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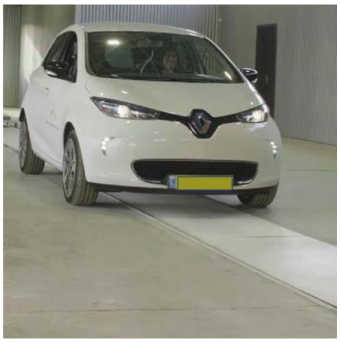

National and EU freight transport strategies

Status quo and perspectives and implications for the introduction of electric road systems (ERS)

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CollERS: Freight transport strategies – Status quo and perspectives at EU and national level – 3 June 2020

The research collaboration "collERS" consists of the core members from the Swedish Research and Innovation Platform for Electric Roads and the two national German research projects Roadmap OH-Lkw and StratON:

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Content

Introduction

National and international freight transport in Europe is significantly influenced by both, national and the European Union (EU) strategies and regulations. The successful market launch of Electric Road Systems (ERS) can only succeed with knowledge of the current state of the European freight transport system and its framework conditions. Within the framework of the collERS project, a possible ERS corridor between Sweden and Germany via Denmark is being investigated. The present paper therefore examines the current strategic orientation of freight transport in the affected countries and at EU level with a view to a possible introduction of ERS. The aim is to identify barriers and opportunities for ERS on a national and European level as well as potential fields of governmental action and possible conflicts with regard to a successful international market ramp-up of ERS.

After an overview of the economic and ecological importance of the **European transport sector**, the following section first deals with the development of **greenhouse gas (GHG) emissions in transport** and especially in road freight transport at national and European level. In this context, strategies for reducing GHG emissions in transport that have been adopted so far will also be discussed.

Subsequently, an overview of the **socio-economic conditions** in the countries considered and their logistics markets is given and possible opportunities and risks for the use of ERS are discussed.

A look at the **status and perspectives of freight transport** in the countries under consideration and at the available transport infrastructure provides further indications of the importance that alternative drive technologies could have for road freight transport in the future.

The analysis of the framework in terms of **policy measures in the transport sector** provides an overview of the conditions already existing or to be expected at EU and national level for the use of alternative propulsion technologies in road freight transport.

Finally, based on the preceding analyses, the possible **implications of the existing framework conditions in the transport sector for the introduction of ERS** are discussed and potential fields of action are defined.

The EU transport sector

Background

Mobility of persons and goods is a key prerequisite for social integration and economic development in Europe. A functioning common market and a free movement of people can only be ensured if a reliable transport system is available. However, increasing transport performance does not automatically lead to improved accessibility or higher economic power, although the development of the past decades partly suggests this assumption. In the last two decades transport activity increased by about 1 % per year on average, only slightly below the annual increase in gross domestic product (GDP). In addition to its primary task of transporting people and goods, the European transport sector is of particular relevance to the EU in many other aspects, as discussed below.

The transport industry accounts for about 7 % of the European gross value added and about the same share of total employment in the EU (15 million people) (EC 2016). Many European companies producing goods and offering services for the transport sector are not only relevant for the European market but are often among the world leaders in the respective business sector, resulting in a high share of global activities.

Increasing transport activity in Europe resulted in a rise in transport-related energy demand over the last decades. It grew by 30 % between 1990 and 2015. The economic recession in 2008 led to a decline in energy consumption caused by significantly lower transport activity and was complemented by increasing efficiency of passenger transport. Today (2016), the transport sector is responsible for about one third (367 million tonnes)[1] of final energy consumption in Europe and thus represents the sector with the highest energy demand (Eurostat 2018). Energy consumption of the transport sector is dominated by road transport which is responsible for about three quarters of overall transport-related energy consumption (300 million tonnes)[2]. Energy supply in the transport sector is to a large extent still based on fossil fuels, due to the continued dominance of the internal combustion engine in road transport. In addition to problematic ecological consequences of burning fossil fuels, this fact also has strong economic implications due to strong dependence on a single energy carrier, almost 90 % of which is imported to the EU. Renewable energy only plays a minor role in the transport sector, making up about 8 % of final energy consumption (Eurostat 2020a).

Transport activity is associated with considerable environmental impacts, imposing high costs on society. The reduction of transport related GHG emissions and the transition towards a low-carbon transport-system can be considered as the biggest and the most urgent challenge. However, reduction of air pollutants and noise emissions as well as lowering the use of natural resources and reducing impacts of infrastructure on biodiversity are also of great importance from an environmental perspective.

Transport related greenhouse gas emissions and targets

European Union

In 1990, CO_2 emissions in the EU amounted to 5.6 billion tonnes. By 2016, emissions had fallen by 24 % to 4.3 billion tonnes. The high relevance of the transport sector for further climate mitigation efforts is demonstrated by the fact that emissions in this sector rose by 18 % from 787 million tonnes to 931 million tonnes per year over the same period.

While a slight reduction in total emissions has been achieved, the transport sector faces major challenges. In order to be in line with the Paris Agreement, emissions must continue to decrease in the coming years. The EU itself has set the target of reducing total emissions by 40 % by 2030 compared to 1990 levels (EC - European Commission 2014). The transport sector is covered by the so-called Effort Sharing Regulation (ESR). A reduction of at least 30 % compared to 2005 is to be achieved

[1] taking into account an additional 44 Mtoe for maritime bunker fuels, the total energy demand for transport amounts to 411 Mtoe

[2] Eurostat (2018): Simplified energy balance – annual data. Last update: 31.05.2018

across various sectors. For the transport sector, this target would mean a reduction from 931 million tonnes in 2016 to 683 million tonnes in 2020.

According to the 2011 Transport White Paper (EC 2011b), achieving the EU long-term target of 80 % to 95 % reduction in overall domestic GHG emissions by 2050 requires a reduction in traffic-related emissions of at least 60 % compared to 1990.

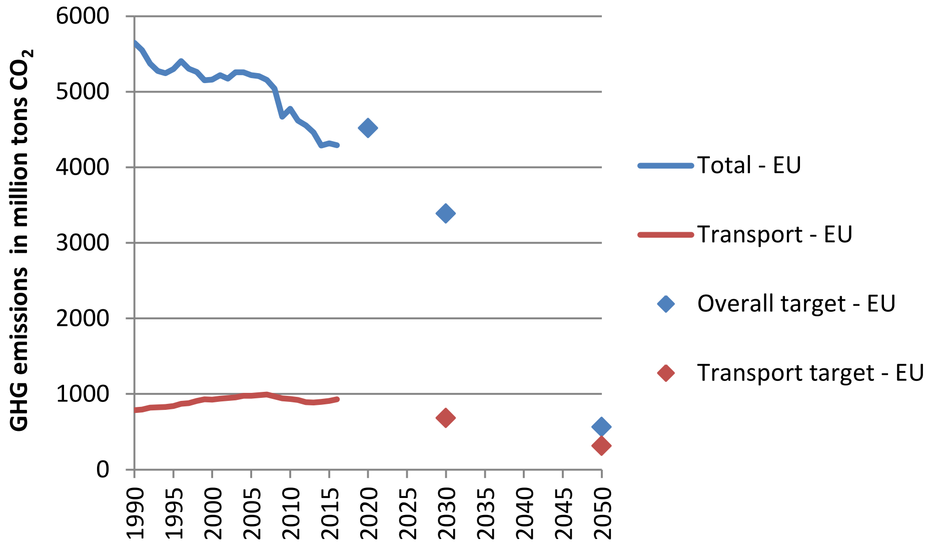

Figure 1: Historic development and targets of EU GHG emissions of all sectors and the transport sector. Source: own illustration based on data from EEA greenhouse gas - data viewer

The EU's long-term strategy emphasises (EC - European Commission 2014) that in order to achieve the 1.5° target, it is necessary to reach net zero CO_2 emissions by the middle of this century and describes a number of solutions that could be pursued for the transition to a net zero GHG economy. These solutions include energy efficiency and deployment of renewables and the use of electricity combined with carbon capture and storage.

Regarding the transport sector these solutions include:

- a better organisation, use of digitalisation,
- elimination of technical and operational barriers for railway,
- alternative fuels like liquid and gaseous biofuels,
- hydrogen based fuel cell vehicles and
- carbon free efuels.

For long-haul trucks and coaches, the strategy mentions uncertainties as to whether battery technology will develop sufficiently in terms of costs and performance and draws attention to the possibility electric road systems or dynamic charging. The focus, however, is clearly on synthetic fuels, as can be seen in particular from the small share of only 10 % of electric vehicles assumed to be in the vehicle fleet in 2050.

The recently elected EU Commission President, Ursula von der Leyen, has made climate change a major topic of her presidency and announced a European Green Deal aiming to achieve European climate neutrality by 2050. In this context, she aims to raise the GHG reduction target for 2030 to at least 50 % and stresses that all sectors must contribute to this.

Central pillars of the Green Deal are a significant carbon price for all sectors and a sustainable investment strategy that promotes green investment. The industry should be supported in the introduction of disruptive green technologies and negative social consequences minimized in the transition (Leyen 2019, Claeys et al. 2019).

The EU has already adopted a number of directives to achieve the above-mentioned climate protection targets. On the one hand, these measures address energy efficiency of combustion-engine vehicles and promotion of vehicles with alternative drive technologies. These include, for example, CO_2 emission standards for cars ((EU) 2019/631 2019) and trucks, which define a reduction in emissions of 37,5 % for cars and 30 % for trucks (EC 2018) by 2030 which will be reviewed in 2022.

In the so called RED II directive (PE/48/2018/REV/1 2018), the overall EU target for Renewable Energy Sources consumption has been raised to 32 % by 2030. RED II includes a transport sub-target. Member States must require fuel suppliers to provide at least 14 % of the energy consumed in road and rail transport as renewable energy by 2030.

The Eurovignette Directive 1999/62/EC (European Parliament (EP) 1999) provides a detailed legal framework for charging heavy-duty vehicles (HDVs) for the use of certain roads. A proposal for a Directive amending Directive 1999/62/EC on the charging of HDVs for the use of certain infrastructures is currently under consideration. It is proposed to phase out the variation of charges according to the Euro emission class of the vehicle and introduce the variation of infrastructure charges according to the CO_2 emission of HDVs.

The Directive on the Promotion of Clean and Energy Efficient Road Transport Vehicles aims at a broad market introduction of environmentally-friendly vehicles. It requires that energy and environmental impacts linked to the operation of vehicles over their whole lifetime are taken into account in all purchases of road transport vehicles, as covered by the public procurement Directives and the public service Regulation (EU) 2019/1161 2019). For heavy duty vehicles purchased in the public procurement sector, country-specific targets are proposed for Member States for the share of alternative fuels electricity, hydrogen and natural gas including biogas. These proposed minimum target for the share of heavy-duty vehicles in the total public procurement of HDVs at Member State level vary from 6 % to 10 % (2025) and from 7 % to 15 % (2030).

The Alternative fuel infrastructure directive (AFID 2014) currently sets non-binding targets for Member States with regard to the establishment of infrastructure for alternative fuels such as electricity, hydrogen and LNG. With regard to HDVs, Member States should establish an appropriate number refuelling points on the TEN-T core net by 2025. This Directive will be revised in 2020.

Germany

While total CO_2 emissions in Germany fell by 27 % from 1,252 million tonnes per year in 1990 to 909 million tonnes per year in 2016, emissions in the transport sector rose by 1 % from 164 million tonnes per year to 167 million tonnes per year over the same period.

Overall, the German government has set itself the target of reducing CO_2 emissions by 40 % by 2020, 55 % by 2030 and 80 to 95 % by 2050 compared to 1990 levels (BMWI 2007). It is currently considered likely that the target for 2020 will be met (Agora Energiewende 2020).

With regard to the transport sector, emissions are to be reduced by 40 to 42 % by 2030 compared to 1990 levels (BMUB 2016).

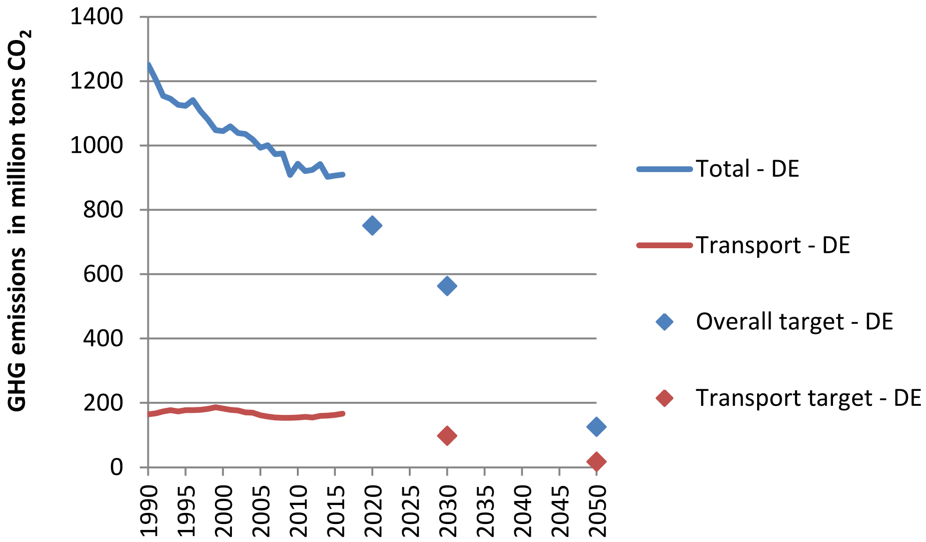

Figure 2: Historic development and targets of German GHG emissions of all sectors and the transport sector. Source: own illustration based on data from EEA greenhouse gas - data viewer

In 2018, the National Platform Future of Mobility (NPM) was launched to develop possible paths to achieve the 2030 climate protection targets in the transport sector. Several fields of action were identified. These are: changing drive technology and increasing the efficiency of cars and trucks, the use of regenerative fuels, strengthening environmentally friendly modes of passenger and freight transport and the use of digitisation (BMVI 2019).

A number of already adopted instruments promote road vehicles with alternative propulsion technologies and the necessary infrastructure. These include, among other things, financial support for the purchase of electric vehicles and the development of charging infrastructure, as well as tax incentives for natural gas and liquefied petroleum gas. These instruments are flanked by information campaigns and concrete targets for procurement in vehicle fleets of federal ministries. Research and development in the area of alternative drive concepts, such as overhead catenary trucks, are also supported.

Some economic instruments directly address road freight transport. These instruments comprise, e.g., the extension of the truck toll. Since 2005, tolls have been applied to federal motorways for vehicles with a permissible total weight of more than 12 tonnes and have recently been extended to federal roads and vehicles with a permissible total weight >7.5 tonnes. Incentives for the use of zero-emission vehicles (BEV, PHEV and FCEV) and natural gas vehicles (CNG, LNG) are created by the fact that they are exempted from tolls. Furthermore, the purchase of these trucks will be financially subsidized.

The Climate Protection Act, which came into force in December 2019, established binding reduction targets for the year 2030 (-55 %) and the goal of GHG neutrality by 2050 (BGBl 2019).

In the transport sector, the reduction is to be achieved through a number of measures: The introduction of a CO_2 price, which is to rise from €25 per tonne in 2021 to €55 in 2025 and to be in the range of €55 to €65 from 2026[3].

Rail freight transport and the use of low-CO_2 trucks are also to be promoted. Low-CO_2 trucks are to be subsidised by means of a CO_2 differentiation of the truck toll and the introduction of a CO_2 surcharge on the truck toll effective from 2023. The current infrastructure charge is to be reduced by 75 % for CO_2-neutral alternative drives. In addition, vehicles and charging infrastructure are to be encouraged. With regard to energy supply, concepts for possible charging options for battery trucks, overhead line infrastructure for ERS trucks and filling station infrastructure for hydrogen-powered trucks are to be developed. The aim is that by 2030 about one third of the mileage in heavy road freight transport will be provided electrically or on the basis of electricity-based fuels including hydrogen (Klimakabinett 2019).

Sweden

While Sweden still produced a total of 72 million tonnes of CO_2 in 1990, emissions in 2016 amounted to 53 million tonnes, a decrease of 26 %. Over the same period, emissions in the transport sector fell by 12 % from 19 million to around 17 million tonnes.

Sweden aims to reduce emissions by 40 % until 2020 and to have net zero GHG emissions into the atmosphere by 2045. Negative net emissions are targeted for the period after 2045. The sector-specific target for emissions from domestic transport (excluding domestic aviation) is to reduce emissions by at least 70 % by 2030 compared to 2010. Additionally, Sweden aims to fully shift electricity production to renewable energies by 2040 and to increase energy efficiency by 50 % by 2030 compared to 2005 (Naturvårdsverket 2019).

[3] https://www.bundesrat.de/SharedDocs/pm/2019/015.html

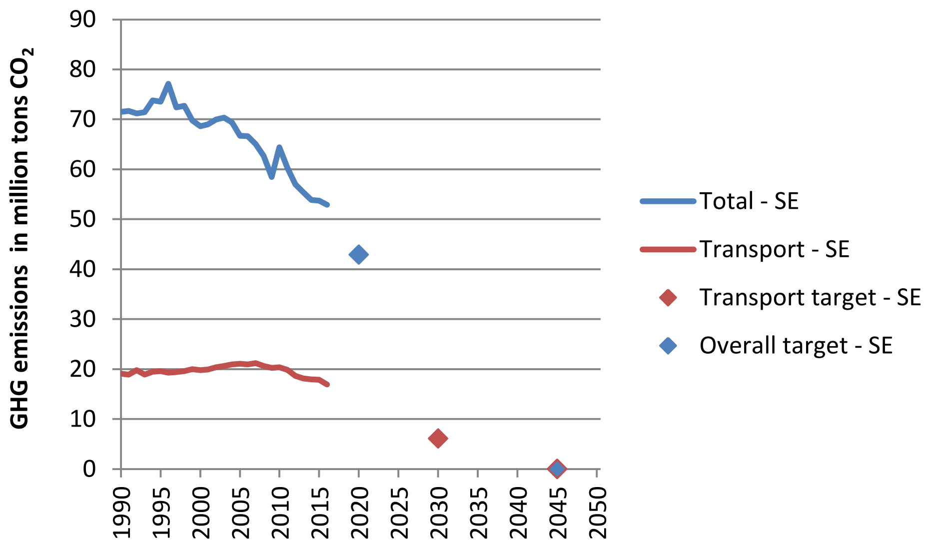

Figure 3: Historic development and targets of Swedish GHG emissions of all sectors and the transport sector. Source: own illustration based on data from EEA greenhouse gas - data viewer

In order to achieve this goal, it is under investigation to phase out petrol and diesel vehicles by stopping new registrations from 2030. Additionally, a new bonus-malus-system within the framework of vehicle taxation was introduced.

The increased use of biofuels should contribute significantly to reducing emissions in the transport sector. Instruments such as the fuel charge and the taxation of fuels on the basis of CO_2 intensity are intended to achieve the goal of a 40 % reduction in emissions (see page 33).

As early as 2017, Sweden created a climate policy framework consisting of three components: a Climate Act, climate goals (see above) with binding targets and a climate policy council.[4]

Denmark

GHG emissions in Denmark have decreased by 28 % since 1990 from 69 million tonnes to 50 million tonnes in 2016. In the transport sector, however, emissions increased by 21 % from 11 million tonnes to 13 million tonnes over the same period.

The current overall reduction target for the year 2030 is a reduction of 40 % compared to 1990. However, the new government plans to make the target much more ambitious with -70 % (Socialdemokratiet, Radikale Venstre, SF og Enhedslisten, Danmark 2019). The goal of a low emission society in 2050, anchored in the Danish climate law, is not further specified (Danish Energy Agency 2016). However, the new government wants to achieve a consensus for carbon neutrality by 2050.

Denmark has committed to reduce emissions from non-ETS[5] sectors by 39 % until 2030 compared to 2005 levels. According to Denmark's Energy and Climate Outlook 2018, Denmark will miss these targets and accumulate a shortfall of 32 to 37 million tonnes by 2030. According to the Outlook, emissions in the transport sector in 2030

[4] https://www.government.se/articles/2017/06/the-climate-policy-framework/
[5] Emission Trading Scheme

will be only 11 % lower than in 2005, at 13 million tonnes (Danish Energy Agency 2018).

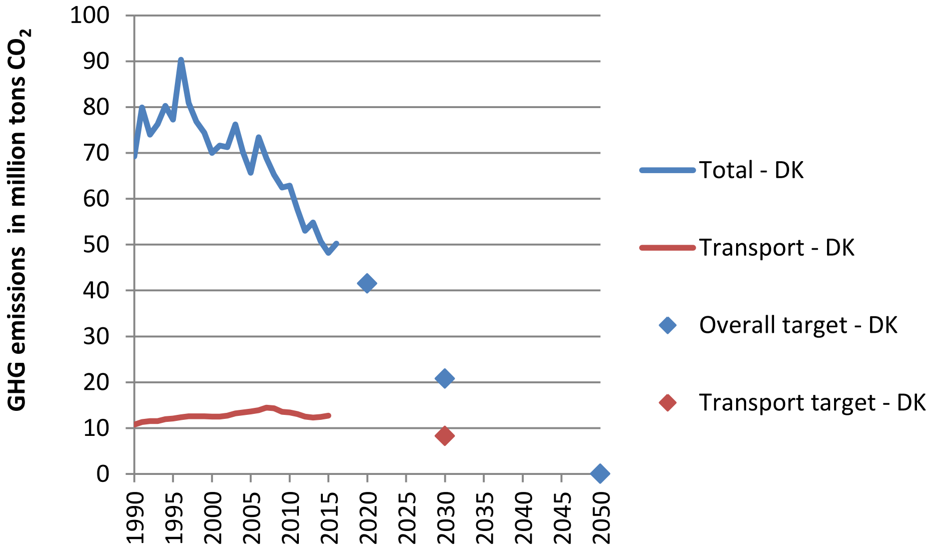

Figure 4: Historic development and targets of Danish GHG emissions of all sectors and the transport sector. Source: own illustration based on data from EEA greenhouse gas - data viewer

The regulatory framework for the Danish climate related policies is laid out in the Danish climate law. Within this framework, the Danish Council on Climate Change was established in 2015. It consists of extinguished academic experts in the fields of energy, transportation, agriculture, environmental protection, nature and economics and publish their recommendations to the government on the climate effort. In addition, the Minister is required by law to submit an annual report to Parliament on energy policy, outlining the state of current GHG emissions and prospects for meeting international commitments. At least every five years, the Ministry must propose national climate targets with a ten-year perspective.

The electrification of road transport plays an important role in reducing GHG emissions. While for passenger cars there are concrete exit paths for internal combustion engine vehicles by stopping the sale of diesel and petrol passenger cars (2030) and from plug-in hybrid vehicles (2035), there are so far no specific action plans for heavy commercial vehicles with the exception of inner-city buses, buses and coaches.

Overview and implications for freight transport

Between 1990 and 2016, overall CO_2 emissions in the EU, Sweden, Germany and Denmark fell by around a quarter. In all four cases, emission reductions were achieved primarily in sectors beyond the transport sector. Only Sweden has seen a reduction in transport-related emissions since 1990 (mainly from use of biofuels). Germany is currently at 1990 levels, and the EU as a whole and Denmark are showing a clear increase in transport-related GHG emissions.

Main reasons for the below-average or even negative emission reduction contribution are a further increase in engine power and transport performance as well as a very low share of renewable energies in final energy consumption of transport.

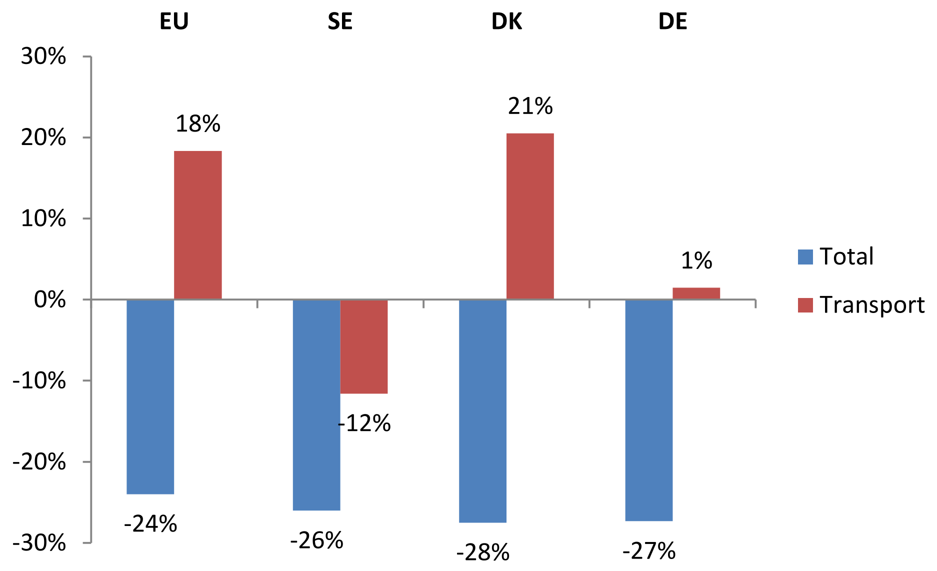

Figure 5: Development of overall and transport-related GHG emissions 2016 compared to 1990 levels in the EU, Sweden Denmark and Germany. Source: own illustration based on data from EEA greenhouse gas - data viewer

Today, domestic transport GHG emissions within the entire EU as well as in the member states Sweden, Denmark and Germany with a share of above 90 % are by far dominated by road transport. Since 1990, the share of road transport has continued to increase.

After passenger cars, HDVs are the second largest emitter of GHG emissions. HDVs have the greatest importance regarding GHG emissions in Denmark with a share of about 28 %. In all four cases their share of total emissions has increased since 1990.

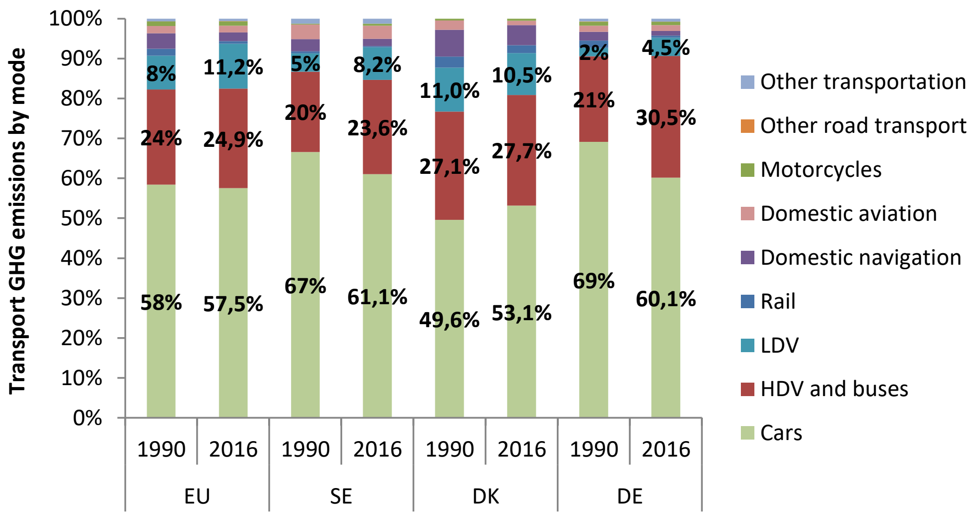

Figure 6: Transport GHG emissions by mode in the EU, Sweden, Denmark amd Germany EU in 1990 and 2016. Source: own illustration based on data from EEA greenhouse gas - data viewer

With regard to GHG emissions from the transport sector, it can be summed up that, with the exception of Sweden, no sufficient reduction has taken place so far or that emissions have even increased. The share of road freight transport in transport sector emissions has generally increased in recent years. This has raised the need for action to implement reduction measures in this area. Considering the ambitious targets in Sweden and Denmark, this seems particularly relevant.

Both, the European long-term strategy and national strategies do not provide a clear direction regarding concrete alternative powertrains in road freight transport. To date, they have rather relied on a mix of measures with regard to the CO_2-intensity of fuels, increased energy efficiency and fiscal measures as well as economic incentives for vehicles with lower CO_2 emissions. While Sweden and Denmark set clear targets for passenger cars with respect to a phase out of combustion engine vehicles, this is not the case in Germany. For heavy commercial vehicles, there is no such target in any of the cases considered.

The high pressure for action at national level to achieve the climate protection targets and the agenda of the new Commission President van der Leyen make it likely that decarbonisation options for road freight transport will be given greater public focus in the near future.

Currently, ERS does not play a prominent role beyond pilot projects. A role at European level equivalent to that of other alternative propulsion systems (LNG, BEV, FCEV) requires consideration within infrastructure development strategies. Since ERS implies the creation of a new energy supply infrastructure compared to the use of alternative fuels, a reduction of CO_2 emissions by ERS is more likely to contribute to long-term goals after 2030 and not to lead to relevant short-term reductions.

Socio-economic background

Population and economy

The combined population of Germany, Sweden and Denmark (as a potential ERS corridor link between these two countries) amounts to almost 100 million inhabitants, thus almost 20 % of the EU population. This considerable share of EU population, however, is dominated by Germany with currently about 83 million inhabitants. Due to its central geographic location Germany also provides a link of Scandinavia to a range of neighbouring countries in Western, Eastern and Southern Europe. All three countries are characterized by unemployment rates below and a per capita GDP significantly above EU average. Though the economies are dominated by services, the industrial sector remains a strong pillar of the GDP, especially in Germany with a share of GDP over 30 %, but also Sweden with 26 %.

Compared to EU average, especially Sweden and Denmark are highly urbanised (> 80 % urban population), but also Germany with an urbanisation rate of 75 % ranks above the EU average. Major differences, however, can be found in terms of population density, which in Germany is almost 10 times higher than in Sweden. The major urban areas in Sweden, however, are concentrated in the southern part of the country and thus closer to Denmark and Germany (especially Gothenburg and Malmö).

	EU	DK	SE	DE
Million inhabitants (2016)[1]	512.0	5.71	9.85	82.18
Medium age of population (2016)[2]	42.6	41.5	40.9	45.8
Share of urban* / rural population (2014)[3]	62.0 % / 28.0 %	87.8 % / 12.2 %	85.8 % / 14.2 %	75.5 % / 25.5 %
Inhabitants per km[2] (2016)[4]	117.7	136.4	24.4	233.1
GDP per capita (2016)[5]	27,100	46,300	42,500	34,900
Unemployment rate (2016)[6]	8.7	6.2 %	7.0 %	4.1 %
Share of GDP by sector (2016)[7]:				
Services	73.7 %	75.2 %	74.3 %	68.7 %
Industry	24.7 %	23.7 %	24.4 %	30.5 %
Agriculture	1.6 %	1.1 %	1.3 %	0.8 %

***Including suburbs**

Table 1: Comparison of socio-economic key parameters for the EU, Denmark, Sweden and Germany. Source: own illustration based on Eurostat data (Eurostat data[6])

Logistic market

Logistics play a vital role in today's economy with its division of labour. Logistic activities comprise the planning, organisation, management, execution and monitoring of transport of materials, goods or just information from A to B. The type of physical goods moved by logistic operations varies from bulky raw materials to low volume consumer goods and also includes food, chemicals and other items which require special handling.

With its high significance in a global economy, the logistics sector represented a volume of almost €878 billion in 2012[7]. This means a contribution of 7 % to total European GDP. This market volume includes all expenses for logistics services, including costs for personnel, vehicle stock, and administration and planning of logistical activities. About 44 % of the logistics market volume is related to transportation, followed by warehousing (24 %) and capital costs (22 %).

Due to its size, central location and high industrialisation, the German logistics market is by far the largest in Europe with a volume of €228 billion (2012). The Swedish market has a volume of €29.7 billion. This corresponds to only about 13 % of the German logistics market, but nevertheless makes it the 8th largest logistics market in the EU. The Danish logistics market has a volume about half the size of the Swedish market (€14.9 billion).

[6] Datasets: source 1: demo_gind and proj_15npms; 2: demo_pjanind; 3: ilc_lvho01; 4: TPS00003; 5: SDG_08_10; 6: TIPSUN20; 7: TEC00114

[7] More than € 1000 bn. in 2016 according to Schwemmer (2017): TOP 100 in European Transport and Logistics Services

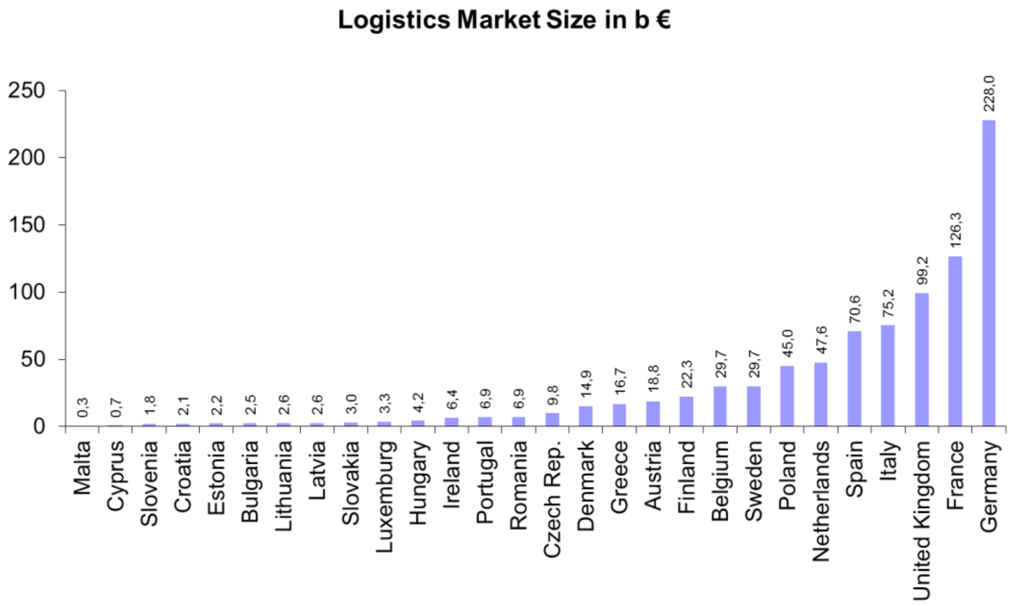

Figure 7: Logistics market size of EU member states in billion € in 2012. Source: Ecorys et al. 2015

The transport infrastructures of Germany and Sweden are currently ranked first and fifth in the EU respectively in the World Bank's 2014 assessment. Important indicators are customs, infrastructure, ease of arranging shipments, quality of logistics services, tracking and tracing and timeliness. Regarding logistics quality Germany is ranked second and Sweden fifth.

Road freight transport

Road transport dominates the European logistics market in respect to transport volumes, overall turnover and the number of companies. In 2014, the share of goods transported by road in EU-28 inland transport (74.9 %) was more than four times higher than the share of goods transported by rail (18.4 %)[8]. While in the EU 75 % of all companies in the logistics market are operating in road transport, this figure is even higher for Sweden (80 %) but considerably lower for Germany (about 55 %).

In terms of turnover, in the EU nearly 35 % of the logistics market is related to freight transport by road (nearly 20 % in Germany, more than 30 % in Sweden). At the same time the road freight transport sector holds the lowest turnover per company and is characterized by a very low mean number of persons employed per enterprise, 11 per company in Germany and 5 per company in Sweden, which is also EU average. Only inland navigation shows a similar low average company size. All other sectors consist of much bigger individual enterprises.

Costs of road freight transport

Road transport costs are composed of many different positions, most notably personnel costs (mainly driver costs), fuel costs, investment-related costs such as interest, leasing and depreciation costs. Furthermore, other variable costs, such as maintenance and road tolls apply. Personnel costs usually dominate and can amount

[8] It should be noted that this analysis refers only to inland freight transport and that a significant part of the goods may also have been transported by sea and certain product groups by air freight or pipelines.

up to 72 % in the road transport sector. Differences in total costs between the European countries are therefore relatively high, depending on the wage levels. An average road transport operation in Sweden, e.g., is more than three times more expensive than a comparable shipment in Bulgaria. Also Germany is among the 10 countries with the highest personnel costs.

Fuel costs in comparison are rather low despite recent price increases with a share on total costs between 9 % to 32 %. Only in countries with a low wage level, such as Bulgaria and Romania, fuel costs represent the most important cost factor.

Road transport costs rose by an average of 19 % in the EU Member States between 2006 and 2012, which marks a relatively high increase compared to other transport sectors. A significant increase in personnel costs, also in Central and Eastern Europe, together with steadily rising fuel costs and road tolls can be identified as main drivers of this trend.

By comparison, the differences in rail freight transport between countries are less pronounced and personnel costs do not play such a prominent role. Again, Sweden has the highest costs in the EU, followed by Denmark, Germany ranks eighth. Compared to road freight transport, however, the costs increase of 13 % between 2006 and 2012 has been slightly less significant.

It can be concluded that Sweden, Denmark and Germany are mature and established markets. Despite an increase in wages and salaries in European ”low labour cost countries”, there is still a considerable cost difference compare to established ”high labour cost countries”. As of 2012, road transport costs were still about three times higher in Sweden than in Bulgaria. Differences can also be found in terms of the cost development: While the ”low labour cost countries” still have the advantage of low personnel costs, they face more difficult conditions for financing the vehicles. In Germany and Sweden, on the other hand, financing of vehicles and equipment can be realised at particularly low costs.

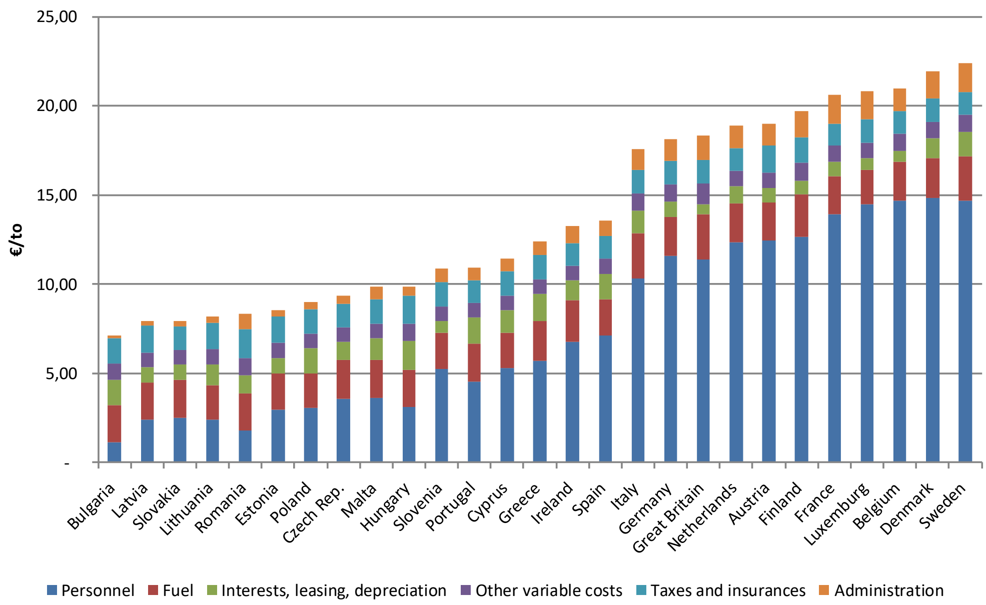

Figure 8: The cost structure of road transportation in the EU Member States 2012. Source: Ecorys et al. 2015

Overview and implications for freight transport

Germany, Sweden and Denmark represent a significant part of the EU economic area in terms of total population and size of the logistics market. The high turnover in road freight transport is contrasted by low turnover per company. This fact is underlined by the small average size of the companies and the number of employees in road freight transport in the EU average as well as in the countries considered. The three countries are relatively similar in their economic structure. Rather high national wage costs in the logistics market are offset by particularly favourable capital costs compared to other EU member states. In a EU comparison, the countries are characterised by a high quality of transport infrastructure.

With regard to the market introduction of new technologies in road freight transport, such as ERS, the economic area under consideration is characterised by a relevant size. The comparatively high quality of the transport infrastructure is also a good prerequisite for the introduction of new technologies. At company level, the rather low cost of capital is a good starting point for the procurement of more investment-intensive propulsion technologies. The small average size of road freight transport companies, on the other hand, represents a possible obstacle in view of the individual economic investment risk.

Status quo and development of national (freight) transport

Transport volume

EU countries in general and Germany, Sweden and Denmark in particular show an increase in freight transport performance over the past years (Figure 9). The temporary decline is attributable to the European economic and financial crisis in 2008. Since 2005, freight transport performance in Denmark has increased by 23 % (2.1 % p.a.), in Germany by 17 % (1.5 % p.a.) and in Sweden by 9 % (0.8 % p.a.). Since 1990, the average rate of increase has been as high as 1.5 % p.a. (total +47 %) in Germany and at about 1.4 % p.a. (total +45 %) in Sweden.

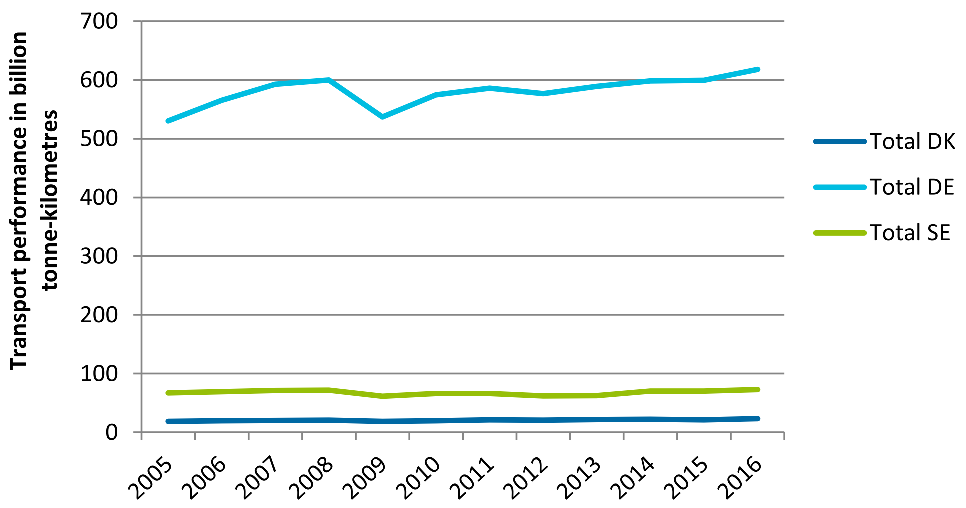

Figure 9: Total freight transport performance in Sweden and Germany (2004-2016). Source: own illustration based on data from EU transport in figures 2018 (Eurostat 2019b)

Road and rail are the most important modes in all countries regarding freight transport. In this section the focus is on road transport. The following part deals with the modal split and interdepencies between road and railway.

Transport volume highly correlates with GDP (Figure 10). Large economies have a higher transport and logistics performance which is driven by consumption of private and industrial demanders. The six largest EU economies represent more than 70 % of the tonnes moved by the EU 28. A decision for ERS introduction in those countries would presumably have a strong effect on the transportation strategies of smaller neighbouring countries.

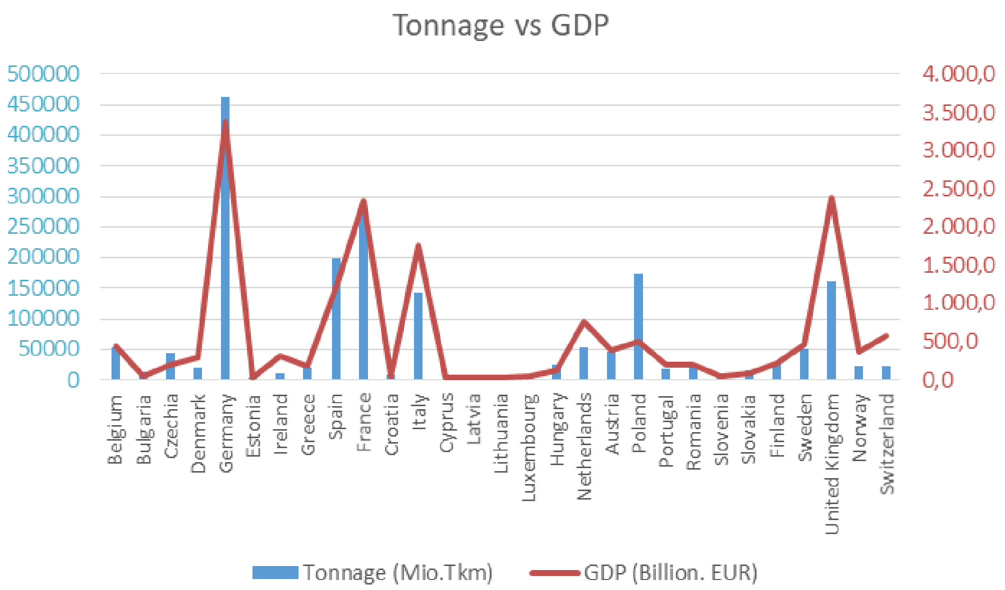

Figure 10: Economic activity with respect to transport volume (all transport modes), Source: own illustration based on data from Eurostat (2019b) and Eurostat (2020a).

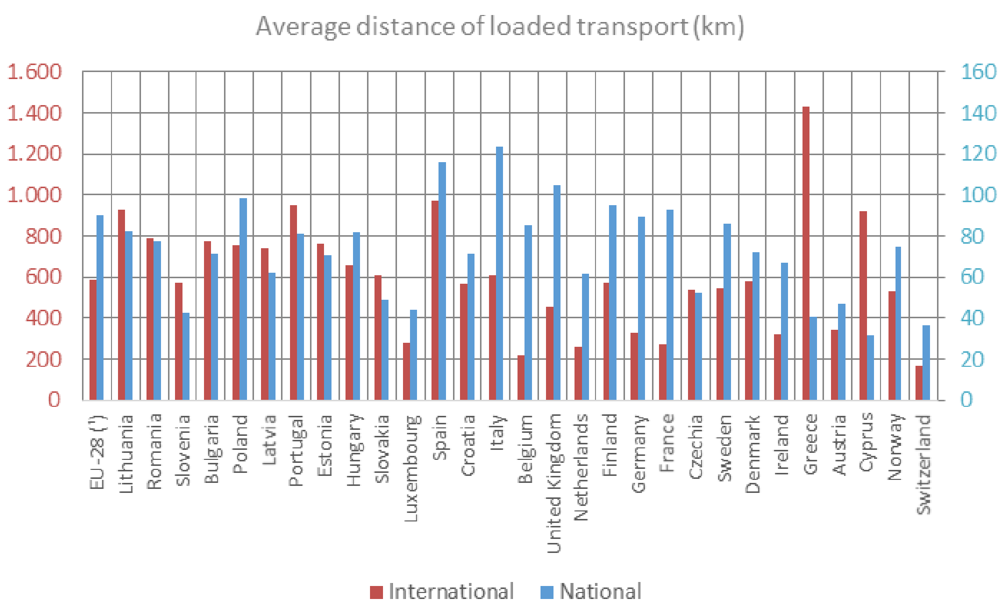

Figure 11: Average trip distances in road freight transport, Source: own illustration based on data from Eurostat (2020b).

Figure 11 represents the average distance of loaded goods transport, calculated by dividing the total tonne-kilometres (tkm) travelled by the total volume of tonnes carried in national and international transport. The national average transport length correlates to the countries' area size and shape. The overall mean distance is about 73 km with a maximum of 123 km in Italy and a minimum of 31 km in Cyprus. In Denmark, Germany and Sweden the distances are round about 72 km, 89 km and 86 km, respectively. Regarding international transport, the highest distances are given by countries which are geographically located in the outer regions of the European union, like Greece with over 1,400 km as well as Portugal, Spain, Cyprus and Lithuania with over 900 km. The average international transport distances of vehicles registered in Denmark, Germany and Sweden are about 580 km, 332 km and 543 km, respectively. Thus, countries in the periphery of the EU will likely face particular challenges in the transition to ERS without neighbouring countries also investing in infrastructure.

In Denmark and Germany as "transit countries", the share of the transport performance that is provided by trucks registered in other countries is much higher than in Sweden (Figure 12). It constitutes more than one third of total road transport volume in these countries. In terms of ERS, that means that the truck operators in Sweden can be more easily targeted with national policy measures (such as a vehicle purchase subsidy) when the government seeks to initiate an ERS introduction. This could mean a lower uncertainty for the government with regard to the future ERS user base.

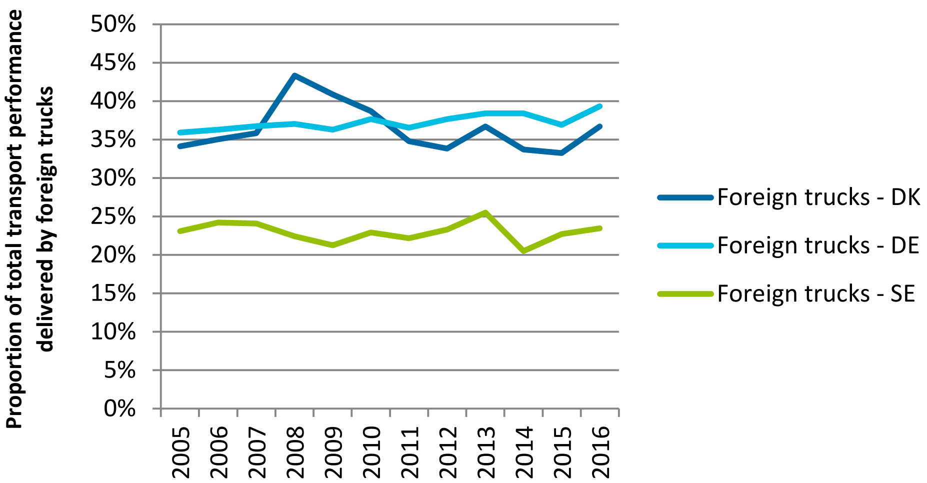

Figure 12: Proportion of HDV transport performance (tonne-kilometres) by foreign trucks within the territory of Denmark, Germany and Sweden (2005-2016). Source: own illustration based on data from EU transport in figures 2018

Modal Split and intermodal transport

In Germany, Denmark and Sweden, freight transport is by far dominated by road transport (more than two third or nearly 90 % in Denmark). The share of HDVs within the road freight transport has increased further since 2005. Rail is the second most important option for freight transport in the aforementioned countries. A slight increase in the share in Germany contrasts with a slight decrease in the share of freight transport in Sweden. Inland navigation plays a relevant role only in Germany, but with a declining trend regarding its share of transport performance.

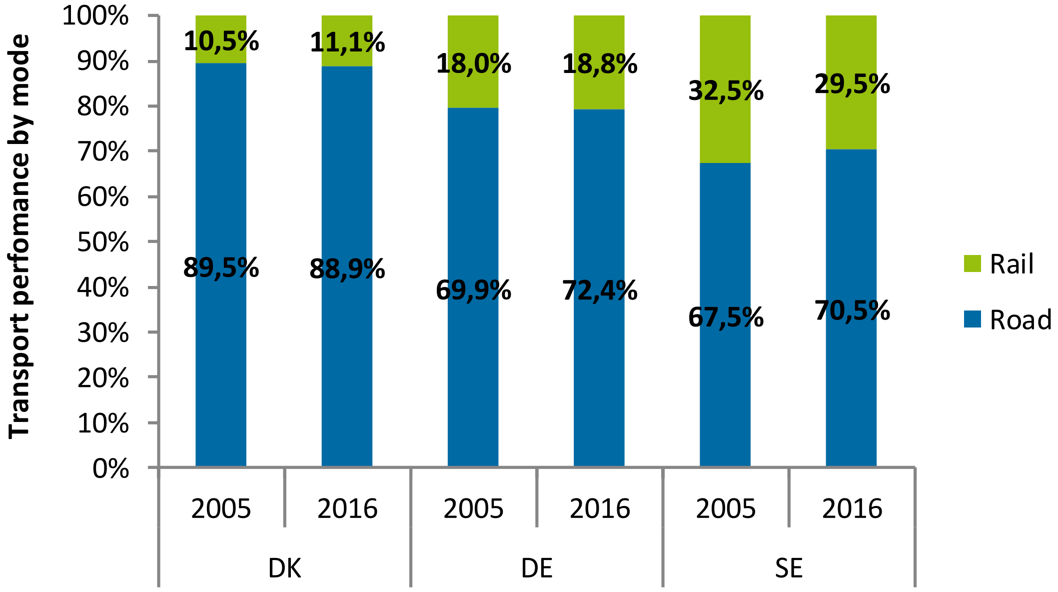

Figure 13: Transport performance by mode; Source: own illustration based on data from EU (2018)

The EU strategy sets out to shift 30 % of road freight transport of more than 300 km distance to rail and waterborne transport by 2030 for reducing CO2 emissions from the transport sector (EC 2011a). Figure 14 shows the share of road transport within this distance category for Germany, Sweden and Denmark. While Sweden already has the highest share of rail freight transport (also due to a large amount of iron ore transports in northern Sweden), it also has the highest potential for further shift to rail according to the distance categories. Hence, particularly in Sweden, it needs to be ensured that ERS introduction does not undermine efforts for modal shift from road to rail. That means that ERS expansion should focus on routes that are particularly challenging for railway freight traffic.

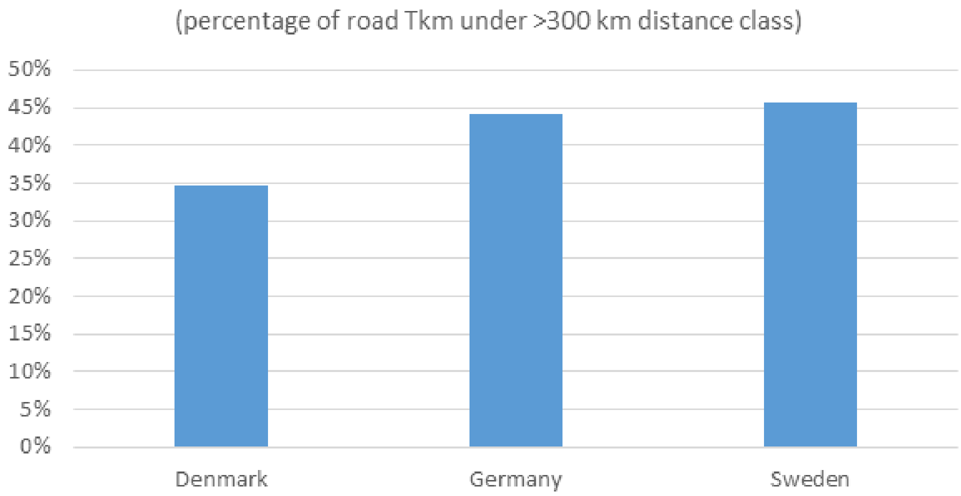

Figure 14: Proportion intended by the EU to shift from road freight to rail and waterborne transport based on the transport distance for Denmark, Germany and Sweden. Source: own illustration based on data from Eurostat (2020b).

Among the rail freight transport, the proportion of intermodal transport is especially high in Germany, which can be attributed to the scattered settlement structure with no equally dense railway network. The number of intermodal terminals in Germany is however limited, leading to considerable feeder traffic to and from the terminals. If this feeder traffic concentrates on specific road stretches, it can pose an interesting ERS application: In this case, ERS would complement rail transport and for environmental-oriented customers, it allows for decarbonisation of supply chains.

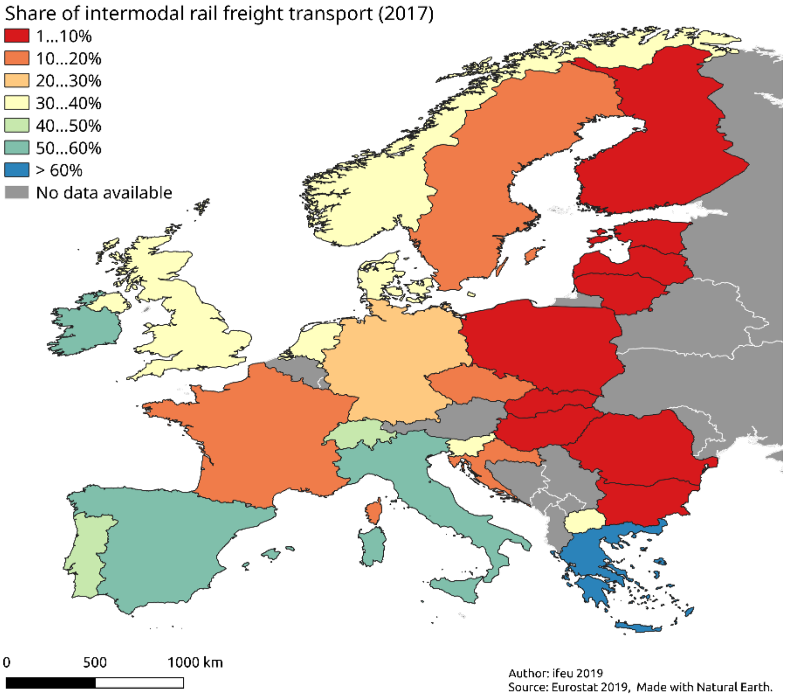

Figure 15: Intermodal rail freight transport in European countries (figures in % of total rail freight transport measures in Tkm, Containers and swap bodies). Source: own illustration based on data from Eurostat (2019b).

Unitisation[9] of goods in EU is increasing in rail transport. Unitisation in road transport has not seen an increase in the EU in the last few years. While Germany had the highest volume of road transport by containers in 2017, the unitisation in rail transport is higher than unitisation in road transport in most countries. The unitisation rate for rail freight covers not only containers and swap bodies, but also accompanied road vehicles (with driver) and unaccompanied semi-trailers (without driver). Germany (40 %) and Denmark (43 %) had one of the highest unitisation rates in rail transport in 2017.

An increasing unitisation increases the probability that the share of intermodal transport will further increase in the future. This would have consequences for the planning of ERS networks; if intermodal transport chains become easier, the importance of establishing ERS in order to decarbonise intermodal feeder traffic would increase and respective routes should be in the focus of network planning.

[9] Freight unitisation' is defined as the use of standardised packaging units that can easily be transferred from one mode of transport to another without handling the goods themselves. In simple terms, 'unitisation' describes how much of the total freight transport has been transported in containers. The main types of standardised packaging units, called intermodal transport units (ITUs) are containers, swap bodies, trailers and semi-trailers.

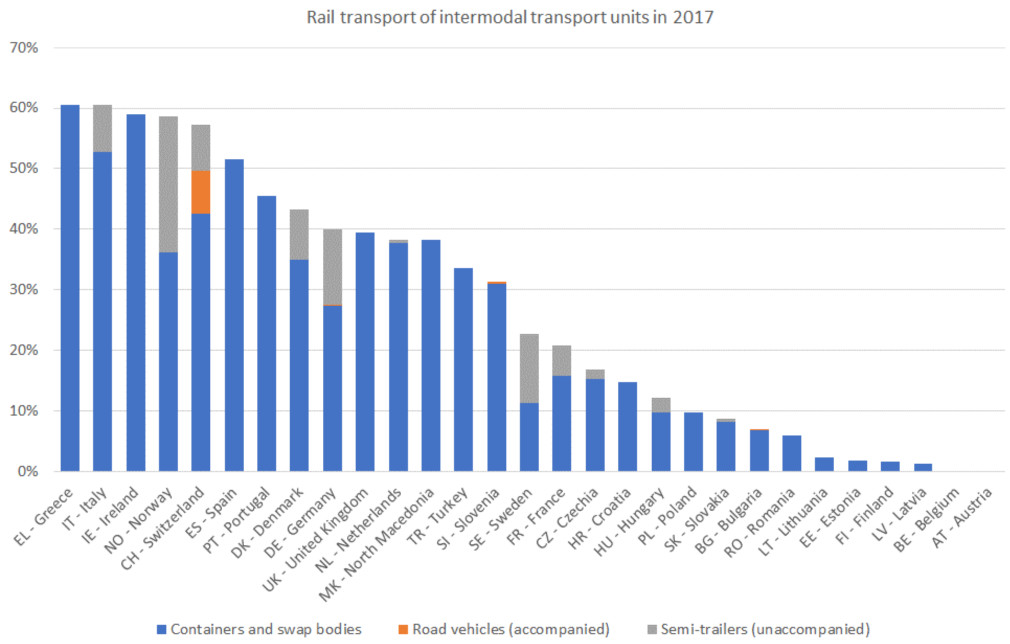

Figure 16: Unitization in rail transport, a prerequisite for intermodality. Share on total rail freight transport in tkm. Source: Eurostat (2019c)

The low unitisation rates in road transport may be attributed to barriers faced by road haulier companies with regard to vehicle fleet that is not adopted for rail, small transport volumes and congestion on terminal access roads (Behrends 2015).

Transport infrastructure

At around 13,000 km, the German motorway network is almost 50 % larger than the network of motorways and European roads in Sweden (around 8,900 km) and almost six times larger than the network in Denmark (2,200 km), see Figure 17. Taking main and national roads into account the Swedish road network is about 30 % and the Danish about 7 % of the length of Germany's network. Since the freight transport performance in Germany, at around 448 billion tkm in 2016, is about an order of magnitude higher than in Sweden (51 billion tkm) and Denmark (21 billion tkm), the average utilisation of trunk roads is about six times as high as in Sweden and four times as high as in Denmark.

The railway network in Sweden corresponds to about a quarter of the length of the German network. The average transport performance per rail-km is about 50 % higher in Germany than in Sweden. In Denmark, which has the smallest railway network with about 2,500 km, the average freight transport performance per rail-km is about half as high as in Sweden. Navigable inland waters are only of importance in Germany. In the period from 2007 to 2016, transport performance on waterways in Germany fell by 16 %.

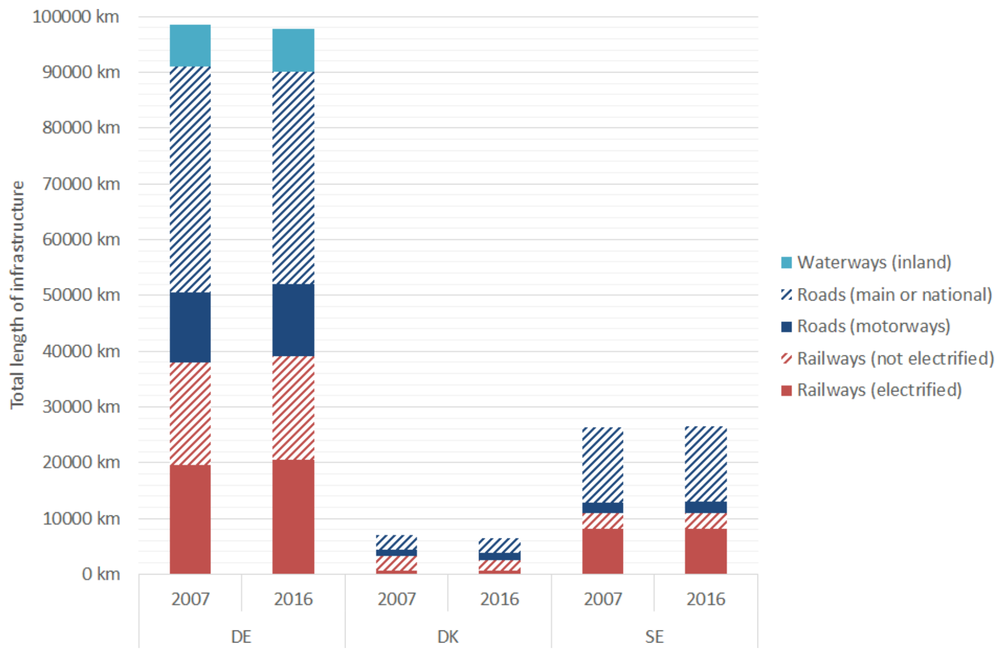

Figure 17: Length of transport infrastructure in Sweden, Germany and Denmark (2007 and 2016). Source: own illustration based on data from Eurostat and from EU transport in figures 2018)

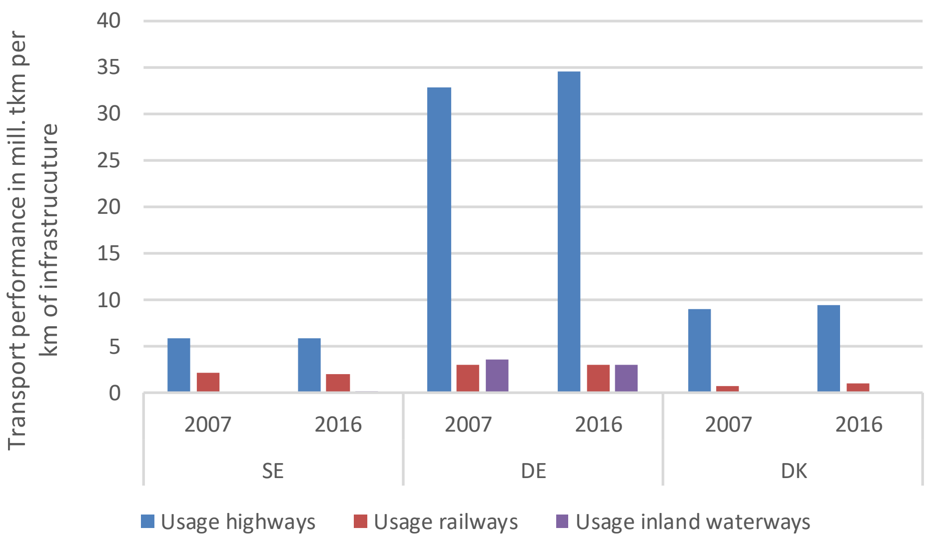

Figure 18: Infrastructure usage in Sweden, Germany and Denmark (2007 and 2016). Source: own illustration based on data from Eurostat and from EU transport in figures 2018)

Figure 18 depicts that in Germany, transport infrastructure is by far most heavily utilised among the three considered countries. Yet, in Germany a bigger proportion of road freight transportation takes place on the secondary road network. However, also a view on the average daily traffic (ADT) on motorways shows clearly a much higher utilisation (Figure 19). This means that infrastructure restrictions generally play a more important role in Germany and significantly effects the modal split. Without a substantial capacity expansion of the German railway network, a shift of road transport towards railway transport will be virtually impossible and effective decarbonisation of road transport remains a key issue. If 30 % of the road transport performance of HGV in the distance class above 300 km would be shifted to waterways and railways in Germany, the transport performance of these modes would have to increase by approximately 24 %, neglecting route distance changes and future change of transportation demand. The question in which cases ERS make sense from a system point of view therefore is particularly closely related to infrastructural restrictions in the case of Germany.

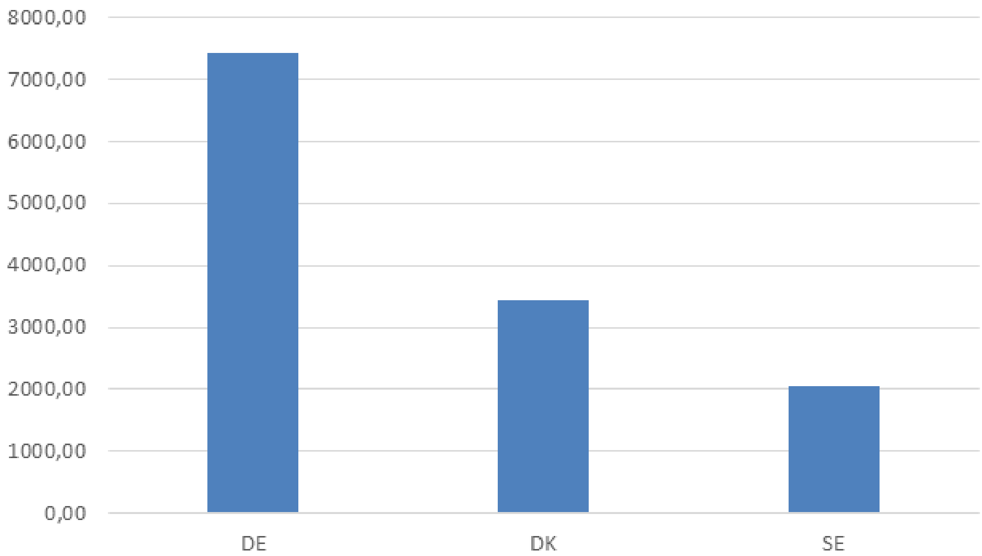

Figure 19: Mean annual average daily traffic (AADT) of HGV on the TEN-T road network in Denmark, Germany and Sweden. Source: own illustration based on CEDR working group performance of the road network (2018)

Moreover, this can have an effect on the suitability of certain ERS configurations: If the railway network in certain regions generally has got capacity reserves (as e.g. in Denmark), this could be a reason to concentrate ERS efforts on feeder traffic for intermodal transport there.

On the other hand, the high capacity utilisation of motorways, especially in Germany, offers a high potential for an early economic operation of ERS. Since the same proportion of electrified vehicles in Germany would mean a significantly higher number of users in absolute terms than on the average much less heavily frequented main national roads or motorways in Sweden or Denmark.

Status quo of political measures in the transport sector

A number of activities, both at European level and at Member State level in Denmark, Germany and Sweden, have already been launched to reduce GHG emissions in the transport sector and to promote alternative propulsion concepts. This section gives a brief overview of measures in the fields of vehicles, vehicle operation, fuels and infrastructure that create a supportive environment for greener road transport (EEA 2018; EEA EEA 2017a; EEA 2017a; 2017a).

Most of the policies and measures (PaM) described in this chapter are taken from the EEA database on climate change mitigation PaM in Europe (EEA 2019).

Vehicles

European Union

At EU level, the recently adopted **CO_2 standards for HDVs** (EC 2018)can be regarded as the essential measure to reduce GHG emissions from road freight transport. Compared to 2019, emissions from newly registered commercial vehicles are set to fall by 15 % by 2025 and by 30 % by 2030. The regulation sets emissions limits for delivery vehicles for rigid and tractor trucks with a gross vehicle weight (GVW) exceeding 16 tonnes and an 4x2 and 6x2 axle configuration. In the coming years, the standards will be extended to further vehicle configurations and subjected to a revision in 2022. The average CO_2 emissions of new registrations per manufacturer are calculated from the emissions of each registration and the proportion of its share in fixed groups of different vehicle configurations. If the manufacturer's average CO_2 emissions of new registrations exceed the manufacturer's specific targets, they face high penalty fines.

In addition to improving the efficiency of internal combustion engine vehicles, the regulation aims to create market incentives for zero and low-emission vehicles (ZLEV). In a first phase, manufacturers are granted super credits for ZLEV. The total ZLEV incentives can only reduce the average emissions of a manufacturer up to 3 % After this first phase, a ZLEV benchmark will come into force in 2025 (ICCT 2019) (European Parliament (EP), European Council 2019). Manufacturers are only rewarded by the sale of ZLEVs after a sales benchmark of 2 % has been met.

As part of the preparatory work for the directive, the simulation tool Vecto was developed, which is used to determine vehicle-specific CO_2 emissions. For the first time in the EU, it provides a standardized method for comparing fuel consumption and CO_2 emissions of various heavy commercial vehicles. The specific consumption and emission values could become more relevant in the future, for example if they are considered in the calculation of the vehicle tax or the rate of the vehicle toll.

Along with the standards for CO_2 emissions go adjustments regarding the permissible total weight for ZEV. The EU will increase the maximum permissible total weight of ZEV by up to two tonnes from 2020, which will reduce the disadvantages in terms of payload for these vehicles (DieselNet 2019).

Another EU directive that promotes the market entry of vehicles with alternative propulsion concepts is the Directive on the Promotion of Clean and Energy Efficient Road Transport Vehicles (**Clean Vehicles Directive**) (EU) 2019/1161 2019). The directive aims at a broad market introduction of environmentally-friendly vehicles. It requires that energy and environmental impacts linked to the operation of vehicles over their whole lifetime are taken into account in all purchases of road transport vehicles, as covered by the public procurement Directives (European Parliament (EP), European Council 2014a) (European Parliament (EP), European Council 2014b) and the public service Regulation (European Parliament (EP), European Council 2007). For HDVs purchased in the public procurement sector, country-specific targets are proposed for Member States for the share of alternative fuels electricity, hydrogen and natural gas including biogas. These minimum target for the share of HDVs in the total public procurement of HDVs at Member State level vary from 6 % to 10 % (2025) and from 7 % to 15 % (2030) (EU) 2019/1161 2019). A minimum target of 10 %

and 15 % is set for the three Member States Denmark, Germany and Sweden. In contrast to buses, however, the impact on new truck registrations as a whole is likely to be relatively small. The underlying reasons are, on the one hand, the much more ambitious target values for buses and the presumably much higher proportion of vehicles covered by public procurement.

At **EU level**, the introduction of **EURO VII emission standards** ((EU) 2019/631 2019) with stricter air pollutant limits for trucks is being discussed. Due to the additional costs for exhaust treatment, such a more stringent approach should help to support the market introduction of trucks with alternative drive concepts. DG GROW is currently working on a proposal, which should be completed by the end of 2020.[10] At present, however, the exact way and timing of such a tightening is still unclear. The current standards are listed in Table 2.

The EU first introduced heavy-duty vehicle emission standards in 1988. The "Euro" track was established beginning in 1992 with increasingly stringent standards implemented every few years (see Table 3). Euro VI standards have applied to all new diesel and gas engines since 2013. Testing is performed on engines alone rather than on complete vehicles, and limit values are expressed in terms of grams per kilowatt-hour (g/kWh) (TransportPolicy.net 2017). Provisions of the Euro VI regulation include:

- An ammonia (NH_3) concentration limit of 10 ppm applied to diesel (WHSC + WHTC) and gas (WHTC) engines.
- A maximum limit for the NO_2 component of NO_x emissions may be defined in the implementing regulation.
- New testing requirements for off-cycle emissions (OCE) and in-service conformity (in-use testing).

EU Member States are allowed to use tax incentives in order to stimulate marketing and sales of vehicles meeting new standards ahead of the regulatory deadlines.

Tier	Date	Test	CO	HC	NO_x	PM	Smoke
Euro I	1992 (< 85 kW)	*R-49*	4.50	1.10	8.00	0.61	
	1992 (> 85 kW)		4.50	1.10	8.00	0.36	
Euro II	10/ 1996		4.00	1.10	7.00	0.25	
	10/1998		4.00	1.10	7.00	0.15	
Euro III	*Voluntary EEV (10/1999 to 01/2013)*	*ESC & ELR*	*1.50*	*0.25*	*2.00*	*0.02*	*0.15*
	10/2000	ESC & ELR	2.10	0.66	5.00	0.10 0.13	0.80
Euro IV	10/2005		1.50	0.46	3.50	0.02	0.50

[10] Personal note from James Nix, T&E

Tier	Date	Test	CO	HC	NO_x	PM	Smoke
Euro V	10/2008		1.50	0.46	2.00	0.02	0.50
Euro VI	01/2013	WHSC	1.50	0.13	0.40	0.01	

Table 3: EU Emission Standards for HD Diesel Engines, g/kWh (smoke in m-1) (TransportPolicy.net 2017)

Germany

In Germany, **subsidies for the purchase of energy-efficient and low-carbon trucks** are currently being granted. In June 2018, the Federal Ministry of Transport (BMVI) presented a funding scheme for this purpose. According to this, the purchase of trucks (>7.5 tonnes GVW) and semitrailer tractors with a GVW of 7.5 tonnes or more powered by natural gas (CNG), liquefied natural gas (LNG) or certain electric drives (pure battery electric vehicles and fuel cell vehicles) will receive financial support until December 2020. Subsidies will be provided for additional investment costs incurred if a comparable truck or a semitrailer tractor with one of the above-mentioned alternative drive systems is purchased instead of a diesel-powered EURO VI vehicle. The subsidy may not exceed 40 % of the additional investment costs and is fixed at a flat rate of €8,000 for vehicles powered by natural gas, €12,000 for vehicles powered by liquid gas, €12,000 for electric trucks up to 12 tonnes GVW and €40,000 for trucks and electric tractors with a GVW of 12 tonnes or more. The annual funding volume amounts to €10 million (BMVI 2018).

In Germany, the amount of motor vehicle tax payable on a truck depends on the weight of the vehicle, air pollutant emissions and the noise caused. The maximum tax rate for heavy goods vehicles is between €556 /a and €1,681 /a. In contrast to passenger cars, the motor vehicle tax for trucks does not currently contain a CO_2 component that would favour the market launch of low emission vehicles (LEVs). However, through a 10-year **tax exemption for electric vehicles** purchased by 31 December 2020, there is a support for zero-emission vehicles. In Germany, trailers are also taxed by weight. The tax amounts to €7.46 per 200 kilograms total weight or part thereof, but not more than €373.24 in total.

To promote electric mobility, a total of around €2.2 billion has been made available in Germany since 2009 for research and development in the field of transport electrification. However, this funding did not specifically relate to electric mobility in road freight transport (BMWi 2019).

Sweden

Sweden introduced the **super green car rebate** (supermiljöbilspremie) for passenger cars with the main aim of contributing to technology development and application and creating understanding within society to reduce the barriers to the widespread introduction of electric and hybrid electric cars. Super green cars must meet the Euro V or Euro VI standard and emit a maximum of 50 g CO_2/km and be registered until the 30 June 2018. The discount was SEK 40,000 for electric vehicles / SEK 20,000 for hybrids for private buyers or 35 / 17.5 % of the cost difference between the price of a super green car and a conventional car of a similar type for companies. Trucks, however, did not fall under the super green car rebate (Naturvårdsverket 2017). in 2019 a proposal for the promotion of environmentally friendly heavy-duty vehicles was presented and a subsidy of up to 60 % of the additional costs compared to a comparable diesel vehicle was proposed (Trafikanalys 2019). The proposal has not yet been implemented.

A **bonus-malus system for new light vehicles** was introduced in Sweden on 1 July 2018. Vehicles with low CO_2 emissions receive a bonus of up to SEK 60,000 on purchase, while vehicles with high carbon dioxide emissions are taxed more heavily in the first three years. This new regulation affects cars, light buses and light trucks (Naturvårdsverket 2019).

Denmark

A high vehicle **registration tax** is payable in Denmark for the first-time registration of passenger cars. This is 85 % of the taxable value up to DKK 185,100 in 2017 and 150 % of the rest of the value. For vehicles with electric drive, tax reductions are granted until 2022. For trucks, there is no comparable incentive for vehicles with alternative drives, as these are not subject to this taxation.

Apart from the registration tax and the implementation of the EU requirements under the CO_2 regulation for passenger cars and vans, i.e. the mechanism that imposes fines on manufacturers if they do not meet the CO_2 targets, the PaM database does not mention any other policy measures with regard to vehicles.

However, in 2018 Denmark proposed a **ban on the sale of new petrol and diesel cars** from 2030 and hybrid cars from 2035 (Nielson and Goodman 2018). While there are concrete exit routes for cars with internal combustion engines, there are currently no concrete exit routes for HDVs with the exception of city buses, buses and coaches.

Operation

European Union

The **Eurovignette Directive 1999/62/EC** (European Parliament (EP), European Council 1999) provides a detailed legal framework for charging HGVs for the use of TEN-T network and motorways.A proposal for a Directive amending Directive 1999/62/EC on the charging of HGVs for the use of certain infrastructures is currently under consideration. It is proposed to phase out the variation of charges according to the Euro emission class of the vehicle and introduce the variation of infrastructure charges according to the CO_2 emission of HDVs. Currently, a reduction of toll rates for zero emission trucks by 75 % compared to EURO I vehicles is being discussed. Since truck tolls have a large influence on the total costs in some countries, such an adjustment could represent a major incentive for ZEV operation.

The operation of HGVs is governed by different directives and regulations. These include vehicle approval and competition as well as occupational safety and environmental protection. Based on the importance of cross-border freight transport, regulations in this context are implemented uniformly throughout the EU:

- The driving and rest periods of professional drivers are regulated uniformly throughout the EU by European law (CEPS; Chatham House; Ecologic Institut 2011) (European Parliament (EP), European Council 2006) . The driving and rest time regulations for truck drivers require that the driving time may not exceed 9 hours a day, a maximum of 56 hours a week and a maximum of 90 hours within 14 days. After a maximum of 4.5 hours of steering, the driver is obliged to take a break. The at least 45 minutes break can also be set up for at least 15 minutes and at least 30 minutes of break.

- The regulation on common rules for access to the international road haulage market defines cabotage as a commercial road haulage operation involving loading and unloading in a state by a contractor who has neither registered office nor branches in that state. Such cabotage operations following cross-border carriage are only permitted after the complete unloading of the vehicle. In addition, a cabotage service may be carried out within three days of the entry of an unloaded vehicle into the territory of a member state. This presupposes that a cross-border transport to another member state has previously taken place. The scope of the regulations also covers vehicles with a gross vehicle weight of up to 3.5 tonnes (CEPS; Chatham House; Ecologic Institut 2011) (European Parliament (EP), European Council 2009a).
- Although not regulated at EU level, driving bans for trucks on Sundays and public holidays exist in almost all EU countries. There are exceptions for certain goods groups, such as ultra-fresh goods or vehicles that are used in combined transport as a provider of rail freight.

The rules on driver rest periods may have an impact on the use of battery electric vehicles (BEV), provided that these periods can be used for battery charging. If these break times are not sufficient for charging, this can have a negative effect on the economic efficiency of the vehicles.

Germany

Since 2005, trucks with a GVW of more than 12 tonnes have been charged with **truck tolls** for highways in Germany, which has been extended to selected federal road sections in 2012. Since 2013, a revision of the toll rates includes a spread according to pollutant classes. In 2015, the toll was extended to other sections of the federal highway as well as to all vehicles with a permissible total weight of 7.5 tonnes (BReg 2017). Currently, the toll rate for infrastructure costs for vehicles or vehicle combinations with five or more axles (equivalent to trailer trains) is €0,135 per km. Depending on the pollutant class, the toll rate varies between 0 (Euro VI) and €0,083 per kilometre (Euro 0 / I) (ÖI 2018). Further development of the federal highway toll law (Hausding 2018)

- Gradual expansion of the toll on all heavy commercial vehicles with a maximum permissible mass of 7.5 tonnes and on all federal highways (40,000 km).
- From 01.01.2019, electric trucks will be completely exempt from truck tolls.
- Toll exemption until 2020 for natural gas-fueled trucks (from 2021, partial costs for infrastructure and noise pollution caused have to be paid).

In a number of cities in Germany the permissible limit values for nitrogen oxides are exceeded. The air-quality in cities has to comply with the limits set by the EU for nitrogen oxides, which are at 40 mg/m^3 (EC 2019a). In order to ensure air pollution control, **driving bans for diesel vehicles** may be imposed by the federal states according to a ruling of the Federal Administrative Court. At present, driving bans for diesel vehicles have already been introduced in Hamburg, Stuttgart and Darmstadt. The introduction in Berlin and Mainz is also planned for 2019. With the exception of Stuttgart, where the driving ban is valid throughout the city, the driving bans are limited to individual roads with particularly high air pollutant emissions and to diesel vehicles up to and including the Euro IV or Euro V emission standard (ADAC 2019). Clean Air Plans contain measures to permanently improve the air in German cities. For example, many municipalities have listed "environmental zones" or the construction of bypasses in their clean air plans.

Sweden

As in Denmark, the operation of trucks from 12 tonnes also requires a **Eurovignette** in Sweden (see above). The Eurovignette is required on all motorways for vehicles registered in Sweden, the routes E10, E12 and E14, the E4 between Gävle and the Finnish border, the E22 between Karlskrona and Norrköping and the E65 between Svedala and Ystad for foreign vehicles.

Sweden has a national framework of low emission zones, and congestion charges in two cities (Gothenburg and Stockholm). Stockholm for example **regulates all heavy, diesel-powered trucks** and buses over a certain length, width and weight and also has a night time ban for trucks in place. The low emission zone framework means that only the location varies for each city. The congestion charges are through a national scheme and very similar, but not identical for Swedish cities (Sadler Consultants Europe 2020).

In 2018, the Swedish government allocated SEK 150 million to the **Eco-Bonus system**. Its aim is to reduce greenhouse gas emissions from heavy goods traffic by supporting the shift from road to shipping. The Eco-Bonus system is to exist until 2020. It can be granted either to new intermodal routes or to upgrades of existing routes and covers up to 30 % of the operational costs for coastal and short sea shipping transport services or10 % of the costs for the purchase of trans-shipment equipment to supply a planned service[11] (Naturvårdsverket 2019).

Denmark

Denmark participates in the **Eurovignette** system. The Eurovignette is a road charge which is applied in four countries: Denmark, Luxembourg, the Netherlands and Sweden. Heavy trucks with a permissible total weight of 12 tonnes or more must buy it before driving on roads where the charges apply. The amount of the charge depends on the emission standard and the number of axles. There is no reduction for vehicles with alternative drive systems.

In Denmark there are **environmental zones** in Copenhagen, Aalborg, Aarhus and Odense. This affects diesel-powered buses and trucks over 3.5 tonnes (Sadler Consultants Europe 2020).

In order to reduce GHG emissions from road traffic, the number of mobile **speed measurement devices** (mobile cameras) was increased from 25 to 100 nationwide in 2015. While this measure is estimated to reduce annual GHG emissions by 55,000

[11] https://ec.europa.eu/competition/state_aid/cases/275541/275541_2025774_144_2.pdf

tonnes, it is not further specified whether long-distance freight transport also contributes to the reduction.

In addition, DKK 200 million was made available in 2009 for energy-efficient transport projects focusing on the **promotion of environmentally friendly freight transport**. These funds were used for projects such as container transfer systems for rail vehicles to promote multimodal transport (EEA 2017b).

Germany	Denmark	Sweden
Road toll for all heavy commercial vehicles with a maximum permissible mass of 7.5 t	Eurovignette for trucks and truck/trailer combinations, with a total weight of 12 tonnes or more	
all federal highways (40,000 km)	all motorways	
toll-exemption for electric trucks and gas-fueled trucks	No exemption for particular drive systems	

Table 4: Road user charges in comparison

Fuels

European Union

Efforts have been made at European level for some time to promote the use of renewable fuels to reduce the greenhouse gas emissions in transportation. The first targets of 2 % for 2005 and 5.75 % for 2010 were set by the **directive 2003/30/EC** on the promotion of the use of biofuels or other renewable fuels for transport (EC 2003).

This was followed by the **Renewable Energy Directive** 2009/28/EC (European Parliament (EP), European Council 2009b), which set more ambitious and binding EU targets: 20 % of final energy consumption of the EU from renewable energies and a minimum share of 10 % renewable energies in the transport sector are to be achieved by 2020. The directive provided differentiated binding national targets for the use of renewable energies in the EU member states, ranging from 10 % for Malta to 49 % for Sweden. The Member States had to draw up a National Renewable Energy Action on the promotion of the use of energy from renewable sources.

According to the **Fuel Quality Directive** 2009/30/EC, Member States shall require suppliers to reduce as gradually as possible life cycle greenhouse gas emissions per unit of energy from fuel and energy supplied by 6 %[12] (EC 2009).

In 2015 with the directive (EU) 2015/1513 (European Parliament (EP), European Council 2015) new rules came into force to reduce the risk of indirect land use change (ILUC) in both the RED 2009/28/EC and the **Fuel Quality Directive** 2009/30/EC. In addition, the amendment included the preparation of the transition towards advanced biofuels.

According to the EU Fuel Quality Directive, greenhouse gas emissions from fuels must be reduced by at least 6 % by 2020. Biofuels will play a key role in achieving both targets (EC 2009).

[12] Additionally there are indicative targets of 2 % e.g. by carbon dioxide capture and storage (CCS) and of 2 % by the purchase of credits trough the clean development mechanism (CDM).

The 2018 revision of the Renewable Energy Directive (EU) 2018/2001 (**RED II**) continues European activities. Under RED II, the overall EU target for renewable energy consumption (RES) will be increased to 32 % by 2030. For road and rail transport, the Member States have a target of 14 % by 2030. Within this target, there is a sub-target for advanced biofuels produced from raw materials such as algae, straw or bio-waste. By 2022, these fuels must have a minimum share of 0.2 %. By 2025 the quota will rise to 1 % and by 2030 to at least 3.5 %. Advanced biofuels will be double-counted towards both the 3.5 % and 14 % targets. In addition, biofuels produced from used cooking oil and animal fats will be limited to 1.7 % by 2030 and also doubled towards the 14 % target (PE/48/2018/REV/1 2018).

The Directive defines sustainability criteria for liquid biofuels used for transport and for solid and gaseous biomass fuels used for electricity, heating and cooling. Suppliers must meet the criteria to count biofuels and bioenergy towards the RES target (PE/48/2018/REV/1 2018).

With the **Energy Taxation Directive** (2003/96/EC) (European Council 2003), the EU restructured the Community framework for the taxation of energy products and electricity. The Directive sets minimum levels of taxation applicable to motor fuels (Table 5). These differ depending on the type of fuel. To promote biofuels, tax relief to the fraction produced from biomass is also permitted.

Germany

To achieve the goals set at EU level, the Federal Government in Germany has set greenhouse gas reduction quotas in the Federal Immission Control Act (Bundes-Immissionsschutzgesetz - BImSchG 1974). Companies in the petroleum industry are obliged to reduce their greenhouse gas emissions by 3.5 % in 2015 and 2016, by 4 % in 2017 to 2019, and by 6 % from 2020 onwards of the total amount of fossil fuel, fossil diesel and biofuels they sell. Currently in Germany, biogenic fuels account for only 4.8 % of total fuel consumption in the transport sector (based on the energy content) (BMVI 2016b). The majority of biofuels are sold via blending with fossil fuel. Thus, there are no additional requirements for infrastructure development.

The **37th and 38th BImSchV** (BMJV - Bundesministeriums der Justiz und für Verbraucherschutz 2017) as well as the UER Regulation adapted the regulations on the greenhouse gas quota to the EU legal requirements issued in 2015. In particular, these include the following changes:

- Electricity-based fuels produced with renewable electricity of non-biogenic origin can be offset against the greenhouse gas quota.
- Electric power used in electric road vehicles can be counted towards the greenhouse gas quota based on the average GHG emissions of the electricity mix in Germany (the Federal Environment Agency publishes the value for the electricity mix annually in the Federal Gazette).
- To avoid indirect land-use changes, an upper limit of 6.5 % is introduced for the share of conventional biofuels in road traffic (based on energy content). Conventional biofuels above the upper limit are treated like fossil fuels.
- For advanced fuels (i.e. including fuels from renewable electricity as well as fuels from certain waste and residual materials and lignocellulose) a sub-

target will be introduced, starting in 2020 and increasing to 0.5 % of the final energy demand of road transport from 2025.

- The base value used to determine the greenhouse gas reduction required was raised from 83.3 to 94.1 kg CO_2 equivalent per gigajoule in accordance with EU guidelines.
- The scope of the greenhouse gas quota will be extended to include other fossil fuels, in particular natural gas and liquefied petroleum gas. In addition, biogenic liquefied petroleum gas will in future be counted towards the quota.
- Upstream emission reductions will be offset against the greenhouse gas quota from 2020 up to a maximum of 1.2 percentage points.

The **taxation of fuels** is regulated in the Energy Tax Act (BMJV - Bundesministeriums der Justiz und für Verbraucherschutz). Since 2003, the energy tax on petrol has been 65.45 Ct/l and on diesel 47.04 Ct/l. Unlike in Sweden and Denmark, there is no indexed adjustment to the consumer price index or GDP. In addition to the lower taxation of diesel fuel compared to petrol and the tax relief on biofuels, the tax relief on natural gas is of particular relevance for the long-distance road haulage. Under the Energy Tax Act (EnergieStG), the taxation of natural gas (CNG and LNG) for motor vehicles is reduced from €31.80 per MWh to €13.90 per MWh by 2024 and then gradually increased until the end of 2026.

Sweden

In 2018, Sweden introduced an obligation system to reduce emissions, known as **Fuel Change.** It requires suppliers of petrol and diesel fuels to reduce carbon dioxide emissions from petrol and diesel fuels by increasing the proportion of blended biofuels. The aim is to phase out fossil fuels in transport. An indicative emission reduction target of 40 % was set for 2030. This corresponds to a share of biofuels of around 50 %(Naturvårdsverket 2019).

Since 2006, petrol stations with an annual turnover of petrol and diesel above a certain level must supply at least one type of renewable fuel, resulting in an increased availability of E85. In 2015, the requirements were loosened to an annual sales threshold of 1,500 m^3 of petrol or diesel (Naturvårdsverket 2019).

In 2017 biofuels account for 19.5 TWh or around 21 % of total fuel consumption in the transport sector in Sweden. Compared to 2016, there has been an increase of 2.3 TWh (Sherrard 2018).

The Swedish **energy taxation-system** consists of a carbon dioxide tax and the energy tax on fuels. The carbon dioxide tax is based on the fossil carbon content in the fuel and was introduced in 1991 to reduce CO_2-emissions in sectors outside the EU ETS. The tax has been raised in several steps since it was first implemented. Since 1991 the tax has increased from SEK 0.25/kg CO_2 to SEK 1.18/kg CO_2 in 2019. In addition, the tax level has been indexed annually to the consumer price index (CPI) since 1994 and to the gross domestic product (GDP) since 2017. With the introduction of the above mentioned obligation scheme, the tax exemption for low blended biofuels was replaced. Since 2018 biofuels covered by the scheme are subject to the same volumetric tax rate as fossil fuels. At the same time, CO_2 and energy tax rates was reduced. Highly blended biofuels are not covered by the scheme and are exempt from both carbon dioxide and energy taxes until the end of 2020 (Naturvårdsverket 2019).

Denmark

The Danish long term goal is independency from fossil fuels by 2050. To reach these goal renewable energy sources are promoted with economic measures, including use of energy and CO_2 taxes on fossil fuels and through the Public Service Obligation Schemes (PSO). The PSO is a supplement to the price of electricity paid by all consumers. It will be phased out during a period of 5 years (2017-2022), and the financing of support to renewables will gradually shift to the State Budget.

Since 1992, energy products have been taxed according to their contribution to CO_2 emissions. In 2010, a structural change in the CO_2 tax was implemented as an adjustment to the EU Emissions Trading Scheme. This included an increase in the tax rate to DKK 150 per tonnes of CO_2. From 1 January 2008, CO_2 taxes followed an annual adjustment of 1.8 % until 2015, similar to energy taxes. From 2016, the tax was adjusted using the consumer price index (EEA 2017a).

In the road freight transport sector, there is a possibility for VATable companies to obtain a refund of energy taxes on electricity used for charging electric trucks[13].

Comparison of energy taxes

Table 5 shows the national energy duties on diesel, petrol, natural gas and electricity (non-business use) on 1 January 2019 as well as the minimum excise duty rates established in the Energy Taxation Directive (European Council 2003).

	Petrol (Unleaded) €/1,000 l	Diesel €/1,000 l	Natural gas €/GJ	Electricity €/MWh
EU minimum	359	330	2.6	1.0
DE [1)]	655	470	3.9	20.5
DK [2)]	626	426	11.8	118.6
SE [3)]	649	457	6.1	33.6

1) petrol and diesel: sulphur content <=10 mg/kg
2) petrol 4.8 % bio Petrol, diesel: 6.8 % biodiesel; Companies subject to VAT may receive a refund of the energy tax paid on the charging of electric trucks (Skatteforvaltningen DK 2019).
3) petrol and diesel: Envirenmental class 1, conversion factor natural gas: 40 GJ/1.000 m^3
4) exchange rates: 10.33 SEK/€; 7.46 DKK/€

Table 5: Excise duties on fuels (1st January 2019) (EC 2019b)

For better comparability, the costs in the following figure are related to their energy content and are given in €/GJ. The following figure shows the national energy taxes on diesel, petrol, natural gas and electricity as well as the minimum excise duty rates established in the Energy Taxation Directive (European Council 2003).

[13] https://skat.dk/skat.aspx?oid=2061608&chk=216359

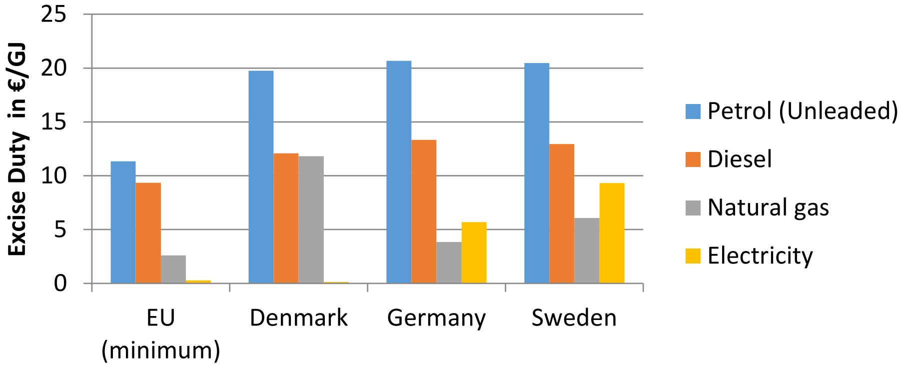

Figure 20: Excise duties on fuels Germany, Denmark, Sweden, EU (1st January 2019)[14] (EC 2019b)

While in all three countries and in the EU minimum tax rates there is a considerably lower tax on diesel fuel than on petrol, there is a relevant tax relief and thus promotion of natural gas as a fuel in Germany and Sweden, but not in Denmark.

However, energy prices differ between the three Member States not only because of differences in taxation. Especially with regard to the price of electricity, other levies and charges play an important role (see Figure 21).

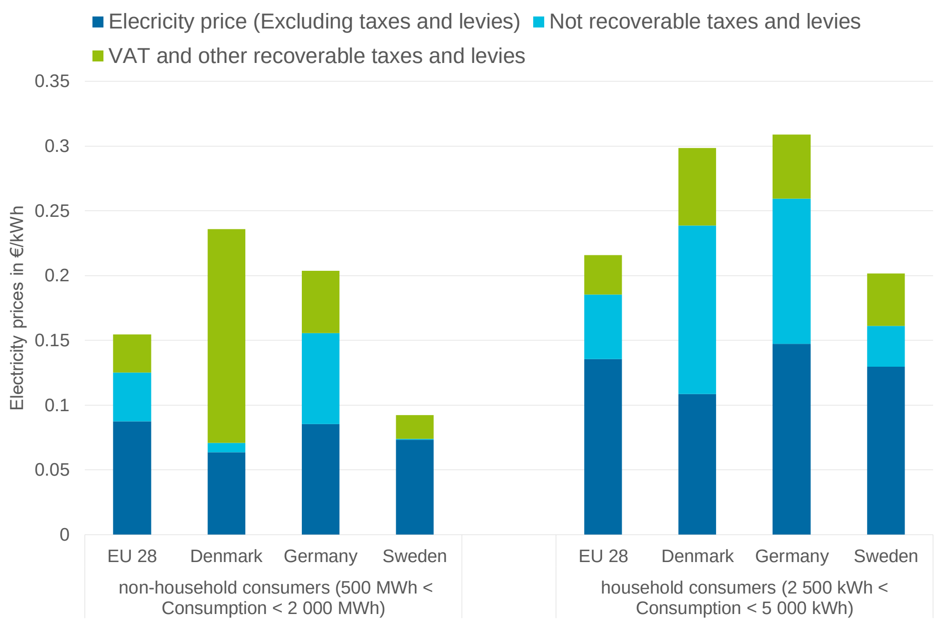

Figure 21: Avarage price of diesel electricity in first half of 2019 in the EU, Germany, Denmark and Sweden (own illustration based on Eurostat (2019a))

[14] For the conversion, the following assumptions were made: lower heating value petrol: 8.8 kWh/l, diesel 9.8 kWh/.

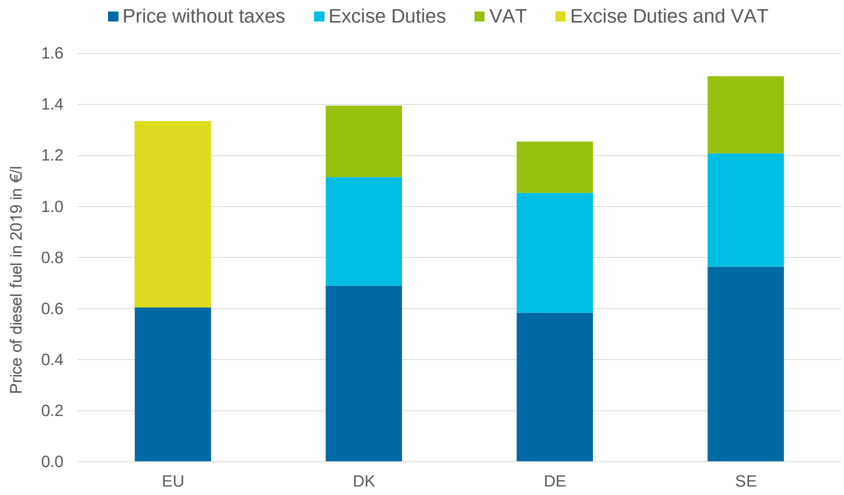

Figure 22: Avarage price of diesel fuel in 2019 in the EU, Germany, Denmark and Sweden (own calculation based on (EC 2020b)

While the average price of diesel fuel was the highest in Sweden, the price of electricity is particularly low in comparison. In Germany, the opposite is true, where electricity is relatively expensive and diesel fuel relatively cheap. However, only a small part of the differences in diesel fuel price are due to the structure of the levies. The high excise duties in Germany are more than compensated for by the low prices without taxes.

Infrastructure

European Union

The European Commission aims to facilitate the development of a single market for alternative fuels for transport in Europe. The **Directive on Alternative Fuels Infrastructure (AFID)** of the European Parliament and of the Council sets the appropriate infrastructure for the alternative fuels electricity, hydrogen and natural gas in all EU Member States (EC 2014). The individual Member States are obliged to implement this directive however with quite high level of freedom.

Member States must set targets for publicly accessible charging points and ensure that electric vehicles can circulate at least in urban and suburban agglomerations by 2020 and in the TEN-T core network by 2025. The directive does not contain specific requirements for charging stations for electric trucks or for an ERS infrastructure. There is currently no standard that meets the requirements for heavy trucks in long-distance traffic that require power levels of 1-3 MW or higher. However, standards such as HPCVC (High Power Commercial Vehicle Charging Standardization) are being developed and could be realized until 2022[15] (Daimler AG 2019).

In the field of compressed natural gas, Member States must ensure that a sufficient number of publicly accessible standardized service stations are built to allow natural gas vehicles to circulate in both urban and suburban areas by 2020 and in the TEN-T core network by 2025.

[15] personal message from Ricardo Michaelis, CharIN e.V. (22.08.2019)

More relevant for road freight transport could be the LNG infrastructure requirements. The Directive requires Member States to ensure a sufficient number of publicly accessible service stations along the existing TEN-T core network by 2025 unless the costs are disproportionate to the benefits, including environmental benefits (EC 2014).

As regards hydrogen, the Directive aims to ensure by 2025 a sufficient number of publicly accessible filling stations with common standards in the Member States that opt for the hydrogen infrastructure (Thiel 2017).

A review of the Directive with a view to its implementation will take place in 2020 and, where appropriate, a proposal for amendment will be prepared with regard to new common technical specifications for alternative fuel infrastructure.

Table 6 shows the status quo of infrastructure development for alternative fuels in the EU and in the Member States considered. It should be noted that only part of the available energy supply infrastructure is suitable for truck use. Despite an already strongly developed charging network, current estimates indicate that only about 10 charging stations in Europe are dedicated to truck use (ACEA 2020)

	EU	DE	DK	SE
CNG-filling stations	3,466	862	17	178
LNG-filling stations	146	21	0	6
H_2-filling stations	79	75	10	6

Table 6: Infrastructure of alternative fuels and vehicle fleet with corresponding drive system (NGVA 2020; H2 MOBILITY 2020)

Promotion of the interoperability: Standardization across Europe forms the basis for the **interoperability of transport systems**. In order to avoid technical island solutions and to support cross-border traffic, the goal for all modes of transport is to create compatible intersections. Activities include the following areas (EC 2014):

- Rail electrification and rail transport system technology
- Charging infrastructure for battery-electric vehicles (BEVs)
- Transport and distribution of LNG as a fuel

Under the EU **LNG Blue Corridor** project, 14 LNG filling stations and 100 LNG trucks have been funded in 11 EU countries to drive market development for LNG infrastructure and LNG commercial vehicle drives and to establish them on Europe's major transport routes (Google My Maps 2018). However, even after the pilot project there is a lack of a sufficient range of standard vehicles, which is why there was no increase in fuel demand, which was among other factors attributed to the low diesel price. The experience gained in the LNG Blue Corridor project thus shows that ensuring demand is crucial for the investment decision of potential filling station operators (BMVI 2016b).

The Regulation concerning a **European Rail Network** for Competitive Freight requests member state to establish international market-oriented Rail Freight Corridors in order to meet three challenges (EC 2020a):

- strengthening co-operation between Infrastructure Managers on key aspects such as allocation of path, deployment of interoperable systems and infrastructure development;
- striking the right balance between freight and passenger traffic along the Rail Freight Corridors, giving adequate capacity and priority for freight in line with market needs and ensuring that common punctuality targets for freight trains are met;
- promoting intermodality between rail and other transport modes by integrating terminals into the corridor management and development.

Germany

In the framework of the implementation of the AFI Directive, the Federal Government has developed **the National Strategic Framework for the Development of Infrastructure for Alternative Fuels** (BMVI 2016b).

The central objective of the Federal Government with regard to the **charging infrastructure** for electric vehicles is the establishment of a needs-based nationwide network of publicly accessible charging points. On the basis of various studies, the Federal Government assumes that 36,000 charging points for normal charging and 7,000 charging points for rapid charging will be required by 2020 (BMVI 2016a).

To implement directive 2014/94/EU[16] in Germany the specification of minimum requirements for the construction and operation of publicly accessible charging points for electric vehicles as well as clear and binding regulations on charging plug standards became effective in 2016 (BMWi 2016). Currently, there are approximately 13,500 public and semi-public charging points at approximately 6,700 charging stations in Germany (BDEW 2018). For 2017 to 2020, the federal government provides €300 million for the expansion of the charging infrastructure. The goal is to build at least 15.000 charging stations by 2020. Normal charging points with a charging power of up to 22 kW, fast charging points with more than 22 kW, as well as the required connection to the low- and medium-voltage network are subsidized. This should create 10.000 normal and 5.000 fast charging stations nationwide (BMWi 2016):

In autumn 2019, Germany has set itself the goal of further expanding the publicly accessible charging infrastructure and making a total of 1 million charging points available in Germany by 2030 (Klimakabinett 2019).

By summer 2020, a concept for the charging points for battery trucks is to be drawn up and, on this basis, corresponding funding programs for the development of charging infrastructure for trucks are to be developed. This should include international cooperation and standardisation of ultra-fast commercial vehicle charging infrastructure, cross-border commercial vehicle charging infrastructure (>150kW) and EU roaming requirements. At the same time, the planning of long-distance test routes for the practical testing of high-performance charging of trucks is to be started (BReg 2019).

[16] Directive on the deployment of alternative fuels infrastructure.

However, currently no publicly accessible charging infrastructure suitable for long haul trucks exists in Germany.

Germany already has a relatively dense network of **CNG filling stations**. The existing infrastructure in Germany today (862, of which 90 suitable for trucks) could probably carry more than five times as many CNG vehicles on the roads (Thiel 2017).

For the **LNG supply of heavy commercial vehicles**, a filling station backbone network along the Trans-European Transport Core Network (TEN-T) is to be initiated by 2025 in order to facilitate the pan-European traffic of LNG trucks. According to the National Strategy Framework, an appropriate basic network is already in place with a few (<10) locations along the TEN-T core network (BMVI 2016a). Currently, four publicly accessible LNG filling stations are in operation; the Federal Government assumes that a network of 20 filling stations will be available in the coming years (Deutscher Bundestag 2019).

For the **hydrogen supply** of fuel cell vehicles, the objective is to create a network of 100 filling stations by 2020 and around 400 filling stations by 2025 (BMVI 2016a).

In Germany, the National Innovation Program Hydrogen and Fuel Cell Technology (NIP) is a national innovation program to promote research and development activities in the field of fuel cell technology as well as the construction of a hydrogen filling station infrastructure (BMVI 2018). The federal government and the industry provided a total of €1.4 billion for technology promotion and demonstration projects till 2016. With the continuation of this innovation program (NIP2) a funding volume of € 250 million will be set up between 2016 and 2020. The funding program aims to make hydrogen and fuel cell technology competitive in the transport sector. Thereby research is consistently continued to further reduce costs and market activation is started with a strong application-oriented focus (BMVI 2016).

While for passenger cars as well as for light duty vehicles electric drives have already reached market maturity and are recording high growth rates, the electrification of heavy commercial vehicles is still in the research and development stage and is limited to a few prototypes and first small series. Commercial transport can also benefit from the nationwide network of publicly accessible charging infrastructure if for example the usage profiles enable recharging while the vehicle is stationary in urban areas.

In addition to the first applications of battery-operated electric trucks, **three field tests of an overhead line ERS** system for trucks will be conducted in Germany from 2019. This ERS system is based on continuous power transmission via overhead contact line. The field trials will take place on three motorway sections, each about 10 km long, in the federal states of Hesse, Schleswig-Holstein and Baden-Württemberg and are funded with €45,3 million.

Germany adopts a **master plan to strengthen rail freight traffic** (BMVI 2017)**.** The package of measures includes the Reduction of system and route prices, the upgrade of the rail network for the operation of 740 meter long freight trains (until the end of 2018 in test mode), the reduction of electricity tax and EEG surcharge for railway companies (from 2018), special permits for vehicles in the lead and lag to the rail as well as the simplification and acceleration of the planning of important freight transport projects.

Compared to other countries, however, the investment volume per inhabitant for the maintenance and expansion of rail infrastructure in Germany is rather low (see Figure 23).

In autumn 2019, however, Germany has set itself the goal of increasing the efficiency and attractiveness of the rail network by investing €86 billion by 2030. Specifically, the aim is to promote rail freight transport by eliminating bottlenecks, increasing capacity and strengthening combined transport (Klimakabinett 2019).

Sweden

In 2018 the Swedish Parliament implemented a **grant for investments in charging infrastructure** of SEK 50 million in 2019 and an SEK 100 million in the timeframe from 2020 to 2024. The grant is technology neutral and aims at building infrastructure for battery charging as well as other renewable fuels along the roads (Naturvårdsverket 2019).

In 2015, the Swedish Transport Administration approved **two ERS projects for trucks**, one with overhead lines and one with electric rail in the track. Both projects proceeded according to plan. In 2016, the world's first ERS for heavy-duty trucks on a public road with overhead contact lines was inaugurated and in operation until 2020. 2018 was the year in which the world's first ERS based on an electric rail (and the third ERS in total) was inaugurated on a public road. In 2019, two further ERS demonstration projects based on conductor rail and inductive transmission were approved. With the **National roadmap for electric road systems**, a strategy has been developed and published in Sweden as early as 2017 to promote ERS. The objectives are to continue scientific research and to support a wider market and competition between different transmission systems by bringing more systems up to TRL level 5-6. Furthermore, the roadmap includes the preparation and implementation of a major electric road system pilot with a length of at least 20-30 km with a high volume of traffic. The aim is to raise ERS technology to TRL 7 and thus demonstrating the entire electric road system with peripheral services, payment and access systems. Finally, the roadmap includes the development of a long term plan for the construction and development of electric road systems. (Trafikverket 2017)

In **Sweden** the Nordic Hydrogen Corridor project will establish 8 new hydrogen stations by 2020. The project is funded within the Connecting Europe Facility Fund. “In addition to the stations, there is co-financing for 100 hydrogen cars and a central electrolysis production plant” (FuelCellsWorks 2018; Scandinavian Hydrogen Highway Partnership 2018).

The Swedish government has adopted a **national infrastructure plan** for the period 2018-2029. The plan includes funding of SEK 193 billion for the operation and maintenance of state railways, major investments to develop the rail system and increase capacity, activities to promote the shift of freight transport from road to rail and shipping, and the strengthening of international rail freight (Ministry of Enterprise and Innovation Sweden 2018).

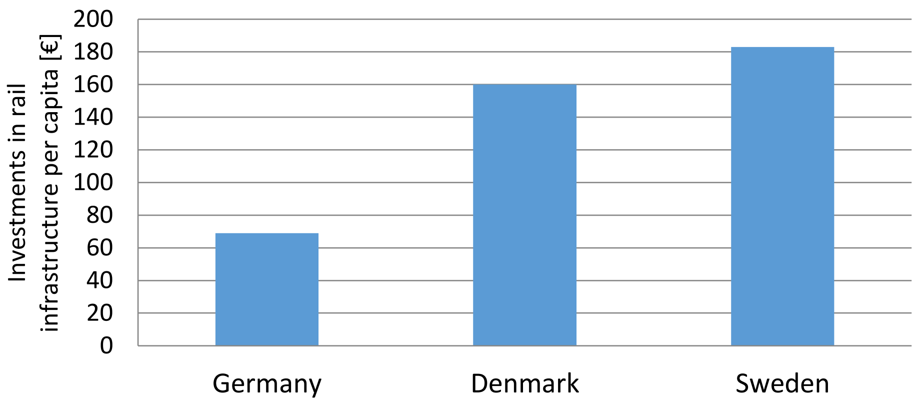

Figure 23: Investments in rail infrastructure per capita (2017) (Allianz pro Schiene 2019)

Denmark

In 2014 DKK 70 million has been allocated to transport infrastructure projects in the fields of electric vehicles, gas and hydrogen. Additionally, DKK 15 million for a pilot scheme for electric vehicles has been provided (EEA 2017b). There are currently 8 hydrogen filling stations in Denmark.

Denmark adopts a comprehensive investment program for **strengthening and expansion of the rail infrastructure** (Rasmussen 2014). An important aspect is the electrification program, which aims to install an overhead line for electric trains over a distance of approx. 550 km on four separate sections of the Danish railway network by 2021.

The Fehmarn Belt Fixed Link providing a 17.6 km-long immersed tunnel for combined rail and road traffic connecting Denmark and Germany, scheduled to open in 2028. The reduction of CO_2 emissions through the tunnel under the Fehmarn Belt was estimated at 200,000 t/a. The reduction results from a shift of goods from road to rail, a shortening of the route and the discontinuation of ferry operations (EEA 2017b).

Furthermore, the investment program includes the construction of a railway line that will connect to the future fixed link across the Fehmarn Belt. The project includes the construction of double lanes, electrification and signaling as well as the modernization of the tracks, allowing a maximum speed of 160 km/h to 200 km/h.

Overview and implications for freight transport

Both at EU level and at national level in the Member States Denmark, Sweden and Germany, various policy measures have been implemented to reduce greenhouse gas emissions in the transport sector. Other measures that do not focus primarily on reducing greenhouse gas emissions may additionally have an impact on the fleet and its use.

As far as road freight **vehicles** are involved, the main measure is the CO_2 regulation for heavy goods vehicles, which aims to reduce greenhouse gas emissions by 30 % by 2030. Manufacturers also receive an incentive to bring ZEV onto the market. The procedure developed in this context for modelling fuel consumption and CO_2 emissions can also provide the basis for the implementation of further future CO_2-based measures. At the national level, the financial support of trucks with alternative drive systems (DE: BEV, LNG) and the exemption from the motor vehicle tax should be mentioned. Due to the early market stage for trucks with alternative drive systems compared to passenger cars, the promotion of research a development is highly relevant.

Other measures and strategies, such as the bonus-malus system (SE), the reduction of registration tax (DK) and the phasing out of internal combustion engine vehicles (DK, SE), are still limited to passenger cars.

Especially relevant for the **operation** of vehicles in road freight transport is the user charges, which is levied as a vignette(road charges) (DK, SE) or as a performance-related road toll (DE). The current revision of the European legal bases will probably allow ZEV to be incentivised by a lower toll rate in the future. In addition, there are driving bans for diesel vehicles, which are increasingly being issued (DE). However, these mainly relate to inner-city, locally limited areas as well as to vehicles with older exhaust emission standards.

With regard to **fuels**, measures have been implemented that address an increasing share of biofuels and require a greater reduction in these fuels compared to fossil fuels. This is intended to reduce the CO_2 intensity of the fuels. In addition to biofuels, LNG as a fossil fuel also benefits from tax advantages compared to diesel fuel at national level (DE, SE). This is not the case in Denmark, but VAT-liable companies can obtain a tax refund for energy taxes on electricity used for charging electric trucks here. In the past, the focus in Sweden has been on the use of biofuels. This was encouraged, for example, by the fact that petrol stations with a certain fuel sales volume have to offer biofuels. In contrast to Germany, the tax system in Sweden and Denmark includes a CO_2 component on fuels. In view of current energy prices, Sweden, with high diesel and low electricity prices, provides a particularly favourable environment for ERS. Compared to Germany, with low diesel prices and high electricity prices, electric trucks in the use phase in Sweden will perform better in terms of costs.

With regard to alternative fuel **infrastructure**, the Directive on Alternative Fuels Infrastructure (AFID) (EC 2014) sets requirements for the stock of charging infrastructure and the number of hydrogen and natural gas filling stations for the TEN-T Core Network Corridors by 2025, but with a relatively high degree of freedom in implementation by Member States. In order to achieve these goals, the construction of the infrastructure for LNG and hydrogen will be financially supported (DK, DE). ERS are currently not part of AFID. However, Germany and Sweden are testing ERS in pilot projects. Various systems are being tested: overhead catenary (DE, SE), power supply rail (SE) and inductive power supply (SE).

Strengthening rail transport is a declared objective in all the countries considered. This will be implemented through infrastructure investments (DK, DE, SE), reduced track prices (DE) and an upgrade of the existing network to enable the use of longer trains (DE).

The analyses clearly show that, in contrast to passenger cars in the truck sector, significantly fewer measures to reduce greenhouse gas emissions have been implemented to date. There are probably two main reasons for this. First, the level of technological development and thus vehicle availability for trucks with alternative drive technologies is far behind that for passenger cars. This applies not only to vehicles but also to infrastructure. Secondly, the introduction of effective measures such as a bonus-malus system or toll differentiation has so far lacked the essential basis: a standardized determination of vehicle type-specific CO_2 emissions. This gap was recently closed with the development and introduction of VECTO within the framework of the European CO_2 Regulation. Vecto is the short name for the Vehicle Energy Consumption Calculation Tool, with which the CO_2 emissions of heavy duty vehicles are simulated on the basis of measurement results of individual components such as the engine map or rolling resistance and default values. The European CO_2 standard for HDV is an essential measure to reduce fuel consumption and thus greenhouse gas emissions. However, efficiency improvements can also lead to a reduction in mileage costs, which can lead to a rebound effect under unfavorable circumstances. This could lead to an increase in freight transport performance. In the future, however, this could be counteracted by a truck toll based on CO_2 emissions.

Various infrastructural measures such as the Fehmarnbelt Link are intended to strengthen rail traffic. Nevertheless, the projections for this corridor (see Jöhrens et al. (currently unpublished)) also show the continuing high relevance of road freight transport, which means that international transport strategies beyond this remain necessary.

The current policy measures and strategies tend to be technology-neutral and thus favour technologies that are very close to the market and promise a reduction in operating costs in the near future. In the case of LNG trucks, the latter is the case, for example, due to the reduced energy taxes (DE, SE) and the toll exemption (DE).

The incentives granted to ZEV as part of the CO_2 regulation represent an important measure to provide incentives for vehicle manufacturers to develop and offer these vehicles.

Vecto as part of the CO_2 regulation can be the basis for a differentiation of tolls and tax rates in the future. This is advantageous for all alternative drives, especially for drives where there are no direct emissions (BEV, ERS, FCEV). But even for LNG trucks, where the benefits in terms of reducing WTW emissions are at least questionable, incentives will be created if toll and tax rates are reduced.

A further tightening of the exhaust emission standards could make the purchase costs of diesel trucks more expensive and thus mean slight incentives for ZEV trucks.

The above overview makes it clear that strategies for climate protection in road transport, some of which differ greatly from country to country, have been pursued. While in Germany technology neutrality was held particularly high and many parallel infrastructures for alternative drive concepts were developed, Sweden in the past relied heavily on the use of biofuels. This is particularly problematic for cross-border freight transport, as the different concepts make the use of alternative drive systems for trucks more difficult or impossible.

Measures and strategies to promote ZEV generally favor the use of electric vehicles on ERS. However, this requires an infrastructure that does not currently exist and for the expansion of which there are no concrete targets. In contrast, the European requirements at least for the European corridors included targets for the expansion of alternative infrastructures for natural gas and hydrogen filling stations.

At the international level, the roll-out of ERS not only lacks concrete ERS expansion targets, but also requires a commitment with regard to the possible design of an ERS (overhead catenary system, power supply rail, inductive power supply). This makes the dissemination of ERS even more difficult. An international cooperation for the development of an ERS would require such a decision in order to facilitate the way for the standardization of both the technical design of the system and the operational aspects, e.g. with regard to billing.

Synthesis of framework conditions and their implications for the introduction of ERS

In the following, important framework conditions at EU and national level for Germany and Sweden are summarized and their possible effects on the introduction of ERS are discussed. The theses derived from the study indicate the opportunities and risks of introducing ERS at an international level and refer to a potential first ERS corridor between Sweden and Germany via Denmark.

Contribution of transport sector to binding GHG emission targets

So far, the transport sector has made hardly any contribution to achieving the GHG reduction targets. In goods transport, road transport is mainly responsible for this and the lack of alternative fuels and drives in combination with a persistent increase in transport volume is the main cause.

While average emissions in the EU and the countries considered have fallen by about 25 % since 1990, **GHG emissions from transport** - with the exception of Sweden - **have increased** further. **Road transport** accounts for **more than 90 % of transport-related emissions** and is still dominated by combustion engines and fossil fuels. The further increase in freight transport performance takes place primarily on the roads and the share of commercial vehicles (especially trucks) in transport-related emissions has continued to rise in recent decades.

Alternative fuels and drive systems for trucks have played a very **minor role** so far, also in comparison to passenger cars, but are of **great importance** in view of the pressure to act in order **to achieve the GHG reduction targets**.

Using ERS, particularly long-haul freight transport can be electrified with high resource and energy efficiency, effectively limiting the necessary capacity of traction batteries or hydrogen tanks. Thus ERS can contribute to both climate gas mitigation and resource efficiency, two main goals of European policy.

Limits to modal shift

Although rail infrastructure plays an important role in Europe and efforts are being strengthened to shift freight from road to rail, it is likely that the major proportion of freight will continue to be transported by road. Therefore, GHG reduction measures for road freight transport are also necessary.

Rail plays **an important role in freight transport**. In terms of transport performance, however, there is a high dominance of **road transport with a share of more than 70 %**, followed by rail transport by a large margin.

EU policy has so far **focused on a strong shift to rail** or intermodal rail transport, especially for routes over 300 km, and on market liberalisation that allows more competition among railway companies.

In recent decades, however, **rail freight transport has not been able to increase its market share** despite increasing transport volumes. Even if a stronger shift to rail should be achieved in the next few years, road freight transport remains of great importance in view of the initial situation and requires its own decarbonisation options.

ERS will only then threaten the modal share of rail transport if ERS transports are considerably cheaper than conventional road transports. However, road capacity is limited and overall transport performance needs to be limited too in order to reach climate targets in a sustainable way. Thus, transport policy will anyway have to ensure that all relevant external costs (also those only occurring in the long run) are included in operators costs for freight transport. If this is considered, it should not be expected that ERS rules out rail freight transport.

Introduction of alternative propulsion systems for long-haul trucks

The introduction of alternative powertrains for trucks is increasingly favoured by changing framework conditions at EU and national level. Development is still lagging behind the passenger car sector.

The **market maturity of alternative drive technologies for long-distance trucks is lagging behind** developments in passenger cars. So far, **no clear technology favourite** has emerged, even though the propulsion alternatives show relevant differences in technological readiness. The promotion of alternatives has so far focused strongly on passenger cars. In the recent past, however, changes have also been observed in the truck sector. At EU level, the **CO_2 standards for commercial vehicles set incentives** for manufacturers to offer alternative drive systems. At the national level, **procurement and operation is promoted** through tax breaks, purchase incentives and temporary toll exemptions. A **technology definition has not yet taken place** and transitional technologies (e.g. LNG) have also been taken into account in the promotion to date.

The economic as well as CO_2 reduction potential of ERS depend strongly on national conditions, most notable electricity and fuel prices and taxation as well as the electricity supply mix. In addition, traffic volume differs considerably, leading to different payback times for infrastructure investments if a user-based financing is desired. Thus, we can expect that ERS introduction in Europe will happen in different speeds depending on the region. However, a coordinated roll-out of ERS in Europe would most likely improve technical feasibility and enhance financial benefits.

Strategy for the development of an infrastructure for alternative fuels

So far, there is no clear strategy for the development of an infrastructure for alternative fuels for trucks at EU and national level, despite certain requirements introduced by the alternative fuel infrastructure (AFI) directive.

The **availability of an energy supply infrastructure** is a **key success criterion** for alternative drive systems. The requirements at EU level and the implementation at national level have **so far focused on the passenger car sector** and pursue various alternative fuels (including electricity, hydrogen, LNG) in parallel, although to varying extents. ERS is not yet part of these expansion plans at EU level. At the same time, the **national plans** for the expansion of a supply infrastructure for trucks are **not yet fully developed** and **implementation is limited to pilot projects**.

Against this background, the **chicken or egg dilemma** also **arises in road freight transport**, i.e. the interaction between infrastructure availability and vehicle supply and demand. This problem in the truck sector **is further accentuated by the unresolved choice of drive technology**.

In terms of ERS, a predictable infrastructure installation (public commitment) at least on certain regional markets is a sine qua non for the market introduction of ERS trucks.

Introduction of alternative drives at hauliers

In view of the great importance of small and medium-sized enterprises in the logistics sector, government support measures are likely to be necessary in the introductory phase in order to minimize the individual economic risk.

The logistics industry in Europe and in the countries under review shows a particularly high turnover in road freight transport. The **individual companies**, on the other hand, are **characterized on average by a very small size** (5 employees per company). The introduction of investment-intensive new drive technologies is therefore associated with **high economic risks** under the current framework conditions. **Incentives that ensure economic operation of the vehicles and provide planning security** in procurement are therefore likely to be **important success criteria.**

Early transnational cooperation

ERS are a network-bound drive technology. First, that means that system introduction will benefit a great deal from standardization. Second, the value of the system will scale with its extension in a non-linear way. Since a significant part of freight transportation is international and the ERS technology is associated with high up-front investments, its deployment will benefit from cross-country cooperation.

With regard to the examined German-Swedish corridor, the geographical area considered (DE, SE, DK) shows some **favourable factors:**

- the **size of the logistics market** of the three affected countries, which together represent a critical mass and a relevant market within Europe,
- the **high quality of transport infrastructure**, which may encourage the introduction of innovation,
- the **low cost of capital** compared to the EU, which favours the procurement of more investment-intensive technologies.

While certain international agreements on technology standards, interoperability and system design promise a high benefit for all sides, the actual implementation of ERS may happen in different speeds and according to traffic flows and local peculiarities, such as air quality or electricity availability.

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