41]. The country aims for a climate neutral transport sector by 2040. Austria plans on reaching this target through using a set of tools and policies such as shifting traffic from road to rail, phasing out fossil fuels by electrifying the fleet of passenger cars, and electrifying or using climate-neutral fuels for commercial vehicles [42].

4.1 Administrative policy instruments

Austria's climate action in the transport sector is presented through Austria's 2030 Mobility Master Plan. The aim of the plan is to realign Austria's mobility sector to meet the requirements of the Paris Climate Agreement [42]. Austria aims for climate-neutral long-distance transport by 2040. To achieve the targets set in the mobility master plan, it is acknowledged that realigning current laws as well as creating new legal frameworks will be crucial. It is stated that new mobility legislation will be drafted to address the challenges of transitioning to a climate-neutral transport system through effective measures. The legislation will focus on innovation and climate protection in transport law [42].

To achieve the goal of climate neutrality by 2040, the plan states that "seamless zero-emission operation of vehicles for freight transport must be possible throughout Austria no later than 2035" [42]. The mobility plan further states that the framework for implementing large battery electric and hydrogen fuel cell fleets must be in place by 2030, including establishment and expansion of required infrastructure [42].

4.1.1 Requirements for new registrations of heavy-duty vehicles

Austria's mobility plan presents the goal that 100% of all new registrations of heavy-duty vehicles weighing less than 18 tons should be zero-emission vehicles by 2030. For heavy-duty vehicles exceeding 18 tons, the goal is that 100% of new registrations should be zero-emission vehicles by 2035 [42]. These goals are not official targets but are seen as key in setting ambitions and achieving climate neutrality by 2040.

4.2 Financial incentives and economic instruments

Austria's Mobility Master plan contains a framework for economic mechanisms – stating that the country will use "innovative mechanisms to create cost transparency and mobilize investment for the mobility transition" [42]. Austria's Green Finance Agenda further outlines the pathways to invest in sustainable and climate-friendly measures of transition.

This chapter presents the most substantial financial incentives that has been introduced in Austria to facilitate the transition to zero-emission heavy-duty vehicles.

4.2.1 Investment subsidies for ZEV (commercial) and infrastructure

The Climate Protection Ministry (BMK) in Austria is providing a new investment subsidy program called ENIN (Zero emission commercial vehicles and infrastructure) [43]. This program aims to promote E-mobility using subsidies for battery electric trucks, trucks for electric road systems and fuel cell trucks using hydrogen as well as the corresponding infrastructure.

The ENIN program has a total budget of 365 million EUR and funds will be distributed based on different calls. The first and second calls are planned for late 2022 and will have a budget of 35 million EUR and 50 million EUR, respectively. The first call will be available for N1 vehicles, and the second call will be available for N2 and N3 vehicles. Thereafter there will probably be two or three calls annually between 2023-2025. From 2023 there will probably also be a specific call for special vehicles such as garbage trucks [44].

The investment subsidy is 80% of the additional cost for electric trucks compared to conventional trucks and 40% of the cost for infrastructure [44]. A subsidy of up to 30,000 EUR is available for company and public fast-charging stations designed to accommodate heavy-duty goods vehicles (DC charging).

4.2.2 Road toll exemption

In Austria, vehicles heavier than 3.5 tons must pay a toll when driving on highways and expressways [45]. The total length of the toll road network is 2 233 km [46]. The toll rates depend on the type of vehicle (number of axles) and engine, see Table 2.

Electric and hydrogen fuel cell vehicles are only charged approximately 25% of the toll rate applied for vehicles with conventional engines. An electric 3 axles trucks will for example save 0,2142 EUR/km compared to a Euro VI truck. Within this study, the average milage of trucks in Austria has not been identified but assuming a truck that drive 40 000 km annually on toll roads, the truck operator saves approximately 8 500 EUR annually. For comparison, the average annual milage of a Swedish heavy-duty truck is more than 70 000 km during its first 5 years of operation [47]. Over a five-year period, the truck operator would save more then 40 000 EUR.

Table 2: Mileage-based road toll in Austria 2022 (EUR/km) [45]

	2 axles		3 axles		4 axles and more	
	Day	Night	Day	Night	Day	Night
E/H2	0.05010	0.05050	0.07077	0.07169	0.10577	0.10693
EURO VI	0.20310	0.20350	0.28497	0.28589	0.42332	0.42448
EURO V and EEV	0.21250	0.21290	0.29813	0.29905	0.43966	0.44082
EURO IV	0.21940	0.21980	0.30779	0.30871	0.45070	0.45186
EURO 0 to III	0.24000	0.24040	0.33663	0.33755	0.48366	0.48482

5 Germany

There are approximately 3 million light commercial vehicles in Germany and 1.1% of these vehicles are battery electric. The total number of medium- and heavy-duty commercial vehicles are estimated to be 950,000 and only 0.1% of these are battery electric [48].

The commitment of the Paris Agreement and the EU climate law is translated into German climate law through the Climate Action Programme 2030 and the Climate Change Act (Klimaschutzgesetz) [49]. As EU's largest national economy and home to Europe´s largest car market, Germany is believed to play a significant role in reducing EU's transport emissions [50]. To reach the EU goal of 55% emissions reduction by 2030, emissions from the German transport sector must be reduced by around 40-42% by that same time [51].

The German federal government has set up targets to make Germany "a lead market and top provider in the field of electric mobility" [52]. To speed up the market development for electric mobility, the government adopted a package of measures in May 2016 – the Government Programme for Electric Mobility. The programme contains investments of close to one billion EUR [53].

Further, the Climate Action Program 2030 includes several measures to promote climate friendly mobility. The Federal government has set a target of seven to ten million electric vehicles registered in Germany by 2030 [49]. This program also directs large funding to subsidies and tax incentives to electrify the country's transport sector.

5.1 Administrative policy instruments

5.1.1 Establishing uniform charging and payment standards

The German federal government states that "optimum use of electric mobility requires uniform charging and payment standards" [53]. Standards are believed to create security for further investments in the market as it ensures interoperability and provides clarity for manufacturers [54]. For this reason, the German federal government adopted the Charging Station Ordinance – a directive that regulates the establishment of infrastructure for alternative fuels. The directive puts rules in place to ensure certain technical requirements, e.g. rules to harmonize socket standards and payment standards for publicly accessible

charging stations [55]. Standardization activities for high power charging are ongoing – for example regarding communication interfaces between vehicles and charging stations [54].

5.1.2 Electric Mobility Act

The Electric Mobility Act is a law that was passed in 2015. The law allows federal states and local authorities to create privileges for electric vehicles in public spaces, such as reduced parking fees and removed access restrictions [55].

5.2 Financial incentives and economic instruments

The main focus areas of Germany's package of economic policy instruments are temporary purchase incentives, the development of charging infrastructure, and the purchase of electric vehicles by public authorities [53].

5.2.1 Economic supports and grants for the automotive sector

Germany has allocated 3 billion euros to support development and production of zero-emission vehicles. The economic support first started as the automotive industry struggled due to challenges caused by the COVID-19 pandemic but has now been renewed. The renewed support is allocated through three separate programs; 1) the "Zukunftsfonds Automobilindustrie" which can be translated as the "future fund for the automotive industry", 2) the innovation premium, and 3) a support program for heavy-duty vehicles.

The future fund for the automotive industry will be allocated a total of 1 billion EUR between 2021 and 2025 to address medium- and long-term challenges of structural change in the automotive industry. 1 billion euros will be allocated to the innovation premium, which is a consumer rebate for buying electric passenger cars. The program is planned to end by 2023. Finally, 1 billion EUR will be allocated to a program to renew fleets of heavy-duty vehicles. The renewal scheme aims to support more efficient and environmentally friendly fleets of heavy-duty vehicles and includes renewal to the latest EURO VI emission standard as well as incentives for zero-emission vehicles [56].

5.2.2 State Aid

In July 2021, EU approved a German state aid for the purchase of light- and heavy-duty commercial vehicles with climate-friendly propulsion systems and ancillary charging stations. The aid is designed to ramp up the market of zero-emission commercial vehicles in order to reach European climate targets. The total budget of the aid is 507.5 million EUR [51].

Through the aid it is possible to receive a purchase grant covering up to 80% of the additional cost of purchasing a zero-emission vehicle. The grant for charging and hydrogen refueling infrastructure also covers up to 80% of the total investment cost – including costs for grid reinforcement and/or energy storage [57]. Lastly, the grant can cover a maximum of 50% of the cost of related environmental studies. The total receivable aid is limited to 15 million EUR per project and calendar year [51].

The selection of projects is based on "non-discriminatory, transparent and open competitive bidding procedures" [51]. The bidding procedures will be initiated by up to four calls for funding. The first call for funding was closed the 27th of September 2021.

5.2.3 Road toll

In Germany, all trucks with a total gross weight exceeding 7.5 tons must pay a distance-based toll for the use of highways and motorways [58]. However, all electric vehicles are completely exempt from the toll system [59]. The toll rates are based on three shares – air pollution, noise pollution and infrastructure costs [60]. The proportion of the toll rate for infrastructure costs depends on axles and weight class of the vehicle. The share for noise pollution is currently charged equally for all types of vehicles. The share for air pollution is determined based on the vehicle's emission class. For EURO 6 vehicles, the toll rates range from 7,9 to 18,3 cents/km [60]. Assuming a annual milage of 40 000 km, an electric truck would save more than 7 000 EUR annually or 36 600 over a 5 year period.

Table 3: German toll rates (cents/km) from October 1st, 2021

Emission class	Air pollution	Noise pollution	Axle and weight class	Infrastructure cost	Total toll rate
EURO 6	1.2	0.2	7.5 – 11.99 tons	6.5	7.9
			12 – 18 tons	11.2	12.6
			> 18 tons to 3 axles	15.5	16.9
			> 18 from 4 axles	16.9	18.3

6 The Netherlands

The number of light commercial vehicles on the market in the Netherlands is estimated to be 1 million, whereas 0.6% are battery electric. The number of medium- and heavy commercial vehicles are around 160 000, with only 0.1% being battery electric [48].

In line with the Paris Agreement and Fit for 55, the Dutch government has set out goals to reduce the country's GHG emissions by 55% by 2030 compared to 1990s levels [61]. This goal was set in the Climate Act in 2019. In addition to the Climate Act, the Netherlands has implemented a Climate Plan, a National Energy and Climate Plan, and a National Climate Agreement. Together they contain policies and measures to achieve the GHG emission reduction goals of the Climate Act [61].

6.1 Administrative policy instruments

6.1.1 National Climate Agreement

The National Climate Agreement, concluded in 2019, contains agreements with various sectors to ensure action on climate goals. The sectors committed to the agreement are: built environment, mobility, industry, electricity, and agriculture and land use [62].

As a part of the National Climate Agreement, agreements on electric transport are included. The agreement on electric transport contains further agreements regarding standards for electric heavy-duty transport. The climate agreement states that the Netherland must follow EU regulations and hence are unable to independently impose carbon standards on heavy-duty vehicles [62]. The national government of the Netherlands has agreed on working towards more stringent EU standards and will "collaborate with leading countries to advance electric transport and coordinate corresponding measures" [62]. Another commitment of the agreement is that regional authorities of the Netherlands will set up regional programmes with requirements to procure zero-emission heavy-duty vehicles "to the extent possible" in 2030.

6.1.2 Zero-emission commercial vehicle zones

The Government of the Netherlands has set a goal to eliminate exhaust fumes and CO_2 emissions from delivery vehicles in cities. To reach the goal, zero-emission zones will be implemented in various cities across the Netherlands starting 2025 [63]. The country's Climate Agreement sets out that by 2025, a minimum of 30 cities must have implemented zero-emission zones.

A key goal when implementing zero-emission zones has been to ensure that logistics actors will be able to continue to do their jobs properly. Hence, agreements have been created to facilitate a feasible and affordable transition into zero-emission zones, even for small businesses and enterprises [63]. For example, municipalities are required to have a four-year notice when implementing zero-emission zones. There will also be subsidies and grants available to make purchasing zero-emission vehicles more attainable.

In the city of Rotterdam, a zero-emission zone for trucks have been in place since 2015. Only zero-emission trucks are allowed to drive the 1.6-kilometer-long street Gravendijkwal located in the west of Rotterdam's centre. The zero-emission zone applies to all trucks with a gross weight over 3.5 tons and operates 24 hours a day, 7 days a week [10]. The zero-emission zone is enforced by a number plate camera recognition system and non-compliant vehicles face a penalty of 104 EUR per occasion [10].

For the city of Amsterdam, a low-emission zone is already implemented and there are plans to progressively upgrade it to a zero-emission zone covering the entire city area by 2030, applying to all modes of transport [10].

6.2 Financial incentives and economic instruments

6.2.1 Heavy-duty vehicle toll

The Netherlands currently make use of the Eurovignette system. Eurovignette is a road user charge for heavy-duty vehicles which is more thoroughly described earlier in this report.

However, the Netherlands intends to introduce a road toll for heavy-duty vehicles – applying to both national and international freight traffic. The policy is currently awaiting parliamentary approval but is intended to take effect by 2024 [64]. The toll will affect all trucks exceeding 3,500 kg in gross weight and will be in force on all motorways in the Netherlands as well as on several regional and local roads.

The toll will be based on the driven distance on roads where the toll applies. The payable amount will be based on the driven distance, as registered by the vehicles' on-board units. The toll rate will further depend on the emission level of the truck, cleaner trucks will pay

lower tolls. This implies that zero-emission trucks will pay a lower toll rate than diesel driven trucks, but the final rates have not yet been decided. The tolls will be collected by a private toll service provider on behalf of the Dutch government [64].

6.2.2 Government Incentive Programme

As a part of the Dutch National Climate Agreement, the mobility sector agreed on an incentive program for delivery vehicles. The incentive programme consists of a purchasing arrangement that cover up to 45% of the additional cost of a ZEV compared to a fossil equivalent. The incentive scheme grants 94 million EUR for heavy-duty vehicles and 185 million EUR for delivery vans, until 2025 [62].

7 Sweden

The number of light commercial vehicles in Sweden is estimated to be 0.6 million, whereas 1.0% are battery electric. The number of medium- and heavy commercial vehicles are around 86 000, with only 72 being battery electric in 2021[65]. Sweden´s climate goal is to reach net zero emissions by 2045 with several milestones on the way. In 2030, GHG emissions should be 63% lower than 1990 (not including emissions covered by the EU ETS). Also, emissions from the transport sector, excluding domestic flights, are to be reduced by 70% in 2030 compared to 2010 [66].

7.1 Administrative policy instruments

7.1.1 Environmental zones

Since 2020, it is possible for municipalities in Sweden to establish environmental zones in their municipality. The zones can be as small as a part of a street or city wide [67].

There are three kinds of zones – 1,2 and 3 with increasing requirements. Environmental zone 1 apply to trucks and busses and ban all vehicles that does not fulfil Euro III and has been implemented in 8 different cities. Zone 2 applies to passenger cars and light trucks and require that spark ignition vehicles fulfil Euro V and compression ignition vehicles fulfil Euro VI. So far, environmental zone 2 is only applied on a street in Stockholm. In zone 3, it is only allowed to use zero emission vehicles or gas vehicles that fulfil Euro VI. There is no zone 3 implemented in Sweden [67].

7.2 Financial incentives and economic instruments

7.2.1 Investment subsidies

Sweden has several investment programs for electric vehicles and charging infrastructure.

The climate investment program *Klimatklivet* funds a large variety of investments that reduce GHG emissions including charging infrastructure but not electric trucks. The program is administered by the Swedish Environmental Protection Agency (EPA) and several calls open every year. In each call, applications are prioritized based on how high investment subsidy

they require per kg of GHG reduction. Thus, the most efficient investments are funded and there is no guarantee that funds are provided. The investment subsidy is maximum 70% but more typically 30-65%. For charging infrastructure, the maximum subsidy is 50% [68].

For charging infrastructure that are available for the public it is only possible to get an investment subsidy in a geographic area where there are a need for charging infrastructure of that kind (AC/DC for passenger cars or heavy duty trucks). The Swedish EPA analyse which areas that need additional charging infrastructure and specify these areas in different calls together with various technical and economic requirements. Organizations that would like to own and operate a charging station in such an area give a tender to the EPA and the most favourable are approved. The investment subsidy can in this program be up to 70% [68].

The climate bonus program Klimatpremien provides an investment subsidy for different kinds of environmentally friendly trucks including battery electric trucks. The subsidy is 20% of the total cost or 40% of the additional cost for an battery electric truck compared to a conventional one [69].

For public charging infrastructure for heavy duty trucks there is also a specific program called regional electrification pilots. This program focus on regional freight logistics and requires cooperation between different actors. Projects that are funded are also required to chare different kinds of data. The program has different calls and applications compete in each call. So far, 139 charging stations has been funded and the subsidy is 100% [70, 71].

7.2.2 Road fee

Sweden is part of the Eurovignette system and has so far not announced any changes or planes to change this to a road toll system as in the Netherlands.

For domestic trucks, there are however an annual road fee change according to Euro class. Since electric or zero emission vehicles are not mentioned specifically it is assumed that they are charged the same fee as Euro VI trucks. Thus, there is no incentive for electric trucks.

Table 4: Annual road fee in Sweden [72]

	3 or less axles	4 and more axles
Euro 0	1 371	2 299
Euro I	1 192	1 990
Euro II	1 038	1 731
Euro III	902	1 504
Euro IV	820	1 368
Euro V and EEV	776	1 293
Euro VI and cleaner	731	1 218

8 UK

Trucking is the dominant mode of transport in the UK domestic freight transport sector. In 2019, trucks accounted for roughly 79% of the goods moved (in ton-kilometers) [73]. The number of light commercial vehicles in the UK is estimated to 5.1 million, whereas 0.3% are battery electric. The number of medium- and heavy-duty commercial vehicles are estimated to be 700 000 with 0.1% being battery electric [48].

The 2008 Climate Change Act is a legal act that was passed in the UK in November 2008. The Climate Change Act sets out ambitious emission reduction targets and provides a system of carbon budgeting [74]. The emission reduction target and the carbon budgets legally bind the UK to achieve net zero emissions by 2050, relative to 1990 levels [75]. The UK's net-zero target is the first legally binding emissions reduction target that has been set out by a country [74]. This implies a net-zero targets for all sectors, including the transport sector. The relative contribution expected from a specific sector is controlled through policy [76].

The system of carbon budgeting was created to help the UK meets its net zero-targets through a series of 5-year caps on GHG emissions [76]. There is a total of six sequential carbon budgets that define and regulate the path to reaching the 2050 net-zero target [77]. Each carbon budget is set 12 years ahead of time to provide long-term guidance to investors [76]. The UK's sixth carbon budget was set into law in April 2021 and sets target to cut CO_2 emissions by 78% by 2035 [78].

For the transport sector to contribute towards reaching the 2050 net-zero target, a range of policy documents, plans and strategies have been set out. Some of the most important ones are:

- The Ten Point Plan for a Green Industrial Revolution
- National Infrastructure Strategy
- Future of Transport programme
- Decarbonizing Transport Plan
- Future of Freight Plan
- The Carbon Plan

Together, these documents set the overall direction of the decarbonization of the transport sector using a range of policy instruments, sector-specific targets, financial incentives, and regulations [79, 80].

8.1 Administrative policy instruments

8.1.1 Transport decarbonization plan

UK's plan for transport decarbonization has set ambitious goals to minimize emissions from the freight and logistics sector – the aim is to decrease CO_2 emissions by 200-220 megatons from 2020 to 2050 [73]. To achieve such emissions reductions, the plan presents more detailed commitments, actions and timings.

The first commitment of the freight and logistics part of the Decarbonizing Transport plan is to commit to phase out dates for the sales of all new non-zero-emission heavy-duty vehicles. For vehicles weighing up to 26 tons, the end of sale would be 2035, and for vehicles over 26 tons the phase-out would be 2040. These commitments are however still subject to consultation, but the plan is to establish a regulatory framework to ensure delivery on the phase out dates that are agreed upon [73].

The second commitment is to demonstrate zero-emission heavy-duty vehicle technology on UK roads. This includes electric vehicles, electric road systems, hydrogen fuel cell vehicles and zero-emission refuelling and charging infrastructure [73]. To achieve this, £20 million was allocated to support industry through trials and pioneering projects for zero-emission trucks and lorries in 2021/2022 [3, 73].

The third commitment Is to stimulate the demand for zero emission trucks through financial- and non-financial incentives. The financial incentives are mainly focused on the plug-in grants that are more thoroughly described in the chapter 9.2. Further, increasing the vehicle maximum weights for zero-emission trucks is being discussed as a measure to offset the additional weight from the use of alternative fuelling technologies such as batteries or hydrogen tanks [73]. There are three more commitments remaining in the plan: to support efficiency improvements and emission reductions in the existing fleet, to support and encourage modal shift of freight from road to more sustainable alternatives, and lastly to take measures to transform last-mile deliveries [73].

8.1.2 Government vision for the rapid chargepoint network in England

In May 2020, the UK Department for Transport published a Government vision for rapid chargepoint network in England. In the vision, the UK has committed to achieving the following targets [81]:

- Have at least 6 high-powered (150-350 kW), open access charge points at motorway service areas in the UK by 2023.
- Have around 2,500 high-powered, unrestricted access charge points across motorways and major roads in the UK by 2030.
- Have around 6,000 high-powered, unrestricted access charge points across motorways and major roads in the UK by 2035.

8.1.3 Clean Air Zones and Zero-Emission Zones

The UK Government has introduced Clean Air Zones to improve air quality. These zones have requirements for vehicles to meet minimum emission standards, often with charges applying to non-compliant vehicles. Some of these zones has more stringent emission requirements, e.g. the city of London has plans to develop the whole city into a zero-emission zone by 2050.There are already some zero- and low-emission zones in some parts of central London. The plan is to gradually expand these to cover central London from 2025 and onward, and to make a larger are of inner London a zero-emission zone by 2040 [10].

The zones already in place in London are a congestion zone, a low-emission zone, and an ultra-low-emission zone. The charge is a toll on vehicles operating withing a zone in central London, which has been in place since 2002. The congestion charge applies £15 per day to all vehicles driving in the zone between 07-23 every day of the year except Christmas. The low-emission zone applies to medium- and heavy-duty vehicles in most of greater London, and the ultra-low-emission zone applies in central London only[10]. These zones are in force around the clock. The charges for driving a non-compliant heavy-duty vehicle in the low- and ultra-low-emission zones are £100 per day for vehicles meeting EURO 4 or 5 standards, £300 if below [10].

8.2 Financial incentives and economic instruments

As a part of UK's transport decarbonization plan, large funds have been directed to financially support the transition to a net-zero transport sector by 2050. A total of £582 million has been made available in grants for plug-in vehicles up until 2022-2023 [73]. Further, grants are available for vehicle chargers and demonstrations of zero-emissions heavy-duty vehicles.

8.2.1 Plug-in grant for low-emission vehicles

As a part of the Decarbonizing Transport plan financial incentives, some types of low-emission vehicles are eligible for a plug-in grant. The grant is given directly from the government to vehicle dealerships and manufacturers, and the seller includes the grant as a discount in the purchase price – i.e. there is no application process for the grant [82]. The grant applies to trucks as well as cars, motorcycles and mopeds. Only vehicles/models that has been government approved are eligible for the grant – there is currently more than 30 models of electric vans and trucks qualifying for the grant scheme [82, 83]. The grant was recently extended for 2 years, until 2024 [83].

N2 vehicles (small trucks) can get a grant that will pay for 20% of the vehicle's purchase price, up to a maximum of £16,000. There are some limits to the grants available: a total of 250 grants are available at the £16,000 rate, and up to 10 grants per business or organization can be provided. If either one of these limits are reached, the maximum to apply for is £5,000 [82].

N3 vehicles (large trucks) grant will pay for 20% of the vehicle purchase price, covering a maximum of £25,000. There are a total of 100 grants available at the £25,000 rate. Up to 5 grants can be provided per applying business or organization. If either one of these limits are reached, the maximum to apply for is £5,000 [82].

Since launching in 2012, the UK Government states that the plug-in grant have supported purchase of more than 26,000 electric vans and heavy-duty vehicles in the UK [83].

8.2.2 Grant for truck chargers

For vehicle chargers, there are separate grants. The UK government is offering a set of subsidies to support the use of electric and hybrid vehicles though the Office of Zero Emission Vehicles (OZEV) [82, 84]. One of the available grants for vehicle charges is the EV chargepoint grant, providing funding covering up to 75% of the cost of installing charge points. The EV chargepoint grant replaced the previous Electric Vehicle Homecharge Scheme in April 2022 [84]. Both private and commercial actors such as small- and medium sized businesses, property owners and fleet owners can apply for the EV chargepoint grant.

To be given a grant for chargepoint installation through the OZEV, it is a requirement to use OZEV-authorized installers and chargepoint hardware. A list of authorized installers and models of charge points can be accessed at the UK government's website [84].

8.2.3 Rapid charging fund

The rapid charging fund is designed to help motorway and road service area operators to prepare the network for zero-emission vehicles [81]. The fund size is £950 million but is not yet open for applications [81]. More information is to be published by the UK Government shortly. The reviewed information from the UK Government does not currently state anything about parts of the rapid charging fund being directed explicitly towards heavy-duty vehicles.

8.2.4 Zero-Emission Road Freight Demonstrator programme (ZERFD)

In May 2022, the UK Government announced the £200 million Zero-Emission Road Freight Demonstrator programme. The aim is to create knowledge and data to measure which technology or technology mix that is best suited to decarbonize the heaviest road freight vehicles – heavy-duty vehicles between 40-44 tons [3].

9 California

The total number of heavy-duty trucks registered in California in 2020 was 119 000 [85]. However, heavy-duty vehicles registered in other US states can operate within the state. With 39,4 million citizens, California is the most populated state [86]. New data from 2022 shows that as of July 2022, there were 306 electric trucks on the roads in California. Further, California is home to 43 manufacturers of zero-emission vehicles and related equipment such as batteries and infrastructure products [87].

The state of California has ambitious goals to reduce air pollutants and to meet climate change targets [88]. The body of the state's climate change targets is the state law to reach carbon neutrality by 2045 [89]. Meeting these targets is stated to require a bold transformation of the transport sector. The state's goal is to have one hundred percent zero-emission transportation by 2045 where feasible [90]. To reach this goal, the following targets have been set for the transport sector:

- 100% zero-emission sales of passenger vehicles by 2035.
- Full transition to ZEV drayage trucks by 2035.
- Full transition to ZEV buses and heavy-duty long-haul trucks by 2045.
- Full transition to zero-emission off-road equipment by 2035.

9.1 Administrative policy instruments

California has set ambitious goals and regulations to transition medium- and heavy-duty vehicle sales and operation to zero-emission vehicles. The state law is designed to support widespread transportation electrification. The goal is to achieve a zero-emission truck and bus fleet in California by 2045- For certain market segments such as last mile delivery and drayage applications, the ambition is to achieve zero-emission fleets even earlier. The cornerstone of the regulations supporting electrification of heavy-duty transport in California is the Advanced Clean Trucks Regulation (ACT) and the draft Advanced Clean Fleets Regulation (ACF).

9.1.1 Advanced Clean Trucks Regulation

The ACT aims to accelerate a large-scale transition of zero-emission medium- and heavy-duty vehicles. The regulation is designed to increase the supply of electric trucks on the market by requiring manufacturers to sell increasing shares of zero-emission trucks. The regulation is the first of its kind in the world. The regulation applies to all manufacturers that certify on-road vehicles with a gross weight exceeding 8,500 lbs. (~3,850 kg) for sale in the state of California. A manufacturer is any entity that "manufactures or assembles an on-road vehicle or other incomplete on-toad motor vehicle into commerce in California" [91]. Manufacturers selling less than 500 vehicles are exempt from the rule.

The rule was accepted in 2020 and starts to apply with model year 2024, starting at 5-9% zero-emission vehicle sales requirements. The requirements increase to demanding between 40-75% zero-emission vehicles in sale (based on the weight class of the vehicles) by 2035. Compliance of the rule will be based on a credit and deficit accounting system [92]. The rule further includes a requirement for large entities, large fleet owners and brokers, and government agencies operating heavy-duty vehicles to report shipment business practices and emission reduction goals [88].

Table 5: The percentage of truck sales that must be zero-emission through 2035 [91]

	Class 2b-3 Pickup trucks and vans	Class 4 – 8 Rigid trucks	Class 7 – 8 Tractor trucks
2024	5%	9%	5%
2025	7%	11%	7%
2026	10%	13%	10%
2027	15%	20%	15%
2028	20%	30%	20%
2029	25%	40%	25%
2030	30%	50%	30%
2031	35%	55%	35%
2032	40%	60%	40%
2033	45%	65%	40%
2034	50%	70%	40%
2035	55%	75%	40%

9.1.2 Advanced Clean Fleets Regulation

The ACF regulation requires public and private fleets in California to purchase an increasing number of zero-emission vehicles. The regulation is as of June 15, 2022, still being developed and is subject to change. The ACF rule affects the demand of zero-emission trucks in California and is set to transform the state's medium- and heavy-duty diesel fleets to zero-emission vehicles in less than 20 years. The purchase requirements of the ACF regulation are designed to support the sales requirements of the ACT regulation. CARB is expected to finalize the regulation during 2022, with the regulation coming into effect in mid-2023.

The current draft ACF regulation divides vehicles into three categories: 1) High priority and federal fleets, 2) Drayage fleets (those visiting ports and intermodal rail yards), and 3) State and local government fleets. High priority fleets are fleets that have at least 1 vehicle with a gross vehicle weight exceeding 8,500 lbs. (~3,850 kg) and fulfil at least one of the following requirements [93]:

- Has $50 million or more in gross annual revenue.
- Owns, operates, or controls a total of 50 or more vehicles.

As of today, the ACF regulation only applies to one category of vehicles – high priority and federal fleets. CARB has presented two pathways for high priority and federal fleets to comply with the proposed ACF regulation [94]. The first option is by adding only zero-emission vehicles to the fleet starting in 2024. Additionally, vehicles that has passed their legally defined useful life must be excluded from the fleet. The second option uses so called milestone groups for different types of vehicles to calculate overall zero-emission requirements that a fleet must meet. This option allows fleets to continue adding ICE vehicles as long as they meet the milestone requirements. Table 6 shows the different milestone group requirements by vehicle type and year.

Table 6: Zero-emission vehicle milestones by vehicle typ and year [95]

	Percentage of trucks that must be zero emission				
	10%	25%	50%	75%	100%
Milestone Group 1: Box trucks, vans, buses with two axles, yard tractors, light-duty package delivery vehicles	2025	2028	2031	2033	2035
Milestone Group 2: Work trucks, day cab tractors, buses with three axles	2027	2030	2033	2036	2039
Milestone Group 3: Sleeper cab, tractors and specialty vehicles	2030	2033	2036	2039	2042

Drayage fleets will be regulated through the Drayage Truck Registry (DTR). The DTR is a registry of vehicles allowed to enter ports and intermodal sites. The ACT regulation states that starting in 2024, any new vehicle added to the DTR must be a zero-emission vehicle. Existing ICE-vehicles listed in the DTR can remain there until they have exceeded their legally defined useful life – 18 model years or 800,000 miles [94]. However, any ICE vehicle still active in the DTR within its useful life will be considered noncompliant after 2035.

9.1.3 Executive orders

Executive orders are issued by the US White House and are used to direct the executive branch of the US government. Executive orders state mandatory requirements and have the effect of law [96]. Executive orders direct federal officials or administrative agencies to engage

in the course of action stated in the order. They are enforceable to the extent that they represent a valid exercise of the White House's power.

There are three executive orders that address zero-emission trucks in California:

Executive order B-48-18 states that California has an objective to achieve five million zero-emission vehicles on the road by 2030 and 250,00 public charging stations by 2025, whereof 10,000 fast charging stations. The order is stated with the aim to curb CO_2 emission from cars and trucks and boost the number of zero-emission vehicles in California. Zero-emission vehicles are defined as battery plug-in electric vehicles, plug-in hybrid electric vehicles, and hydrogen fuel cell electric vehicles.

Executive order N-79-20 states that all new cars and passenger trucks sold in California by 2035 must be zero-emission vehicles. By 2045, all new medium- and heavy-duty vehicles should be zero-emission for all feasible operations. All drayage trucks (those that visits post and intermodal rail yards) should be zero-emission by 2035 [97].

The implementation of these two executive orders will be ensure through e.g.:

- A zero-emissions vehicle market development strategy (January 31, 2021) that ensures coordinated implementation of a system of policies, programs and regulations necessary to achieve the goals of the order.
- Existing authorities and agencies shall accelerate deployment of affordable options for zero-emission vehicles.
- Biennial statewide assessment of zero-emission vehicle infrastructure.
- By July 15, 2021, identify near term actions and investment strategies to improve clean transportation, sustainable freight and transit options.

9.1.4 CPUC Decisions

CPUC decisions are made by the California Public Utilities Commission (CPUC), a state agency. There are two decisions specifically affecting the position of electric trucks in the state:

- Decision 19-08-026, authorizing SDG&E (San Diego Gas & Electric Company) to spend >USD 107 million to support the installation of charging infrastructure for medium- and heavy-duty electric vehicles. The program is expected to support electrification of approximately 3,000 vehicles.
- Decision 19-10-055, authorizing PG&E (Pacific Gas & Electric Company) to implement a subscription-based EV rate designed for commercial and industrial customers [98]. PG&E is one of the largest combined natural gas and electric energy

companies in the United States [99]. Industrial customers include transit fleet operators, owners of electric delivery trucks, and providers of public charging stations. The subscription-based rate aims to eliminate demand charging through a model similar to cell phone bills, with time-of-use volumetric energy charges that encourage customers to charge off-peak [98].

9.1.5 Zero-emission delivery zones

In 2021, the City of Santa Monica has together with partners implemented the first zero-emission delivery zone in the US. The partners consist of tech companies, delivery companies and community actors. Notably, though, the zone is voluntary and there are no charges or other enforcements applied for not complying with the guidelines. The zone covers only one square mile, but is located in an commercial activity area with high traffic density [11].

9.2 Financial incentives and economic instruments

There are several grants and subsidies targeted directly to low- or zero-emission heavy-duty vehicles in California.

9.2.1 HVIP

The California Air Resources Board provides grants in the form of vouchers to fleets operated in California. The grant is designed to reduce the incremental cost of qualified electric, hybrid, or natural gas trucks and buses. This is part of a project called the Hybrid and Zero Emission Truck and Bus Voucher Incentive Project (HVIP). The vouchers are available on a first-come, first-served basis. The number of available vouchers vary from year to year.

The vouchers can only be applied to a pre-selected list of vehicles in a catalogue. There are currently seven models of battery electric heavy-duty trucks and tractors to choose from, from seven different manufacturers (BYD, Freightliner, Kenworth, Lion Electric, Nikola, Peterbilt and Volvo). The incentive amount is $120,000. For medium-sized trucks, there is 38 different battery electric models available with incentive amounts ranging from $60,000-85,000 (HVIP, 2022). Any manufacturer of a vehicle that meets the HVIP technology requirements can apply to become an HVIP eligible manufacturer.

Alongside each vehicle in the catalogue on the HVIP website, the participating dealers are listed. The incentive amount works as an immediate price reduction, and the total payable amount for a vehicle will be the total order invoice minus the incentive amount. The dealer is responsible for submitting the voucher request. As a purchaser, you are limited to

requesting a maximum of 30 vouchers per calendar year, except for drayage fleets that are limited to 50 vouchers per calendar year [100].

HVIP states that out of the 730 zero-emission trucks on the road in California as of January 2022, more than 60% are directly funded by HVIP. Incentive requests in 2021 totaled more than $240 million. “HVIP is designed to make sales happen. Vouchers directly benefit purchasers and dealers – helping close the price gap between advanced technology vehicles and their conventionally fuelled counterparts.” [100]

9.2.2 EnergIIZE

EnergIIZE (Energy Infrastructure Incentives for Zero-Emission Commercial Vehicles) is a first of its kind project that will provide funding for electric vehicle charging and hydrogen refueling infrastructure. The project was announced in April 2021 and is designed to support Executive order N-79-20 by speeding up deployment and installation of ZEV infrastructure for commercial vehicles [101]. The project is funded by the California Energy Commission and implemented by CALSTART – a national non-profit for clean transportation technology [102].

EnergIIZE aims to provide a user-friendly and streamlined process to seek funding. The project offers four different “funding lanes” to support needs of different types of commercial fleet users:

- EV Fast Track Lane: For commercial EV fleet users currently participating in a vehicle incentive project like HVIP. The EV Fast Track Lane covers electric vehicle charging equipment, DC fast chargers included, as well as charge management software. Applicants are eligible of 50% of equipment and software cost, with a $500,00 funding cap per project [103].
- EV Jump Start Funding Lane: For commercia EV l fleet users who are located in or operate at least 50 percent in disadvantage and/or low-income communities; transit agencies; school bus fleets; tribal entities; small fleet owners; or small business enterprises. The EV Jump Start Funding Lane covers electric vehicle charging equipment, DC fast chargers included, as well as charge management software. It also covers switchgears, electrical panel upgrades, wiring and conduit work, and meters. Applicants are eligible of 75% of equipment and software cost, with a $750,000 project cap [104].
- EV Public Charging Station Funding Lane: This is a funding for commercial fleet users or station owners that are interested in deploying publicly accessible charging infrastructure for commercial medium- and heavy-duty EVs. The application process is competitive, and applications are scored on the following criteria: project readiness,

cost effectiveness, and community benefit. Applicants are required to install DC fast-chargers of 150 kW or greater. Applicants are further encouraged to provide at least one 350 kW charger and prepare for 1 MW charging rates. Applicants are eligible of 50% of equipment and software cost, with a $500,000 funding cap per project [105].

- Hydrogen Funding Lane: For commercial fleet users or station owners who seek to deploy hydrogen refuelling infrastructure for medium- and heavy-duty vehicles.

The application process has been designed to be easy and straightforward – it consists of a zip file containing a checklist and an excel application form.

9.2.3 Volkswagen Environmental Mitigation Trust for California

The Volkswagen Environmental Mitigation Trust provides about $423 million for California to mitigate nitrogen oxide (NOx) emissions that was caused by Volkswagens use of illegal emission testing devices in certain of its diesel vehicles. The trust provides grants for "scrap and replace" projects in the heavy-duty vehicle sector [106]. The first instalment of funding from the trust is currently underway, and the second instalment is upcoming.

- The grants are offered and allocated across five project categories [107]:
- Combustion freight and marine projects,
- Zero-emission transit, school, and shuttle buses,
- Zero-emission freight and marine projects,
- Zero-emission class 8 freight and port drayage trucks, and
- Light-duty electric infrastructure.

The first instalment of funding granted $35 million to zero-emission freight and marine projects, and $27 million to zero-emission class 8 freight and port drayage trucks (ibid).

9.2.4 PG&E Electric Vehicle Fleet Program

PG&E Electric Vehicle Fleet Program offers incentives to facilitate installation of charging stations for medium- and heavy-duty electric vehicle fleets. The offer includes design and construction services and reduced costs for work. Schools, transit agencies and disadvantaged communities can receive rebates for purchase of charging stations, up to 42,000 USD.

PG&E further offers rebates for purchase of electric medium- and heavy-duty fleet vehicles. Applicants are limited to 25 vehicle rebates per site and covers up to 4,000 USD per vehicle.

9.2.5 Goods Movement Emission Reduction Program

The Goods Movement Emission Reduction Program provides funding for projects that reduce emissions from freight movement in California. This includes replacement of conventional heavy-duty trucks, re-power or retrofit as well as electrification of truck stop infrastructure. In total, the program supports 1 billion USD [108].

9.2.6 Carl Moyer Program

The Carl Moyer Program for infrastructure provides funding for infrastructure projects that enable the deployment of “alternative, advanced, and cleaner technologies”. Participation and eligibility of the program is decided in each local air district [109].

9.2.7 LTCI Advanced Technology Demonstration and Pilot Projects

The LTCI Advanced Technology Demonstration and Pilot Projects support transportation of fleets to clean technologies by demonstration and advancement of commercial viability. All demonstration projects are in and/or will benefit disadvantaged communities [110]. The project is funded by CARB, and a full list of funded projects can be found here.

10 Concluding discussion

Battery electric trucks are currently being introduced in all countries included in this study. Although the number of trucks is still very low, all countries have implemented various policy instruments to support an increasing electrification of the freight sector. However, each country has its own political, economic and social context which mean that policies that are successful in one country are not always successful in others. Therefore, policies cannot always be directly transferred from one country to another. Even so, all countries studied seem to have a similar approach when implementing policy instruments to increase the number of electric trucks although there are also interesting differences that could be used for inspiration when designing new policies.

10.1 Administrative policy instruments

Most countries presented in this study use administrative policies to favour the introduction of electric heavy-duty trucks. Some of these policies are focused on objectives of future sales of zero emission trucks. Austria has for example an objective that 100% of all new registrations of heavy-duty trucks (>18 tons) should be zero-emission in 2035 and the UK are suggesting an end of sales for non-zero-emissions trucks (> 26 tons) in 2040. In a similar way, California states that there should be a full transition to zero-emission buses and heavy-duty trucks by 2045. Sweden, on the other hand, focus its objectives on GHG emissions and climate neutrality and not specifically on electric or zero-emission vehicles.

Such policies are normally not legally binding, but they send a message to companies, citizens and other actors in the society of the political will and ambition and the path the country is on. They can also be the starting point and the motivation for more specific measures.

Such measures can for instance be found in California where authorities have implemented both push and pull instruments aiming at manufacturers as well as private fleet owners. These instruments create an obligation for manufacturers to sell and for fleet owners to buy and thus ensuring a minimum share of zero emission trucks operated in California. Similar policy instruments have not been identified in any of the other countries included in this study. Instead, the EU requires that manufacturers fulfil CO_2 emission standards for heavy duty vehicles that they put on the market which also creates an incentive for zero emission trucks although not as specific as in California.

Zero emission zones are another kind of administrative policy instrument that is implemented or will be implemented in several countries. Such instrument creates an obligation for all truck operators in a specific geographic area, often the centre of large cities, to use zero-emission trucks instead of conventional trucks. Thus, policy makers can choose to push for zero emission trucks where they give the highest benefits from a society perspective.

10.2 Financial incentives and economic instruments

In addition to various administrative policies and policy instruments, all countries have also implemented economic policy instruments. The most common economic policy instrument is investment subsidies for vehicles as well as infrastructure. Countries within the EU provide investment subsidies to cover a share of the additional cost for electric trucks compared to a similar conventional truck. In Austria and Germany, the investment subsidy is 80% of the additional cost while the Netherlands only subsidies 45% and Sweden 40%. The reason for this large difference has not been identified in this study. However, the investment subsidy in the Netherlands is directed to delivery vehicles while Austria, Germany and Sweden have a more general approach. One reason for this difference could thus be that smaller delivery vehicles are closer to break-even than larger trucks. Also, it could reflect that the economic context is not the same in these countries and that there are no one-size fits all solution.

The UK and California also have investment subsidies with a slightly different design. In the UK the subsidy is based on the total investment and in California there is a fixed number. The big difference is, however, not in the actual numbers but in how the subsidy is given. In the EU, the buyer of the truck must apply for the subsidy, and it will be given in competition with other applications. Outside the EU, the subsidy is directed to dealerships and there is no application process for the individual costumer which seem like a more convenient and less complex process for the customer. Although it has not been fully investigated in this study it is assumed that the reason for this difference can be found in the EU state aid regulation.

In addition to investment subsidies for vehicles, most countries have also implemented subsidies for charging infrastructure. Sometimes in combination with investments in electric trucks and sometimes as stand-alone investments. In this study, Sweden stands out with several subsidies for infrastructure that does not require investments in trucks at the same time. Several countries are also working with different road toll systems on high-ways or zones in cities where conventional trucks are not forbidden but must pay a fee that is higher than the fee for zero-emission trucks. Thus, policy makers can create an incentive for zero-emission trucks without banning conventional trucks.

10.3 Take home messages from a Swedish perspective

This study has identified several policy instruments implemented in different countries including Sweden. Although there are many similarities there are also differences.

Regarding investment subsidies, Sweden has a system where it is possible to apply for subsidies for truck and infrastructure separately which seems like a flexible solution for investors. However, the application system seems to require more administration and uncertainties for the end consumer compared to the voucher system applied in the UK and California. It would therefore be interesting to further analyse if such a system could be implemented under EU state aid regulations.

Also, some countries, especially Austria and Germany give a higher subsidy for investments in trucks. Since market conditions is changing rapidly, Swedish policy makers should always have updated TCO calculations to make sure that investment subsidies are on the required level.

Another way to increase incentives for truck operators to invest in battery-electric heavy duty trucks is to implement an obligation for large fleet owners to purchase or operate a certain number of trucks following the example from California. Since there is no such instrument in Sweden today it could be interesting to analyse possibilities and challenges for such a system in a Swedish context.

Finally, Sweden have not implemented any zero-emission zones, road tolls or any other system that affect the operation cost of an electric truck compared to conventional trucks which is the case in several other countries. Since such policy instruments make it possible to target measures to areas where electric vehicles have the highest benefits this should also be further analysed in a Swedish context.

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