Driving Polish future

Challenges and opportunities for the electrification of heavy road transport in Poland

Analysis, conclusions, recommendations

Electric Vehicles Promotion Foundation

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Electric Vehicles Promotion Foundation

The Electric Vehicles Promotion Foundation is a key player and a strong advocate of e-mobility in Poland providing education, a best practice sharing platform and advice to all interested parties.

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Executive Summary

The purpose of this report is to present available tools to support the development of the zero-emission truck market, taking into account the specificity of the sector in Poland. The transport sector in the European Union (EU) is facing major changes related to climate policy. This means the transformation of the transport system - including truck transport - towards zero-emission solutions, which also makes more and more economic sense. These changes are inevitable, but their effective support can make the transformation faster and would give transport companies that will efficiently carry it out a competitive advantage. This is particularly important for the Polish transport sector, as it is an important part of our economy. Support for its development is needed so that it can maintain its competitiveness and strong position on EU markets. **Delaying electrification could result in a loss of position in key markets to competitors and a crisis in the sector.**

Effective support to the transformation of the truck transport industry is important for Polish economy and labor market. Truck transport is a significant emitter of greenhouse gases. However, unlike passenger transport, before the COVID-19 pandemic, the level of emissions of the industry was growing even in the most developed countries. In order to achieve the goals of the Paris Agreement, reducing emissions from this sector is crucial. Actions in this direction are taken by not only the European Union through further legislative initiatives, but also other economies, e.g. the United States under the Inflation Reduction Act. The electrification of the industry also makes more and more economic sense: technological progress has resulted in availability of zero-emission trucks capable to replace combustion vehicles on most routes, and the total cost of ownership zero-emission trucks over the next 10 years should become significantly lower than for diesel trucks. Transformation of this industry is important for Poland, because transport and storage are one of the main sectors of the Polish economy. Road freight transport is responsible for the largest parts of the value generated and the employment. At the same time, it seems that this should not change in the coming decades, despite competition from i.a. railways and intermodal transport.

Although uncertainty about the exact direction of market development remains high, we can identify main technological trends determining future changes. In particular, primarily because of the needs of the passenger vehicle market, electric batteries technology is rapidly developing, resulting in a gradual decrease of difference of the prices between battery trucks and internal combustion ones. Therefore, it seems that battery powertrain should be the basis for the development of the zero-emission vehicle market in the coming years. In the longer term hydrogen fuel cell vehicles are a technology potentially complementing the zero-emission truck market in niches where battery technology cannot be used. Currently, the main barrier to market development is no longer the availability of technologies and vehicles but increasingly the lack of infrastructure. The issue of the development of public charging infrastructure is to be addressed by the EU AFIR regulation, imposing significant obligations on Poland to expand the battery charging network and hydrogen refueling stations on roads within the TEN-T network but according to vehicle manufacturers, it is insufficient. **Poland should consider the possibility of taking more ambitious actions aimed at the development of infrastructure.** At the same time, however, due to the structure of the energy mix based on coal, electric vehicles in Poland will not be realistically zero-emission in the coming years unless HDVs are charged from dedicated RES installations. **To truly ensure zero-emission transport, it is necessary to increase investments in the production of electricity from renewable or non-emission sources in Poland.** However, an increase in the share of zero-emission vehicles would significantly reduce other harmful emissions of i.a. nitrogen oxides.

Transformation of Polish road transport industry is important not only from the perspective of Poland, but also of the whole European Union. Polish carriers have specialized in international transport. This is mainly due to the handling of Poland's international trade, but they also have a significant share in other main routes within the European Union, e.g. they are responsible for over 1/3 of ton-kilometers in transport between France and Germany. This translates into high demand for their services by foreign entities, which results in their leading role in the cabotage market in the EU. At the same time, however, more than 30% of the mileage and almost 80% of the tonnage handled by the industry falls on intra-Polish transport. This means that although foreign trends should support the electrification of our industry, Poland itself should care about supporting the process. At the same time, from the perspective of other EU countries, support for Polish road transport in this process would be beneficial for their climate goals. However, this also means that the delay in the implementation of the electrification of the industry by Poland may result in the loss of position on key markets to competition and the crisis of the industry.

Although the industry currently has high investment needs, investment level is limited i.a. because of the market structure. Road transport is based on micro-enterprises and is highly labor-intensive. This results in a relatively low level of investment compared to the value of the industry. At the same time the investment needs of the market are high. Polish carriers on average use significantly older vehicles. Moreover, the pace of fleet replacement for new vehicles after the COVID-19 pandemic is relatively slow compared to the EU. This is partly offset by the import of used vehicles from abroad. Poland is characterized by a high potential for electrification of the fleet. Although the market is dominated by the heaviest vehicles (over 301 of permissible weight), vehicles of 3.5-10 t still play an important role in Poland. This should encourage the electrification of transport, as due to shorter routes and the lack of need to charge along the routes covered daily, they are the easiest to replace technologically. In addition, the high proportion of older vehicles is not necessarily a negative feature: they are easier for retrofitting, i.e. the conversion of diesel vehicles into battery vehicles. At the same time, despite a series of strong negative shocks on the market, the forecasts for the development of the road freight transport market are positive for the coming years. However, inflation and potential costs of market consolidation in relatively high interest rates environment may result in companies lacking the resources to purchase zero-emission vehicles in the coming years.

The EU regulatory environment provides for a number of solutions supporting the decarbonisation of transport. Its impact on the development of zero-emission truck transport can be seen in two dimensions. Firstly, the energy and climate objectives applicable to Member States are an incentive for them to introduce national instruments aimed at reducing greenhouse gas emissions and increasing the share of RES in the energy mix. This is achieved i.a. through the objectives of reduction of CO2 emissions for non-ETS sectors, sectoral objectives for transport, and air quality standards. Secondly, EU regulations directly improve the competitiveness of zero-emission drives compared to combustion engines. This is achieved both through an increase in the costs of operating internal combustion vehicles, e.g. the introduction of EU Emissions Trading System (CO2) for the road transport sector and by improving the competitiveness of zero-emission vehicles, e.g. the requirement to develop charging infrastructure or the mandatory share of zero-emission vehicles in public procurement; or by acting simultaneously in both directions, e.g. Eurovignette differentiating infrastructure charges depending on emissivity. Polish strategic documents currently lack provisions directly related to the development of zero-emission trucks. Nevertheless, stricter emission standards and support for the development of zero-emission trucks are part of a broader framework of national strategic documents such as the Strategy for Responsible Development until 2020 (with a perspective until 2030) or the Electromobility Development Plan in Poland.

The EU's decarbonisation policy should be complemented by a instruments implemented at national level. Although the development of zero-emission heavy transport is a relatively new regulatory area, several European countries have already implemented policies in this area. Among the European countries with highest number of registered electric trucks by February 2023, all have implemented comprehensive support policies using instruments from at least two of the five categories: subsidies for the purchase of a vehicle, tax reductions, **subsidies for investments in charging stations, infrastructure development strategies, facilitation of use.** In addition, the support instrument may also be **green public procurement and the introduction of restrictions on movement in urban areas and/or clean transport zones/low emission zones. Experience of other countries shows that comprehensive development and support policy of zero-emission transport can be effective.**

Considering the above factors instruments that can be used to support the development of the zero-emission vehicle market can be identified. The tool with the greatest potential impact on the competitiveness of zero-emission vehicles is **direct financing of their purchase**, but the cost of this instrument is high and its use should be limited to the first period of transition of the sector. In particular, this applies to medium-sized electric vehicles, as their cost is already approaching the cost of using internal combustion vehicles. Therefore, other tools of public support should also be used, and their selection should take into account a number of factors i.a. existing market barriers, the impact of the tool on the total cost of ownership of a vehicle, the impact on **public** finances, as well as the **diversity of needs of specific recipients, in particular the needs of micro-entrepreneurs.** Instruments aimed at taxing CO2 emissions will be of great importance, i.e. differentiation of taxes and charges related to the use of a vehicle according to CO2 emissions. It will be extremely important to take into account the needs of micro-enterprises and prepare dedicated solutions for them, as they represent the majority of market players and have limited financial resources, low availability of tools from financial markets and are vulnerable to market shocks. The availability of infrastructure is also important. It can be addressed in a short time by **subsidies for the purchase of private charging infrastructure, but in the longer term development of a public vehicle charging and hydrogen refueling network** is needed.

Financing the green transport transition can benefit from many sources. In addition to state founds, **financial instruments for implementation of EU Green Deal strategy** should be used, especially as Poland has strong negotiating arguments in this regard. It is also worth using trends in the financial sector - **redirection of financing towards sustainable and green investments, in line with the EU Taxonomy.**

Due to the dynamic changes on the market, constant monitoring of the effectiveness of instruments is necessary. It is also recommended to repeat the TCO analysis and review instruments and program parameters every 2-3 years.

The following report is divided into five chapters.

1. **The first Chapter (Context)** presents the environmental, economic and technological context of changes in the truck transport market. It shows why the promotion of zero-emission road transport is necessary to achieve climate goals, why changes in the transport sector are particularly important from the perspective of the Polish economy and what technologies play a key role in the transformation of the market. This chapter also points to the existence of barriers limiting the pace of achieving zero emissions in truck transport, in particular related to the energy sector.

2. **Chapter Two (Analysis of the market and fleet structures of heavy goods vehicles)** contains an analysis of the truck transport market in the European Union and Poland: the role it plays in the transport of goods, the structure of transport companies, the structure of demand for truck transport services with particular emphasis on demand in international transport and the structure of the truck fleet. The analysis is supplemented by an indication of the main barriers to market development and prospects for its development in the coming years.

3. **Chapter Three (Regulatory environment and support instruments)** presents in detail the legal aspects of the promotion of zero-emission truck transport. It reviews the regulatory environment at the level of the European Union and the support instruments used by countries within the European Economic Area, with particular emphasis on Germany, France, and the Netherlands, as the countries that support development of zero-emission trucks to the greatest extent.

4. **In Chapter Four (Analysis of the Total Cost of Ownership (TCO) by Powertrain Technology)** a calculation of the total cost of ownership of the truck (TCO) depending on the drive technology is presented. In particular, the elements affecting TCO for battery and hydrogen vehicles compared to diesel vehicles today and in the perspective of 2030 and 2040 for medium and heavy-duty vehicles are analyzed.

5. **Chapter Five (Recommendations)**, based on the analyses presented in the previous chapters, presents recommended support tools. It indicates the context of the selection of instruments, presents a set of available market support tools, assesses their usefulness, and informs about the impact of selected instruments on TCO. The chapter also contains information on the possibilities of financing the transformation.

Chapter 1. The importance of decarbonizing the road transport

Need for zero-emission transport

There are both environmental and economic arguments in favor of developing zero-emission road freight transport. Heavy-duty vehicles are a major source of greenhouse gas emissions to the atmosphere in the road transport sector. After the adoption of the Paris Agreement[1], among other things, governments started to introduce changes aimed at cutting emissions, also from the transport industry. However, **without changes in powertrain technologies, achieving climate neutrality will be impossible. The development of new zero-emission technologies leads to improved competitiveness of zero-emission vehicles in relation to traditional internal combustion engines.** This issue is particularly important for Poland. Transport and storage are an important sector of the Polish economy. Its segment of road freight transport has a significant share in generating value and is an important employer. **In view of these processes, in the next few years the gradual replacement of the fleet with zero-emission vehicles should be an important part of building the competitive position of the Polish economy and Polish transport companies.**

Despite strong arguments for the development of zero-emission transport, Polish carriers will need support in replacing their fleets. The promotion of zero-carbon transportation entails significant market change. Concurrently, **the relevant technologies are at an early stage of development,** with causes **uncertainty as to the optimal course of action.** This is particularly true of hydrogen fuel cell technology (FCEV), which potentially has many advantages, but currently faces multiple challenges in the area of hydrogen production, transport and storage technologies. A solution that today is far **more mature in terms of its market adoption is the battery technology (BEV)**, which enjoys rapid market growth driven by the use of the technology in passenger cars and light commercial vehicles. However, it has its own **specific challenges, including charging times and the lack of dedicated, publicly accessible charging infrastructure for heavy-duty vehicles.** Although an important part of regional or national transport may be based on private charging infrastructure at the place where vehicles park or are loaded/unloaded, the development of publicly available, dedicated charging infrastructure for heavy-duty vehicles along transportation routes is a prerequisite for the electrification of all market segments. This aspect is addressed by measures provided for in the draft Regulation of the European Parliament and of the Council on the alternative fuels infrastructure (AFIR)[2], but vehicle manufacturers alarm that the targets proposed in the planned legislation may prove insufficient. **In the case of Poland, there are additional challenges related to the need to decarbonize the energy sector.**

Climate objectives versus truck transport

Road freight transport carried out by medium- and heavy-duty vehicles was a significant source of emissions in the road transport sector in Poland. In 2019, trucks with a gross vehicle weight (GVW) of more than 3.5 t:

- accounted for <6% of the vehicle fleet in the country,
- were responsible for about 30% of road fuel consumption,
- accounted for 12.5% of total oil demand (passenger cars - 22%);
- were responsible for 22% of CO2 emissions from transport;
- were responsible for some 33% of NOx emissions, approximately 50% of PM2.5 emissions and 7% of SO2 emissions in transportation.

At the same time, before the COVID-19 pandemic diesel oil consumption for heavy-duty vehicles was on a sharp growth path, in contrast, for example, to passenger cars, for which diesel oil consumption stabilized and began to decline in an increasing number of developed countries[3]. In the European Union, the role of heavy-duty transport as a disproportionate emitter is even more pronounced. Although trucks make up about 2% of the total fleet, in 2020 they accounted for 28% of CO2 emissions in transportation and 42% of diesel oil consumption, which represented about 30% of total consumption of energy from oil and petroleum products[4]. At the same time, with no

[1] United Nations. Paris Agreement 2015.
[2] European Commission. Proposal for a Regulation of the European Parliament and of the Council on the deployment of alternative fuels infrastructure, and repealing Directive 2014/94/EU of the European Parliament and of the Council COM(2021) 559 final.
[3] International Energy Agency. Energy Technology Perspectives 2020 2021.
[4] According to Eurostat, diesel oil accounted for about 70% of energy consumption from oil and petroleum products in the EU.

significant changes, by 2030 the increase in the sector's emissions will be equal to the decline in emissions generated by passenger cars and light commercial vehicles[5].

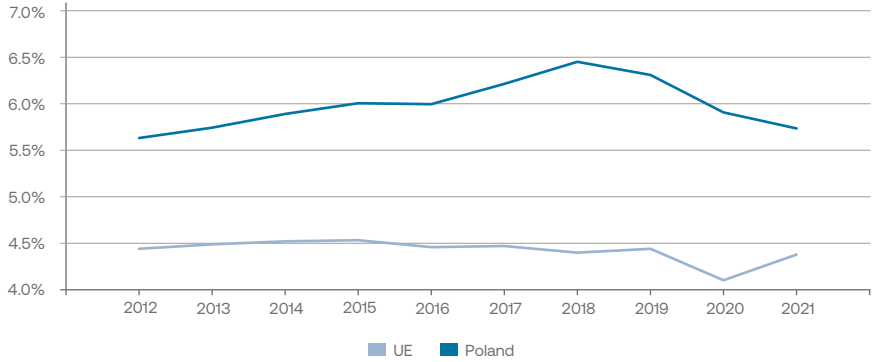
Reducing emissions from transport, particularly greenhouse gas emissions, is an important factor in the context of efforts to curb climate change. At the global level, emission reduction targets are set by the Paris Agreement[6]. As part of the commitment, the signatories agreed to limit the increase in global temperature so that it would be significantly below 2°C compared to pre-industrial levels, with a target of no more than 1.5°C. One of the measures to be taken by countries to achieve these objectives is the adoption of emission reduction targets. By 2018, this had been done by Canada, China, Japan and the United States[7]. To achieve the goal of the Agreement, as part of its Green Deal[8] and the Fit for 55 package[9] the European Union has adopted a target to reduce emissions by 55% from 1990 levels by 2030 and to achieve climate neutrality by 2050. Common EU standards for heavy-duty vehicles to reduce CO2 emissions were first introduced in 2019.[10]

Climate policies are a catalyst for changes in the sector, but they alone are not enough to achieve the desired emission reductions. To determine the set of required changes, the International Energy Agency (IEA) has developed the Sustainable Development Scenario: a development path consistent with the UN goals to the achievement of the Paris Agreement targets and global net-zero emissions from 2070, taking into account the diverse needs and capabilities of different sectors. The main conclusion is that the solutions adopted so far are insufficient to achieve the adopted emission reduction targets[11]. Enhanced technological and operational efficiency should help the sector reduce its energy demand, but in order to achieve emissions reductions in the heavy-duty transport industry as envisaged by the Sustainable Development Scenario changes in engine and fuel technology are also needed.

Role of transport in the economy

Transport is one of the main sectors of the Polish economy. In 2021, transport and storage accounted for 5.7% of Poland's GDP[12]. However, its role is much more important: it is one of the critical cost items in industries that produce 50% of Poland's GDP[13], in particular trade, both wholesale and retail trade, for which in 2015 it was the second largest cost of operations after salaries and wages (10.6% and 6.1%, respectively)[14]. Transport plays a greater role in the Polish economy than in the EU economy. In the EU, the share of transport in GDP has remained stable at 4.4-4.5%, except in 2020, when it dropped to 4.1% due to the COVID-19 pandemic. In Poland, despite the rebound in demand in the EU, in 2021 the value of the transport sector did not return to its pre-pandemic levels. In particular, with the recovery seen in other sectors, this sluggish growth caused its share in GDP to further decline. At the same time, this marked a reversal of the development trend: this was the third consecutive year when the sector's share in GDP shrank, whereas in the past decade its contribution to the economy had grown significantly to 6.4% of GDP in 2018 (Fig. 1).

Fig. 1. Transport and storage in GDP.



Source: In-house analysis based on Eurostat data[15].

[5] Transport & Environment. Addressing the heavy-duty climate problem. Why all new freight trucks and buses need to be zero-emission by 2035 2022.
[6] United Nations. Paris Agreement 2015.
[7] Climate Action Tracker. The highway to Paris: Safeguarding the climate by decarbonising freight transport 2018.
[8] European Commission Communication. The European Green Deal, COM(2019) 640 final 2019.
[9] European Commission Communication. "Fit for 55": delivering the EU's 2030 climate target on the way to climate neutrality COM(2021) 550 final.
[10] Regulation (EU) 2019/1242 of the European Parliament and of the Council of 20 June 2019 setting CO2 emission performance standards for new heavy-duty vehicles and amending Regulations (EC) No 595/2009 and (EU) 2018/956 of the European Parliament and of the Council and Council Directive 96/53/EC.
[11] International Energy Agency. Energy Technology Perspectives 2020 2021.
[12] Information of Statistics Poland on the revised estimate of gross domestic product for 2021, 2022.
[13] TLP Transport and Logistics Poland. Road transport in Poland 2021+2022.
[14] Statistics Poland. Input-output balance at current base prices in 2015, 2019.
[15] Eurostat Data Browser. All data https://ec.europa.eu/eurostat/databrowser/explore/all/all_themes?lang=en&display=list&sort=category (accessed on: 6 April 2023).

Climate policies as a source of competitive edge

With the growing importance of the climate agenda, environmental issues are becoming an increasingly important factor in companies' decisions on the location of their investment projects. In particular, more than 4,600 companies committed to reducing emissions under the Science Based Targets initiative, with more than half of them adopting specific targets they intend to meet and the remaining group of more than 1,300 enterprises officially seeking to achieve climate neutrality in the long term[16]. Although the methodology mentioned focuses on Scope 1 (directly generated in a company's own operations) and Scope 2 (generated in the production of energy used directly by the company) emissions, companies are paying increasing attention to Scope 3 (emissions in the supply chain).

The companies' concern to reduce their own emissions means that factors affecting the economy's carbon footprint are becoming an important part of its competitiveness. This is indicated by a change in the economic policy philosophy of the major players. This is particularly true in the European Union, but can also be seen in the main documents setting out China's economic strategy (the new five-year plan), where a detailed emissions intensity reduction target is set for the economy as opposed to, for example, an economic growth rate target[17], or in the USA, where the Inflation Reduction Act offers a wide range of instruments to support the development of technologies designed to cut emissions[18].

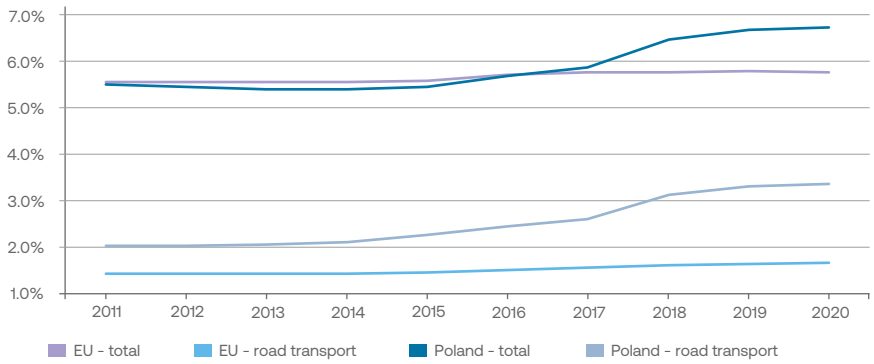
In the European Union, the impact of emission performance on competition between countries to attract investments from large companies is expected to further increase in connection with the obligation to report their emissions as part of corporate sustainability reporting[19]. The companies subject to this obligation are required to report emissions in all three scopes. Therefore, from the companies' perspective, the availability of RES is crucial due to its impact on both Scope 2 and Scope 3.

This means that zero-emission heavy-duty transport could be an important element of competitive advantage in the next decade, as it is included in Scope 3 emissions of the majority of businesses. However, in order to achieve this, it must be powered by zero-carbon energy, e.g. renewable or nuclear.

The transport and storage sector, particularly the road freight transport industry, is a major employer in Poland. In 2020, there were 946,000 people employed in transport and storage sector in Poland. Despite the pandemic, employment in the sector continued its upward trend, resulting in a raise in its share of total employment from 4.7% in 2011 to 5.8%. More than 90% of the growth was due to the development of the road freight transport industry, which employed 486,000 people, i.e. more than half of the sector's workforce, which accounted for 3.0% of the total employment in the economy. The special role of this industry in Poland's economy results in its relatively larger role (as well as that of the transport and storage sector as a whole) in employment in Poland than in the EU. In 2020, there were 10,271 people employed in the transport and storage sector in the EU, which represented some 5.0% of the workforce. As a result of the pandemic, this value fell for the first time since 2012. An important part of the sector's growth is attributable to the development of the road freight transport industry: about 50-60%, which at the same time showed particular stability during the pandemic. Despite this, the industry's share of the EU's employment is nearly twice as low as in Poland (Fig. 2).

[16] Science Based Targets. Companies taking action https://sciencebasedtargets.org/companies-taking-action#dashboard (accessed on: 4 April 2023).
[17] United Nations Development Programme. China's 14th five-year plan Spotlighting climate and environment Issue Brief July 2021.
[18] United States Environmental Protection Agency. The Inflation Reduction Act https://www.epa.gov/green-power-markets/inflation-reduction-act (accessed on: 4 April 2023).
[19] Directive (EU) 2022/2464 of the European Parliament and of the Council of 14 December 2022 amending Regulation (EU) No 537/2014, Directive 2004/109/EC, Directive 2006/43/EC and Directive 2013/34/EU, as regards corporate sustainability reporting.

Fig. 2. Share of transport in total employment in the EU and Poland.



Source: In-house analysis based on Eurostat data[20].

Despite both the European Union's and Poland's ambition to shift some of the demand for road transport to other modes of transport through intermodal connections, its role should remain stable, and the size of the market should grow at a stable rate in the long term. Current transport development strategies for both the EU and Poland point to the need to reduce the share of road transport in total transport. In particular, the European Green Deal points to the need to switch a significant share of intra-Union road transport to rail and inland waterway transport [21]. This could be achieved primarily through the development of intermodal transport, both in inter- and intra-urban last-mile transport. In the case of transport between cities, this would require, in particular, the development of intermodal infrastructure, the creation of information systems that would allow coordination between different modes of transport, as well as an appropriate regulatory framework to reduce barriers to its development. In Poland, a greater role in freight transport would be assumed primarily by railroads through the development of transshipment points, especially in major hubs[22]. Despite these measures, it currently seems that the road freight transport market will continue to grow. In accordance with the EU Reference Scenario 2020,[23] it should grow by more than 50% by 2050 relative to 2015 across the EU, which is slower than rail (about 83%) but still faster than inland waterway transport.

This would shrink the share of road transport in total freight transport by only about 1.5pp. For Poland, the road transport market is expected to grow even more (over 100%), which should allow it to maintain, or even slightly increase, its share in total freight transport (Table 1).

[20] Eurostat Data Browser. All data https://ec.europa.eu/eurostat/databrowser/explore/all/all_themes?lang=en&display=list&sort=category (accessed on: 6 April 2023).
[21] European Commission Communication. The European Green Deal, COM(2019) 640 final 2019.
[22] Ministry of Infrastructure. Sustainable Transport Development Strategy until 2030, 2019.
[23] European Commission, Directorate-General for Climate Action, Directorate-General for Energy, Directorate-General for Mobility and Transport, De Vita, A., Capros, P., Paroussos, L., et al., EU reference scenario 2020: energy, transport and GHG emissions: trends to 2050, Publications Office, 2021, https://data.europa.eu/doi/10.2833/35750.

Table 1: Projection of demand for intra-EU transport, EU and Poland.

		2005	2010	2015	2020	2025	2030	2035	2040	2045	2050	Share of freight transport in 2015	Share of freight transport in 2050
		Gtkm										%	%
European Union	Road	1677	1645	1628	1721	1955	2135	2235	2340	2407	2473	70.4	68.8
	Rail	395	375	396	382	473	549	604	655	690	726	17.1	20.2
	Inland waterways and national maritime	291	301	290	274	324	344	361	374	385	396	12.5	11.0
Poland	Road	90	121	152	179	215	247	270	292	300	308	74.9	75.5
	Rail	50	49	51	52	65	77	85	92	96	99	24.9	24.3
	Inland waterways and national maritime	0	0	0	0	0	1	1	1	1	1	0.1	0.2

Source: EU Reference Scenario 2020.

Experience with LNG/CNG

One potential constraint to the development of the zero-emission vehicle market in the coming years may be the lower willingness of companies, particularly micro- and small enterprises, to make investments in new types of vehicles regardless of environmental and economic arguments based on TCO. It should be noted, though, that such risk aversion has a market rationale.

In connection with the drive to reduce emissions in the transport sector, alternatives are being developed, both for traditional vehicles running on petrol or diesel fuel and zero-emission vehicles. The main technologies of this type are natural gas vehicles using LNG or CNG. The main arguments supporting the development of this segment in freight transport were the benefits related to the inclusion of natural gas in the list of alternative fuels, resulting in lower road tolls in some countries and lower fuel costs, among other things. As a result, the total cost of ownership (TCO) of the vehicle, despite higher initial capital expenditure, was lower for the natural gas vehicle.

However, in 2022 TTF gas prices soared (even more than 15-fold compared to the beginning of 2021), significantly outpacing the rise in oil prices, causing the economic balance to change and the operation of gas vehicles becoming commercially unviable. By comparison, diesel prices roughly doubled over that period.

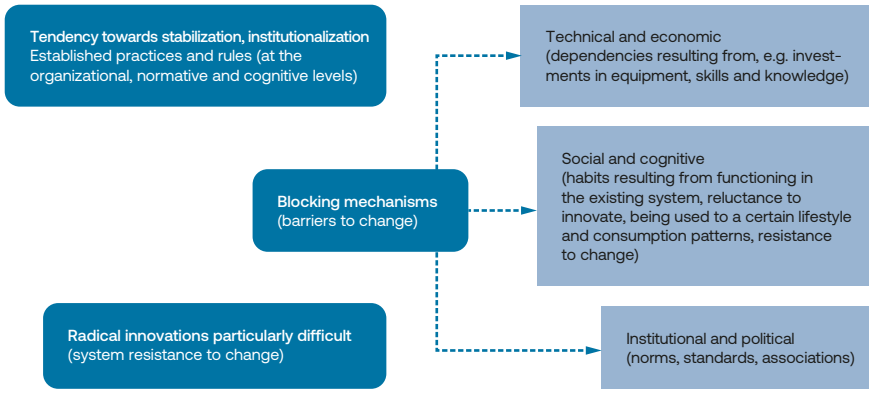
There may be similar concerns with regard to electric vehicles, particularly for carriers with limited ability to charge vehicles with inexpensive renewable energy. The increase in electricity prices in 2022 relative to early 2021 was more than five-fold in August, with the average annual price rising about three times.

The development of the zero-emission vehicle market should be viewed as a transformation of the entire transport system. The transport system consists of interconnected stable structures and elements, serving to satisfy one of the basic needs - the movement of people and goods by various modes of transport. Creating a low-carbon transport system requires the transformation of the entire socio-technical system. The mere behavioral changes among individual consumers and the availability of technology may not be enough to change the system - or the changes will need a take long time to materialize, which could lead to losses to be suffered by companies in the sector. From the perspective of users and demand for zero-emission vehicles, there is a need to revise business models, change user habits, launch appropriate information campaigns, improve the availability of charging infrastructure and take into account the increasing importance of aspects of sustainable development and growing consumer pressure to aim towards climate neutrality along the entire value chain. In order for this demand to be satisfied, supply is needed firstly in the sense of availability and maturity of technologies that can then be used for production that ensures economies of scale and returns on investment, and secondly in terms of a positive economic balance for manufacturers and users that would encourage the development of this segment. The day-to-day operation of means of transport requires adequate vehicle charging infrastructure (fuel stations, charging stations), as well as their maintenance and repair. All of these elements are subject to a broader regulatory and economic environment in the form of applicable policies, norms and standards. The complexity of the transport system, including the large number of entities that operate in it, significant amounts of capital expenditure, the long horizon and time required for market development complicate the transition. The transformation to a more sustainable system is a particularly large challenge.

System transformation requires overcoming resistance to innovation and barriers to change. Complex systems show a tendency to becoming stable and institutionalized and are naturally resistant to change. At the organizational, normative and cognitive level, certain practices and mechanisms are established and professions and entities specific to the system operation are created (carriers, service centers, infrastructure, manufacturers and their subcontractors). Change requires overcoming a number of barriers: technical and economic (dependencies resulting, for example, from investments in equipment, skills and knowledge); institutional and political (associations, norms, standards); social and cognitive (habits resulting from functioning in the existing system, reluctance to innovate, being used to a certain lifestyle and consumption patterns). All this makes radical innovation particularly difficult.

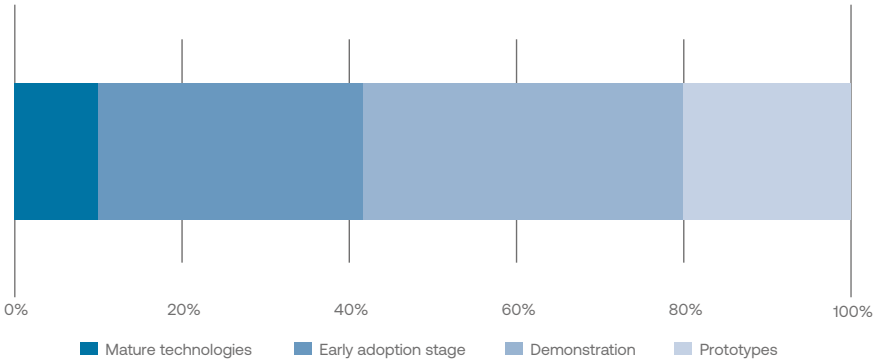
Transformation of the transport system - barriers

Why is it so difficult to change the socio-technical system?



It is not possible to simply use the infrastructure and solutions developed for the passenger transport to decarbonize the heavy-duty transport sector. In particular heavy-duty transport requires significantly more energy, which means that, for example, it would take too long to charge batteries with lower-capacity charging stations designed for passenger vehicles. In effect, the sector requires technologies specifically tailored to its needs. However, in the most part they are still in a preliminary state of development (Fig. 3). As a result, there can be significant uncertainty in the market, among manufacturers, potential customers and policymakers alike, as to the optimal course of action. Taking into account both environmental and economic aspects, it currently seems that road freight transport will most likely rely on battery (particularly N2 category vehicles) or hydrogen fuel cell vehicles.

Fig. 3. Cumulative CO2 capture by technology readiness level.



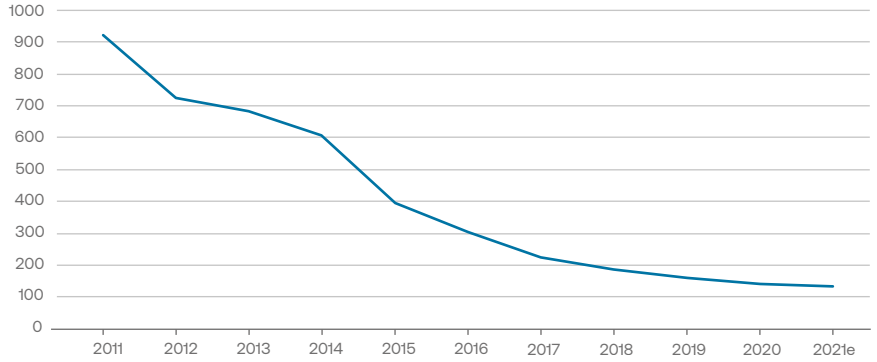
Source: International Energy Agency. Energy Technology Perspectives 2020.

Battery technology: mature alternative for internal combustion engines

The zero-emission technology with the highest potential to displacing internal combustion engine trucks, especially in the medium-duty vehicle category in the near term, but in the longer term also in the category of heavy-duty vehicles, is battery-electric vehicles (BEV). At present, the main pillar of battery technology are lithium-ion batteries. Apart from lithium, cobalt or nickel, among other critical raw materials, are used to manufacture batteries[24]. With current technology, trucks are typically able to travel about 300 km on one charge[25] [26], although Tesla Semi has even reportedly achieved a distance of more than 800 km for a loaded vehicle[27]. Traction battery technology has undergone rapid development in the past decade. This allowed their prices to fall considerably: between 2011 and 2020 by 85.2%, from 924 USD/kWh to 140.4 USD/kWh (Fig. 4).

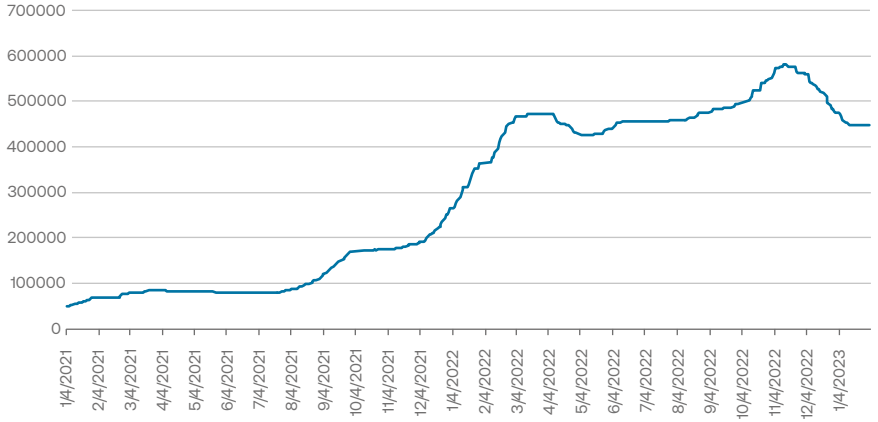
[24] However, lithium batteries that do not use these elements, e.g., lithium-iron-phosphate (LFP) batteries, are beginning to play an increasingly important role.
[25] The record-long distance travelled on one charge, under specially adjusted conditions and without the load, is 1,099 km; Futuricum. Guinness World Records Official Attempt Longest driven distance without intermediate charging with an e-truck https://roadtorecord.futuricum.com/ (accessed on: 4 April 2023).
[26] Volvo Alternative Fuels for Trucks A Guide to the Pros and Cons 2020.
[27] Tesla. Tesla Semi driving 500 miles, fully loaded, on a single charge https://www.youtube.com/watch?v=GtgaYEh-qSk (accessed on: 4 April 2023).

Fig. 4. Average price of lithium-ion battery pack 2011-2021 (USD/kWh).



Source: International Energy Agency. Average pack price of lithium-ion batteries and share of cathode material cost, 2011-2021.

Fig. 5. Price of lithium carbonate 99% (CNY/t).



Source: In-house analysis, Investing.com data[33].

However, the dynamic development of technology comes with new challenges, particularly related to the supply of raw materials and the concentration of production. In the post-pandemic period in particular, the supply of lithium has not kept up with demand[28]. This resulted in a strong increase in its price relative to the beginning of 2021 - (CNY/t): even 12-fold in November 2022. The following months saw a stabilization of the market situation, but prices at the end of January 2023 still remained about 9 times higher than in early 2021 (Fig. 6). Battery production is also heavily concentrated. In 2022, **77% of battery production capacity (measured in GWh) was located in China**, while 6% in the USA. In the EU, countries with the highest production capacity were **Poland (6%, 2nd highest in the world)**, Hungary (3%, 3rd highest in the world) and Germany (3%)[29]. In addition, the development of technology has so far been driven by the growth of the passenger car market, hence the specific challenges related to trucks, mostly resulting from their weight, have not been fully resolved. Electric drives[30] are significantly heavier than the corresponding internal combustion powertrains[31] and they have a limited range, although there are reports of significant improvements in this area. The limitations regarding the distance that can be traveled on one charge are all the more important as the charging time for such vehicles is relatively long, e.g. using high-capacity DC charger (250 kW) it would take about 2 hours to charge the battery from empty to full.[32]

[28] Sanin M. E. Why are lithium prices skyrocketing? https://www.polytechnique-insights.com/en/columns/economy/why-are-lithium-prices-skyrocketing/ (accessed on 4 April 2023).
[29] Bhutada G. Visualizing China's Dominance in Battery Manufacturing (2022-2027P) https://www.visualcapitalist.com/chinas-dominance-in-batterv-manufacturing/ (accessed on: 4 April 2023).
[30] Engine and battery together.
[31] Dooley E. C. Battery-Powered Trucks Bring Weighty Questions to Climate Fight https://news.bloomberglaw.com/environment-and-energy/battery-powered-trucks-bring-weighty-questions-to-climate-fight (accessed on: 4 April 2023).
[32] Engdahl H. How a good charging strategy can extend an electric truck's range https://www.volvotrucks.com/en-en/news-stories/insights/articles/2021/nov/How-a-good-charging-strategy-can-extend-an-electric-trucks-range.html (accessed on: 4 April 2023).
[33] Investing.com. Lithium Carbonate 99%Min China Spot - () https://www.investing.com/commodities/lithium-carbonate-99-min-china-futures-historical-data (accessed on: 4 April 2023).

Planned and ongoing investments in electric batteries

Due to the growing role of battery technology, including due to the development of electromobility, the EU is pushing for more autonomy in their production. Consequently, in 2017 the European Battery Alliance was brought to life to associate market participants. By 2021, investments in battery value chain projects amounted to EUR 127 billion, and another EUR 382 billion is expected to be invested by 2030, which should make it possible to achieve self-sufficiency[34].

Taking into account only projects at an advanced stage of acquiring financing and building permits, battery production in the EU should increase from approximately 69 GWh of energy capacity to 773 GWh by 2030. This, however, is not enough to achieve self-sufficiency. However, taking into account all the announced investments, the figure could rise to even 1,395 GWh, which would mean not only self-sufficiency, but also the need to export part of the output from the EU. According to these plans, production would be concentrated primarily in Germany (493 GWh) and Hungary (217 GWh). Poland, together with France and Italy, would be comparable producers ranked 3rd-5th in the EU (about 120 GWh each)[35].

However, there have been signs of possible decline in the investment momentum in Europe. The implementation of some projects has slowed down (such as the Northvolt and Tesla plants), especially after the announcement of the program of support for green investments in the United States (Inflation Reduction Act). In addition, due to problems in obtaining raw materials, primarily lithium, there is a risk that some investors will abandon their capacity expansion plans[36]. Nonetheless, rapidly developing alternative battery technologies using other, more accessible metals, e.g. sodium instead of lithium, provide solid ground for further development of battery technology also in the heavy-duty vehicle segment.

Work is underway to solve the challenges related to battery technology, in particular the rapid expansion of the market. The problems with supply of raw materials resulted from a surge in demand and not from the shortage of available raw materials[37]. The increase in prices, combined with the termination of Chinas program of state subsidies for electric cars, caused the demand growth rate to cool in 2023[38]. At the same time, the same price increase has made it more profitable to extract raw materials from previously untapped deposits, leading to higher supply[39]. To that end, work is underway to develop and find new lithium deposits. In the European Union, for example, such activities are carried out in Finland, Germany, the Czech Republic and Portugal[40] [41]. **The dampened growth rate of demand and higher supply resulted in a sharp decline in the price of raw materials used in batteries - for example, lithium carbonate prices fell 58.2% in Q1 2023**[42]**.** In addition, more efficient methods of the use of resources by recycling batteries as part of circular economy are being developed[43], which could solve the problem not only of the availability of lithium, but also of so-called critical raw materials. Investments are also made in new battery factories (Box 2), which should significantly increase the EU's share in the global market, in particular in the case of Germany (even up to 11% in 2025)[44] [45].

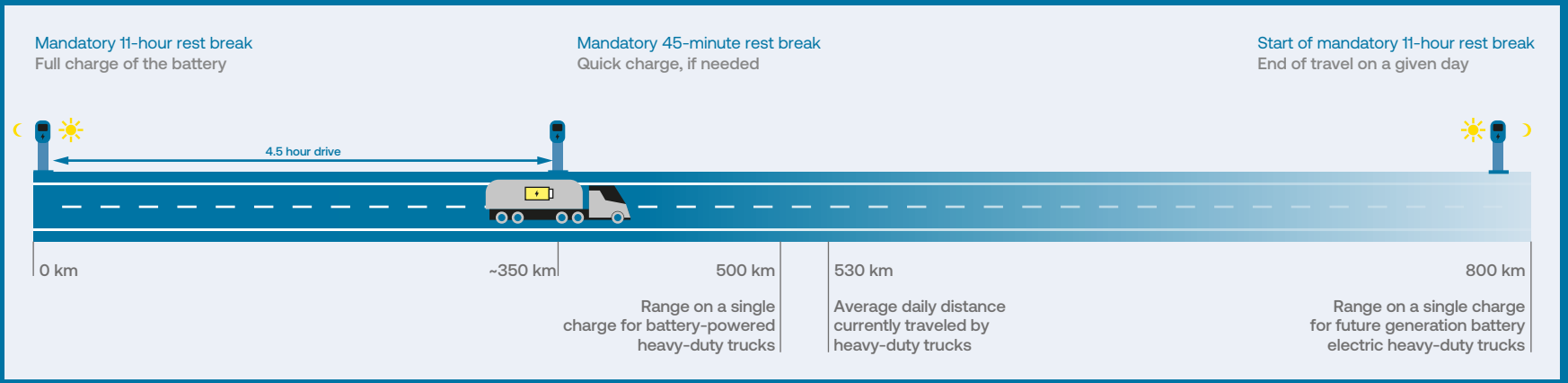
[34] European Commission Questions and Answers. The European Battery Alliance: progress made and the way forward https://ec.europa.eu/commission/presscorner/detail/en/QANDA_22_1257 (accessed on: 4 April 2023).
[35] Transport & Environment. A European Response to US IRA How Europe can use its soft and financial powers to build a successful electric vehicle value chain 2023.
[36] Electrive.com. Tesla rumoured to postpone battery production in Germany https://www.electrive.com/2022/09/15/tesla-rumoured-to-postpone-battery-production-in-germany/ (accessed on: 4 April 2023).
[37] Derski B. Kiedy skończą się lit i kobalt do baterii? https://wysokienapiecie.pl/82533-kiedy-skoncza-sie-lit-i-kobalt-do-baterii/ (accessed on: 4 April 2023).
[38] Pang I., Luman R. The dominant Chinese electric car market is slowing https://think.ing.com/articles/dominant-chinese-electric-car-market-is-slowing (accessed on: 4 April 2023).
[39] Shan L. I. Bank of Am erica sees lithium surplus in 2023 as demand eases https://www.cnbc.com/2023/03/07/bank-of-america-sees-lithium-surplus-in-2023-as-demand-eases.html (accessed on: 4 April 2023).
[40] Due to the estimated low level of deposits in Poland, no such work is conducted.
[41] Zglinicki K. Lit. Metale zielonej rewolucji https://www.pgi.gov.pl/aktualnosci/display/13364-lit-metale-zielonej-rewolucji.html (accessed on: 4 April 2023).
[42] Investing.com. Lithium Carbonate 99%Min China Spot - () https://www.investing.com/commodities/lithium-carbonate-99-min-china-futures-historical-data (accessed on: 4 April 2023).
[43] European Parliament News. New EU rules for more sustainable and ethical batteries https://www.europarl.europa.eu/news/en/headlines/economy/20220228STO24218/new-eu-rules-for-more-sustainable-and-ethical-batteries (accessed on: 4 April 2023).
[44] At the same time, however, other economies are taking steps to improve their position in the market, for example the USA with its Inflation Reduction Act.
[45] Yu A., Sumangil M. Top electric vehicle markets dominate lithium-ion battery capacity growth https://www.spglobal.com/marketintelligence/en/news-insights/blog/top-electric-vehicle-markets-dominate-lithium-ion-battery-capacity-growth (accessed on: 4 April 2023).

Charging a vehicle during rest break in working hours

One of the main challenges with currently available battery truck technologies is their relatively short range on one charge. One of the proposed solutions is optimization involving mandatory rest break during working hours. According to the EU law, if a working day is more than 9 hours, a driver is entitled to a 45-minute break during the day in addition to the mandatory uninterrupted 11 hours of rest between working days. It is proposed this break be used for additional recharging of the vehicle to extend its range.

This would enable electrification of most of the trips currently made in the EU. In particular, vehicles currently travel an average distance of about 530 kilometers, and the latest generation of battery vehicles are able to travel about 500 kilometers on one charge. At the same time, technology development forecasts indicate that future generation vehicles should extend their range to as much as some 800 km, which would allow them to cover about 97% of trips in the heavy transport in the EU[46].

Potential operation of trucks



Source: Transport & Environment, HDV CO2 standards: T&E's view on the review and zero emission trucks.

At the same time, while lithium-ion batteries are currently the dominant technology, alternative technologies that could potentially complement or replace them are being developed. Examples of such solutions include sodium-ion, magnesium-ion, graphene-based (e.g., graphene aluminum-ion) or manganese batteries[47]. The development of these technologies is currently at an early stage, and they face their specific challenges related to, for example, the reactivity of the elements used, production costs, or energy capacity, but each has certain advantages that give them the potential to complement or replace lithium batteries in various segments of the economy. For instance, sodium-ion batteries are less susceptible to temperature, which makes them safer and enables their energy capacity to fall less in lower temperatures[48]. Also, the raw materials they require can be obtained with less environmental pressure[49]. With recent technological advancement resulting in raising their energy density to a level approximating (though still lower than) that of lithium-ion batteries, they may begin to replace lithium batteries in specific applications, such as vehicles for markets with long

[46] Tol D., Frateur T., Verbeek M., Riemersma I., Mulder H. Techno-economic uptake potential of zero-emission trucks in Europe TNO report TNO 2022 R11862 2022.
[47] Cavallo C. 7 Lithium Battery Alternatives https://www.thomasnet.com/insights/ 7-lithium-battery-alternatives/ (accessed on: 4 April 2023).
[48] Contemporary Amperex Technology Co., Ltd. (CATL). CATL Unveils Its Latest Breakthrough Technology by Releasing Its First Generation of Sodium-ion Batteries https://www.catl.com/en/news/665.html (accessed on: 4 April 2023).
[49] University of Texas News. Sodium-based Material Yields Stable Alternative to Lithium-ion Batteries https://news.utexas.edu/2021/12/06/sodium-based-material-yields-stable-alternative-to-lithium-ion-batteries/ (accessed on: 4 April 2023).

periods of low temperatures and light vehicles for which high capacity is less important, which would reduce demand pressures on lithium. Moreover, some other technologies still under development may have a higher energy density than lithium batteries and in effect they have the potential to replace the latter in heavy-duty vehicles.

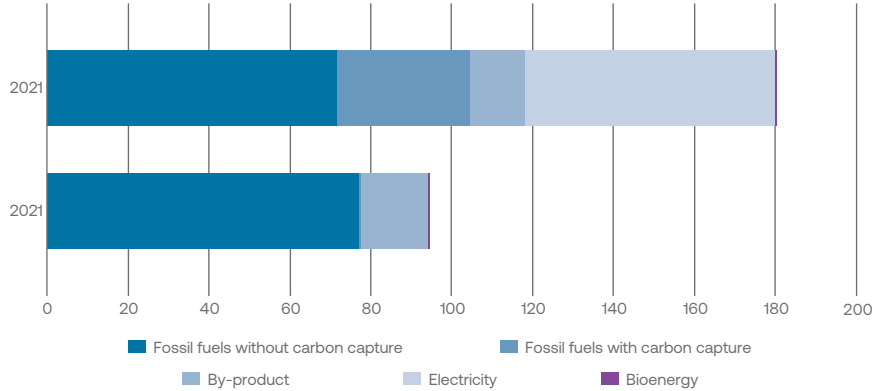
Regardless of the further development of battery technology, work is also underway on alternative methods of overcoming the associated challenges, for example, by reducing a vehicle's dependence on batteries. In Sweden, for instance, the Electric Road System (ERS) is being tested: infrastructure solutions that allow **vehicles to be charged while driving** using, for example, an overhead power line over the road or a rail in the road[50].

Hydrogen: technology of the future?

The key zero-emission alternative to battery technology, particularly in the segment of heavy-duty vehicles for long-distance transport, is hydrogen fuel cells. They rely on the process of cold hydrogen combustion to generate electricity[51], which is then used to power the engine. The only chemical product of the process is steam. The benefits of this solution are typical of electromobility: no emissions are generated, and the engine operates with low noise[52]. In addition, they have a comparable driving range per charge as internal combustion vehicles and a short charging time[53].

Despite its advantages, a number of challenges associated with the technology need to be solved before it will become widespread in road transport. These include the cost of hydrogen transport and the process of its production. At present, transporting hydrogen is technically difficult. This is due to the fact that, among other things, hydrogen causes embrittlement of metal casings, can be expensive to liquefy, and loses large amounts of energy efficiency when converted to and from a compound that may be used for its transport, such as a liquid organic hydrogen carrier (LOHC) or ammonia[54]. Another limitation of the technology is its low energy efficiency: estimates of the technology's development indicate that in 2035 its total energy efficiency taking into account all stages of the fuel chain will be 25-35%, which is more than two times less than for battery technology, although slightly more than for other alternative fuels[55] [56]. In addition, an important barrier is that pure hydrogen does not occur in the nature and must be obtained by breaking down its compounds, primarily water.

Fig. 6. Global hydrogen production in 2021 and 2030 by technology in the Net Zero Emissions Scenario.



Source: International Energy Agency. Hydrogen https://www.iea.org/reports/hydrogen (accessed on 6 April 2023).

For hydrogen to be a truly zero-carbon alternative, it should be produced using zero-carbon technologies (Box 3). **However, this is not currently the case** (Fig. 8). Hydrogen production relies on fossil fuels: according to 2019 data, about 75% of hydrogen is produced from natural gas, and 23% is produced from coal. As a result, global hydrogen production is responsible for significant CO2 emissions, comparable to those of Indonesia and the United Kingdom combined[57].

[50] Hasselgren B., Nässtrom E. Electrification of Heavy Road Transport - business models phase 5 The Swedish Transport Administration 2021.
[51] Siemens Mobility Solutions Portfolio. How a hydrogen drive works - the innovative components of Mireo Plus H https://www.mobility.siemens.com/global/en/portfolio/rail/stories/hydrogen-drive-how-it-works.htm #:~:text= How%20does%20a%20hydrogen%20drive,the%20energy%20to%20the%20wheels. (accessed on: 4 April 2023).
[52] Volvo Alternative Fuels for Trucks A Guide to the Pros and Cons 2020.
[53] Korniejew T. Polska wodorowym eldorado? Tak słyszymy, ale jak zwykle diabeł tkwi w szczegółach https://moto.pl/MotoPL/7,175393,28937850,polska-wodorowvm-eldorado-tak-slyszymy-ale-jak-zwykle-diabel.html (accessed on: 4 April 2023).
[54] Day P. Hydrogen costs hang on solving transportation https://www.reutersevents.com/renewables/renewables/hydrogen-costs-hang-solving-transportation (accessed on: 4 April 2023).
[55] 70-90% for batteries and 10-20% for other alternative fuels. The estimated efficiency of diesel engines is 20-25% with standard fuel, up to 35% for biodiesel, and up to 40% in optimal conditions (Hjelkrem OA, Arnesen P, Aarseth Bø T et al. Estimation of tank-to-wheel efficiency functions based on type approval data. Applied Energy 2020;276:l15463.)
[56] Volkswagen Newsroom. Battery or fuel cell, that is the question https://www.volkswagen-newsroom.com/en/stories/battery-or-fuel-cell-that-is-the-question-5868 (accessed on: 4 April 2023).
[57] International Energy Agency. The Future of Hydrogen Seizing today's opportunities 2019.

Many colors of hydrogen

Due to the development of diverse hydrogen technologies and various amounts of emissions they generate, a naming convention has been adopted by assigning colors to them.

A theoretically pure hydrogen in its naturally occurring version is referred to as "white", but it rarely exists on Earth. It is currently generated primarily from natural gas or methane through a process called "steam reforming", and this version is referred to as "gray" hydrogen. This process generates quite a lot of emissions, but still less than hydrogen generation from hard coal ("black") or lignite ("brown").

A zero-emission process of hydrogen generation is electrolysis based on renewable energy ("green", hydrogen from electrolysis powered by nuclear energy is referred to as "pink"). However, it is rarely used today due to both its low efficiency and the still low prevalence of RES. The development of the technology is supported by its potential role not only in hydrogen generation, but also as a method of stabilizing energy production: surplus output would be used for electrolysis, while during periods of low production hydrogen would be used as a power source.

A significant potential for growth in the years to come is seen in the technology of "blue" hydrogen, which is "gray" hydrogen with added carbon capture technology that could help cut emissions by up to 80-90%.

Other technologies are also being explored but are rather experimental. One of them is "turquoise" hydrogen generated through methane pyrolysis, which generates solid carbon as a byproduct, making the method a potentially zero-emission process[58].

The primary technology currently developed and expected to replace current methods of hydrogen production is electrolysis. However, its current energy efficiency is low. Replacing today's global production with electrolysis would require 3,600 TWh of energy: more than the annual output of the EU. At the same time, demand for hydrogen is expected to increase sevenfold by 2070, partly due to an increase in its use in industrial manufacturing and power generation. However, it is estimated that in most part the boost in demand will be attributable to transport, with nearly a third of it resulting from road transport[59]. Electrolysis would also require significant amounts of water, which could be a problem for areas with limited water resources. In addition to work on improving the efficiency of electrolysis, alternative methods of obtaining pure hydrogen are also developed, such as methane pyrolysis, which produces hydrogen and solid carbon. The technology uses less electricity than electrolysis to produce the same amount of hydrogen but involves a significant loss of heat[60].

Infrastructure

The availability of infrastructure plays a key role in developing the direction of the transport market. For example, research on the market since its beginnings indicates that the problem of infrastructure availability was the factor that mostly contributed to the abandonment of electric vehicle development in favor of internal combustion vehicles in the United States in the early 20th century[61]. In the first few years, it may be much more important for carriers to set up charging stations at their own transport depots, which would require significant capital expenditures (and involve investment uncertainty) and also depends on the parameters of local power grids. Taking this into account, the greatest potential for electrification is in regional and local transport services, which are characterized by shorter distances, making them less dependent on public infrastructure[62]. However, the barrier is the significant cost of such charging stations, as well as the availability of power, power allocation, the cost of a suitable service line and the time required to install it.

The rapid growth of the electric truck market will require the development of an adequate charging infrastructure dedicated to these vehicles. Electric heavy-duty vehicles require more powerful chargers than electric cars. At present, this type of infrastructure is virtually

[58] World Economic Forum. Grey, blue, green - why are there so many colours of hydrogen? https://www.weforum.org/agenda/2021/07/clean-energy-green-hydrogen/ (accessed on: 4 April 2023).
[59] International Energy Agency. Energy Technology Perspectives 2020 2021.
[60] International Energy Agency. The Future of Hydrogen Seizing today's opportunities 2019.
[61] Taalbi, J., Nielsen, H. The role of energy infrastructure in shaping early adoption of electric and gasoline cars. Nat Energy 6,970-976 (2021) https://doi.org/10.1038/s41560-021 -00898-3.
[62] However, due to the specific structure of the cost of zero-emission vehicles: a relatively high purchase price and low costs of operation, a greater potential for electrification is seen in intensively used vehicles (Tol D., Frateur T., Verbeek M., Riemersma I., Mulder H. Techno-economic uptake potential of zero-emission trucks in Europe TNO report TNO 2022 R11862 2022).

unavailable at public charging stations[63]. In 2021, there were 2,580 charging stations in Europe with a capacity of more than 349 kW, mainly in Germany (829) and France (655). Also, hydrogen refueling infrastructure is virtually unavailable, with a total of 136 refueling points in the EU, including 89 in Germany[64]. The construction of public infrastructure is hindered by investment uncertainty and the lack of a stable regulatory framework, including ambitious, binding (intermediate) targets as part of the adopted transformation strategy. This makes investors unwilling to take the risk of this type of investment. They are also looking for larger groups of prospective users, potentially favoring larger transport companies and putting smaller operators at a disadvantage. There is also the challenge of cooperation between different actors in the sector, which would allow the exchange of knowledge and experience and accelerate the harmonization and standardization of infrastructure. What also stands in the way are legal issues resulting from technical requirements for recharging points, similar to those applicable to large industrial plants. Issues of ensuring adequate allocation and connection power by network operators also require a flexible and coordinated approach - at present, the relevant procedures and realization times are long[65].

The EU plans to address this issue in the AFIR Regulation[66]. According to the proposal for TEN-T roads, a recharging pool should be available every 100 km, have a total power output of at least 1,400 kW by 2030 and 3,500 kW by 2035, and should include at least one recharging station with a power output of at least 350 kW, and two in 2035. On routes along the TEN-T core network, a recharging pool should be deployed every 60 km, and the remaining targets should be achieved 5 years earlier, respectively. For hydrogen refueling stations, the EC is proposing their initial deployment by the end of 2030 "with a maximum distance of 450 km in-between them" (150 km in-between them along the TEN-T core).

Manufacturers believe that the EU's proposal is insufficient, which, in particular, may be due to a different perception of the market's development potential in the near future. The CION forecasts that there will be 80,000 zero-emission HDVs in Europe by 2030[67]. Meanwhile, manufacturers anticipate faster market growth in the coming years, primarily in the fleet of battery trucks; by 2030 there should be about 270,000 of them in Europe. Hydrogen-powered heavy-duty vehicles should be more prevalent on long-haul routes, and it is expected that there will be about 60,000 of them by 2030[68]. In effect, they point to the need for greater than proposed power output at charging hubs and the introduction of more charging stations. They also indicate that the power output of charging points should be higher than 350 kW, up to as much as 1,200 kW (Table X). There are also differences in projections of demand for hydrogen refueling infrastructure. Manufacturers are proposing to accelerate deployment by 2025 and a maximum distance betweenstations of 300 km.

Public recharging infrastructure in Poland

The assessment of the existing experience of developing public infrastructure supporting electromobility is ambiguous. The standard in this regard the EU is provided by the AFID Directive[69]. It recommended that recharging infrastructure coverage be based on the number of vehicles and indicated 10 light-duty vehicles (LDVs) per publicly accessible recharging point with a power output of 1 kW per battery vehicle. According to the International Energy Agency, Poland currently meets these criteria: 1 recharging point is available per 10.3 light-duty vehicles, and the power output per electric vehicle is 2.5 kW[70]. This indicates that infrastructure development matches demand for its use.

However, this does not result from strong infrastructure availability, but the low number of vehicles. Poland is one of six EU Member States with less than one recharging point for electric vehicles per 100 km of road[71]. In total, there are 3,295 of them in Poland, fewer than e.g. in the Czech Republic or Hungary. 2,313 points are standard AC stations, and 982 are DC fast charging stations[72]. Poland also has a lot of catching up to do in terms of development of infrastructure for electric trucks: in 2021, Poland had 17[73] recharging stations with a power output of more than 349 kW and no hydrogen refueling point.

[63] Broback M. Why the charging infrastructure for heavy electric trucks is set to expand https://www.volvotrucks.com/en-en/news-stories/insights/articles/2021/nov/charging-infrastructure-for-electric-trucks.html (accessed on: 4 April 2023).
[64] European Commission European Alternative Fuels Observatory. Country comparison https://alternative-fuels-observatory.ec.europa.eu/transport-mode/road/european-union-eu27/country-comparison (accessed on: 4 April 2023).
[65] Van Grinsven A., Otten M., Van den Toom E., Van der Veen R., Kiraly J. & Van den Berg R. Alternative fuel infrastructures for heavy-duty vehicles Research for TRAN Committee 2021.
[66] European Commission. Proposal for a Regulation of the European Parliament and of the Council on the deployment of alternative fuels infrastructure, and repealing Directive 2014/94/EU of the European Parliament and of the Council COM(2021) 559 final.*The regulation has been adopted by the EU on 25th July 2023, source: https://www.consilium.europa.eu/en/press/press-releases/2023/07/25/alternative-fuels-infrastructure-council-adopts-new-law-for-more-recharging-and-refuelling-stations-across-europe/
[67] Communication from the European Commission. Sustainable and Smart Mobility Strategy - putting European transport on track for the future COM(2020) 789 final.
[68] ACEA Position Paper. Heavy-duty vehicles: Charging and refueling infrastructure requirements 2021.
[69] Directive 2014/94/EU of the European Parliament and of the Council of 22 October 2014 on the deployment of alternative fuels infrastructure.
[70] International Energy Agency. Charging points per EV and kW per electric LDV in selected countries, 2021 https://www.iea.org/data-and-statistics/charts/charging-points-per-ev-and-kw-per-electric-ldv-in-selected-countries-2021 (accessed on: 4 April 2023).
[71] ACEA Press releases. Electric cars: 6 EU countries have less than 1 charger per 100km of road; 1 charger in 7 is fast https://www.acea.auto/press-release/electric-cars-6-eu-countries-have-less-than-1-charger-per-100km-of-road-1-charger-in-7-is-fast/ (accessed on: 4 April 2023).
[72] European Commission European Alternative Fuels Observatory. Recharging and refueling stations map https://alternative-fuels-observatory.ec.europa.eu/interactive-map (accessed on: 4 April 2023).
[73] European Commission European Alternative Fuels Observatory. Country comparison https://alternative-fuels-observatory.ec.europa.eu/transport-mode/road/european-union-eu27/country-comparison (accessed on: 4 April 2023).

Table 2: Comparison of the European Commission's proposal for heavy-duty vehicle charging network under AFIR versus expectations of heavy-duty vehicle manufacturers (ACEA).

Proposal	TEN-T network	2025	2027	2030	2035
EC	Core	Recharging station every 60 km			
		• power output of at least 1,400 kW per recharging pool • one recharging station with a power output of at least 350 kW per recharging pool		• power output of at least 3,500 kW per recharging pool • two recharging stations with a power output of at least 350 kW per recharging pool	• power output of more than 3,500 kW per recharging pool - at least two recharging stations with a power output of at least 350 kW
	Comprehensive	Recharging station every 100 km			
				• power output of at least 1,400 kW per recharging pool • one recharging station with a power output of at least 350 kW per recharging pool	• power output of at least 3,500 kW per recharging pool • two recharging stations with a power output of at least 350 kW per recharging pool
ACEA	Core	Recharging station every 60 km, considering local conditions			
		• power output of at least 5,000 kW per recharging pool • four recharging stations with a power output of at least 350 kW and four recharging stations with a power output of at least 800 kW per recharging pool		• power output of at least 6,500 kW per recharging pool • four recharging stations with a power output of at least 1,200 kW per recharging pool	
	Comprehensive	Recharging station every 100 km, considering local conditions			
			• power output of at least 1,400 kW per recharging pool • two recharging stations with a power output of at least 350 kW per recharging pool	• power output of at least 3,000 kW per recharging pool • two recharging stations with a power output of at least 800 kW per recharging pool	• power output of at least 5,000 kW per recharging pool • two recharging stations with a power output of at least 1,200 kW per recharging pool

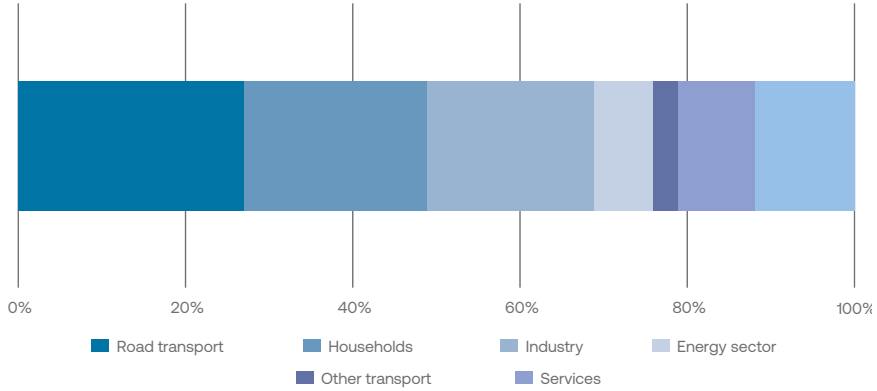
Source: ACEA Position Paper. Proposal for the Alternative Fuels Infrastructure Regulation (AFIR) 2021.

Achievement of the targets included in the already approved draft of the AFIR requires significant investment from Poland, but it is still possible. To meet the requirements, Poland should increase installed capacity in relation to the size of the park[74] in the public infrastructure from 89.7 MW to 435.8 MW in 2025, 1,383.5 MW in 2030 and 2,613.1 MW in 2035. By 2025, the infrastructure should be easily accessible on 15% of roads along the TEN-T network, and by 2027 on 40%, which is equivalent to almost the entire core network. To achieve the required coverage, 188 potential locations of charging stations have been identified, of which 27 should be ready by 2025, 71 by 2027, and the rest by 2030. The cost of developing the required infrastructure: building connections and rolling out the network, is about PLN 1,561.3 million, of which PLN 224.2 million is needed to meet the targets for 2025.

Challenges for Poland

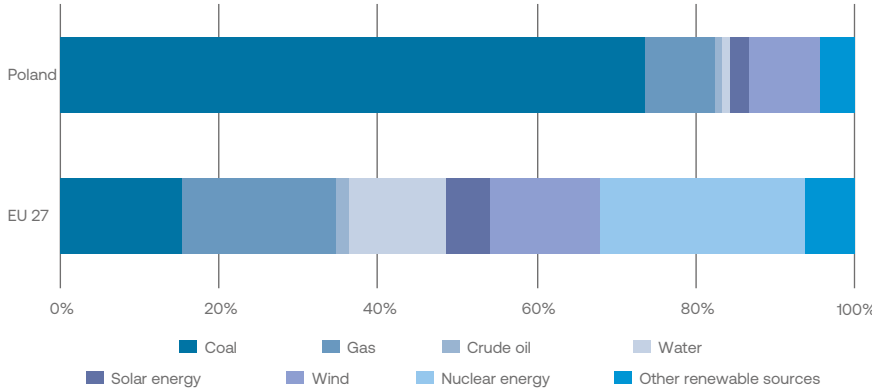
The development of zero-emission transport may be a particular challenge for Poland due to the structure of the energy sector. Transport accounted for 27% of Poland's final energy consumption in 2019: the most of all categories designated by Statistics Poland (Fig. 9). This involved significant reliance on oil energy. In 2021, Poland consumed 62% more energy from oil than electricity[75]. While the higher energy efficiency of zero-emission engines may cover some of the changes in energy demand, a significant increase in generated power will also be needed. The forecast of the National Centre for Emission Management (KOBiZE)[76] indicate that, taking into account the increase in electricity production by 2050, electromobility may represent up to 15% of electricity demand. Meanwhile, the Polish power generation sector is currently based on coal (Fig. 10). As a result, the electrification of transport may be not efficient enough as a form of CO2 reduction in the short term. To realize the potential of electrification of transport, it is necessary to accelerate the process of phasing out coal and other fossil fuels in the electricity production sector[77], while meeting additional demand for electricity.

Fig. 7. Final energy consumption by functional sector and direction of consumption in 2019.



Source: Statistics Poland. Energy statistics in 2019 and 2020, 2021.

Fig. 8. Share in electricity output by source.



Source: In-house analysis, data sourced from Our World in Data - Energy mix (accessed on: 5 April 2023).

[74] BEV and PHEV.
[75] ARE. Resulting statistical information https://www.are.waw.pl/wydawnictwa (accessed on: 5 April 2023).
[76] Rabiega W. P., Sikora P. CO2 Emission reduction paths in the transport sector in Poland in the context of "The European Green Deal", National Centre for Emission Management (KOBiZE) at the Institute of Environmental Protection – National Research Institute 2020.
[77] In particular, that due to the war in Ukraine, the role of gas-fired power plants may be reduced as an intermediate solution for increasing electricity production amid strong decarbonization efforts in the medium term.

The efforts undertaken in the energy sector should at least partially allow additional demand to be met with energy from zero-emission sources. Renewable energy production capacity in Poland is growing rapidly and is expected to be further supported by nuclear power in the future. In 2022, the share of RES in electricity output was 20.6%[78]. In 2021, it was 17.0%. This resulted from a 20.7% increase in electricity production from RES with a concurrent 5% decline of the output of conventional power plants. Poland is also taking steps towards launching nuclear energy production. Poland's nuclear power plants are planned to have a target capacity of 6-9 GW[79] by 2043. On 2 November 2022, the government passed a resolution on the construction of the first power plant with a capacity of up to 3,750 MWe[80]. The development of infrastructure for heavy-duty vehicles will also require investment in the transmission and distribution network[81], although at the current rate of electromobility development, potential grid problems should not occur[82].

Regardless of the issue of decarbonization of the power sector, electrification of transport should make it possible to reduce emissions of some other pollutants, particularly nitrogen oxides and particulate matter.

Summary and conclusions for the zero-emission vehicles industry

Considering climate goals and technology development, the large-scale development of the zero-emission heavy-duty transport should begin in the next few years. Given Poland's key role in the road transport market, it is in the public interest for the state to provide its strong support to the transition process. However, in order to achieve the desired results, it is necessary to create a system of support for Polish transport companies in replacing their fleets and promoting infrastructure investment: the cost of investment in recharging stations and connecting them to the grid is estimated at more than PLN 1.5 billion by 2030.

- In order to achieve climate objectives by Poland it is necessary to develop the zero-emission truck market.
- Maintaining a competitive edge in the road transport sector is important for the Polish economy and Polish businesses in the transport industry, thus Poland should endeavor to become one of the market change leaders.
- In order to ensure smooth development of the zero-emission heavy-duty vehicle market, it currently requires public support to switch the transport system from traditional internal combustion vehicles to zero-emission vehicles.
- Although some freight transport may be taken over by rail as part of intermodal transport, which is supported by EU policies, it seems that road transport will remain its core in the coming decades.
- The zero-emission technology for heavy-duty vehicles with the best prospects for development in the coming years is battery electric vehicles.
- In the longer term, the technology that may potentially complement the zero-emission truck market is hydrogen fuel cell vehicles, which may prove to be successful in niches where battery technology cannot be used. However, this technology currently requires significant improvements, particularly in the area of hydrogen production and transport, before it can become a truly zero-emission and economically viable alternative.
- The key issue of development of the public charging infrastructure is to be addressed by the EU AFIR Regulation, which imposes binding obligations on Poland to expand the network. However, according to vehicle manufacturers the EC proposal is insufficient and requires additional action.
- In the case of Poland, due to the structure of the energy mix, electric vehicles not be realistically zero-emission in the coming years, as electricity is currently produced mainly from coal. However, it should be noted that this is not the reason to limit the development of the electromobility market, because RES technologies have been intensively developed in recent years and nuclear power plants are planned to enter the arena of power generation. It should be stressed that zero-emission vehicles would help reduce both CO2 emissions and other pollutants, mostly nitrogen oxides.

[78] ARE. Resulting statistical information https://www.are.waw.pl/wydawnictwa (accessed on: 5 April 2023).
[79] Ministry of Climate and Environment. Poland's Energy Policy until 2040. 2021.
[80] Resolution No. 215/2022 of the Council of Ministers of 2 November 2022 on the construction of large-scale nuclear power plants in the Republic of Poland.
[81] Ministry of Energy. Electromobility Development Plan in Poland "Energy for the future", 2017.
[82] Najwyższa Izba Kontroli (Supreme Audit Office). Information on the results of the audit – Support for electromobility development 2020.

Chapter 2. Analysis of the market and structure of heavy-duty vehicle fleets in Poland against the background of the European Economic Area

Characteristics of the road transport industry in Poland

Poland's transport sector is significantly more based on road freight than that of the EU, which results from its focus on handling both domestic and international routes within the EU. The share of road transport in gross output of the entire transport industry in 2020 was **more than two times higher in Poland than in the EU** and was **well above 50%**. Both the Polish and EU road transport industries are highly professionalized and based on micro-enterprises[83] with limited investment capabilities. They make up the core of the internal transport of goods, but **Poland has significantly developed not only internal transport services, but also transport services on international routes**, including for domestic needs[84] and for the main EU Member States, especially Germany. The Polish industry's specialization in international freight translates primarily into longer trips, in particular, its share in trips on routes longer than 500 km is approximately 2-3 times higher than that of the EU. For that reason, in 2021 the average travel distance of a loaded vehicle[85] of Polish carriers was about 100 km longer than the EU average. At the same time, it does not seem to have a significant effect on the tonnage transported, although Poland has significantly lower statistics on shorter distances (Table 2). This is due to the still significant share of medium-duty vehicles in Polish transport[86].

Taking into account the data on both the age and tonnage capacity of the fleet, it is reasonable to assume that domestic trips in Poland are significantly more often covered by older medium-duty vehicles, while newer heavy-duty vehicles are more used on international routes. Although according to fleet data the average vehicle age in Poland is lower than the EU average, the actual utilization of vehicles indicates that the Polish fleet is significantly older. This applies in particular to vehicles used on shorter routes. At the same time, the fleet in Poland is replaced with new vehicles at a slower rate than in the EU. This is partly offset by the import of used vehicles from abroad. The Polish fleet is strictly dominated by heavy-duty vehicles (30-40 t). With that being said, medium-duty vehicles have still maintained market share in Poland, but they lose ground to competitors in the European Union. Both in Poland and in the entire EU, the market is dominated by diesel vehicles with electrification of the industry only taking its first steps. The high share of medium-duty and older vehicles, with a still significant level of used vehicle imports, poses the risk that, as in the case of passenger cars, Poland could become an export market for diesel vehicles replaced in Western Europe, which would slow down the transition among domestic carriers. **However, it should be said that such a market structure: a large fleet of older vehicles, including with a significant share of older vehicles, supplemented largely by imports of used vehicles, can create positive conditions for the development of entities offering retrofitting services, namely the conversion of diesel vehicles to battery vehicles. This could be an important part of the market in the coming years and could accelerate the transition to zero-emission transport, especially because lower technological complexity makes the process easier and less expensive in the case of older vehicles, which is crucial for micro- and small enterprises.**

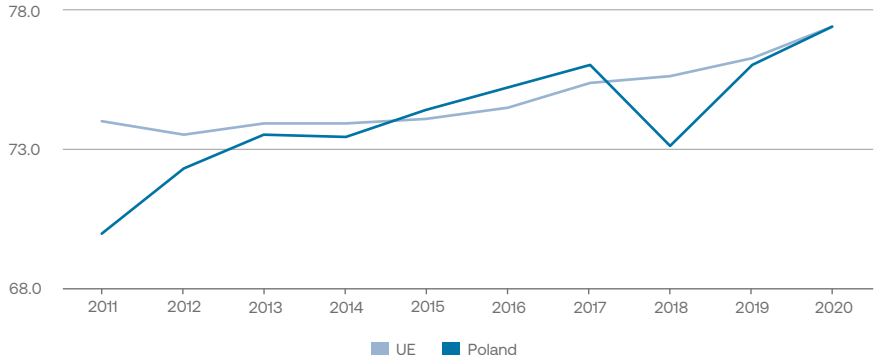
[83] In accordance with the definitions adopted by Statistics Poland, these include entities with up to 9 employees.
[84] Imports and exports.
[85] Measured as tkm / t.
[86] N2 category vehicles, gross vehicle weight (GVW) 3.5-12 t.

Table 3: Road transport in Poland and the EU.

	Poland	EU
Average travel distance per ton in total road transport (km)	240.3	140.7
Share of tonnage transported (%) • per less than 50 km • per distance from 50 to 300 km • >300 km	 41.1 37.8 21.1	 47.9 38.2 13.9
Average transport tonnage (t)	13.5	13.5
Average tonnage in transport up to 50 km (t)	11.9	12.4
Average tonnage for longer distances (1,000-2,000 km, t)	16.2	16.5

Source: In-house analysis based on Eurostat data[87].

Fig. 9. Share of road transport in internal transport (% tkm) in Poland and the EU.



Source: In-house analysis, Eurostat data[88].

Role of road transport

Road transport is the main method of transporting goods within the EU and Poland and is an important mode of transport in international trade. In 2020, it accounted for 77.4% of all ton-km of inland freight in both the EU and Poland (Fig. 11). At the same time, its share is growing rapidly, especially in Poland. This indicates its key and growing role in internal distribution of goods. It also constitutes an important part of transport in trade with non-EU countries. In particular, it accounts for a significant portion of EU exports, where it is the second most important mode of transport by tonnage (18%). The share in the financial value of exports on extra-EU routes is even higher. In imports, it is primarily used to transport relatively valuable goods, making it responsible for a significant portion of the value (19%) despite representing a relatively low share of tonnage (6%). In the context of trade with non-EU countries, road transport is even more important for Poland. It is the most important means of transport in terms of value: it accounts for almost half of it. Despite its much lower share in imports, it is also an important channel, accounting for 10% of tonnage and nearly 18% of value (Table 3).

[87] Eurostat Data Browser. All data https://ec.europa.eu/eurostat/databrowser/explore/all/all themes?lang=en&display=list&sort=category (accessed on: 6 April 2023).
[88] Eurostat Data Browser. Modal split of inland freight transport https://ec.europa.eu/eurosta t/databrowser/view/TRAN_HV_FRMOD_custom_4358787/default/table (accessed on: 6 April 2023).

Table 4: Share of different modes of transport in total EU and Polish trade.

		Eksport				Import			
	Mode of transport	Tonnage (thousand tons)	%	Value (EUR million)	%	Tonnage (thousand tons)	%	Value (EUR million)	%
European Union	Maritime	564 393	75.7	951 403	43.6	1 166 704	72.7	1 116 446	52.5
	Road	**132 638**	**17.8**	**545 624**	**25.0**	**101 627**	**6.3**	**405 613**	**19.1**
	Rail	20 335	2.7	39 686	1.8	73 373	4.6	44 531	2.1
	Air	11 184	1.5	561 986	25.8	4 571	0.3	403 204	19.0
	Fixed mecha-nism (pipelines)	7 041	0.9	11 627	0.5	240 744	15.0	110 695	5.2
	Other / Unknown	10 108	1.4	69 663	3.2	17 847	1.1	44 083	2.1
Poland	Maritime	16 335	55.9	26 066	36.2	40 409	49.9	53 774	55.2
	Road	**10 056**	**34.4**	**34 497**	**47.9**	**8 125**	**10.0**	**17 331**	**17.8**
	Rail	2 565	8.8	1 415	2.0	23 149	28.6	11 416	11.7
	Air	92	0.3	7 766	10.8	115	0.1	10 886	11.2
	Fixed mecha-nism (pipelines)	0	0.0	0	0.0	9 121	11.3	3 629	3.7
	Other / Unknown	195	0.7	2 236	3.1	16	0.0	395	0.4

Source: In-house analysis, Eurostat data[89].

[89] Eurostat Data Browser. Extra-EU trade since 2000 by mode of transport, by HS2-4-6 https://ec.europa.eu/eurostat/databrowser/view/DS-058213_custom_4521150/default/table (accessed on: 5 April 2023).

Barriers to market development

On the demand side, financing high capital expenditures appears to be one of the main barriers to increased user demand, especially in an uncertain economic environment. This is particularly important in the current environment of significant inflationary pressures in the economy and the resulting high interest rates. This translates into limited access to financing and its high cost. The anticipated economic slowdown and the uncertainty of the general economic and geopolitical situation do not improve conditions for conducting a business and making investment decisions with long-range effects. This applies particularly to owners of small fleets, who may require special support.

Based on interviews with market participants, the three main barriers from the perspective of small fleet owners are the cost of ownership, insufficient support from the public sector and the high cost of purchasing zero-emission vehicles[90]. Margins in the segment of small companies are generally small, access to external financing is more difficult, and they often rely on used (not new) internal combustion vehicles. From the perspective of such users, the development of a market for used zero-emission vehicles may be crucial for the transition. Owners of smaller fleets, especially sole proprietorships, also rely more heavily on public infrastructure and often cannot afford to purchase their own charging station. Such entities also rarely participate in pilot programs related to zero-emission vehicles (limited organizational resources) and have superficial knowledge about such vehicles. Lack of dedicated support for this segment poses a risk that small fleet owners will not be able to switch to zero-emission vehicles, which in turn may put at risk the achievement of emission reduction targets at the national level. In addition, the growing interest of recipients of services in reducing their carbon footprint through fleet electrification (e.g. the EV100 initiative[91]) means that unavailability of support for Polish micro-enterprises could damage their competitiveness in the international market and make them susceptible to being replaced by foreign entities.

At the same time, the offering of manufacturers, although consistently expanding, does not necessarily meet the needs of users and existing business models. So far, the market has been fairly homogeneous - seven largest manufacturers accounts for about 97% of sales of internal combustion vehicles (Box 4). In contrast, for zero-emission trucks, the same seven manufacturers account for only one-third of the models offered, with smaller manufacturers making their way in the market. An analysis of manufacturers' offerings indicates that users can currently choose from 74 models of zero-emission heavy-duty vehicles[92], but in the case of some, production is realized only on a small scale. Another problem is a rather limited offer when it comes to alternatives for the heaviest vehicles with the highest emissions, although it should be noted that major manufacturers have ambitious plans to decarbonize their production. For example, Daimler Truck and Scania intend to sell only zero-emission vehicles after 2040[93]. This commitment results from their positive projections for the development of the zero-emission vehicle market: by 2030, they could account for up to about 50% of newly sold heavy-duty vehicles. As a result, the number of available models is expected to increase significantly in the next few years: for the largest manufacturers targeting for the European market alone (Box 4), the model range is expected to grow from 10 in 2021 to 29 in 2025[94].

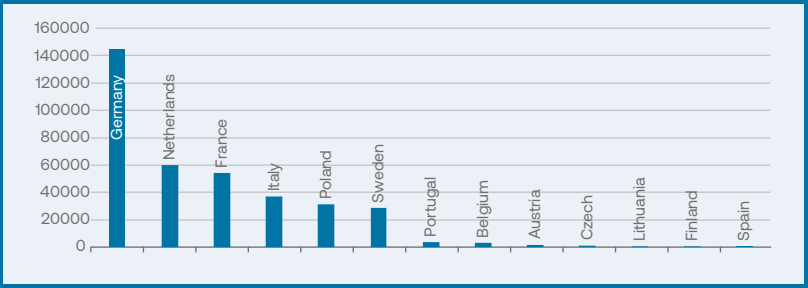
[90] Brito J. No fleet left behind: Barriers and opportunities for small fleet zero-emission trucking International Council on Clean Transportation Working paper 2022.
[91] Climate Group. EV100 members https://www.theclimategroup.org/ev100-members (accessed on: 5 April 2023).
[92] International Council on Clean Transportation Blog. A story of transition: how Europe's faring in its move to zero-emission trucks and buses https://theicct.org/ze-bus-and-truck-transition-europe-nov22/ (accessed on: 5 April 2023).
[93] Basma H., Rodríguez F. Race to Zero How manufacturers are positioned for zero-emission commercial trucks and buses in Europe International Council on Clean Transportation 2021.
[94] Transports Environment. HDV CO2 standards: T&E's view on the review and zero emission trucks.

Production of heavy-duty vehicles in Europe

In 2021, 17% of all commercial vehicles in the world were produced in Europe. In the EU, this included 470,388 heavy-duty vehicles, mostly in Germany (144,125). There are 52 factories in Europe engaged in the production of heavy-duty vehicles[95]. The market in Europe is dominated by seven brands: Mercedes (approximately 19% of the market), MAN (about 16%), DAF (about 15%), Volvo Trucks (about 15%), Scania (about 13%), Iveco (about 11%) and Renault (about 8%). Due to issues with the supply of chips, production in 2022 could have been lower by as much as 10% despite strong demand[96].

These brands also dominate the Polish market, accounting for more than 97% of all new vehicles sold in the medium and heavy-duty category in 2022. The share of other brands, though, has consistently increased: in 2017 they represented less than 0.7% of the market. For years, the most popular manufacturer among Polish customers has been DAF (21.0% of vehicles sold in 2022, 18.3% in 2017), although in recent years in terms of market share it has been nearly caught up by Mercedes (20.1% in 2022, 15.6% in 2017). Important other manufacturers, despite their relatively low share of the overall market for vehicles with GVW>3.5 t (6.7% in 2022, 6th overall), is Iveco, which is the main supplier of medium-duty vehicles (GVW in the range of 3.5-16 t), where they accounted for nearly 53% of new vehicles sold in 2022[97].

Fig. 10. Heavy-duty vehicle production in the EU in 2021.



Source: In-house analysis, ACEA data[98].

Market structure

The road transport industry is highly professionalized. Nearly 90% of ton-kilometers in the EU are covered by leased operators. Transport for own use is primarily relied on in the final part of distribution, making its share of tonnage significantly higher, but still below 25%. Professionalization is significantly higher in international than in domestic transport. More than 90% of its tonnage and 95% of its ton-kilometers were covered by leased operators. For Poland, the shares of leased transport are close to the EU average in both tonnage and ton-kilometers, but this is for slightly different reasons. The level of professionalization for domestic needs is lower than that of the EU, hired transport is responsible for about two-thirds of the tonnage, but this is compensated by even more professionalized international transport[99].

Road freight transport is relatively labor intensive and dominated by micro- and small enterprises. According to 2020 data, the industry's relative share of employment is higher than the relative value of output compared to the overall transport sector. At the same time, it was characterized by a significantly lower relative level of investment (Table 4). The total amount of investments made in the industry in 2020 was EUR 19.5 billion. At the same time, the share in the number of enterprises was considerably higher than in employment in the entire transport sector. On average, enterprises employed 5.9 people. Over the decade from 2011, the value increased, particularly as a result of market consolidation between 2011 and 2015 (a 5.4% drop in the number of companies) as well as market growth in subsequent years (the number of enterprises in 2020 was similar to that recorded in 2011). Due to strong fragmentation of the market, recipients of service may have an important role in shaping the market and in setting trends. In particular, large companies, such as those in the trade sector, can have a significant impact on the development of zero-emission transport due to their own climate goals.

For the Polish transport sector, road freight transport is much more important than for the EU. The share of the industry in the 2020 output was more than two times higher than in the EU and was well above 50%. As for the entire EU, the Polish industry was dominated by microenterprises, with their total number exceeding 100,000 (18.3% of enterprises in the EU). Although the employee productivity in the industry exceeded that of the transport sector, it was characterized by a relatively low level of investment.

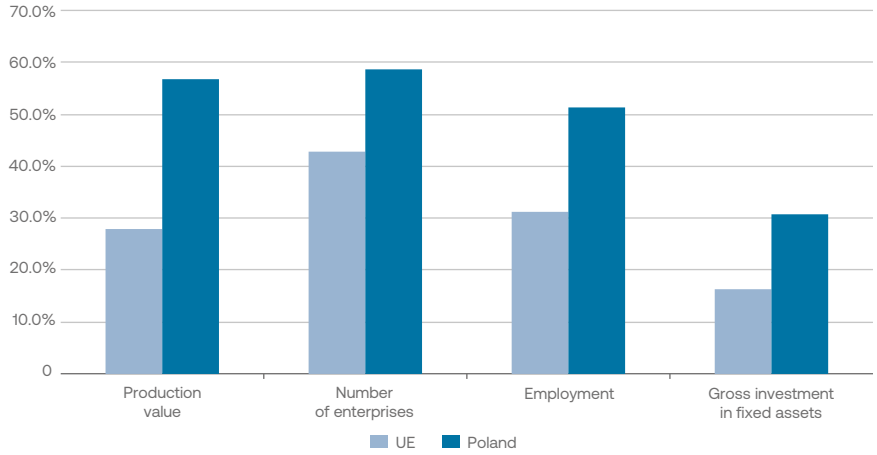
[95] ACEA The Automobile Industry Pocket Guide 2022/2023.
[96] Luman R., Soroka O. It's all about capacity in the truck market https://think.ing.com/articles/its-all-about-capacity-in-the-truck-market (accessed on: 5 April 2023).
[97] PZPM. Statistics, Automotive market, Vehicle registrations, Registrations - trucks including buses, 2022, December 2022 https://www.pzpm.org.pl/pl/Rynek-motoryzacyjny/Rejestracje-Pojazdow/Reiestracje-samochody-ciezarowe-w-tym-autobusy/Rok-2022/Grudzien-2022r (accessed on: 5 April 2023).
[98] ACEA The Automobile Industry Pocket Guide 2022/2023.
[99] Eurostat Data Browser. Summary of annual road freight transport by type of operation and type of transport (1000 t, Mio Tkm, Mio Veh-km) https://ec.europa.eu/eurostat/databrowser/view/ROAD_GO_TA_TOTT__custom_4525234/default/table (accessed on: 5 April

The industry's rapid growth was based primarily on growth in employment: its share in the sector's output has increased by 8.3pp since 2011 and in employment by 12.0pp. This also allowed the size of medium-sized enterprises to grow despite a significant increase in their number (by 19.3% from 83,870 in 2011 to 100,063 in 2020), from 3.4 to 4.9 employees.

Table 5: Share of road transport in the total value of transport for the main economic variables in the EU and Poland.

	Production value	Number of enterprises	Employment	Gross investment in fixed assets
UE	28.0%	42.7%	31,3%	16.2%
Poland	56.8%	58.7%	51.4%	30.8%

Fig. 11. Share of road transport in the total value of transport for the main economic variables in the EU and Poland.



Source: In-house analysis, Eurostat data[100].

Demand for road transport in the EU

The road freight transport industry in EU Member States is geared toward the distribution of goods within individual countries by domestic carriers. In 2021, it accounted for more than 90% of the total tonnage and more than half of the annual distance traveled. Considering that domestic trips are more often empty than foreign trips, realistically domestic trips accounted for nearly 70% of kilometers traveled. When cabotage (transport within one country by an entity from another country), treated as international transport[101], is also taken into account, this indicates that the industry is primarily focused on the final distribution of goods. However, the specific nature of cross-border routes means that cross-border transport still accounts for a major part of resource use. In particular, goods are transported over longer distances: its share in ton-kilometers exceeded 35% (Table 6). This also results from relatively lower number of empty vehicle trips than in domestic transport, and performance further improved thanks to relatively higher level of professionalization and the resulting greater focus on efficiency and fewer empty trips. In international transport in the EU, 92.5% of goods were carried by hired operators, while in domestic transport it was 74.4%, which translated into 95.9% and 85.8% of ton-kilometers, respectively[102].

Cross-border road freight transport in the EU is concentrated. Four countries: Germany, France, the Netherlands and Belgium, account for more than half of the tonnage of both cargo loading and unloading, which chiefly results from the location of major transshipment ports. Germany alone accounts for more than 20% of both values. The routes between these four countries[103] are among the main transport routes[104] in the EU, together with routes between Poland and Germany and between France and Spain (Table 7).

[100] Eurostat Data Browser. Annual detailed enterprise statistics for services (NACE Rev. 2 H-N and S95) https://ec.europa.eu/eurostat/databrowser/view/SBS_NA_1A_SE_R2__custom_4304077/default/table (accessed on: 6 April 2023).
[101] International transport refers to transport settled internationally. It includes cross-border transport and cabotage.
[102] 102 Eurostat Data Browser. Summary of annual road freight transport by type of operation and type of transport (1000 t, Mio Tkm, Mio Veh-km) https://ec.europa.eu/eurostat/databrowser/view/ROAD_GO_TA_TOTT__custom_4525234/default/table (accessed on: 5 April 2023).
[103] In addition to the route France – The Netherlands considered in both directions.
[104] Defined as routes, counted in both directions, that covered more than 2% of the entire cross-border road transport tonnage in the EU in 2020. The Germany-Austria route accounted for 2.4% of transport from Germany to Austria, but only 1.8% in the other direction.

Table 6: Characteristics of the road freight transport industry[105] in the European Union in 2021.

	Tonnage (thousand tons)	%	Ton-km (million tkm)	%	Vehicle kilometers (million veh-km)	%
Internal	12,386,973	90.7	1,178,069	61.3	86,477	52.0
Cabotage	192,589	1.4	55,030	2.9	3,651	2.2
Export	441,561	3.2	267,533	13.9	17,069	10.3
Import	356,084	2.6	215,867	11.2	13,275	8.0
Cross-trade	274,184	2.0	204,681	10.7	12,306	7.4
Total	1,580,517	100.0	1,921,179	100.0	166,330	100
Empty journeys - national transport	-	-	-	-	26,928	16.2
Empty journeys - international transport	-	-	-	-	6,624	4.0

Source: Eurostat[106].

Table 7: Key cross-border transport routes in the EU (t% / tkm%).

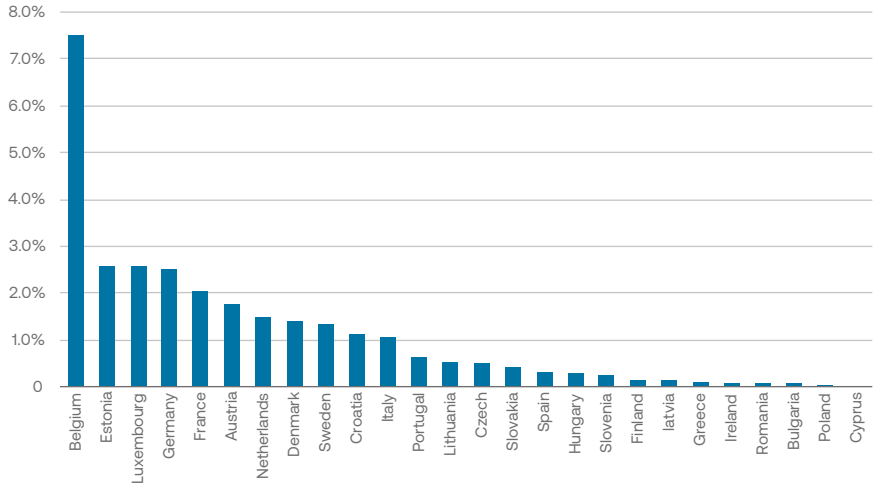
Route	PL-UE	PL-DE	DE-FR	DE-NL	DE-BE	FR-NL	FR-BE	NL-BE	FR-ES
From-To	9.4 / 11.8	4.1 / 3.9	2.7 / 2.3	5.0 / 2.1	2.2 / 1.2	0.0 / 0.0	2.7 / 1.3	3.2 / 0.0	2.2 / 2.5
To-From	8.1 / 11.0	3.2 / 3.4	2.2 / 2.0	4.4 / 2.2	2.3 / 1.4	1.2 / 1.1	3.1 / 1.6	2.8 / 0.0	2.8 / 3.5

Source: In-house analysis, Eurostat data[107].

[105] Data excludes vehicles with load capacity of up to 3.5 t and non-EU vehicles.
[106] Eurostat Data Browser. Summary of annual road freight transport by type of operation and type of transport (1000 t, Mio Tkm, Mio Veh-km) https://ec.europa.eu/eurostat/databrowser/view/ROAD_GO_TA_TOTT__custom_4525234/default/table (accessed on: 5 April 2023).
[107] Eurostat Data Browser. International annual road freight transport by country of loading and unloading with breakdown by reporting country (1000 t, Mio Tkm) https://ec.europa.eu/eurostat/databrowser/view/ROAD_GO_IA_RC__custom_4171867/default/table (accessed on: 5 April 2023).

Demand for cabotage in the EU is also highly concentrated. In 2021, more than 46% of demand expressed in tonnage came from Germany, with France and Belgium combined accounting for further more than 27%. In terms of ton-kilometers, the concentration is even greater: Germany and France accounted for almost 80% of demand[108]. Despite this, in these countries cabotage accounts for a relatively small part of all tonnage transported by road. This is due to the use of cabotage primarily on long routes: for almost all countries, the share in ton-kilometers is significantly higher than in tonnage in total domestic transport. In this regard, its role is much more important, especially in Germany and France. The exception is Belgium[109], where it share of tonnage was much more significant than in the other countries (7.5%) and was higher than in ton-kilometers (Fig. 13).

Fig. 12. Share of cabotage in total intra-state road transport in 2020 (% of tonnage).



Source: In-house analysis based on Eurostat data[110].

Demand for road transport is met by Polish carriers

The Polish road freight transport industry is focused on handling international demand. This is attributable to Poland's competitive advantages that promote the development of the industry: in addition to relatively low costs, these include high-skilled labor[111], its location next to Germany and on important transport routes, and the strong development of the internal market facilitating the expansion of the fleet[112]. Although the vast majority of tonnage is transported within Poland, this is done over relatively short distances. Measured in ton-kilometers, which allows for a better assessment of resource utilization, the share of internal transport shrinks to just over a third. Concurrently, internal transport is very inefficient: more than one-third of its vehicle-kilometers is traveled without cargo. In cross-border transport, the shares of export, import and cross-trade[113], measured in ton-kilometers, are similar, but have different characteristics: in cross-trade, more tonnage is transported, but it takes place over shorter distances than transport for Polish international trade. A smaller, albeit important niche from the perspective of Polish transport, is cabotage. Its lower share in international transport, however, is mostly attributable to its international nature and the resulting shorter trip distances. In terms of tonnage, it posted similar volumes to transport for the purposes of Polish import. International transport is also characterized by relatively high efficiency: only 12.5% of trips are empty, which translates into 6.9% of all trips of the Polish transport sector (Table 7).

[108] Eurostat Data Browser. Road cabotage by reporting country and country in which cabotage takes place (10001; 1000 tkm) - as from 1999 (Regulation (EC) 1172/98) https://ec.europa.eu/eurostat/databrowser/view/ROAD_GO_CA_HAC__custom_4176661/default/table (accessed on: 5 April 2023).

[109] Another exception was Croatia, where the share in tonnage exceeded the share in ton-kilometers, but the share of cabotage in domestic transport was much lower than in Belgium (0.5-1.5%).

[110] Eurostat Data Browser. All data https://ec.europa.eu/eurostat/databrowser/exp lore/all/all_themes?lang=en&display=list&sort=category (accessed on: 6 April 2023).

[111] CBRE, Panattoni Europe. Poland Logistics & Supply Chain Confidence Index 2017.

[112] Jezierski A. Competitiveness of the Polish system of road transport on the EU system of road transport - selected issues. Ekonomika i Organizacja Logistyki 2019;4:87-98.

[113] The main difference between cross-trade and cabotage is the location of loading and unloading goods. In the case of traditional cabotage, goods are loaded in the same country. Cross-trade, however, involves transport between two different countries, with the proviso that the carrier does not have its registered office in one of them.

Table 8: Characteristics of the Polish road freight transport industry in 2021.

	Tonnage (thousand tons)	Tonnage (% of total)	Ton-km (million tkm)	Ton-km (% of total)	Vehicle-km (million vkm)	Vehicle-km (% of total)
Internal	1,237,253	78.3%	134,730	35.5%	9,638	30.1%
Cabotage	72,173	4.6%	24,882	6.6%	1,632	5.1%
Export	92,486	5.9%	77,130	20.3%	5,055	15.8%
Import	77,370	4.9%	68,694	18.1%	4,066	12.7%
Cross-trade	101,235	6.4%	74,384	19.6%	4,448	13.9%
Total	1,580,517	100.0%	379,820	100.0%	32,049	100%
Empty journeys - national transport	-	-	-	-	5,001	15.6%
Empty journeys - international transport	-	-	-	-	2,209	6.9%

Source: In-house analysis, Eurostat data[114].

Table 9: Share of Polish carriers in cross-border road freight transport on key EU routes (%t / %tkm).

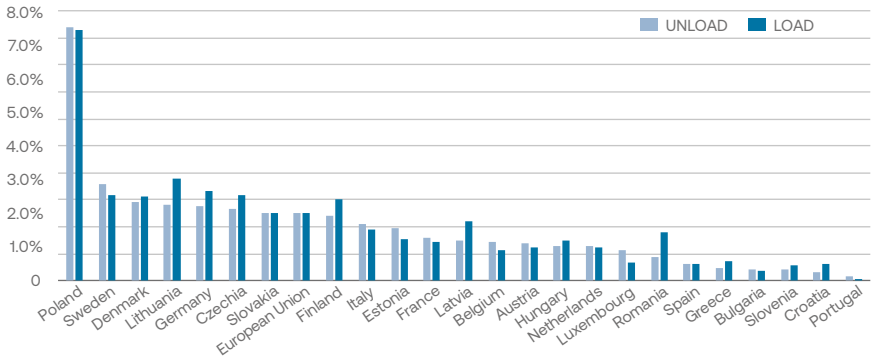
Route	Intra-EU	PL-UE	PL-DE	DE-FR	DE-NL	DE-BE	FR-NL	FR-BE	NL-BE
From-To	25.2 / 31.6	93.7 / 93.9	95.7 / 96.7	26.0 / 33.3	10.8 / 18.1	18.1 / 27.4	15.1 / 16.8	6.7 / 9.8	2.6 / 3.8
To-From	25.2 / 31.6	92.9 / 94.0	94.3 / 96.1	33.8 / 40.5	13.0 / 19.8	24.1 / 30.4	10.3 / 11.8	6.3 / 9.6	3.1 / 4.0

Source: In-house analysis, Eurostat data[115].

[114] Eurostat Data Browser. Summary of annual road freight transport by type of operation and type of transport (1 000 t, Mio Tkm, Mio Veh-km) https://ec.europa.eu/eurostat/databrowser/view/ROAD_GO_TA_TOTT__custom_4525234/default/table (accessed on: 5 April 2023).
[115] Ibid.

The specialization of the Polish industry makes it play a key role in the EU. It accounted for 11.6% of the tonnage carried in the EU in 2020, but this figure accounts for intra-state transport. In cross-border transport, the share was as high as 25.2%. In particular, this was due to the dominant role of national carriers in transport to and from Poland, but also their significant share in other main routes (Table 8), in particular between Germany and France. This translated into a substantial share of cross-trade (36.9%). For 9 of the 27 EU Member States, Polish carriers accounted for at least 20% of tonnage in export or import by road (Fig. 14). In addition, Polish carriers operated on routes with above-average distances, making the share in ton-kilometers even higher (31.6%). In addition to its significant role in cross-trade, the Polish transport industry is also responsible for 37.5% of cabotage in the EU. In particular, it is the main service provider for Germany, where it accounted for 58% of the market in 2021. In addition, it is also an important service provider for Denmark, Sweden, the Netherlands, France and the Visegrad group countries, among others. In total, the different forms of transport carried more tons than, for example, the volume of Polish international trade and accounted for more than 25% of market demand measured in ton-kilometers (Table 7).

Fig. 13. Share of Polish carriers in the international road freight transport within the EU (2020, % of tonnage).



Source: In-house analysis, Eurostat data[116].

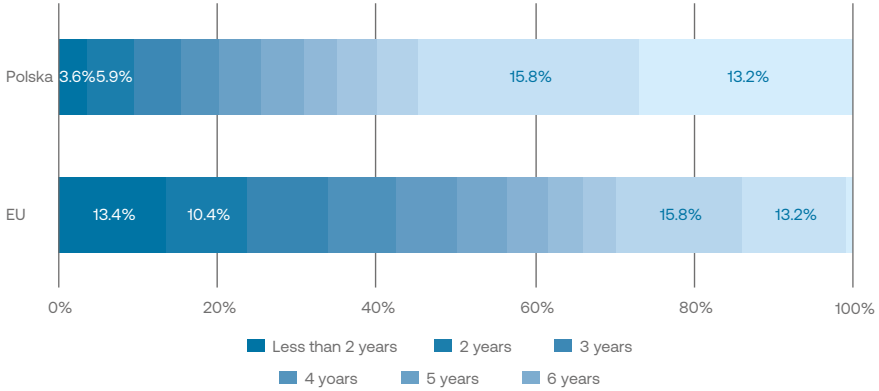
Fleet: age

The rapid growth of road transport in the EU is resulting in a relative rejuvenation of the fleet. In 2021, the average age of a vehicle with a total gross vehicle weight of more than 3.5 t was 13.9 years in the EU, according to ACEA[117]. However, given the data on their actual use measured in basic transport operations (BTO), realistically is most likely lower[118]. In 2021, more than a third of heavy-duty vehicle trips were made by vehicles younger than 4 years, and nearly a quarter by vehicles less than 2 years old (Fig. 15). To compare, vehicles older than 10 years covered 29.0% of trips. New vehicles are used on average longer-distance routes: the distance per route[119] drops for almost each earlier year of manufacture from more than 169 km for 2-year-old vehicles to about 56.5 km for vehicles more than 15 years old. New vehicles also carry more weight on average[120] [121].

Poland's fleet of heavy-duty vehicles is relatively old compared to the EU. Officially, the average age of a vehicle is lower, at 13.2 years in 2021. However, looking at fleet utilization data, it must be concluded that Polish vehicles are older than EU's. Vehicles above 10 years old accounted for more than a half of trips. In addition, the pandemic stalled the gradual replacement of the 2019-20 fleet, which has reduced their share from over 60%. At the same time, in terms of the rate of fleet replacement with new vehicles, Poland lagged behind the EU average in 2021 (Fig. 16). Although, as in the EU, in Poland the oldest vehicles are used, on average, to cover shorter distances with lighter cargo, for newer vehicles there is no clear trend as to distances traveled and weight carried[122].

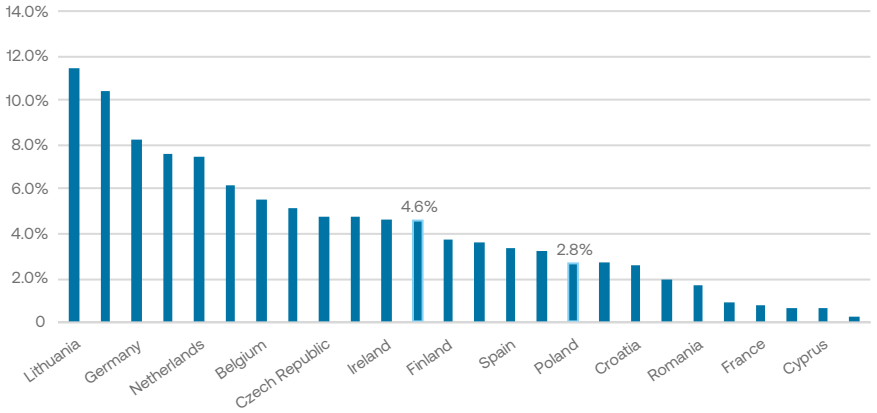
[116] Eurostat Data Browser. International annual road freight transport by country of loading and unloading with breakdown by reporting country (1000 t, Mio Tkm) https://ec.europa.eu/eurostat/databrowser/view/ROAD_GO_IA_RC_custom__4171867/default/table (accessed on: 5 April 2023).
[117] ACEA. Vehicles in use Europe 2022.
[118] However, Eurostat's data on actual fleet utilization does not take into account vehicles with a load capacity of less than 3.5 tons included in the set of vehicles with a gross vehicle weight of more than 3.5 t and vehicles older than 25 years.
[119] Measured as vehicle-kilometers/trip.
[120] Measured as ton-kilometers/vehicle-kilometers.
[121] Eurostat Data Browser. Annual road freight transport, by age of vehicle (Mio Tkm, Mio Veh-km, 1 000 Jrnys) https://ec.europa.eu/eurostat/databrowser/view/ROAD_GO_TA_AG_EV_custom__4176757/default/table (accessed on: 5 April 2023).
[122] Ibid.

Fig. 14. Share of vehicles by age in trips made in road freight transport in 2021.



Source: In-house analysis, Eurostat data[123].

Fig. 15. New registrations in 2021 vs. fleet size in 2020.



Source: In-house analysis based on PZPM[124] and ACEA[125] data.

Imports of used vehicles are similar to purchases of new vehicles, but demand for used vehicles is likely to decline. It accounted for about 50% of newly acquired vehicles by Polish companies since 2018. Demand for them proved stable during the pandemic, resulting in an increase in their share in total HDV sales in 2020. Despite this, their gradual abandonment has been observed in recent years, with the exception of 2021, when an increase in demand as part of the post-pandemic rebound resulted in a surge in demand for heavy-duty vehicles. Their share in sales most likely fell below 42% in 2022 (Table 10).

Table 10: Registration of new and import of used vehicles.

	2018	2019	2020	2021	2022
New	29870	28317	20671	32684	36061
Imported used	29066	28246	27174	32908	26000
Share of import	49.3%	49.9%	56.8%	50.2%	41.9%

Source: In-house analysis, PZPM data[126] [127].

Fleet: tonnage categories

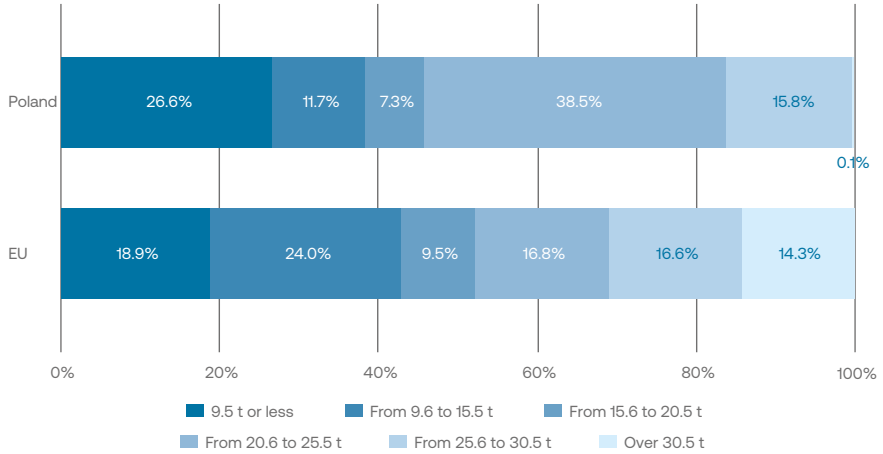
The drive to make the most efficient use of resources is promoting vehicles with higher gross vehicle weight in road transport. More than half of the trips in 2021 in the EU were made by vehicles with GVW of more than 30 t. At the same time, the COVID pandemic had a strong impact on the operation of this segment. Before the pandemic, growth was recorded in the segment of the heaviest vehicles: with GVW of more than 40 t, which partially crowded out the 30-40 t vehicles. This was most likely due to the development of intermodal transport, as under EU regulations such vehicles could only be used for it, although in 2019 an exception was made for zero-emission vehicles by allowing them to exceed 40 t by the difference in the weight of the powertrain[128].

[123] Ibid.
[124] PZPM. Statistics, Automotive market, Vehicle registrations, Registrations – trucks including buses, 2021, December 2021 https://www.pzpm.org.pl/pl/Rynek-motoryzacyjny/Rejestracje-Pojazdow/Rejestracje-samochody-ciezarowe-w-tym-au-tobusy/Rok-20212/Grudzien-2021r (accessed on: 6 April 2023).
[125] ACEA. Vehicles in use Europe 2023 January 2023.
[126] Data from annual reports for specific years, where data is adjusted in subsequent years, there may be slight differences compared to data from later reports and Statistics Poland data.
[127] PZPM. Statistics, Automotive market, Vehicle registrations, Registrations – trucks including buses, February 2023 https://www.pzpm.org.pl/pl/Rynek-motoryzacyjny/Rejestracje-Pojazdow/Rejestracje-samochody-ciezarowe-w-tym-autobusy/Luty-2023 (accessed on: 5 April 2023).
[128] Council Directive 96/53/EC of 25 July 1996 laying down for certain road vehicles circulating within the Community the maximum au©thorized dimensions in national and international traffic and the maximum authorized weights in international traffic.

Between 2012 and 2019, demand for their services measured by the number of trips increased by more than a third, while for 30-40 t vehicles it fell by about 10%. However, in 2020-2021 demand for the services of more than 40 t vehicles collapsed so much that it fell by more than a fifth relative to 2012. It was replaced by stronger demand for the services of 30-40 t vehicles, leaving the demand for the services of the entire segment of vehicles above 30 t unchanged relative to 2012. Apart from vehicles with GVW of more than 30 t, an important segment consists of vehicles with GVW of 10-20 t. Its development also accelerated during the pandemic: the number of trips rose by more than 30% after stability recorded in previous years.

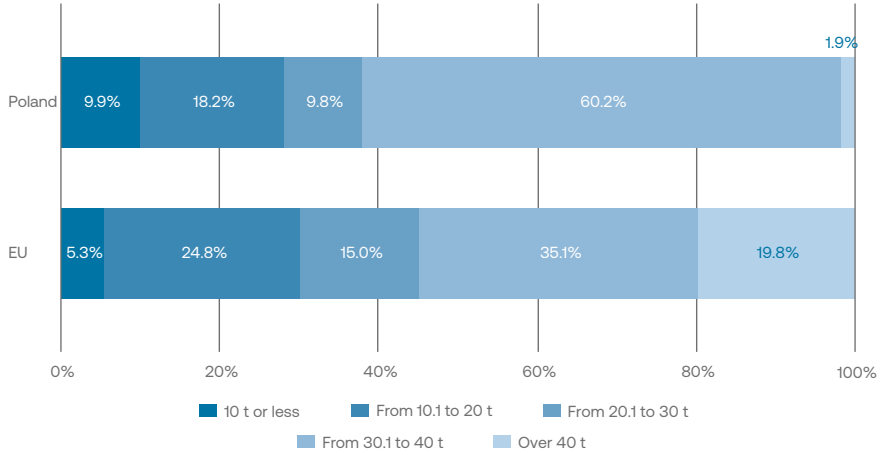
In terms of carried weight, Polish fleet is strongly specialized and focused on the 20.5-30.5 t range, which results in domination of vehicles with GVW of 30-40 t. In 2021, approximately 60% of trips and 80% of vehicle-kilometers were attributed to vehicles with GVW of 30-40 t. The development of this segment was so strong that in terms of trips, demand in this segment increased by nearly 55% over ten years, while dropping in other segments, the exception being vehicles up to 10 t (up 8.7%). These vehicles also cover the longest routes on average. This entails the development of vehicles with specific load capacity. The main group consists of vehicles with a load capacity of 20.5-25.5 t. In 2021, they accounted for 38.5% of all vehicles, and in 10 years demand for their services nearly doubled. On average, they are operated on the longest routes, making their share of kilometers traveled significantly higher, at more than 64% in 2021. Apart from them, the 25.5-30.5 t segment has grown rapidly, with its share of trips increasing by more than 80% in 10 years, largely thanks to a surge in demand in 2021 by about 24%. They are mostly used on shorter routes. The growth of these groups reduces demand for services of vehicle with lower load capacity, except for medium-duty vehicles[129], while vehicles with a load capacity higher than 30.5 t have an insignificant share of the overall market (Fig. 16).

Fig. 16.



Source: In-house analysis, Eurostat data[130].

Fig. 17.



Source: In-house analysis, Eurostat data[131].

[129] Here defined as vehicles with a load capacity of less than 9.5 t.
[130] Eurostat Data Browser. Annual road freight transport, by load capacity of vehicle (Mio Tkm, Mio Veh-km, 1 000 Jrnys) https://ec.europa.eu/eurostat/databrowser/view/ROAD_GO_TA_LC__custom_4176494/default/table (accessed on: 6 April 2023).
[131] Eurostat Data Browser. Annual road freight transport by maximum permissible laden weight of vehicle (Mio Tkm, Mio Veh-km, 1 000 Jrnys) https://ec.europa.eu/eurostat/databrowser/view/ROAD_GO_TA_MPLW__custom_4176932/default/table (accessed on: 6 April 2023).

Drivetrain technologies

The electrification of the sector, while growing rapidly, is still at an early stage, and the market is dominated by diesel vehicles. In view of Eurostat data on the number of vehicles by type of drivetrain (Box 5) in the countries that reported such data, more than 90% of registered heavy-duty vehicles with GVW of more than 3.5 t used this propulsion. For tractor units[132] the figure is even higher, at 96.5%. This is consistent with data on sales of these vehicles by fuel used. In 2021, the share of diesel vehicles exceeded 95% (Fig. 18). In the case of electrification of the segment, it is currently difficult to assess its level due to conflicting data (Box 5). Given the sales data provided by manufacturers, it should be pointed out that this market has developed more and more rapidly. Their share of EU sales increased fivefold between 2018 and 2021 (Fig. 17). However, this largely results from the base effect, and in total they account for only about 0.5% of the market. Due to the early stage of market development, it is currently difficult to identify clear market leaders: according to ACEA, relatively the largest share of electric vehicles is in the Czech Republic[133], but this is a small market; according to EAFO, in terms of absolute size of the zero-emission fleet, Germany is the leader with 902 battery and 27 hydrogen fuel cell vehicles[134]. Potentially, according to Eurostat data, Poland could also be the leader, but considering other sources of information this does not seem to be true, with the number of such vehicles not exceeding 10 (Box 5).

Data

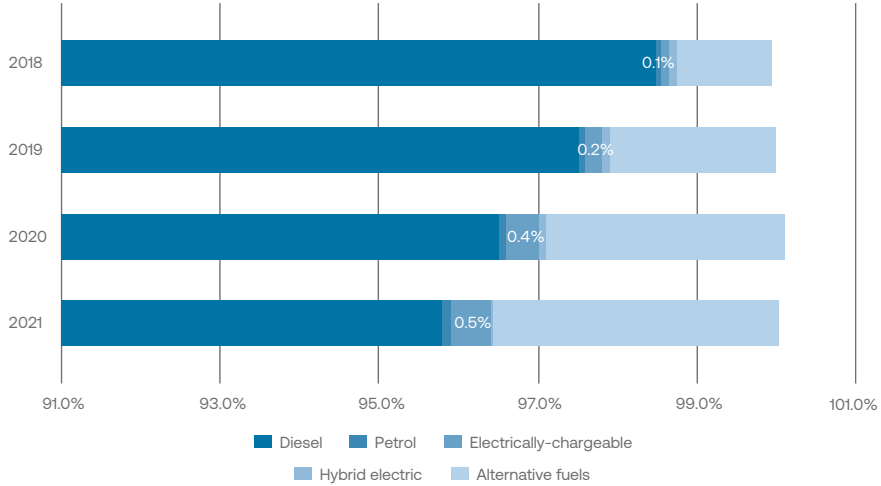
The availability and quality of publicly available data on road transport, particularly its electrification, is limited. Eurostat data is based on information collected by national statistical centers and is not always complete, or is based on assumptions and should be treated as an approximation. For example, Statistics Poland collects data on heavy-duty vehicles based on their load capacity, not their GVW. For the purposes of Eurostat, it has been assumed that load capacity of more than 1.5 t is equivalent to GVW of more than 3.5 t.

Another source of challenge when analyzing data is its correspondence with real-life use of vehicles. Public data based on vehicle records may include vehicles that are not actually operated, if for some reason they have not been unregistered. To avoid such errors, various solutions can be applied, e.g. in its yearbooks PZPM uses the concept of archived vehicles: vehicles that are over 10 years old (age computed in reference to their first registration date) which were not updated in the CRV databases in the past six years, provided these are not vintage cars. According to their estimates, these accounted for as many as over 9 million of the 34 million vehicles in the base[135]. In order to minimize errors related to this aspect, the report estimates the fleet primarily on the basis of Eurostat estimates of actual fleet utilization[136].

The shortcomings in public data make it particularly difficult to assess the number of zero-emission vehicles because of the fact that the technology is new: small errors in absolute values have a significant impact on the interpretation of information. An extreme example of this is Poland, which, depending on the data source, may be a market leader (Eurostat) or have no share of the market (ACEA). According to Eurostat, there are 701 vehicles with GVW of more than 3.5 t with an electric motor in Poland, which means that among the countries for which Eurostat provides such data (namely excluding Germany, for example), more than half of the vehicles are in Poland. However, considering other sources and interviews with market participants, it seems that this number is incorrect and the most reliable one is given by EAFO: 5 in 2021.

[132] For which the data was based on information from more countries.
[133] ACEA. Vehicles in use Europe 2023 January 2023.
[134] European Commission European Alternative Fuels Observatory. Country comparison https://alternative-fuels-observatory.ec.europa.eu/transport-mode/road/european-union-eu27/country-comparison (accessed on: 4 April 2023).
[135] PZPM. PZPM and KPMG Yearbook of Automotive Industry 2022/2023 https://www.pzpm.org.pl/pl/Publikacje/Raporty/Rocznik-Raport-Branzy-Motoryzacyjnej-PZPM-i-KPMG-2022-2023 (accessed on: 5 April 2023).
[136] Eurostat. Methodologies used in road freight transport surveys in Member States, EFTA and Candidate Countries 2021.

Fig. 18. New trucks in the EU by fuel type.



Source: ACEA[137] [138].

Current challenges and market development forecasts

Despite numerous challenges, the Polish road transport industry has significant potential for further growth, although this may be primarily based on consolidation in the next few years. The entry into force of the Mobility Package in 2022 has raised costs for businesses, primarily due to the introduction of the need for periodic return of vehicles operated on cross-trade and cabotage routes. In the medium term, however, these changes are an opportunity for Polish carriers due to:

- the location;
- the fact that about half of trips already meet the introduced standards;
- the relative ease of finding goods to be carried on additional trips[139].

In particular, the position of the Polish industry relative to Eastern European competitors[140] should improve significantly. Potentially, the change should result in the relocation of some operations from countries more distant from the main transport routes to Poland[141]. Another problem is the shortage of drivers - in 2021, it was estimated that there was a shortage of more than 380,000 drivers in Europe[142]. Continued recovery of demand resulted in a further aggravation of the shortage in 2022 to about 450,000, of which potentially some 150,000 in Poland alone. The situation has been made more difficult by the war in Ukraine, as may have been the reason why approximately 25-30% of the 110,000 Ukrainian drivers left Poland[143]. The war also resulted in a spike in fuel and energy prices[144]. The difficulty of raising capital has also become greater due to higher cost of credit, which also involved the additional problem of the cost of debt service. In 2022, outstanding liabilities to counterparties[145] were reported by more than 28,000 enterprises in the "transport, forwarding, logistics" sector, totaling more than PLN 1.1 billion[146]. At the same time, the market outlook is positive. It is expected that demand will continue to grow, potentially resulting in a 26% increase in value in real terms by 2026 relative to 2019. For Poland, forecasts are potentially even more promising, as growth is expected to be stronger in the segment of international transport (up approximately 30%)[147]. The industry's financial problems in the short term, combined with the market's potential for growth in the medium term, should be conducive to its consolidation, but in the short term may limit investment, as funds may be used to absorb market shocks and the cost of business combinations.

[137] ACEA. New trucks in the EU by fuel type https://www.acea.auto/figure/trucks-eu-fuel-type/ (accessed on: 6 April 2023).
[138] Due to the rounding error, data may not add up to 100%.
[139] European Commission, Directorate-General for Mobility and Transport. Amaral, S., Scammell, H., Pons, A., et al., Assessment of the impact of a provision in the context of the revision of Regulation (EC) No 1071/2009 and Regulation (EC) No 1072/2009: final report, Publications Office, 2021, https://data.europa.eu/doi/10.2832/991950.
[140] Significant role will be played by Lithuania and Romania, as the main countries besides Poland operating cross-trade and cabotage routes.
[141] Transport Intelligence. European Road Freight Transport Market Forecasts: 2021 and 2026 2022.
[142] IRU Intelligence Briefing. Driver Shortage Global Report 2022: Summary, Understanding the impact of driver shortages in the industry.
[143] Nowak K. Alarmujące dane - w Polsce brakuje aż 150 tys. kierowców ciężarówek. Wielu wyjechało na Ukrainę https://natemat.pl/466322,w-polsce-brakuje-az-150-tys-kierowcow-ciezarowek-to-wplynie-na-ceny (accessed on: 5 April 2023).
[144] It must be noted that it was not the only factor that affected the situation; in particular, the post-pandemic recovery in demand and the drought in Western Europe reinforced these trends.
[145] Data until September.
[146] Money.pl. Firmy transportowe toną w długach. Do oddania jest ponad miliard złotych https://www.money.pl/gospodarka/firmy-transportowe-tona-w-dlugach-do-oddania-jest-ponad-miliard-zlotych-6834139072780992a.html (accessed on: 5 April 2023).
[147] Transport Intelligence. European Road Freight Transport Market Forecasts: 2021 and 2026 2022.

Summary and conclusions for the zero-emission vehicles industry

The electrification of road transport is hindered by the limited funds that transport companies can earmark for investment. These chiefly/mainly include micro-enterprises for which the purchase of an electric vehicle would represent a significant cost. The industry development outlook is positive. Electrification of the Polish fleet is also in the interest of other EU Member States.

- The structure of the market: based on micro-enterprises and highly labor-intensive, as a result of which the level of investment is relatively low compared to the value of the industry. This situation is not exclusively true of Poland, as in most EU markets road transport is dominated by small and micro-enterprises.
- Due to the important role of Polish transport in other EU markets, electrification of the fleet is not only in the interest of Poland, but also other EU Member States, particularly Germany.
- The fleet operated in Poland is large and relatively old compared to the EU, making it important to encourage and support vehicle replacement in order to achieve the best environmental performance. Activities focused solely on supporting the acquisition of a new vehicle may prove ineffective.
- The significant share of N2 category vehicles in Poland should support the electrification of transport, as from the technological point of view such vehicles should be the easiest to replace, given their shorter routes and the fact that they do not need to use publicly accessible charging stations.
- However, to ensure that the electrification process is carried out effectively and smoothly, support should also be aimed at the heaviest vehicles, which make up by far the largest part of the market (GVW of 30-40 t).
- Despite a series of strong negative shocks on the market (pandemic, surge in fuel prices, shortage of qualified staff aggravated by an outflux of employees from Ukraine), the forecasts for the development of the road freight transport market are positive for the coming years.
- Nonetheless, inflation and potential costs of market consolidation in relatively high interest rates environment may result in companies lacking the resources to electrify their fleets in the coming years.

Chapter 3. Regulatory environment and review of support instruments

Regulatory environment in the EU

Given the European Union's ambitious climate goals, namely, to cut greenhouse gas emissions by at least 55% by 2030 and achieve climate neutrality by 2050, decarbonization of the transport sector is one of the key areas contributing to the achievement of these targets. In this chapter, we present the regulatory framework that takes into account both the regulations already in place and the initiatives under way as part of the European Green Deal (EGD)[148], in particular the Fit for 55 package[149]. In the transport sector, although the legislative work is focused mainly on passenger cars, there are also provisions aimed at increasing the share of zero-emission heavy-duty vehicles (GVW>3.5 t) in road transport (see Diagram 1).

Diagram 1. EU regulatory framework - decarbonization of heavy-duty vehicles.

EU regulatory framework - transition to zero-emission heavy-duty vehicles			
Strategy papers	Key horizontal regulations addressing transport	Regulations directly related to zero-emission heavy-duty vehicles	Other regulations to improve the competitiveness of zero-emission heavy-duty vehicles
Sustainable and Smart Mobility Strategy	EU CO2 emissions trading scheme for building and transport sectors	Directive on the Promotion of Clean and Energy-Efficient Road Transport Vehicles	Fuel Quality Directive
	Revision of the Effort Sharing Regulation	Alternative Fuels Infrastructure Regulation	Directive as Regards the Charging of Vehicles for the Use of Certain Infrastructures (Eurovignette)
	Revision of Directive on the Promotion of the Use of Energy From Renewable Sources	Revision of the Regulation setting CO2 emission standards for new heavy-duty vehicles	Proposal for an Update of the Energy Tax Directive
			New Euro 7 standards
			Proposal for a revision of the Air Quality Directive

Source: In-house analysis.

Strategy papers

Sustainable and Smart Mobility Strategy

Status of document: effective

One of the initiatives within the framework of the European Green Deal is the **Sustainable and Smart Mobility Strategy**[150], released in December 2020, which calls for at least 30 million of zero-emission passenger cars and 80,000 zero-emission trucks by 2030, and assumes that nearly all cars, vans, buses as well as new heavy-duty vehicles will be zero-emission by 2050. In addition, the strategy points to the need to increase the use of renewable and low-carbon fuels and increase the number of public recharging points.

Key indicators

- 80,000 zero-emission trucks by 2030.
- nearly all heavy-duty vehicles will be zero-emission by 2050.

Key horizontal regulations addressing transport

Emissions Trading System for buildings and road transport, ETS2

Status of document: provisions agreed, preparation for entry into force

As part of the Fit for 55 legislative package, on 18 December 2022 the European Parliament and governments of Member States participating in the Council of the EU reached

[148] European Commission Communication. The European Green Deal, COM(2019) 640 final 2019.
[149] European Commission Communication. "Fit for 55": delivering the EU's 2030 climate target on the way to climate neutrality COM(2021) 550 final.
[150] European Commission Communication. Sustainable and Smart Mobility Strategy – putting European transport on track for the future COM(2020) 789 final.

an agreement to amend the EU ETS (Emission Trading System)[151]. In early February 2023, the final text of the directive containing the agreed changes was released[152].

The outcome of the talks is also of great importance for the European transport and heating sectors. One of the main changes is the creation of the so-called "ETS2", i.e. the coverage of the transport and buildings sector (both commercial and private) with a separate mechanism of the EU's emission trading system[153]. In particular, the new system is to apply to suppliers of fossil fuels that are used in the sectors referred to above. In the latest negotiations, the ETS2 was proposed to be introduced in 2027 or 2028. The pace at which the system would be introduced for the transport and heating sectors would depend on energy prices - if they were very high, the effectiveness of allowances would be delayed until 2028[154]. The EU will also introduce a mechanism to regulate the price of allowances - if it exceeded EUR 45, 20 million additional allowances could be released. Part of the ETS2 auction revenues is to support vulnerable customers, including households and micro-enterprises, under the Social Climate Fund (SCF). From the perspective of electrification of heavy-duty vehicles, this means that the resources accumulated in the Fund will have limited use as priority will be given to other groups of beneficiaries. More investment opportunities may come from the Modernization Fund, earmarked for energy transition for less wealthy countries and benefiting from EU ETS auction revenues, which already offers support for the development of electric vehicle charging infrastructure[155].

In the next steps, the concluded agreement will be officially adopted by the Parliament and the Council, after which it will be published in the Official Journal of the EU, which will mark its effective date.

Key indicators

- coverage of the transport and buildings sector with a separate mechanism of the EU's emission trading system, resulting in a higher cost of use of fossil fuels in the sector

Revision of the Effort Sharing Regulation (higher reduction targets for non-ETS sectors)

Status of document: provisions agreed, preparation for entry into force

Separate, binding EU-wide and national greenhouse gas reduction targets for 2021-2030 have been set for sectors not covered by the EU's CO2 emissions trading scheme (non-ETS), namely transport, buildings, agriculture, industry and waste. In this context, emissions from heavy-duty vehicles, in addition to their inclusion in the new ETS2, will also count towards the reduction targets specified based on the Effort Sharing Regulation (ESR)[156]. According to the proposal for a revision of the regulation[157], presented as part of the Fit for 55 legislative package, the EU-wide reduction target for all non-ETS sectors is to be 40% by 2030 compared to 2005. At Member State level, the binding target is determined depending on GDP per capita. For example, the reduction target for Poland by 2030 is to be 17.7% compared to 2005. Each Member State accounts for its targets based on annual limits of AEA (Annual Emission Allocation) units. If there is a shortage or surplus of AEAs, Member States can trade them. Therefore, this creates not only regulatory but also financial incentives for Member States to achieve emission reduction in the sectors covered by the regulation - including in heavy-duty transport. The final text of the regulation[158] containing the aforementioned solutions was agreed by the EU institutions in late 2022.

[151] European Parliament News. Climate change: Deal on a more ambitious Emissions Trading System (ETS) https://www.europarl.europa.eu/news/en/press-room/20221212IPR64527/climate-change-deal-on-a-more-ambitious-emissions-trading-system-ets (accessed on: 5 April 2023).
[152] Directive (EU) 2023/... of the European Parliament and of the Council of... amending Directive 2003/87/EC establishing a system for greenhouse gas emission allowance trading within the Union and Decision (EU) 2015/1814 concerning the establishment and operation of a market stability reserve for the Union greenhouse gas emission trading scheme.
[153] European Commission. Proposal for a Directive of the European Parliament and of the Council amending Directive 2003/87/EC establishing a system for greenhouse gas emission allowance trading within the Union, Decision (EU) 2015/1814 concerning the establishment and operation of a market stability reserve for the Union greenhouse gas emission trading scheme and Regulation (EU) 2015/757 COM(2021) 551 final.
[154] ETS2 will have an emergency brake, triggered if natural gas prices exceed 106 EUR/mWh. At this price, ETS2 will come into effect in 2028; Di Sario F. EU reaches deal on critical climate policy after marathon talks https://www.politico.eu/article/climate-policy-deal-emissions-trading-system-european-union/ (accessed on: 5 April 2023).
[155] Elektromobilni.pl. Inwestycje w infrastrukturę. Konkursy na dofinansowanie ruszają https://elektromobilni.pl/konkursy-na-dofinansowanie-ruszaja/ (accessed on: 5 April 2023).
[156] Regulation (EU) 2018/842 of the European Parliament and of the Council of 30 May 2018 on binding annual greenhouse gas emission reductions by Member States from 2021 to 2030 contributing to climate action to meet commitments under the Paris Agreement and amending Regulation (EU) No 525/2013.
[157] European Commission. Proposal for a Regulation of the European Parliament and of the Council amending Regulation (EU) 2018/842 on binding annual greenhouse gas emission reductions by Member States from 2021 to 2030 contributing to climate action to meet commitments under the Paris Agreement COM(2021) 555 final.
[158] Proposal for a Regulation of the European Parliament and of the Council amending Regulation (EU) 2018/842 on binding annual greenhouse gas emission reductions by Member States from 2021 to 2030 contributing to climate action to meet commitments under the Paris Agreement, and Regulation (EU) 2018/1999.

Key indicators

- emissions from non-ETS sectors (including transport) are subject to a binding 2030 emission reduction target, which for Poland totals 17.7% compared to 2005. As a result, Poland will have to introduce legal and financial instruments leading to emission reductions in road transport.
- these emissions are covered by a separate emissions trading system (AEA) at Member State level, which creates financial incentives for governments to implement appropriate national regulations to ensure reductions in individual sectors - including in road transport, which currently accounts for about 30% of the emissions covered by the regulation[159].

Revision of Directive (EU) 2018/2001 of the European Parliament and of the Council of 11 December 2018 on the promotion of the use of energy from renewable sources (more ambitious RES targets)

Status of document: provisions agreed, preparation for entry into force

As ambitions for the share of renewable energy sources, also in the transport sector, are being raised at the EU level, from the perspective of heavy-duty vehicles it is worth noting the Directive **on the promotion of the use of energy from renewable sources**[160], which sets a target for the share of renewable energy in total EU's energy production of at least 32% by 2030. To support Member States in achieving this goal, the directive introduced a range of sector-specific measures, including for the transport sector:

- obligation to ensure at least that **renewable energy accounts for at least 14% in the final energy consumption in the transport sector by 2030** using, among other things, biofuels and biocomponents, including advanced biocomponents or renewable fuels of non-biological origin (RFNBO)[161] or recycled carbon fuels[162],
- the share of advanced biofuels in final energy consumption in the transport sector was set at no less than 3.5% in 2030.
- The greenhouse gas emissions savings from the use of renewable liquid and gaseous transport fuels of non-biological origin should be at least 70% from 1 January 2021.

A proposal to update the Fit for 55 document was proposed in July 2021 (the so-called RED III)[163]. Initially, the new RES target was supposed to be 40%, but in the RePowerEU plan[164], published in 2022, in response to the energy crisis caused by Russia's aggression against Ukraine, the European Commission proposed to further raise the EU's ambition in this area and achieve a RES share of 45% by 2030. One of the elements to achieve this goal is to accelerate the electrification of the transport sector based on RES.

At the end of March 2023, the Council of the European Union and the European Parliament reached a preliminary agreement on the revision of the Renewable Energy Directive[165], which raised **the binding target for the share of RES in final energy consumption to 42.5%** from 2030, with a non-binding trajectory to increase the target to as much as 45%. In addition, the following provisions concerning the transport sector were revised:

- individual decision of each Member State to set a specific target for the transport sector for 2030:
  - reduction of greenhouse gas emissions from transport fuels by **14.5%** or
  - increasing the share of renewable energy in transport to **29%** from the existing 14%,
- the share of advanced biofuels and RFNBO (green hydrogen and related fuels) in final energy consumption in the transport sector was set at **5.5%** from 2030 (of which at least **1% for RFNBO**).

The next step is the final approval of the agreement by the entire Parliament and Council of the European Union, followed by its publication in the Official Journal of the European Union.

[159] Ministry of Climate and Environment. Poland's National Inventory Report 2022, Greenhouse Gas Inventory for 1988-2020, National Centre for Emission Management (KOBiZE) at the Institute of Environmental Protection – National Research Institute 2022.
[160] Directive (EU) 2018/2001 of the European Parliament and of the Council of 11 December 2018 on the promotion of the use of energy from renewable sources.
[161] Liquid and gaseous fuels the energy content of which is derived from renewable sources other than biomass. E.g. green hydrogen.
[162] Liquid and gaseous fuels that are produced from liquid or solid waste streams of non-renewable origin which are not suitable for material recovery, or from waste processing gas and exhaust gas of non-renewable origin which are produced as an unavoidable and unintentional consequence of the production process in industrial installations. Definition consistent with Directive (EU) 2018/2001 of the European Parliament and of the Council of 11 December 2018 on the promotion of the use of energy from renewable sources.
[163] European Commission. Proposal for a Directive of the European Parliament and of the Council amending Directive (EU) 2018/2001 of the European Parliament and of the Council, Regulation (EU) 2018/1999 of the European Parliament and of the Council and Directive 98/70/EC of the European Parliament and of the Council as regards the promotion of energy from renewable sources, and repealing Council Directive (EU) 2015/652 COM(2021) 557 final.
[164] European Commission. Proposal for a Directive of the European Parliament and of the Council amending Directive (EU) 2018/2001 on the promotion of the use of energy from renewable sources, Directive 2010/31/EU on the energy performance of buildings and Directive 2012/27/EU on energy efficiency COM(2022) 222 final.
[165] Council of the European Union Press release. Council and Parliament reach provisional deal on renewable energy directive https://www.consilium.europa.eu/en/press/press-releases/2023/03/30/council-and-parliament-reach-provisional-deal-on-renewable-energy-directive/ (accessed on: 5 April 2023).

Key indicators

- to be chosen by the Member State - a 14.5% reduction in greenhouse gas emissions by 2030 or a target to increase the share of renewable energy in transport to 29%
- the share of advanced biofuels and RFNBO in final energy consumption in the transport sector was set at 5.5% in 2030, of which at least 1% for RFNBO

Regulations directly related to zero-emission heavy-duty vehicles

Directive (EU) 2019/1161 of the European Parliament and of the Council of 20 June 2019 amending Directive 2009/33/EC on the promotion of clean and energy-efficient road transport vehicles

Status of document: effective

An important way to stimulate demand for low-emission vehicles, including heavy-duty vehicles, is to increase their share in public procurement. To that end, the directive on the promotion of clean and energy-efficient road transport vehicles[166] defines, among other things, clean vehicles and zero-emission heavy-duty vehicles, and sets national targets for their share in public procurement.

According to the definition, a clean heavy-duty vehicle is a truck or a bus that uses one of the following alternative fuels: hydrogen, electric battery (including plug-in hybrids), natural gas (both CNG and LNG, including biomethane), liquid biofuels, synthetic and paraffinic fuels, LPG.

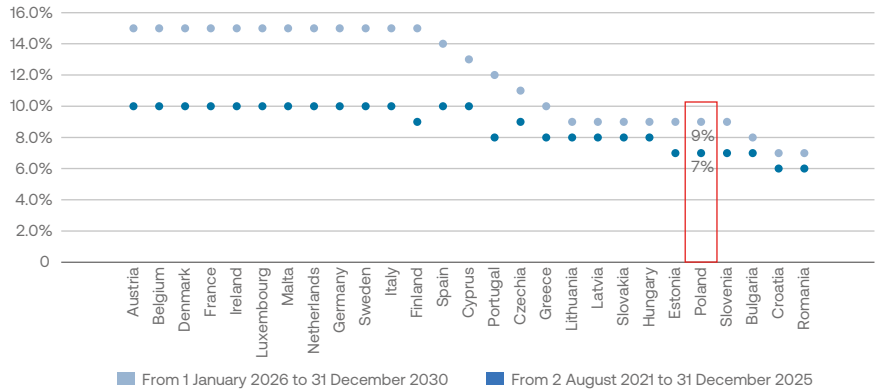
The directive applies to public procurement related to:
- contracts for the purchase, lease, rental and hire-purchase of road transport vehicles,
- passenger public transport service contracts,
- public road transport services, special-purpose and non-scheduled passenger transport services, refuse collection services, mail and parcel transport and delivery services.

For Poland, the directive specifies the following minimum percentage of clean heavy-duty vehicles (vehicle of category N2 and N3[167]) in public procurement:

- **7%** - from 2 August 2021 to 31 December 2025
- **9%** - from 1 January 2026 to 31 December 2030

By comparison, the corresponding targets for buses (vehicle of category M3) are respectively 32% and 46%. The specified minimum targets for vehicles of category N2 and N3 for all Member States are shown in Fig. 19.

Fig. 19. Minimum procurement targets for the share of clean heavy-duty vehicles in the total number of heavy-duty vehicles covered by contracts in EU Member States - heavy-duty vehicles of category N2 and N3.



Source: Reform Institute based on Directive (EU) 2019/1161 of the European Parliament and of the Council of 20 June 2019 amending Directive 2009/33/EC on the promotion of clean and energy-efficient road transport vehicles.

Key indicators

Minimum procurement targets for the share of clean heavy-duty vehicles in the total number of heavy-duty vehicles covered by contracts for vehicles of category N2 and N3:

- 7% - from 2 August 2021 to 31 December 2025
- 9% - from 1 January 2026 to 31 December 2030

[166] Directive (EU) 2019/1161 of the European Parliament and of the Council of 20 June 2019 amending Directive 2009/33/EC on the promotion of clean and energy-efficient road transport vehicles.
[167] N2 – vehicles designed and built to carry loads having a maximum weight of more than 3.5 tons, but not exceeding 12 tons; N3 – vehicles designed and built to carry loads having a maximum weight of more than 12 tons.

Alternative Fuels Infrastructure Regulation (AFIR)

Status of document: provisions agreed, preparation for entry into force

Increasing the share of electromobility also involves the development of infrastructure for cars, vans and trucks. In this context, the Commission proposed replacing the existing Alternative Fuels Infrastructure Directive (AFID) 2014/94/EU[168], with the **Alternative Fuels Infrastructure Regulation** (AFIR)[169]. By changing the legal act from a directive to a regulation, the provisions will be directly applicable in all EU Member States, ensuring the uniformity of measures applied in the entire EU.

The change resulted from the fact that AFID did not include any specific or binding methodology for member states to calculate targets and adopt measures to achieve the goals set out in the directive. This has primarily resulted in varying levels of ambition in setting targets at the national level and has led to insufficient and unevenly distributed infrastructure. The Commission's evaluation concluded that the directive was not sufficient to serve its purpose, so a decision was made to reform the document.

In addition to the details of the recharging infrastructure, the new AFIR regulation also emphasizes the need to move away from LNG to the use of decarbonized fuels and the use of zero-emission propulsion systems. From this viewpoint, the Commission sees room for the use of different technologies for heavy-duty vehicles, hence it includes targets for both recharging points and hydrogen refueling stations[170].

The regulation clarifies the distribution of infrastructure in relation to the core and comprehensive TEN-T network. TEN-T stands for trans-European transport network with standardized technical parameters, which includes roads, railroad and aviation infrastructure and ports. TEN-T is aimed at improving the free movement of people and goods within EU Member States. It consists of a core network, i.e. sections that strategically connect the most important urban nodes and others, such as ports, airports and border crossings, as well as a comprehensive network ensuring accessibility and connectivity for all regions of the European Union[171]. A map of the TEN-T network for Poland is shown in Fig. 20.

Fig. 20. Map of the TEN-T core and comprehensive network for Poland.

Source: gov.pl[172] based on maps of the European Commission[173].

[168] Directive 2014/94/EU of the European Parliament and of the Council of 22 October 2014 on the deployment of alternative fuels infrastructure.
[169] European Commission. Proposal for a Regulation of the European Parliament and of the Council on the deployment of alternative fuels infrastructure, and repealing Directive 2014/94/EU of the European Parliament and of the Council COM(2021) 559 final.
[170] European Commission Communication. A hydrogen strategy for a climate-neutral Europe COM(2020) 301 final.
[171] Regulation (EU) No 1315/2013 of the European Parliament and of the Council of 11 December 2013 on Union guidelines for the development of the trans-European transport network and repealing Decision No 661/2010/EU.
[172] Ministry of Infrastructure. Trans-European transport network - TEN-T https://www.gov.pl/web/infrastruktura/transeuropejska-siec-transportowa-ten-t (accessed on: 5 April 2023).
[173] European Commission. Transport, Transport infrastructure, TENtec, TENtec Public Portal, Maps https://ec.europa.eu/transport/infrastructure/tentec/tentec-portal/site/en/maps.html (accessed on: 5 April 2023).

In late March 2023, the Council of the European Union and the European Parliament reached a preliminary agreement on mandatory national targets for the deployment of alternative fuel infrastructure for cars and trucks[174]. Details of the agreed specific distances and capacities of the recharging stations will be available a few weeks after negotiations are completed[175]. According to information provided to the public by the negotiators, the following targets have been defined for trucks:

- 2025: **15%** of the TEN-T network covered with charging stations with a power output of 1,400 kW per charging pool, every **120 km**. A 900 kW charging station at each urban node[176],
- 2027: requirement to deploy charging stations every **120 km** on **50%** of the TEN-T network, with station power output between 1,400 kW and 2,800 kW per charging pool, depending on the type of TEN-T road[177],
- 2030: **100%** of the TEN-T network covered with charging stations - requirement to deploy charging stations with electric charging points every **60 km** along the core network (charging station power output of 3,600 kW) and every 100 km along the TEN-T comprehensive network (charging station power output of 1,500 kW)[178],
- ensuring the availability of charging infrastructure for trucks in urban nodes and on safe and secure parking areas by 2030.

In the next steps, the preliminary agreement must be finally approved by the European Parliament and the EU Council, and will then be published in the Official Journal of the European Union. The provisions will become effective after a six-month transition period.

Key indicators

- binding targets for infrastructure deployment along the TEN-T network roads - creating pan-European corridors for zero-emission heavy-duty transport

Revision of Regulation (EU) 2019/1242 of the European Parliament and of the Council of 20 June 2019 setting CO2 emission performance standards for new heavy-duty vehicles (new standards until 2040)

Status of document: negotiations in progress

From the perspective of heavy-duty vehicles, the **regulation setting CO2 reduction targets for new heavy-duty vehicles** is of particular importance[179]. The regulation was first to set EU CO2 reduction targets for new heavy-duty vehicles, with target emission reduction by **15%** from 2025 and by **30%** from 2030 compared to the reference emissions from 1 July 2019 to 30 June 2020. The reference value is determined based on certified CO2 emissions from new heavy-duty vehicles collected under a separate regulation on the monitoring and reporting of CO2 emissions. The indicated CO2 emission standards currently apply to large trucks, accounting for 65-70% of total CO2 emissions from heavy-duty vehicles.

The regulation also provides for an **incentive mechanism for zero- and low-emission vehicles** (ZLEV). The incentives are implemented with the use of a ZLEV factor, which takes into account manufacturer's specific CO2 emissions. The ZLEV factor is limited to a minimum of 0.97, which translates into a maximum 3% reduction in average emissions of a manufacturer. The mechanism has been divided into the following two stages:

- stage of super credits (2019-2024)
  - under the mechanism, a given manufacturer can obtain special super credits that translate into less stringent CO2 emission targets, awarded for meeting specific levels of sales of zero- and low-emission vehicles
- stage of a determined share of zero- and low-emission heavy-duty vehicles in the manufacturer's fleet (from 2025 onwards)
  - a manufacturer can benefit from preferential CO2 emission corrections, if it achieves a benchmark of a 2% share of sales of zero- and low-emission vehicles
  - each percentage point of exceeding the benchmark reduces the manufacturer's specific CO2 emissions by one percent
  - the support mechanism does not apply to buses and coaches

[174] European Parliament News. Fit for 55: deal on charging and fuelling stations for alternative fuels https://www.europarl.europa.eu/news/en/press-room/20230327IPR78504/fit-for-55-deal-on-charging-and-fuelling-stations-for-alternative-fuels (accessed on: 5 April 2023).
[175] As at 3 April 2023.
[176] Electric Vehicle Promotion Foundation. AFIR - jest porozumienie unijne https://fppe.pl/afir-jest-prozumienie-unijne/ (accessed on: 5 April 2023).
[177] European Parliament News. Fit for 55: deal on charging and fuelling stations for alternative fuels https://www.europarl.europa.eu/news/en/press-room/20230327IPR78504/fit-for-55-deal-on-charging-and-fuelling-stations-for-alternative-fuels (accessed on: 5 April 2023).
[178] Electric Vehicle Promotion Foundation. AFIR - jest porozumienie unijne https://fppe.pl/afir-jest-prozumienie-unijne/ (accessed on: 5 April 2023).
[179] Regulation (EU) 2019/1242 of the European Parliament and of the Council of 20 June 2019 setting CO2 emission performance standards for new heavy-duty vehicles and amending Regulations (EC) No 595/2009 and (EU) 2018/956 of the European Parliament and of the Council and Council Directive 96/53/EC.

- if a manufacturer exceeds a certain level of CO2 emissions, it may be subject to a fine imposed by the European Commission, amounting to 4,250 EUR/gCO2/tkm until 2025 and 6,800 EUR/gCO2/tkm until 2030.

Data on new heavy-duty vehicles should also be reported by Member States and heavy-duty vehicle manufacturers in accordance with Regulation (EU) 2018/956 of the European Parliament and of the Council of 28 June 2018 **on the monitoring and reporting of CO2 emissions from and fuel consumption of new heavy-duty vehicles**[180] and the methodology specified in Commission Regulation (EU) 2017/2400 of 12 December 2017 implementing Regulation (EC) No 595/2009 of the European Parliament and of the Council as regards the **determination of the CO2 emissions and fuel consumption of heavy-duty vehicles** and amending Directive 2007/46/EC of the European Parliament and of the Council and Commission Regulation (EU) No 582/2011[181]. The data collected is made available on behalf of the European Commission by the European Environment Agency.

In February 2023, the European Commission proposed **revised greenhouse gas emission reduction standards** for new heavy-duty vehicles[182]. The more stringent standards compared to 2019 levels assume emission reduction by:
- 45% from 2030 onwards,
- 65% from 2035 onwards,
- 90% from 2040 onwards.

The provisions of the regulation are also to be **extended** to trailers, urban buses, coaches and other types of heavy duty vehicles. In the case of **new urban buses**, it is assumed that a **100% emission reduction will be achieved from 2030 onwards**. Under the proposal, vocational vehicles (e.g., off-road, forestry and agricultural vehicles and garbage trucks) and those used for civil protection purposes are not subject to CO2 emission standards. In addition, small manufacturers registering less than 100 new heavy-duty vehicles in the EU are exempted.

Table 11. Key indicators for CO2 emission performance standards for new heavy-duty vehicles, passenger cars and light commercial vehicles.

Regulation setting CO2 emission performance standards for new heavy-duty vehicles		**Regulation setting CO2 emission performance standards for new passenger cars and new light commercial vehicles**
Current version	Proposal of revised provisions	Revision of provisions under the Fit for 55 package
Reduction of average CO2 emissions from selected categories of heavy-duty vehicles: • by 15% in 2025 • by 30% in 2030 compared to the 2019/2020 reference level	Reduction of average emissions of CO2: • 45% from 2030 onwards, • 65% from 2035 onwards, • 90% from 2040 onwards, compared to the 2019 reference level. Zero-emission urban buses: 100% from 2030 onwards (only zero-emission buses will be allowed to be marketed in the EU from 2030) Extension of the directive's provisions to other types of heavy-duty vehicles, including coaches, trailers and urban buses.	CO2 emission targets set as a percentage reduction relative to 2021 levels: • from 2030 onwards: 55% for cars and 50% for vans, • from 2035 onwards: 100% for cars and 100% for vans.

Source: In-house analysis

[180] Regulation (EU) 2018/956 of the European Parliament and of the Council of 28 June 2018 on the monitoring and reporting of CO2 emissions from and fuel consumption of new heavy-duty vehicles.
[181] Commission Regulation (EU) 2017/2400 of 12 December 2017 implementing Regulation (EC) No 595/2009 of the European Parliament and of the Council as regards the determination of the CO2 emissions and fuel consumption of heavy-duty vehicles and amending Directive 2007/46/EC of the European Parliament and of the Council and Commission Regulation (EU) No 582/2011.
[182] European Commission. Proposal for a Regulation of the European Parliament and of the Council amending Regulation (EU) 2019/1242 as regards strengthening the CO2 emission performance standards for new heavy-duty vehicles and integrating reporting obligations, and repealing Regulation (EU) 2018/956 COM(2023) 88 final.

With toughened CO2 emission performance standards, manufacturers will be forced to place on the market more zero-emission vehicles. Given that, a new proposed change in the legislation is the **removal of the ZLEV incentive mechanism from 2030**.

The general scale of the increase in ambition for CO2 emission performance standards for heavy-duty vehicles can be illustrated by comparing similar regulations for passenger cars and light commercial vehicles, which were adopted by EU institutions in late March 2023[183]. A comparison of the most important assumptions included in the regulations is presented in Table 11.

Key indicators

In the current form of the regulation:

- reduction of average CO2 emissions from selected categories of heavy-duty vehicles by 15% in 2025 and by 30% in 2030 compared to the 2019/2020 reference level
- an incentive mechanism for zero- and low-emission vehicles - a manufacturer can benefit from the mechanism, if it achieves a benchmark of a 2% share of sales of zero- and low-emission vehicles

After the update of the regulation:

- reduction of average CO2 emissions from extended categories of heavy-duty vehicles by 45% in 2030, by 65% in 2035 and by 90% from 2040 onwards compared to the 2019 reference level
- setting a target for zero-emission urban buses from 2030
- removal of the incentive mechanism for zero- and low-emission vehicles from 2030

Additional incentives that increase the cost of owning and using vehicles powered by conventional fuels (including trucks)

In addition to the directives and proposals referred to above, apart from raising emission reduction targets in the transport sector there are a number of additional price incentives that increase the cost of owning and using vehicles powered by conventional fuels (including trucks), at which at the same time are intended to promote and improve the cost efficiency of electrification of transport. Details of selected documents are presented in Table 12.

[183] Council of the European Union Press release. 'Fit for 55': Council adopts regulation on CO2 emissions for new cars and vans https://www.consilium.europa.eu/en/press/press-releases/2023/03/28/fit-for-55-council-adopts-regulation-on-co2-emissions-for-new-cars- and-vans/ (accessed on: 5 April 2023).

Table 12. Additional incentives that increase the cost of owning and using conventional vehicles (including trucks)

<table>
<tr><th>Document</th><th>Targets/indicators</th></tr>
<tr><td>Fuel Quality Directive[184]
Status of document: effective</td><td>• determines the quality characteristics of petrol, diesel oil and biofuels used in road transport and diesel oil used in non-road machinery</td></tr>
<tr><td>Directive as Regards the Charging of Vehicles for the Use of Certain Infrastructures (Eurovignette Directive)[185]
Status of document: effective</td><td>• charging heavy-duty vehicles for the use of certain roads
• setting minimum levels of taxes on heavy-duty vehicles and rules for charging for the use of infrastructure,
• differentiation of charges based on the environmental performance of vehicles
• adjustment of fuel taxation depending on emissivity - the highest taxation for the most polluting fuels
• conventional fossil fuels will be subject to the highest minimum rate (see Table x.)[186]</td></tr>
<tr><td>Proposal for an Update of the Energy Tax Directive
Status of document: negotiations in progress</td><td>Table x. Comparison of current and proposed tax rates for selected fuels.
<table>
<tr><th></th><th rowspan="2">Current value</th><th colspan="2">New values - preliminary (2023)</th><th rowspan="2">New values - final (2033), without indexation</th></tr>
<tr><th>Previous value</th><th>New value</th></tr>
<tr><td>Petrol</td><td>359 EUR/1,000 liters</td><td>385.4 EUR/1,000 liters</td><td>10.75 EUR/GJ</td><td></td></tr>
<tr><td>Diesel</td><td>330 EUR/1,000 liters</td><td>419 EUR/1,000 liters</td><td></td><td></td></tr>
<tr><td>Kerosene</td><td>330 EUR/1,000 liters</td><td>363.2 EUR/1,000 liters</td><td></td><td></td></tr>
<tr><td>Kerosene (aviation)</td><td>0 EUR/1,000 liters</td><td>0 EUR/1,000 liters</td><td>0 EUR/GJ</td><td></td></tr>
<tr><td>LPG</td><td>125 EUR/1,000 kg</td><td>162.5 EUR/1,000 kg</td><td>7.17 EUR/GJ</td><td>10.75 EUR/GJ</td></tr>
<tr><td>Natural gas</td><td>2.6 EUR/GJ</td><td>7.7 EUR/GJ</td><td></td><td></td></tr>
<tr><td>Non-sustainable biofuels</td><td></td><td></td><td>10.75 EUR/GJ</td><td></td></tr>
<tr><td>Non-renewable hydrogen</td><td></td><td></td><td>7.17 EUR/GJ</td><td></td></tr>
<tr><td>Sustainable biofuels (not advanced)</td><td></td><td></td><td>5.38 EUR/GJ</td><td>5.38 EUR/GJ</td></tr>
<tr><td>Electricity, advanced biofuels, e-fuels and renewable hydrogen</td><td></td><td></td><td>0.15 EUR/GJ</td><td>0.15 EUR/GJ</td></tr>
</table></td></tr>
</table>

[184] Directive 2009/30/EC of the European Parliament and of the Council of 23 April 2009 amending Directive 98/70/EC as regards the specification of petrol, diesel and gas-oil and introducing a mechanism to monitor and reduce greenhouse gas emissions and amending Council Directive 1999/32/EC as regards the specification of fuel used by inland waterway vessels and repealing Directive 93/12/EEC.
[185] Directive (EU) 2022/362 of the European Parliament and of the Council of 24 February 2022 amending Directives 1999/62/EC, 1999/37/EC and (EU) 2019/520, as regards the charging of vehicles for the use of certain infrastructures.
[186] European Commission Questions and Answers. Revision of the Energy Taxation Directive (ETD) https://ec.europa.eu/commission/presscorner/detail/en/qanda_21_3662 (accessed on: 5 April 2023).

New Euro 7 standards (Regulation on type-approval of motor vehicles and engines and of systems, components and separate technical units intended for such vehicles, with respect to their emissions and battery durability) **Status of document:** negotiations in progress	• introduction of stricter emission limits and setting limits for previously unregulated pollutants, such as nitrous oxide from heavy-duty vehicles[187] • determination of indicators for tailpipe, brake and tire emissions • regulates the durability of batteries installed in electric cars and vans • the regulation may become effective on 1 July 2025 for light-duty vehicles and on 1 July 2027 for heavy-duty vehicles
Proposal for revision of the Air Quality Directive **Status of document:** negotiations in progress	- strengthening of pollutant emission standards for 12 substances, including particulate matter (PM) and nitrogen oxides (NOx) • zero-pollution for air ambition by 2050

Context of the EU Taxonomy

Investments, costs, and revenues associated with low-emission vehicles and charging infrastructure are important for assessing the environmental sustainability of companies' operations (EU Taxonomy perspective)

At present, all large public interest entities that are required to submit a non-financial statement under the NFRD (that meet two of the three criteria: (i) revenue > EUR 40 million, (ii) total assets > EUR 20 million, (iii) > 500 employees) are required to disclose the percentage of revenue, capital expenditures and operating expenses associated with products or services related to operations that qualify as environmentally sustainable. In connection with the entry into force of the CSRD, as of 2024 (reports for 2023) these requirements will apply to all large companies that meet two of the three criteria mentioned above, regardless of whether they are listed. In subsequent years, the requirements will be extended to include further companies - the taxonomy indicator disclosure obligations for small and medium-sized entities will be effective from 2026. The EU Taxonomy distinguishes a number of transport-related categories, which already makes it possible for revenues generated with Taxonomy-compliant assets (e.g. electric cars) to be treated as compliant with the EU Taxonomy and included in the percentage of revenue related to operations that qualify as environmentally sustainable.

Capital expenditure (CapEx) and operating expenses (OpEx) related to the use of electric cars and/or charging infrastructure are also included in the percentage share of CapEx/OpEx associated with economic activities that qualify as environmentally sustainable.

In the case of lease and rental of electric cars, it is also possible to qualify related costs as compliant with the EU Taxonomy. In accordance with the International Financial Reporting Standards (IFRS) and International Accounting Standards (IAS) lease (including car lease) is generally recognized in the balance sheet on a similar basis to the purchase of a regular item of property, plant and equipment, thus it is included in capital expenditures (CapEx). IFRS 16 provides for a simplification that whenever a lease is short-term (less than one reporting period, i.e. most often 12 months), it is possible not to recognize it in the balance sheet, in which case such an expense may be qualified as an operating expense (OpEx). The same rules apply to rental - accounting standards do not differentiate between the two terms.

Potential support instruments at national level

The following is an overview of potentially useful instruments to be applied at national level as a complementation of EU regulations aimed at decarbonizing transport and achieving climate neutrality. The support instruments are presented from the perspective of users of heavy-duty vehicles and address subsequent steps in the vehicle's life cycle.

Investment expenditure

Direct subsidies for the purchase (or acquisition through lease/rental) of zero-emission vehicles. 16 countries in the EEA have introduced direct subsidies for the purchase of zero-emission vehicles. In several of them (Austria, France, Germany, the Netherlands and Spain), the subsidy covers up to 80% of the difference between the cost of acquiring a zero-emission vehicle and an internal combustion vehicle. In

[187] European Commission – Press service. Commission proposes new Euro 7 standards to reduce pollutant emissions from vehicles and improve air quality https://ec.europa.eu/commission/presscorner/detail/pl/ip_22_6495 (accessed on: 5 April 2023).

Denmark, Ireland and the UK, subsidies are an incentive, but not high enough to overcome the cost barrier, in particular for smaller carriers. Other countries (Bulgaria, Estonia, Latvia, Lithuania, Greece, Hungary Portugal, Romania, Slovakia and Slovenia) have not introduced and do not plan to introduce such a support instrument[188]. By comparison, electric car subsidies for natural persons are applied in as many as 21 EU Member States. In Poland, support was envisaged under the Low Emission Transport Fund (FNT), but no support program had been launched with a call for applications before the FNT was liquidated. It is worth noting that such support is needed at the first stage of market development. When economies of scale are achieved, support should be phased out (in the second half of this decade).

In this context, it is also worth considering the perspective of small fleet owners, reserving for them a separate pool of support as part of type of fund (e.g. in proportion to the number of vehicles in small fleets[189]) along with dedicated financial instruments (e.g. additional bonuses for scrapping older vehicles) (for dedicated support for small fleet owners see also below).

Table 13. Use of tax arrangements and subsidies as instruments to support the uptake of heavy-duty vehicles with alternative propulsion.

		Number of N2 and N3 electric or hydrogen vehicles exceeding 50	
		No	Yes
Existence of policies supporting market uptake	No	BG, HR, CZ, EE, EL, IE, IS, LU, LT, MT, PL, PT, RO, SK, SI	-
	Yes	BE, CY, FI, LT, HU	AT, DK, FR, ES, NL, DE, NO, SE, IT

Source: European Automobile Manufacturers' Association[190], European Alternative Fuels Observatory[191]. The table includes initiatives of Member States beyond the mandatory implementation of policies effective at the EU level.

Tax credits and exemptions for businesses investing in zero-emission heavy-duty vehicles. Such instruments may also include preferential depreciation rates. Preferential treatment of businesses operating within Special Economic Zones may also be considered in this context.

Cost of operation

Preferential toll rates (impact on the total cost of ownership of a zero-emission vehicle). Varying the road tolls according to CO2 emissions is a key element of the EU directive revised in March 2022 (Directive as Regards the Charging of Vehicles for the Use of Certain Infrastructures, Eurovignette Directive[192]). Countries that impose tolls (which are an important component of the total cost of long-distance trips) must comply with the directive[193]. The implementation of the directive is worth considering by taking a comprehensive approach, given the imposed 4 requirements, which provide a considerable opportunity to create appropriate incentives for electrification:

- **Varying charges according to the emission levels.** By March 2024, charges must be varied by countries where the charges depend on the distance traveled and where governments have the right to vary such charges: Austria, Belgium, Bulgaria, the Czech Republic, Germany, Hungary, Poland, Slovakia and Slovenia. In Germany, a full exemption is currently being introduced for zero-emission vehicles. In Denmark, the transition to a charge system based on the distance traveled will take place in 2025, and in the Netherlands in 2026/2027. By 2027, such toll system (distance-based, right of the government to vary charges) will be in place in EU Member States which account for more than half (53%) of EU freight transport operations.
- **Introduction of charges for air pollution.** By March 2026, countries with a charging system based on distance traveled, with the government's right to vary charges, must introduce additional charges for air pollution by vehicles. In four EU Member States - Austria, Belgium, the Czech Republic and Germany - such charges already apply, and this deadline will be an opportunity for them to revise them.
- **Introduction of charges for vans (3.5 t and above)** in all EU Member States by 2027.
- Introduction of a charging system based on distance traveled for the TEN-T network, in most countries by 2030.

[188] Transport & Environment. How to buy an electric truck Public funding helps hauliers to deliver on zero emission road freight 2022.
[189] Brito J. No fleet left behind: Barriers and opportunities for small fleet zero-emission trucking International Council on Clean Transportation Working paper 2022.
[190] ACEA European Automobile Manufacturers' Association. Driving mobility for Europe https://www.acea.auto/ (accessed on: 5 April 2023).
[191] European Commission. European Alternative Fuels Observatory https://alternative-fuels-observatory.ec.europa.eu/ (accessed on: 5 April 2023).
[192] Directive (EU) 2022/362 of the European Parliament and of the Council of 24 February 2022 amending Directives 1999/62/EC, 1999/37/EC and (EU) 2019/520, as regards the charging of vehicles for the use of certain infrastructures.
[193] Transports Environment. Tolling: the highway to green trucking How to implement the Eurovignette reform to clean up trucks 2022.

Taxation - internalization of the cost of CO2 emissions from transport. A broad effective taxation of emissions, i.e. the introduction of higher charges and taxes for vehicles polluting the environment, is a key instrument for supporting the decarbonization of transport (in line with the principle of imposing tax on the source of pollution and the user of a given technology). In this context, in addition to the aforementioned road tolls, a number of instruments used (to a various extent) in EU Member States may be indicated[194]:

- Fuel taxes (excise duty, fuel charge, VAT), inclusion of transport in ETS II. - instruments of first choice favor zero-emission solutions through price and market signals and are the most effective.
- Registration charge/tax for buyers of new vehicles/tax for vehicle owners (in many countries, in the case of passenger cars these are based on emission levels).

These instruments seem to have considerable potential for heavy-duty vehicles, for which the current charges resulting from emission costs are lower than for passenger cars. This results from, for example, higher fuel charges and excise duty for petrol compared to diesel oil and more common tax variation according to emissions for passenger cars.

Although the primary tool for decarbonization is progressive toughening of emission reduction targets for vehicle manufacturers and fuel standards, fiscal instruments can prove to be their important complementation. Taxation also enables the internalization of other transport-related costs. Integrating these instruments into a broader package makes it possible to take a comprehensive approach to existing barriers and provide optimal support for different solutions. Several considerations must be borne in mind:

- In the context of political and social acceptance of such solutions, distributional effects must be considered. In general, taxation of emissions is regressive and the burden on lower-income households is relatively higher than on higher-income ones. The impact on disposable income may also differ for residents of urban and rural areas. Distributional effects can be partially neutralized by directing emissions tax revenues to vulnerable entities.
- Charges and taxes in the transport sector are an important source of public revenue, representing 5-10% of total tax revenue in EU Member States. A higher share of zero-emission vehicles could adversely affect these revenues. Keeping them at a stable level could be a significant challenge for EU Member States in the next decade. The list of instruments applied should also be reviewed regularly.
- Tax instruments remain at the discretion of Member States (leading to significant differences in vehicle taxation levels between individual Member States) in the case of passenger cars[195]. This makes it possible to take action at the level of individual countries to increase the electrification potential of the respective sectors, while emission standards are the same across the EU. This provides an opportunity for a faster transition than that resulting from the tightening of emission standards. Tax instruments may also be revised more frequently than emission standards.

Dedicated tariffs applied to charging of electric heavy-duty vehicles. This type of solution, for example consisting in the application of a lower fixed network charge and a higher variable charge based on the amount of energy consumed, can help reduce fixed costs for private recharging station owners and operators of publicly accessible infrastructure. Such a tariff is already in place in Poland and is used by operators of publicly accessible charging infrastructure.

Recharging infrastructure

Subsidies for investments in private recharging infrastructure (also combined with investments in RES). Supporting market development will involve the creation of public infrastructure in the coming years. However, at the first stage of market development, it will probably be necessary to support the set up of private investments in such projects (e.g. subsidies for the establishment of private charging stations: the cost of purchasing a charger and installing a connection). If power to the charging station is supplied from RES, such a solution could receive additional support.

Tax credits for businesses investing in the construction of recharging infrastructure for enterprises investing in zero-emission heavy-duty vehicles. Such instruments may also include preferential depreciation rates.

Improvement of administrative procedures related to the establishment of private charging stations. This means limiting to the minimum necessary the procedures related to obtaining a permit for the installation of infrastructure and obtaining a connection with adequate capacity, which will speed up implementation time. It also requires a greater coordination effort, including with grid operators and other energy market players[196].

[194] Schroten A., Kiraly J., Scholten P. Pricing instruments on transport emissions Research for TRAN Committee 2022.
[195] Transport & Environment. The good tax guide: A comparison of car taxation in Europe 2022.
[196] Van Grinsven A., Otten M., Van den Toorn E., Van der Veen R., Kiraly J. & Van den Berg R. Alternative fuel infrastructures for heavy-duty vehicles Research for TRAN Committee 2021.

Support for fleet replacement with zero-emission vehicles

Support for replacement of heavy-duty vehicles. In a situation where entities purchase zero-emission vehicles to replace the internal combustion vehicles they already own, comes the question of the residual value of the latter. To recover some of this value and support such replacement, the purchase of a zero-emission vehicle could involve, for example, a discount for scrapping a currently used internal combustion vehicle and recovering recyclable materials, especially for micro- and small enterprises.

Support for conversion of internal combustion engine vehicles to zero-emission vehicles. Given the relatively large share of older vehicles in the fleet of Polish carriers, systemic support for the conversion of internal combustion vehicles to zero-emission vehicles may also be an interesting idea. Support in resolving these issues can be important from the users' perspective, but it must offer repeatable solutions that cover the most popular heavy-duty vehicle models on the European market.

Dedicated support for small fleet owners

Taking into account the specific perspective and needs of small fleet owners can help avoid a situation where solutions that meet ambitious climate goals impose financial hardships on businesses that already have limited financial and institutional resources[197]. The following actions would serve this purpose:

- Lay the groundwork for a used vehicle market (e.g. introduction of specific information requirements that will alleviate uncertainty about long-term battery and vehicle health), continued support for the used vehicle market,
- Establishment of small fleet service centers (external entities: demand aggregation, access to information on incentives, information on financing instruments, consulting services) - increasing the efficiency of operations,
- Reduction of information asymmetries between large and small fleets (access to information from pilot programs).
- Introduction of dedicated financial instruments, e.g. additional bonuses for scrapping vehicles compliant with Euro 5 and lower standards, whereby the amount of the bonus could depend on the emission standard of the scrapped vehicle.

Other instruments

Green public procurement. One way to use public funds to stimulate demand is to apply requirements for a given share of zero-emission vehicles or vehicles with alternative propulsion in the purchased vehicle fleet, imposed as part of green public procurement.

Low emission zones. Restrictions on movement in urban areas and/or low emission zones (LEZ) or areas of high natural value are related to emissions from vehicles. Such a solution can be an important instrument at the local level.

Case studies - a set of solutions and support instruments used in three EEA countries showing a high degree of development of zero-emission truck transport

Policies supporting the use of alternative fuels in commercial vehicles comprise a **relatively new regulatory area** and their implementation in many countries is only in its early stages. Nonetheless, due to the high importance of decarbonizing heavy-duty transport for achieving Europe's medium- and long-term climate and energy goals, the set of policies and support instruments already in place in EEA countries is growing rapidly, laying the groundwork for a rapid transformation of the sector in the years to come.

At the strategic level, the first step is to set targets for key sector indicators, such as the **level of CO2 emissions from the transport sector or the share of alternative fuels** in the fuel mix used in heavy-duty vehicles. Although these targets do not in themselves impose any binding obligations on enterprises, they do have an impact on their expectations as to future regulatory policies, thereby also indirectly affecting the strategies adopted by businesses and their adjustment efforts.

A solution that has a direct effect on the market is the determination of **CO2 emission standards for new vehicles,** whereby vehicle manufacturers become required to achieve a set average CO2 emission level per kilometer traveled for the fleet sold in a given period, otherwise they may be imposed a fine. Such a solution has been implemented i.a. at the EU level.

[197] Brito J. No fleet left behind: Barriers and opportunities for small fleet zero-emission trucking International Council on Clean Transportation Working paper 2022.

An extension of this instrument is defining a zero-emission standard for new vehicles, which in practice means **setting a date for the withdrawal of conventional commercial vehicles from the primary market, which in the case of the European Union will be in 2035.**

The state can also influence the choices made by businesses and consumers by **reducing the relative costs of purchase and operation of an alternative-powered vehicle** relative to a conventional vehicle. The tools available to achieve this goal are:

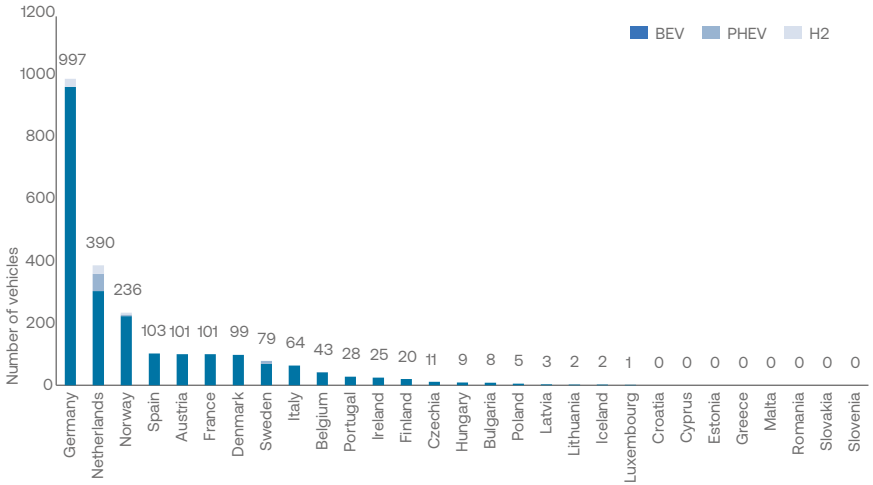
- subsidies for the purchase of alternatively fuelled vehicles,
- tax reliefs and exemptions,
- financial incentives reducing the cost of vehicle maintenance and use (e.g. lower road tolls, subsidies for recharging).

An important aspect, without which the successful transition of transport to a zero-emission standard will be impossible, is the concurrent development of the recharging and refueling infrastructure for vehicles with alternative propulsion. Preparing and implementing dedicated **strategies for expanding the network of charging and refueling stations** makes it possible to efficiently allocate the available public funds and ensure coordinated scaling of the infrastructure and fleet of alternative-fuelled vehicles.

Governments may opt to support infrastructure development with **direct public investment or implementation of policies promoting private investment** in such projects (e.g. subsidies for setting up private charging stations and making them available to third parties).

Another way to use public funds to stimulate demand is to apply requirements for a given share of zero-emission vehicles or vehicles with alternative propulsion in the purchased vehicle fleet, imposed as part of green public procurement.

Fig. 21. Number of N2 and N3 category heavy-duty vehicles in EEA countries in 2022.



Source: Reform Institute based on the European Alternative Fuels Observatory[198], as at February 2023.

In view of the summary of the progress in implementation of support policies and the scale of use of alternatively fuelled heavy-duty vehicles (Table X), it is clear that in the analyzed sample of countries, the two practices most often co-occur. Special **support instruments dedicated solely to e-trucks are relatively rare so far;** 14 EEA countries having such policies have been identified. By comparison, among EU Member States alone, electric car subsidies for natural persons have been applied in as many as 21 states.

[198] European Commission. European Alternative Fuels Observatory https://alternative-fuels-observatory.ec.europa.eu/ (accessed on: 5 April 2023).

Table 14. Types of policy instruments and support tools used over the last 3 years in countries with the most developed market for heavy-duty vehicles using alternative fuel.

Country	Vehicle purchase subsidy	Tax credit	Subsidies for investments in charging stations	Infrastructure development strategy	Use facilitation (exemption from fees, access to green zones)
Germany	+			+	+
The Netherlands	+	+		+	+
Norway	+	+			+
Spain	+		+		+
France	+	+	+		+
Austria	+	+			+
Denmark	+	+			+
Sweden	+		+	+	+
Italy		+			+

Source: European Automobile Manufacturers' Association[199], European Alternative Fuels Observatory[200], International Council on Clean Transportation[201]. The table includes initiatives of Member States beyond the mandatory implementation of policies effective at the EU level.

Among the countries with the most developed EEA market for heavy-duty vehicles with alternative propulsion, most of them choose to **rely on a wide range of policy instruments and support tools.** The most common type of stimulation of demand for this type of vehicles is ensuring preferential conditions for their use - access to clean transport or zero-emission zones, exemption from road tolls or parking fees, subsidies for charging, etc. Almost all of these countries also introduced subsidies for the purchase of heavy-duty vehicles. Relatively fewer common solutions applied include supporting the development of charging and refueling infrastructure. Support through both subsidies for such investments and in the form of preparing a strategy as a basis for expanding this sector was opted for by no more than 3-4 countries.

Germany

In Germany, a number of policies have been implemented to support the development of zero-emission heavy-duty transport. Despite that, the policy documents published so far do not specify a definitive, binding deadline for abandonment of

[199] ACEA European Automobile Manufacturers' Association. Driving mobility for Europe https://www.acea.auto/ (accessed on: 5 April 2023).
[200] European Commission. European Alternative Fuels Observatory https://alternative-fuels-observatory.ec.europa.eu/ (accessed on: 5 April 2023).
[201] International Council on Clean Transportation https://theicct.org/ (accessed on: 5 April 2023).

emission-intensive vehicles in this branch of the transport sector. However, Germany committed to achieving the following intermediate goals:
- to reduce total emissions from the transport sector by 48% by 2030 (relative to 1990),
- to achieve **the share of trips made by heavy-duty vehicles** powered by electric batteries or electricity-based fuels at 33% of total mileage by 2030.

One important aspect of the implementation of these policies is the adoption of the **Master Plan for Charging Infrastructure**[202]. It contains 68 planned measures, whose implementation will ensure the optimal trajectory for the development of electric vehicle charging infrastructure. The Plan also separately considers charging infrastructure for eHDVs. To ensure its development, it is envisaged that a tender for an initial charging network will be organized (the network will be located along the country's main transport routes) and that funds will be earmarked for the construction of charging infrastructure on the premises of enterprises, at handling points, charging pools and in commercial areas. In addition, the plan also emphasizes such elements as:
- close link between the development of electromobility and power grids,
- enabling rapid provision of land necessary for the construction of infrastructure, with low procedural requirements,
- stimulation of private investment.

The funds allocated for the implementation of the entire Plan in the horizon until 2030 amount to EUR 6.3 billion.

The federal government also provides subsidies for the purchase of eHDVs. According to the "Guidelines for the promotion of light- and heavy-duty commercial vehicles with alternative, climate-friendly propulsion and related infrastructure for refueling and recharging of electric commercial vehicles", support of up to **80% of the so-called additional capital expenditure** is provided for the purchase of an electric heavy-duty vehicle. This expenditure is defined as the funds necessary to cover the difference in purchase price between a vehicle with a conventional drive (compliant with Euro 6 emission standard) and a low- or zero-emission vehicle, as well as the conversion of a conventional vehicle to a comparable zero-emission vehicle. The subsidy relates to:
- purchase of commercial and vocational vehicles with battery or fuel cell propulsion (vehicles of category N1, N2 and N3),
- purchase of off vehicle charging hybrid electric vehicles (only vehicles of category N3),
- conversion of diesel vehicles to electric vehicles (vehicles of category N2 and N3).

The maximum amount of the subsidy that may be received by a beneficiary is EUR 25 million.

The guidelines are effective until 31 December 2024, and the funds earmarked for the payment of subsidies amount to approximately EUR 1.6 billion. To receive a payment, a potential beneficiary must submit its application in one of the 4 calls for applications scheduled for each calendar year (organized by the Federal Office for Goods Transport - BAG). The award of the subsidy depends on:
- CO2 emission reduction rate,
- minimum ambition (equal to the average CO2 emission reductions per EUR 1 of subsidy awarded for all applications in the call).

The following entities are entitled to receive the support:
- small and medium-sized enterprises,
- corporations and public law institutions,
- municipal companies and registered associations,
- lessors and rental lessees.

Another incentive to use electric heavy-duty vehicles is that **they are exempt from paying mandatory charges for the use of transport infrastructure.** Electric vehicles qualified to benefit from this regulation include:
- battery electric vehicles,
- externally chargeable hybrid electric vehicles (plug-in),
- fuel cell vehicles.

It is estimated that in Germany the value of road tolls for BEVs or FCEVs traveling on long distances per km will be about EUR 0.1 (which compares to the value of other costs in TCO per km of EUR 0.7-0.95).

France

In France, the establishment of programs to support the decarbonization of the heavy-duty vehicle sector did not begin until recent years and are still undergoing significant changes as the French government is still in the course of developing an optimal national approach to support the transformation of the sector. Some of the policies are also intentionally designed to last for a specific, short period, so as to stimulate

[202] Bundesregierung. Masterplan Ladeinfrastruktur II der Bundesregierung.

the development of the market at a given time, at the same time adding an element of competition for limited budgetary resources earmarked for investment. A special **task force on heavy-duty vehicles** (task force sur les vehicules lourds), associating representatives of carriers, vehicle manufacturers and energy companies, monitors the quality of the related plans and policies prepared. The task force is a body set up at the French Ministry of Transport.

The primary tool implemented to stimulate market development was initially **a subsidy for the purchase of alternatively-fueled heavy-duty vehicles**, launched in 2021. This was in addition to the existing subsidy program (bonus ecologique), which included state aid only for the purchase of electric cars. The subsidy was available for the purchase of vehicles of category N2, N3, M2 and M3 (slightly different rules applied for vehicles designed for passenger transport). The maximum amount of the subsidy for the purchase of an N2 and N3 category vehicle was limited to:

- 40% of the vehicle price,
- EUR 50 thousand.

The subsidy was granted only if the vehicle was driven by **electricity, hydrogen or a combination of the two.** Access to the subsidy was scheduled to expire on 1 January 2023, but it was decided to apply a transitional period, during which heavy-duty vehicles ordered by 31 December 2022 and invoiced by 30 June 2023 will still be eligible for the support.

Funding may be awarded as follows:

- as a direct disbursement of funds to the beneficiary after an application is submitted by the Agency For Services and Payment (ASP),
- or in the form of a discount on the purchase of a vehicle from the seller, if the seller has agreed to pay an advance and if it has entered into an agreement with the ASP under which it can be reimbursed.

In 2022, the "Ecosystem for electric heavy-duty vehicles" subsidy program was also in place. The call for proposals was addressed to entities planning to invest in **ecosystems that would combine the installation of charging infrastructure and the deployment of electric heavy-duty vehicles** in professional fleets for the transport of people or goods. In particular, funds were to be directed to support solutions for developing short-haul and urban logistics. The subsidy could amount to up to 65% of the difference in the cost of purchasing an electric vehicle and its diesel counterpart (according to a scale that takes into account the type of vehicle and its weight). The subsidy was also capped at EUR 100,000 for electric heavy-duty vehicles with a maximum weight of 26 tons; above that threshold, the maximum subsidy was set at EUR 150,000. Installation of charging points for these vehicles was eligible for support of up to 60%. After the first round of calls for proposals in June 2022, the program was discontinued.

Separate funding options were also available for **businesses investing in charging points for trucks.** The first 50 projects or projects for the first 1,000 N2 or N3 category truck charging points were eligible for support[203]. Submitted by a private company or a public body. For chargers with a power output of less than 500 kW, the subsidy could be up to 50% of the costs, and the value could not exceed EUR 15,000. In contrast, for projects involving charging infrastructure with a power output of more than 500 kW, the funding was awarded for entire integrated deployment projects, which also covered the electrical equipment associated with this type of charging power: connection application, transformers, power modules, etc. At that time, the thresholds for the maximum amount of the subsidy depended on the power output of a given charging station and the fulfillment of the minimum requirements, as described in Table Z.

[203] According to estimates by Avere-France (the National Association for the Promotion of Electric Mobility), some 45,000-60,000 heavy-duty vehicle charging points will need to be built in France by 2025 (Avere France Advenir. Etude d'opportunite Infrastructures de recharge des transports routiers en France 2022).

Table 15. Amount of subsidies and requirements in the French subsidy program for heavy-duty vehicle charging stations.

Charging station power	500-1,000 kVA	1,000-2,000 kVA	2,000-4,000 kVA	4,000-8,000 kVA	Over 8,000 kVA
Requirements	At least 4 fast charging points for which the total nominal charging power is greater than 75% of the newly commissioned connection capacity.	At least 8 fast charging points for which the total nominal charging power is greater than 75% of the newly commissioned connection capacity.	At least 12 fast charging points for which the total nominal charging power is greater than 75% of the newly commissioned connection capacity.	At least 14 fast charging points for which the total nominal charging power is greater than 75% of the newly commissioned connection capacity.	At least 48 fast charging points for which the total nominal charging power is greater than 75% of the newly commissioned connection capacity.
Maximum amount of the subsidy	EUR 100,000	EUR 160,000	EUR 240,000	EUR 480,000	EUR 960,000

Source: The Advenir program managed by Avere-France[204] in cooperation with the Agency for Ecological Transition (ADEME) [205].

In addition to subsidies, France also uses tax incentives in the form of two tools:

1. **Additional depreciation** - it allows companies using electric or hydrogen-powered heavy-duty vehicles to receive additional depreciation, ranging from 20% to 60% of the vehicles' value. The rate varies depending on the gross vehicle weight:
   - Gross vehicle weight from 2.6 to 3.5 tons: 20%;
   - Gross vehicle weight from 3.5 to 16 tons: 60%;
   - Gross vehicle weight more than 16 tons: 40%.

   The increased depreciation will be effective until 31 December 2030.
2. Full **exemption from registration tax**

   As of 1 January 2020, all electric vehicles, hydrogen-powered vehicles or vehicles using a combination of the two technologies are fully exempt from the Y1 regional tax, regardless of region.

Also, faster transformation of the entire transport sector is to be achieved thanks to **Low-Emission Zones**. So far, 11 French cities have introduced them[206], but by the end of 2024 they will have to be set up in every French city with more than 150,000 inhabitants. Only vehicles with a Crit'Air (Certificats qualite de l'air - air quality certificate) sticker can enter the zones. The sticker has 6 variants depending on the level of air pollution emitted by the vehicle. Each city sets its own specific rules on how to restrict access to its zone - close it completely to selected types of vehicles, apply less restrictive rules to others, toughen the criteria at a particular time of day or year, day of the week, etc. - but in general, in the zones that have already been established, there is a plan to gradually impose stricter requirements over a long-term period. An example is the low-emission zone of the Paris metropolitan area, where **from 2030 only zero-emission vehicles will be allowed to enter**.

The Netherlands

The Netherlands is one of the countries that has signed the Memorandum of Understanding on Zero-Emission Medium and Heavy-Duty Vehicles[207]. Signatories to the memorandum pledged to work together to identify feasible implementation paths and support activities designed to scale up the use of zero-emission heavy-duty vehicles, so that zero-emission vehicles account for 30% of new medium- and heavy-duty vehicle sales by 2030, and 100% by 2040. The goal is to achieve net-zero emissions at the level of entire economies, including in the transport sector.

To meet the assumptions of the Memorandum, the Netherlands has implemented, among other things, a program of **subsidies for the purchase of zero-emission**

[204] ADEME France. The French Agency for Ecological Transition https://www.ademe.fr/en/frontpage/ (accessed on: 5 April 2023).
[205] Avere France. Accélérer la transition vers la mobilité électrique https://www.avere-france.org/ (accessed on: 5 April 2023).
[206] In Paris, Lyon, Marseille, Toulouse, Strasbourg, Nice, Montpellier, Grenoble, Rouen, Reims, Saint-Etienne.
[207] Other European countries that acceded to the memorandum are: Austria, Belgium, Croatia, Denmark, Finland, Ireland, Liechtenstein, Lithuania, Luxembourg, Norway, Portugal, Scotland, Switzerland, Turkey, Ukraine, United Kingdom, Wales.

trucks (AanZET), which is designed for businesses and non-profit organizations that want to purchase or lease under a finance lease a new, fully zero-emission heavy-duty vehicle. The program is scheduled for 2022-2027 with a budget amounting to EUR 30 million for the period from April to December 2023. The subsidy is intended only for new[208], fully zero-emission vehicles, and the amount depends on the type of potential beneficiary and vehicle category, as shown in Table Y.

Eligibility criteria for the program are as follows:

- the potential beneficiary is **an enterprise, non-profit organization or a lease company** that leases out heavy-duty vehicles under an operating lease,
- the potential beneficiary has previously received funding for **no more than 20 vehicles** in the calendar year,
- the heavy-duty vehicle to be supported with the co-financing is **fully zero-emission, powered by an electric battery or fuel cell**,
- the heavy-duty vehicle to be supported with the co-financing drives with the electric motor only,
- the heavy-duty vehicle to be supported with the co-financing is classified as an N2 category vehicle **with a weight equal to or greater than 4.25 t or as an N3 category vehicle**,
- the vehicle battery must not contain lead,
- at the time of submission of the application for the subsidy, at most a preliminary agreement for the purchase or lease under a finance lease has been signed (its finalization may be stipulated as a condition that excludes the award of the subsidy),
- indefinite agreement on the purchase or finance lease, if entered into on or after 1 January 2022 (for the 2023 call).

If the purchase is also subsidized as part of another government program, the amount of funding from the AanZET program is reduced by the amount provided by the other source of state funding. Receipt of the subsidy entails the following obligations:

- the heavy-duty vehicle for which the subsidy is received must be registered to the applicant,
- registration to the applicant **must be maintained for 4 years without interruption** from the date of the first registration and entry in the register (or made with a temporary reservation in the name of the lease company entered in the vehicle register),
- the lease agreement must be maintained also for a period of 4 years from the date of first registration.

Table 16. Available subsidy levels in the Dutch program of subsidies for the purchase of zero-emission trucks (AanZET).

	Large enterprises		Medium-sized enterprises		Small enterprises	
Vehicle category	Subsidy rate	Maximum amount of the subsidy	Subsidy rate	Maximum amount of the subsidy	Subsidy rate	Maximum amount of the subsidy
N2 category heavy-duty vehicle from 4.25 t	12.50%	EUR 17,800	19%	EUR 26,800	25%	EUR 35,700
N3 category heavy-duty vehicle up to and including 18 t	15%	EUR 43,600	21.50%	EUR 63,700	28.50%	EUR 84,000
N3 category heavy-duty vehicle above 18 t	16.90%	EUR 56,700	24.30%	EUR 81,500	31.70%	EUR 106,300
N3 category tractor unit	20%	EUR 72,700	28.50%	EUR 102,300	37%	EUR 131,900

[208] A truck is considered new when three dates in the entry in the RDW register for the vehicle are the same: the date of first registration in the Netherlands, the date of first registration of the vehicle, and the date of assignment to the applicant's name.

There is also a second subsidy program - **SEBA** (Subsidieregeling Emissieloze Bedrijfsauto - a subsidy program for zero-emission commercial vehicles) for entrepreneurs and non-profit organizations. It can be used for the purchase or lease of zero-emission vehicles of **categories N1 and N2 up to a maximum weight of 4.25 t**. Medium-sized and large enterprises may receive a subsidy of 10% of the sales price, net of VAT (up to EUR 5,000); for small enterprises the rate is 12%. SEBA's total annual budget in 2023 is EUR 33 million. Receipt of the co-financing is subject to meeting the following conditions:

- the potential beneficiary is a **business owner or a non-profit organization**,
- at the time of submission of the application for the subsidy, at most a preliminary agreement for the purchase or lease under a finance lease has been signed (its finalization may be stipulated as a condition that excludes the award of the subsidy),
- at the time of submission of the application for the subsidy, the vehicle has not yet been registered in the RDW vehicle register,
- for the N2 vehicle category, **the list price net of VAT is EUR 20,000 or more**,
- an electric commercial vehicle of category N1 with type approval for light-duty vehicles has a range of at least 100 kilometers; for vehicles of category N1 with type approval for heavy-duty vehicles and vehicles of category N2 up to 4.25 kg, the minimum range does not apply.
- the purchased vehicle is a **fully zero-carbon commercial vehicle** within the meaning of Article 1(1) of the Vehicle Regulation (regeling voertuigen), i.e. emits less than 1 g of carbon dioxide/kWh (electric motor vehicles only).

In order to develop charging infrastructure across the country, **the National Charging Infrastructure Agenda** (Nationale Agenda Laadinfrastructuur) was set up, which is a political multi-year agenda that brings together multiple stakeholders from different affiliations. Under the agenda, the Dutch government works with local governments, companies, industry associations and knowledge institutions in the form of public-private partnerships. It was established under the 2019 Climate Agreement, which is a national action program aimed at facilitating the CO2 emissions reduction by at least 50% by 2030 (relative to 1990). The Agenda's activities and agreements are implemented **at the national, regional and local levels. Representatives of the market, the government and grid operators are working together** to support cities and regions in building adequate, reliable charging infrastructure and an electric grid that is ready for the challenges of the green transition. In support of the alternative-drive heavy-duty vehicle sector, the Agenda is working to develop a roadmap and funding strategy for a network of charging infrastructure for such vehicles and it carries out studies on optimal logistics and standards for creating charging infrastructure.

Inspired by the Agenda, among other things, the Dutch government soon plans to launch another subsidy program to **for hydrogen refueling stations for heavy-duty vehicles**. It is expected to start in early 2024 with a budget of EUR 22 million. Details of the program are yet to be announced later in 2023, but so far it is known that it will be designed to support investment projects which in **addition to the construction of charging stations also involve the purchase of 20-25 fuel cell heavy-duty vehicles**, so that it can simultaneously contribute to the growth of demand and supply of this fuel.

Alternative fuel-powered vehicles are also expected to benefit from favorable tax treatment. Zero-emission vehicles - battery or fuel-cell, including heavy-duty vehicles - are **exempt from the annual motor vehicle tax (MRB)**, while vehicles emitting from 1 and 50 gCO2/km (such as plug-in hybrids) pay half the full rate. The exemption is effective until 2024. In 2025, the rates will be 25% and 75% for zero- and low-emission vehicles, respectively, and from 2026 the rate will return to 100%.

There are also **MIA and Vamil tax tools** designed to help companies invest in environmentally friendly technologies. With MIA, up to 45% of the cost of such an investment can be deducted in addition to the usual investment tax deductions; this support can be combined with support from the AanZet program. In the case of Vamil, it is possible to choose when the beneficiary wants to write off 75% of its investment expenses, which is to help manage liquidity risk. The list of many investments that can be financed under the MIA and Vamil programs include the following:

- category N1 and N2 battery electric vans,
- category N1 and N2 fuel cell vans,
- category N2 and N3 battery electric or fuel cell heavy-duty vehicles,
- category N2 and N3 plug-in hybrid heavy-duty vehicles, tractor units,
- hydrogen refueling stations,
- electric heavy-duty vehicle charging points.

The budget of the MIA and the Vamil program for 2023 is EUR 192 million and EUR 25 million, respectively.

The planned implementation of **zero-emission zones** is also an important regulation. As of 1 January 2025, cities in the Netherlands will be given the option to set up a zero-emission zone, where no light commercial vehicles emitting air pollutants will be allowed to enter and which will be accessible **only to battery- or hydrogen-powered light commercial vehicles**. If the city decides to establish the zone, it must cover at least the central part of the city and surrounding housing estates. So far, the introduction of such a zone has been announced by at least 30 cities (including 5 largest: Amsterdam, Rotterdam, the Hague, Eindhoven and Utrecht); several plan to postpone implementation of the regulation until 2026. A transition period will be established for certain types of light commercial vehicles in which their access to the zero-emission zone will be allowed for 1-5 years more. The Netherlands already has set up low-emission zones where diesel-fueled light commercial vehicles, among others, are not allowed to enter. 15 cities chose to introduce them.

Instruments to support the uptake of alternative-powered heavy-duty vehicles in the Baltic States and the Visegrad Group

Among the countries of Central and Eastern Europe, so far none has taken extensive, coordinated measures aimed at expanding the market for alternative propulsion heavy goods vehicles. However, some countries are beginning to implement individual policy instruments related to the sector. For example, Hungary and Lithuania allow vehicles of category N2 in subsidy programs aimed mainly at promoting the purchase of electric passenger cars, while Latvia offers a use tax exemption for fully electric vehicles. However, the level of advancement of such measures and approach to creation of policies in this regard is low compared to many Western European countries.

Summary and conclusions for the zero-emission vehicles industry

The impact of the EU regulatory framework on the development of zero-emission truck transport can be seen in two dimensions. Firstly, the energy and climate objectives applicable to Member States are an incentive for them to introduce additional national instruments aimed at supporting zero-emission heavy-duty vehicles, which would lead to reducing emissions and increasing the share of RES in the energy mix. Secondly, EU regulations directly increase the cost of operation of vehicles using conventional fuels, thus increasing the competitiveness of zero-emission drives. The impact of each regulation is shown in Tables X and X.

Table 17. Incentives for governments of EU Member States aiming at introducing national regulations for zero-emission heavy goods vehicles.

Incentives for governments of EU Member States aiming at introducing national regulations for zero-emission heavy goods vehicles
• Effort Sharing Regulation: **CO2 reduction targets for non-ETS sectors**
• RES Directive: **sectoral transport objectives**
• Proposal for revision of the Air Quality Directive: **raising air quality standards**

Table 18. Incentives for vehicle owners and users to opt for zero-emission vehicles.

Incentives for vehicle owners and users
• EU CO2 emissions trading scheme for building and road transport sectors: **conventional fuels cost increase**
• Directive on the Promotion of Clean and Energy-Efficient Road Transport Vehicles: **mandatory share of zero-emission vehicles in public procurement**
• Regulation setting CO2 emission standards for new heavy-duty vehicles: **adaptation of vehicle suppliers' offer to new emission standards**
• Alternative Fuels Infrastructure Regulation: **improved access to infrastructure of the TEN-T network**
• Fuel Quality Directive: **conventional fuels cost increase**
• Directive as Regards the Charging of Vehicles for the Use of Certain Infrastructures (Eurovignette): **differentiation of fees depending on emission**
• Update of the Energy Tax Directive: **differentiation in taxation of conventional and alternative fuels**
• New Euro 7 standards (Regulation on type-approval of motor vehicles and engines and of systems, components and separate technical units intended for such vehicles, with respect to their emissions and battery durability): **increase in the cost of purchasing conventional vehicles**

- Polish strategic documents currently lack provisions directly related to the development of zero-emission trucks. Nevertheless, stricter emission standards and support for the development of zero-emission trucks are part of a broader framework of national strategic documents, such as the Strategy for Responsible Development until 2020 (with an outlook until 2030) or the Electromobility Development Plan in Poland. Despite the outdated goals contained in the indicated documents, there is potential to include measures aimed at promoting the use of zero-emission heavy-duty vehicles in their future revision and during preparation of new national instruments, in particular given the changing regulatory environment at the EU level.
- The EU's decarbonisation policy may be complemented by a range of instruments implemented at national level.

Support instruments at national level
• **Support for capital expenditures associated with the purchase of a heavy-duty vehicle.** The most commonly used form of support are direct subsidies for the purchase of a vehicle. Similar effect can be achieved with preferential loans and tax credits and exemptions, as well as preferential depreciation rates.
• **Reducing the cost of operation of zero-emission vehicles.** Great potential in this regard is seen in tax measures, including notably broad effective taxation of emissions, i.e. the introduction of higher taxes and charges for polluting vehicles (taxation of fuels (excise duty, fuel charge, VAT) and charges for vehicle owners and buyers). Importantly, fiscal instruments remain at the discretion of Member States, which means that they have greater potential for electrification of the domestic sector and may facilitate faster transition. Tax instruments may also be revised more frequently than emission standards. The cost of operation of zero-emission vehicles can also be reduced thanks to dedicated tariffs for charging electric heavy-duty vehicles.
• **Support for the creation of vehicle charging infrastructure.** The public alternative fuel infrastructure (AFIR) will be rolled out gradually, so in the first stage support may be needed to establish private infrastructure, e.g. by subsidizing the cost of purchasing a charger and installing a connection (with higher subsidies provided when the installation is powered from a renewable energy source), tax credits for investing enterprises, preferential depreciation rates, and improvement of administrative procedures related to the establishment of private charging stations.
• **Support for the replacement of internal combustion with zero-emission heavy-duty vehicles,** e.g. in the form of a discount for scrapping a currently used internal combustion vehicle and recovering recyclable materials, especially for micro- and small enterprises. Systemic support for the conversion of internal combustion vehicles to zero-emission vehicles may also be an interesting idea.
• **Dedicated support for small fleet owners** in the form of, for example, a separate pool as part of a direct subsidy fund, but also support in laying the groundwork for a used vehicle market, service centers for small fleets, improving access to information, or other dedicated financial instruments (e.g. additional bonuses for scrapping vehicles compliant with Euro 5 and lower standards, whereby the amount of the bonus could depend on the emission standard of the scrapped vehicle).
• A support instrument may also be **green public procurement and the introduction of restrictions on movement in urban areas and/or clean transport zones** (LEZ).

Although the development of zero-emission heavy transport constitutes a relatively new regulatory area, a number of European countries have already implemented policies in this area, creating the basis for a rapid transformation of the sector in the coming years. Among the 9 countries where the market developed by February 2023, with more than 50 such vehicles registered, all implemented comprehensive support policies using instruments from at least two of the five categories: vehicle purchase subsidies, tax credits, subsidies for investments in charging stations, infrastructure development strategies, use facilitation.

Among the three countries whose support policies have been examined in this publication (Germany, France, the Netherlands), all over the last three years have benefited from high subsidies for the purchase of low-carbon heavy goods vehicles, complementing them with instruments from at least two other categories.

Among the countries of Central and Eastern Europe, so far none has taken extensive, coordinated measures aimed at developing the market for alternative propulsion heavy goods vehicles. Some countries are beginning to implement individual measures, but for the time being the level of advancement of their policies in this area is low compared to Western European countries.

Chapter 4. Analysis of the total cost of ownership (TCO) of heavy-duty vehicles for selected tonnage categories and daily mileage by drivetrain technology with a projection for 2030 and 2040

The TCO analysis provides an in-depth comparison of different types of vehicles and shows the changes in cost components for each such type. The total cost of ownership of heavy-duty vehicles was calculated for two technologies compared to a baseline ICE (diesel engine) vehicle.

- **BEV** - battery electric vehicles
- **FCEV** - hydrogen fuel cell electric vehicles

The analysis was carried out for **MHGVs** (Medium Heavy goods vehicles, GVW 3.5-12 t) and **HHGVs** (Heavy Heavy goods vehicles, GVW > 12 t) and takes into account data on the Polish market for 2022. An estimate of the TCO for 2030 and 2040 was also made based on projections of market development. The TCO analysis was prepared based on the assumption that a new heavy-duty vehicle is used for a period of 4 years.

TCO results are affected by several factors. These include: CAPEX (such as the cost of purchasing a vehicle), OPEX (e.g. the cost of fuel, the cost of maintenance) and costs of the infrastructure (private and public) and financing. It is important to remember that in addition to the technological dimension (method of vehicle propulsion and fuel type), TCO results are also affected by vehicle application (total vehicle weight, daily range or loading profile) and the geographic dimension (physical differences, including driving style, road quality, driving patterns, fuel and energy prices, road tolls or implemented policies).

For the purposes of this analysis, the following TCO equation was used:

$$TCO = I_0 - S_0 - \frac{RV_T}{(1+i)^t} + \sum_{t=1}^{T} \frac{\left(c_{ins} + c_{tax} + VKT \cdot \left(c_{O\&M} + c_{toll} + c_{energy}\right)\right)}{(1+i)^t} + infr + fin$$

Where:
I_0 - CAPEX, vehicle purchase price, (PLN)
S_0 - vehicle purchase subsidies, (PLN)
RV_T - residual value, (PLN)
i - discount rate, (%)
T - holding period, (1)
c_{ins} - annual insurance costs, (PLN)
c_{tax} - annual tax related to the vehicle, (PLN)
VKT - annual number of kilometers travelled by the vehicle, (km)
$c_{O\&M}$ - cost of maintenance and repairs, (PLN)
c_{toll} - road tolls, (PLN)
c_{energy} - cost of fuel, energy, (PLN)
infr - costs related to the infrastructure, (PLN)
fin - costs related to financing, (PLN)

Costs related to charging infrastructure were estimated using the following equation:

$$infr = (C_{equipment} + C_{installation}) + \sum_{t=1}^{T} \frac{C_{O\&M}}{(1+i)^t}$$

Where:
$C_{equipment}$ - cost of purchasing a charging station, (PLN)
$C_{installation}$ - cost of installation, (PLN)
$C_{O\&M}$ - annual cost of operation and maintenance, (PLN)
T - period of use of a charging station, (1)
i - discount rate, (%)

Three comparative TCO analyses were conducted, for:

- **MHGVs**, focusing on larger light commercial vehicles/small heavy goods vehicles with a GVW of 3.5-7 t, assuming an average daily distance traveled of 140 km (assuming 251 days of operation). For this type of vehicles, BEVs are assumed to be charged only at private charging stations, using AC, 22 kW chargers.
- **HHGVs**, with a GVW > 26 t, assuming an average daily distance traveled of 200 km (trips between branches). For this type of vehicles, BEVs are assumed to be charged only at private charging stations at night, using DC, 100 kW chargers.
- **HHGVs**, with a GVW > 26 t, assuming an average daily distance traveled of 500 km. For this type of vehicles, BEVs are assumed to be charged both at private charging stations (80%, using DC > 100 kW chargers) and at public charging stations (20%, using DC > 100 kW chargers).

In the case of FCEV technology, it was assumed that there would be no investment in own hydrogen refueling stations, as they require very high capital expenditure. The adopted hydrogen price takes into account both the costs associated with hydrogen production and the investment in the hydrogen station, as well as the profit of the third-party company whose station will be used to refuel the vehicles.

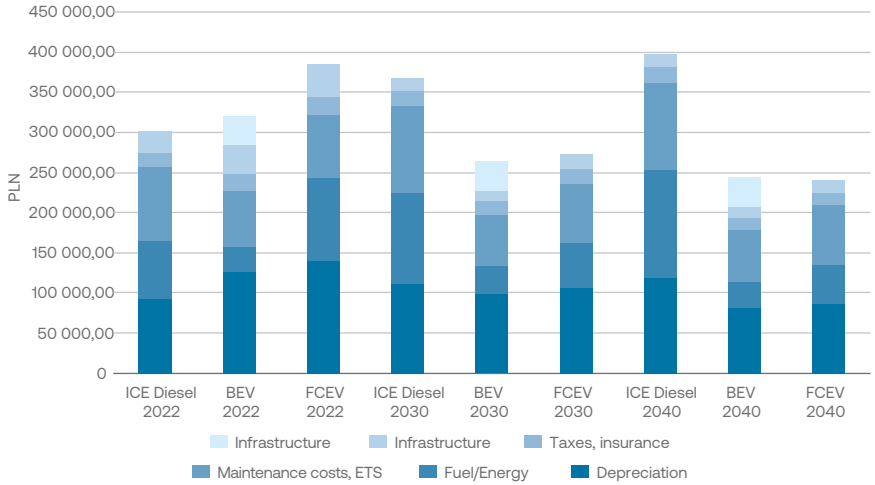
TCO analysis

- The results of the TCO analysis in PLN are presented in the form of charts for the three cases considered in 2022, 2030 and 2040. The components were aggregated into 6 cost groups:
- **Depreciation** - consisting of the cost purchase of the vehicle, subsidies for the purchase and residual value
- **Fuel/energy** - including fuel (energy) costs related to the price of fuel (energy), annual number of kilometers traveled and average combustion
- **Maintenance costs, ETS** - consisting of the average annual costs of vehicle maintenance and repairs, annual road tolls and ETS costs (elements depending on the annual number of kilometers traveled)
- **Taxes, insurance** - including annual vehicle insurance costs and annual tax related to the vehicle
- **Financing** - dependent on the cost of purchase, subsidy for vehicle purchase, residual value, own contribution, vehicle repurchase cost and financing cost (APRC)
- **Infrastructure** - which consists of the number of charging stations, the cost of purchasing a charging station and subsidies for its purchase, installation cost and annual costs of maintenance and repair

The differences between the alternative technology and the standard technology in the baseline year of 2022 indicate what potential support tools should be implemented to bridge the difference in costs that must be incurred over the assumed lifetime of the vehicle.

The results of the analysis are presented below:

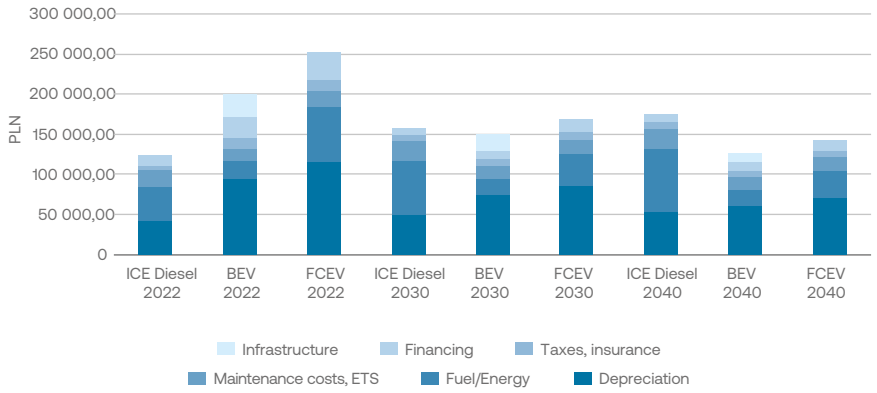
Analysis 1, MHGV, Daily distance: 140 km



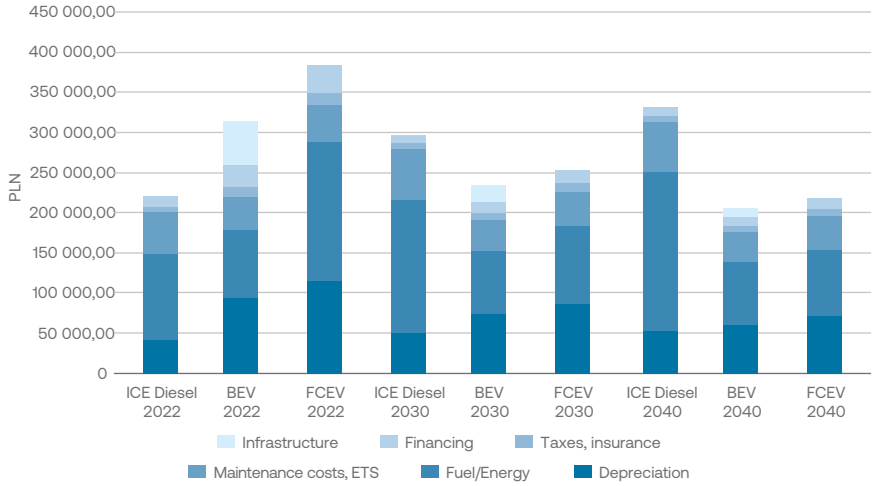
Conclusions: The total cost of ownership of battery and hydrogen vehicles in 2022 was higher than that of conventional vehicles, but the competitiveness of zero-emission technologies can be clearly seen in the following years. At present, alternative-drive cars are not economically affordable, the reason for which is largely due to the barrier to entry, understood as a high purchase price compared to a traditional diesel vehicle.

In 2022, in terms of its operation, a BEV is less expensive, but thanks to the drop in vehicle prices in 2030, the barrier of the high cost of acquiring such a vehicle, and thus the high cost of financing, will decrease, causing the total cost of ownership of an electric vehicle to become significantly more economically affordable. As early as in 2030, the TCO of electric and hydrogen vehicles will be significantly lower than that of diesel vehicles.

Analysis 2, HHGV, Daily distance: 200 km



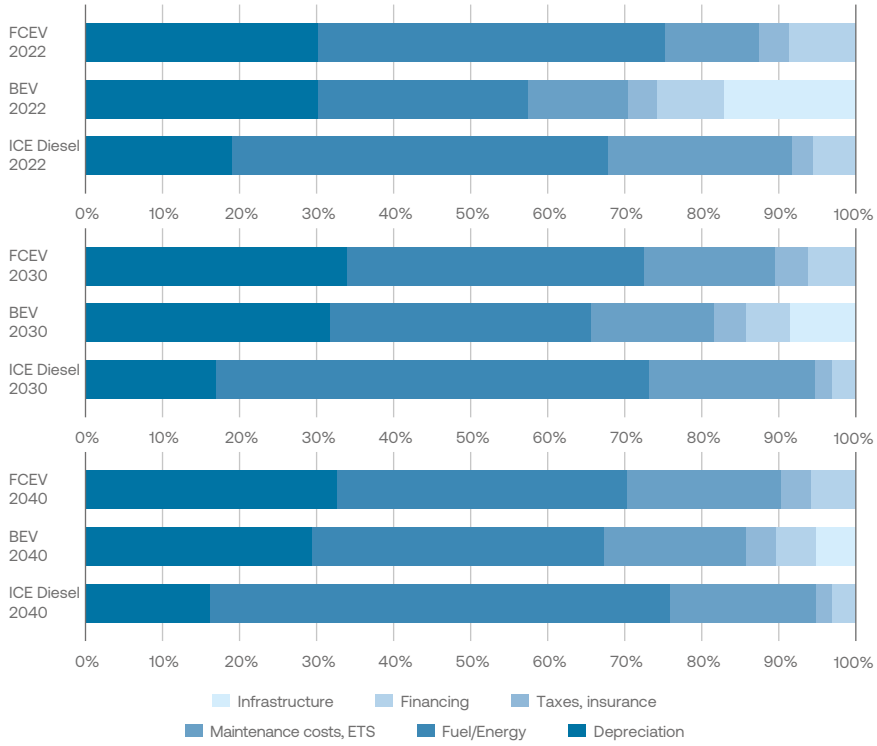
Analysis 3, HHGV, Daily distance: 500 km



Conclusions: As shown in the charts with the results of Analysis 2 and 3, in the case of heavy-duty vehicles, the way the vehicles are used has no significant impact on the outcome of the analysis. In both cases, in 2022 traditional trucks are much more economically affordable.

Due to the expected lower acquisition costs for battery and hydrogen vehicles and the increase in the price of traditional fuels, regardless of average daily number of kilometers traveled, they will have a lower total cost of ownership as early as in 2030.

The percentage distribution of component costs affecting the TCO of HHGVs with a daily distance traveled of 500 kilometers, by year, is presented below:



Conclusions: The operating costs of alternatively-fueled vehicles (purchase of energy/fuel and vehicle maintenance) are lower in each period analyzed compared to a standard vehicle. Based on the TCO analysis, it can be concluded that these technologies are not yet cost-effective, which mostly results from the purchase price of the vehicle, which will decrease significantly in 2030 due to technological advancement and competition between manufacturers. In addition, over the years, the cost of maintaining a diesel truck will increase. This will be caused, among other things, by rising fuel prices and regulations imposing further emission charges.

Summary and conclusions for the zero-emission vehicles industry

Fleet electrification would progress much more quickly if the Total Cost of Ownership of a battery electric or FCEV truck would be comparable to that of an internal combustion engine truck. The results of the conducted TCO analysis show that in 2022 the cost is not equal or lower for any of the analyzed cases.

- For N2 vehicles (Analysis 1, MHGV, daily distance of 140 km), the total cost of ownership is the most competitive in 2022. The similar cost of ownership of electric or FCEV vehicles, compared to internal combustion vehicles, means that it is in this area that the fastest transformation of the sector should take place.
- In the case of N3 vehicles (Analysis 2 and 3, HHGV, daily distance of 200 km and 500 km), the difference in the total cost of ownership between an alternative-fueled and ICE vehicle in 2022 is significant. It is necessary to implement support instruments in the near future in order to be able to introduce zero-emission solutions.
- By 2030, for all classes of vehicles, the TCO of electric vehicles will be lower than that of diesel vehicles, while by 2040 the TCO of FCEV vehicles will also be more competitive than that of diesel vehicles. Once the total costs of ownership are aligned, additional support instruments will no longer be necessary to transform the heavy-duty transport sector into a low-carbon one.

Chapter 5. Summary

Life cycle assessment of a heavy-duty vehicle and the user's perspective

The user's perspective is our starting point for analyzing the life cycle assessment of a heavy-duty vehicle in Poland. The lifetime can be divided into several stages, which have slightly different characteristics and conditions. The first stage is the purchase of a vehicle, which usually involves a significant amount of investment for the user. Over the vehicle's lifetime, there are fixed costs associated with the mere fact of owning a vehicle (e.g. taxes and insurance), but also variable costs of maintenance that depend on the vehicle's use and mileage (e.g. road tolls, fuel costs, repair and maintenance costs). Naturally, the degree of vehicle use will have an impact on the interrelation of these cost groups, thereby affecting the average cost of use per km2. What also matters to the user is access to the infrastructure needed to refuel or charge vehicles. At the final stage of use, there is the question of the residual value of the vehicle and the possibility of its sale to another user.

At each stage of use, there may be barriers that limit the potential of electrification of the sector. One of the most significant barriers is still the much higher cost of purchasing a zero-emission vehicle, which is even more important in an environment of high interest rates and the significant cost of servicing financing. The fixed costs incurred during the vehicle's operation (taxes), which do not take into account the vehicle's emissions level, do not create sufficient incentives for electrification. A potential barrier may also be the higher cost of insurance of a zero-emission vehicle due to its higher value. New technological developments also result in uncertainty about the cost of maintaining and repairing vehicles, especially with respect to battery performance and stability. The sources of uncertainty include the price and the price considerations for different energy sources. Another barrier is the lack of adequate public charging infrastructure for heavy-duty vehicles and the consequent need for users to incur additional expenses to establish their own charging points. This also involves the need to obtain a connection with adequate capacity from the grid operator, which requires additional costs and often lengthy procedures. There is also much more uncertainty involved in determining the residual value of a vehicle at the end of its useful life. A significant barrier may also be the need to sell a currently used internal combustion vehicle, for which the price obtained from the buyer is likely to be lower due to the regulatory framework.

Life cycle assessment of a heavy-duty vehicle

At each stage of use of a heavy-duty vehicle, there are barriers limiting the uptake of the zero-emission vehicle market

Expenditures	Taxes and insurance	Expenses	Cost	Infrastructure	Sale
Higher cost of purchasing zero-emission vehicles High interest rates	Lack of centrally established differentiation of vehicle tax Potentially higher cost of insurance due to higher cost of new vehicle purchase Uncertainty as to the amount of the premium rate (interest rate)	Low road tolls Uncertainty as to maintenance and repair costs Risk of vehicle recall due to battery instability	Uncertainty as to future prices Relatively high electricity price for businesses	Currently almost non-existent public truck charging infrastructure Relatively long vehicle charging time Additional cost when purchasing private charging stations Energy required for private charging stations: grid connection or own RES installations	Uncertainty as to the zero-emission vehicle value at the end-of-life Potential overestimation of leasing costs in the first years The need to sell ICE vehicles

Potential support instruments during vehicle life cycle

It is crucial that support for entrepreneurs in the transition to zero-emission vehicles be available at each stage of use and protect their position also in the future. It is useful to analyze support instruments in several groups relating to the stages of use of a heavy-duty vehicle:

- **Capital expenditure related to the purchase of the vehicle.** Supporting investment in both zero-emission vehicles and private charging infrastructure will be of great importance. This may be crucial at the first stage of market development, when the still limited supply translates into relatively high prices. It is worth noting that support for investment can take different forms - subsidized purchase of a vehicle (which is available in many countries that are pioneers in this market), but also subsidized lease payments, preferential loans (e.g. subsidized from EU funds, or public funds, or guaranteed by the State Treasury). Support can also come in the form of tax credits for such investments and accelerated depreciation of zero-emission property, plant and equipment.
- **Cost of operation.** At this stage, it will be important to internalize the cost of emissions, which means differentiating taxes (for vehicle owners) and road tolls according to the level of emissions. This is the trajectory taken by the EU regulations referred to in Chapter 3, which are either already in force or will be implemented in EU Member States. The pace of implementation of such directives and the setting of national parameters (more stringent than the minimum values provided for in the directive) can also be a form of instrument to support market uptake. This means that the cost of using an internal combustion vehicle will become higher, while in the extreme case zero-emission vehicles may benefit from full exemption from some taxes and charges. This is the case, for example, in Germany, where zero-emission vehicles have been exempted from road tolls (importantly, the differentiation of road tolls also occurred before the deadline specified in the directive). It will also be important to regulate the relations between prices of different propulsion technologies - putting higher taxes on fuel and potentially setting up a dedicated tariff for charging EVs (e.g. with a lower fixed charge).
- **Recharging infrastructure.** An important aspect in the longer term, especially for high vehicle mileage, will be access to public charging infrastructure, the establishment of which is envisaged by the Alternative Fuels Infrastructure Regulation (AFIR). However, the process is staged, and in the initial period of market development it is worth focusing on supporting the establishment of private charging points. This can include direct support for entrepreneurs making capital expenditures (as referred to above), but also organizational and administrative support. It appears that the issue of obtaining a connection and power allocation in order to operate a private charging station is a significant barrier also in terms of the duration of procedures. In the Netherlands, for example, a cooperation platform has been set up, bringing together grid operators, power companies, users and government representatives. A significant role may be played by the establishment of such private charging stations that are powered from renewable energy sources and introducing additional incentives for them. An additional advantage of such a solution is that there is no need to transmit electricity and build network infrastructure.
- **Sale of a vehicle (currently used internal combustion vehicle).** Support for entrepreneurs can address the stage of vehicle disposal - potential options include support for the replacement of an internal combustion vehicle with a zero-emission vehicle (a discount conditional on the scrapping of and recovery of raw materials from an internal combustion vehicle) and for the conversion of an internal combustion vehicle into a zero-emission one. The latter may be particularly important from the perspective of the Polish market, where on average internal combustion vehicles are older. This means that the average lorry operated in the Polish market is less technologically advanced than the average vehicle driven in Western European markets (fewer complex electronics), making such a conversion more likely and easier. The benefit of supporting such a conversion could be twofold, as older vehicles also have higher emissions, so converting them will yield greater carbon emission reductions per vehicle on average and have a greater contribution to achieving climate goals.

It is also worth considering the special position of small fleet owners and creating dedicated support for such users. This means, for example, that a dedicated pool of support for capital expenditure may be earmarked for users of small fleets, which often have limited organizational and financial capacity compared to large operators. Another interesting solution is the creation of regional support centers for small fleets, which could bring together users with this profile to jointly negotiate terms for the purchase of vehicles, provide access to information and financial instruments. Instruments dedicated for these companies could also include a program to support the conversion of diesel vehicles (especially older ones compliant with emission standards up to and including Euro 5) to battery vehicles.

Various preferential arrangements for zero-emission vehicles can also be offered as support. The set of potential instruments may be complemented by elements that do not directly affect the cost of operation of heavy-duty vehicles but offer their preferential treatment. This group of instruments may include green public procurement and low-emission zones. The latter are of great importance at the local level.

Policy toolbox

Different users have different needs

The set of instruments should meet the needs of specific users and remove barriers to electrification in specific segments. The basic assumption for creation of a set of instruments should be to support a change the total cost of ownership of an internal combustion vehicle in relation to that of a zero-emission vehicle. However, it is worth remembering that the transport sector is not homogenous and different users may have different needs. The total cost of ownership will depend on the user profile and their mode of operation/business model. In our analysis, we consider the situation of three users for whom the TCO analysis has been prepared:

- **Medium heavy goods vehicles (N2),** MHDV with a weight of approximately 7 tons, average daily distance of 140 km, charged only at private stations (22 kW AC chargers),
- **Transport between branches (N3),** HHGV with a weight of more than 26 tons, average daily distance of 200 km, charged only at private stations at night and at handling centers, using 100 kW DC chargers,
- **Long-distance transport (N3),** HHGV with a weight of more than 26 tons, average daily distance of 500 km, charged both at private stations (80%, >100 kW DC chargers) and at public stations (20%, >100 kW DC chargers).

The scale of the user's business also matters - a micro-enterprise faces different challenges and needs different support than a large transport company or an operator that outsources transport services to subcontractors.

- **Micro-entrepreneurs** have less financial resources resulting in hindered access to tools from financial markets. This leads to their greater vulnerability to market shocks and lower risk appetite. This means that spreading a significant cost over time with high uncertainty of investment is more problematic for them. For this reason, tools that significantly and directly reduce the cost of financing and facilitate access to financing are of great importance to them. The second group of tools of particular importance to them are those that mitigate risk. In terms of infrastructure, micro-enterprises tend to be dependent on other entities, any investment by a single entity in own infrastructure would represent a significant cost, so cooperation is expected to occur in this regard: either through partnership or through the use of third-party supplier (e.g. Greenway), thus transparent procedures are more important here than direct support.
- **Large enterprises** have better access to financial markets and potentially greater financial resources, particularly if they also conduct other activities. This group also includes operators that engage subcontractors. In the first years, they should be the owners or major lessees of the fleet. For this group, tools geared toward reducing upfront costs are less important, as are tools that improve shock absorption and reduce risk. More important will be instruments geared toward institutional promotion of zero-emission transport and tax measures. Any incentive to establish private infrastructure is potentially important.

Criteria for the assessment of instruments

A number of aspects can be taken into account when choosing instruments. In our analysis we focused on the following criteria:

- **Fiscal cost.** A given instrument is evaluated in terms of its potential cost for public finances, with a three-grade scale applied: (1) high cost, (2) low cost, (3) no significant cost or even positive impact on public finances.
- **Effectiveness of the instrument.** The evaluation of an instrument is based on its effect in terms of its impact on market mechanisms and competition. The scale includes three grades: (1) low efficiency (risk of deadweight loss, i.e. when the instrument has little impact on the market, but only generates costs), (2) positive efficiency (support for the choice of a zero-emission vehicle in the decision to purchase a new vehicle and expand the fleet), (3) high efficiency (support for the replacement of an internal combustion vehicle with a zero-emission vehicle).
- **Impact on TCO.** Assessment of the extent to which an instrument affects the total cost of ownership of a vehicle based on the TCO analysis performed. It can take the following three values: (1) indirect impact, (2) low impact, (3) high impact.

For each of the analyzed instruments, we also indicated an indicative proposed horizon for their application. Here, we identified instruments with a very short horizon (2-3 years), needed at the first stage of market development, when zero-emission technologies are not yet commonly used, the considerations of the cost of ownership for different technologies are still unfavorable for zero-emission vehicles, and there is a lot of uncertainty and risk for entrepreneurs. Instruments in this group, because they are expected to significantly affect the change in TCO considerations, usually also involve a significant cost, so the period of their application should be minimized to limit the cost of such support. Another group of measures are those with a slightly longer horizon - approximately 5 years. Some of the measures, especially those related to EU climate policy and decarbonization of transport, are generally implemented permanently. Their effectiveness is imposed by EU regulations, but the process of their implementation and the selection of specific parameters often takes place at the level of individual Member States.

This provides an opportunity for the adoption of more ambitious solutions faster than envisaged in the EU directives, which can also further support the uptake of the zero-emission vehicle market.

We also consider whether a given measure is applied in countries where market development is at its most advanced stage. This applies to the 3 leading markets analyzed in more detail in the previous chapter: Germany, France and the Netherlands.

Toolbox

How to read the policy toolbox?

The tables on the following pages list potential instruments aimed at supporting the development of the zero-emission vehicle market. Three separate tables are presented for three types of users:

User 1: Medium heavy goods vehicles (N2), average daily distance of 140 km,
User 2: Transport between branches (N3), average daily distance of 200 km,
User 3: Long-distance transport (N3), average daily distance of 500 km.

The instruments are intended to improve the cost-effectiveness of owning a zero-emission vehicle (reduce the total cost of ownership) relative to that of an internal combustion vehicle from the user's perspective. The instruments are grouped into several categories corresponding to the stages of the vehicle's lifetime: capital expenditure, costs of operation, charging infrastructure, vehicle sale/conversion, and others.

Each instrument was evaluated against the following criteria: fiscal cost, the instrument's effectiveness, impact on the total cost of ownership (described in detail above). We also indicated an illustrative proposed horizon of application of a given instrument and provided information whether a given measure is applied in countries where market development is at its most advanced stage (Germany, France, the Netherlands).

The last two columns of the table provide an indication of whether the instrument is intended for micro-enterprises (up to 9 employees) or large enterprises (250 or more employees), taking into account the nature and specificity of both segments.

Medium heavy goods vehicles (N2)

○ high	deadweight loss (perspective!)	indirect	fixed		
◑ low	good (purchase support)	low	5 years		
● none / insignifi-cant / positive	high (exchange support)	high	2-3 years	Y/N	

	Fiscal cost	Effectiveness (market mechanism / impact on competition)	Impact on TCO	Implementation perspective	Use in leading countries	Micro-businesses	Large enterprises
Investment expenditure							
Investment support: financing of purchase, leasing etc., dedicated envelope for MSE	○	○	●	2-3 years	Y	■	
Preferential loans (e.g. BGK, EIB co-financing)	◑	◑	●	2-3 years	N		■
Tax credits, accelerated depreciation	◑	○	◑	5 years	Y	■	■
Cost of operation							
Taxation of CO^2 emissions (fees and taxes differentiated in terms of CO2 emissions)	●	●	◑	Fixed*	Y**	■	■
Increase in fuel taxation (including transport in ETS II) / dedicated charging tariffs, e.g. with lower fixed fee	●	●	●	Fixed*	Y**	■	■
Differentiation of road charges (in terms of CO^2 emissions) - in line with the revised EU Directive (Eurovignette)	●	●	–	Fixed*	Y**		
Recharging infrastructure							
Private infrastructure support (co-financing, also RES, tax credits)	◑	◑	●	5 years	Y***	■	■
Improvement of administrative procedures (related to the establishment of private charging stations)	●	◑	○	Fixed	Y	■	■
Vehicle sale / conversion							
Support for the replacement of ICE trucks with zero emission trucks (a discount for scrapping vehicles with Euro 5 standard or lower / recovery of raw materials from the internal combustion engine vehicle)	○	●	●	5 years	N	■	
Support for conversion of internal combustion engine vehicles to zero-emission vehicles (co-financing)	○	●	●	5 years	N	■	
Other							
Dedicated support for small fleet owners (other than co-financing, inter alia, cooperation, merging small entities into groups)	◑	◑	◑	5 years	N	■	
Green public procurement	◑	◑	–	Fixed*	Y		■
Low-emission zones (at local level)	◑	●	–	Fixed*	Y	■	■

* possible progressive changes** EU regulations, implementation process and parameters at national level ***, but no tax credits

Transport between branches

○	high	deadweight loss (perspective!)	indirect	fixed			
◑	low	good (purchase support)	low	5 years			
●	none / insignifi-cant / positive	high (exchange support)	high	2-3 years	Y/N		

	Fiscal cost	Effectiveness (market mechanism / impact on competition)	Impact on TCO	Implementation perspective	Use in leading countries	Micro-businesses	Large enterprises
Investment expenditure							
Investment support: financing of purchase, leasing etc., dedicated envelope for MSE	○	◑	●	2-3 years	Y	■	
Preferential loans (e.g. BGK, EIB co-financing)	◑	◑	●	2-3 years	N		■
Tax credits, accelerated depreciation	◑	○	◑	5 years	Y	■	■
Cost of operation							
Taxation of CO^2 emissions (fees and taxes differentiated in terms of CO^2 emissions)	●	●	◑	Fixed*	Y**	■	■
Increase in fuel taxation (including transport in ETS II) / dedicated charging tariffs, e.g. with lower fixed fee	●	●	●	Fixed*	Y**	■	■
Differentiation of road charges (in terms of CO2 emissions) - in line with the revised EU Directive (Eurovignette)	●	●	◑	Fixed*	Y**	■	■
Recharging infrastructure							
Private infrastructure support (co-financing, also RES, tax credits)	◑	◑	◑	5 years	Y***	■	■
Improvement of administrative procedures (related to the establishment of private charging stations)	●	◑	○	Fixed	Y	■	■
Vehicle sale / conversion							
Support for the replacement of ICE trucks with zero emission trucks (a discount for scrapping vehicles with Euro 5 standard or lower / recovery of raw materials from the internal combustion engine vehicle)	○	●	●	5 years	N	■	
Support for conversion of internal combustion engine vehicles to zero-emission vehicles (co-financing	○	●	●	5 years	N	■	
Other							
Dedicated support for small fleet owners (other than co-financing, inter alia, cooperation, merging small entities into groups)	◑	◑	◑	5 years	N	■	
Green public procurement	◑	◑	–	Fixed*	Y		■
Low-emission zones (at local level)	◑	●	–	Fixed*	Y	■	■

* possible progressive changes** EU regulations, implementation process and parameters at national level ***, but no tax credits

Long-distance transport

○	high	deadweight loss (perspective!)	indirect	fixed		
◑	low	good (purchase support)	low	5 years		
●	none / insignifi-cant / positive	high (exchange support)	high	2-3 years	Y/N	

	Fiscal cost	Effectiveness (market mechanism / impact on competition)	Impact on TCO	Implementation perspective	Use in leading countries	Micro-businesses	Large enterprises
Investment expenditure							
Investment support: financing of purchase, leasing etc., dedicated envelope for MSE	○	◑	●	2-3 years	Y	■	
Preferential loans (e.g. BGK, EIB co-financing)	◑	◑	●	2-3 years	N		■
Tax credits, accelerated depreciation	◑	○	◑	5 years	Y	■	■
Cost of operation							
Taxation of CO^2 emissions (fees and taxes differentiated in terms of CO^2 emissions)	●	●	◑	Fixed*	Y**	■	■
Increase in fuel taxation (including transport in ETS II) / dedicated charging tariffs, e.g. with lower fixed fee	●	●	●	Fixed*	Y**	■	■
Differentiation of road charges (in terms of CO2 emissions) - in line with the revised EU Directive (Eurovignette)	●	●	●	Fixed*	Y**	■	■
Recharging infrastructure							
Private infrastructure support (co-financing, also RES, tax credits)	◑	◑	●	5 years	Y***	■	■
Improvement of administrative procedures (related to the establishment of private charging stations)	●	◑	○	Fixed	Y	■	■
Vehicle sale / conversion							
Support for the replacement of ICE trucks with zero emission trucks (a discount for scrapping vehicles with Euro 5 standard or lower / recovery of raw materials from the internal combustion engine vehicle)	○	●	○	5 years	N	■	
Support for conversion of internal combustion engine vehicles to zero-emission vehicles (co-financing	○	●	○	5 years	N	■	
Other							
Dedicated support for small fleet owners (other than co-financing, inter alia, cooperation, merging small entities into groups)	◑	◑	◑	5 years	N	■	
Green public procurement	◑	◑	–	Fixed*	Y		■
Low-emission zones (at local level)	◑	●	–	Fixed*	Y		

* possible progressive changes** EU regulations, implementation process and parameters at national level ***, but no tax credits

Impact on TCO

The use of support measures can have a significant impact on the TCO results and the potential of electrification of the sector. To illustrate the impact of support on the TCO results, a set of 3 examples of instruments was selected, for which a TCO analysis was then carried out similarly to that presented in the previous chapter. The analysis was carried out for two users:

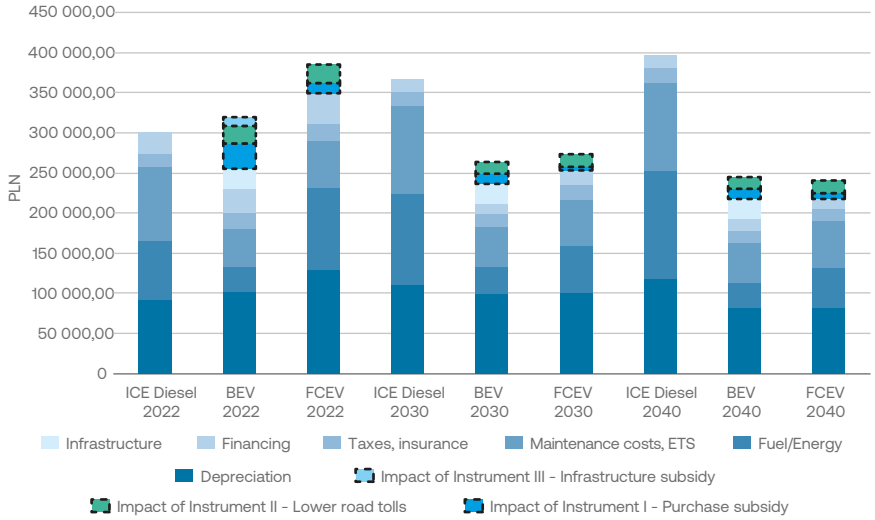
- for a user of a larger van/small heavy-duty vehicle with a GVW of 3.5-7 t, assuming an average daily distance of 140 km (User 1 in the tables above),
- for a user of a heavy-duty vehicle (>26 t) operating an average daily distance of 200 km (User 2 in the tables above).

The charts below show the results of these simulations. The impact of the instruments compared to the total cost of ownership in the baseline scenario (without the use of any support instruments) is also presented.

User 1 - larger van/small heavy-duty vehicle with GVW of 3.5-7 t, average daily distance of 140 km

The TCO analysis was conducted based on the use of 3 support instruments:

- **Subsidy for the purchase of a vehicle.** It was assumed that the purchase of a zero-emission vehicle would be subsidized at 50% of the difference between the cost of purchasing a zero-emission vehicle and the cost of an internal combustion one.
- **Varying road tolls.** We assume that at the starting point, the road toll for zero-emission vehicles will be completely abolished (which is possible until 2025), after that it will be 25% of the toll applicable to an internal combustion vehicle. However, we do not assume that the fee for an internal combustion vehicle will be raised, which is also possible.
- **Subsidies for private charging infrastructure.** We assume a subsidy of 50% of a charger purchase price (but not more than EUR 30,000) and a subsidy of 50% of the installation cost (not more than EUR 15,000). These assumptions are based on the currently available instrument to support the development of alternative fuel supply infrastructure along the trans-European transport network TEN-T[209]. The areas of support under the program include publicly available EV charging stations and charging stations for public transport vehicles in TEN-T urban nodes. Since in our scenario we are analyzing support for private instead of public infrastructure, for illustrative purposes we assumed that the support would be at 50% of the maximum support for public infrastructure under this program (in our example, a maximum of EUR 30,000 for the purchase of a charger and EUR 15,000 for the cost of installation, while in the current program for public infrastructure it is respectively EUR 60,000 and EUR 30,000).



This market segment (user type) has the greatest potential for electrification, and the application of this set of instruments makes it possible to lower the TCO for a zero-emission vehicle below the TCO for an equivalent internal combustion vehicle (this relation will be preserved even without direct subsidies). The use of this set of support instruments results in TCO reduced by about 20% for an electric vehicle and about 9% for a hydrogen-fueled vehicle in the first year of TCO calculation. The largest impact is attributable to the vehicle purchase subsidy, followed by a slightly lower impact coming from road toll reduction for zero-emission vehicles, with the smallest impact resulting from subsidies for private charging stations. The potential of electrification of this segment is the greatest among the three users analyzed (the smallest difference in TCO for a zero-emission vehicle and an internal combustion vehicle). Therefore, in our analysis, even with the use of only 2 instruments (and excluding the direct subsidy for purchasing a low-emission vehicle) the resulting TCO is lower for a zero-emission vehicle. The use of these two instruments makes it possible to reduce TCO by about 10% for an electric vehicle and about 6% for a hydrogen-fueled vehicle in the first year of TCO calculation.

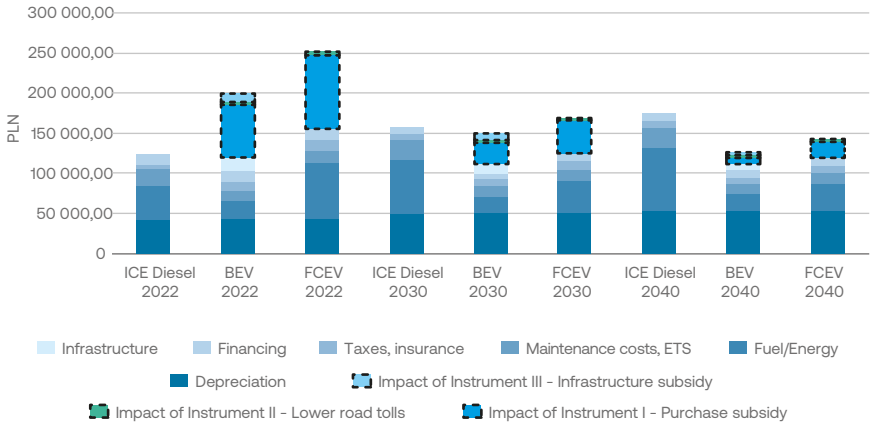
[209] Bank Gospodarstwa Krajowego. CEF Transport - Alternative Fuel Infrastructure Facility https://www.bgk.pl/programi-i-fundusze/program/program-cef-transport-alternative-fuel-infrastructure-facility/#c22442 (accessed on: 5 April 2023).

User 2 - vehicle with a GVW > 26 t, average daily distance traveled of 200 km (trips between branches)

The TCO analysis was conducted based on the use of 3 support instruments:

- **Subsidy for the purchase of a vehicle.** It was assumed that the purchase of a zero-emission vehicle would be subsidized at 65% of the difference between the cost of purchasing a zero-emission vehicle and the cost of an internal combustion one.
- **Varying road tolls.** We assume that at the starting point, the road toll for zero-emission vehicles will be completely abolished (which is possible until 2025), after that it will be 25% of the toll applicable to an internal combustion vehicle. However, we do not assume that the fee for an internal combustion vehicle will be raised, which is also possible.
- **Subsidies for private charging infrastructure.** We assume a subsidy of 50% of a charger purchase price (but not more than EUR 30,000) and a subsidy of 50% of the installation cost (not more than EUR 15,000). These assumptions are based on the currently available instrument to support the development of alternative fuel supply infrastructure along the trans-European transport network TEN-T[210]. The areas of support under the program include publicly available EV charging stations and charging stations for public transport vehicles in TEN-T urban nodes. Since in our scenario we are analyzing support for private instead of public infrastructure, for illustrative purposes we assumed that the support would be at 50% of the maximum support for public infrastructure under this program (in our example, a maximum of EUR 30,000 for the purchase of a charger and EUR 15,000 for the cost of installation, while in the current program for public infrastructure it is respectively EUR 60,000 and EUR 30,000).

This market segment (user type) has lower potential for electrification and requires a higher subsidy for purchasing a vehicle (65% of the difference in the purchase price) to lower the TCO for a zero-emission vehicle below the TCO for an equivalent internal combustion vehicle. The use of this set of three support instruments results in TCO reduced by about 40% for an electric vehicle and about 38% for a hydrogen-fueled vehicle in the first year of TCO calculation. The largest impact is attributable to the vehicle purchase subsidy, with a considerably lower impact coming from road toll reduction for zero-emission vehicles and subsidies for private charging stations.



Financing

An important aspect of establishing a support program is its financing, often based on public funds. Many countries have government support programs in place, but some instruments may also affect the budgets of local government units, which are responsible for setting the rates of certain taxes. Financing may also be provided from special purpose funds, such as the National Fund for Environmental Protection and Water Management. Other national institutions, such as Bank Gospodarstwa Krajowego (the Polish development bank), which offers loans co-financed by the EIB, may also play an important role.

Instruments facilitating the implementation of the EU Green Deal strategy and other instruments supporting the green transition offered by development institutions will be of great importance. An important instrument may be the InvestEU program, which supports investments related to the strategic goal of achieving climate neutrality by 2050. Under the program, additional funds have also been reserved for areas for which the cost of a green transition is relatively more difficult to incur (Just Transition Scheme). Many development institutions, such as the EBRD, are expanding support for projects consistent with the ambitious climate goals.

[210] Ibid.

There has also been an ever-growing interest of the financial sector in financing green investments. This is due to increasing regulatory pressures, more detailed assessment of portfolio quality in terms of climate risk, and shifting funding to sustainable investments compatible with the EU Taxonomy[211].

- **Banking sector.** An example of this type of financing in Poland is the five-year Sustainability Linked Loan (SLL) for EUR 225 million provided to the Raben Group. The margin on the SLL was linked to Raben's fulfillment of conditions defined by five environment, social and governance (ESG) key performance indicators (KPIs) in road transport and logistics sectors. The KPIs applied in the SLL loan are as follows:
  - reduction of emission intensity of Raben's facilities by 30%
  - reduction of emission intensity of transport operations by 10%
  - share of vehicles meeting Euro 5 and 6 standards in the fleet at 96%
  - relative optimization of road transport resulting from improved transport efficiency
  - greenhouse gas emission calculations - updating and expanding the CO2 calculator for transport operations.
- **Capital market.** An rapidly growing segment of the capital market are green bonds and sustainability-linked bonds.
- **Financial innovation. New financial instruments are also being developed to allow financial institutions assume some of the risks associated with the transition.** Examples include dynamic pay-per-mile leases (which reduce the risk for fleet operators by making lease payments conditional on vehicle use) or battery-as-a-service (purchasing batteries as a monthly subscription for the use the product).

The importance of the right choice of support instruments

Strategies and programs to support the uptake of the zero-emission vehicle market should take into account the specifics of the transport market in a given country. The goal should be to remove specific barriers for specific users using a coherent set of multiple instruments, which should lead to significant improvements in the difference between the costs of vehicle operation in favor of zero-emission vehicles. It is important to distinguish between the needs of micro-enterprises and those of large transport companies (or operators outsourcing transport services to subcontractors). Due to the dynamic changes in the market, it is important to constantly monitor and review the performance of instruments and program parameters every 2-3 years. The transition may be supported by the trends increasingly evident in the financial sector - shifting financing to green, sustainable investments. In setting up national support for electrification of heavy-duty vehicles in Poland, the selection of specific tools and instruments from the proposed policy toolbox should take into account the following key issues:

- Support should address the elimination of specific barriers for specific users. Instruments should be considered in terms of their impact on the total cost of vehicle ownership. Application of the measures should lead to a competitive cost of using zero-emission vehicles in relation to the cost of using internal combustion vehicles.
- The specific nature of and challenges inherent in the activities of micro-enterprises and large transport companies are different (financial resources, availability of financial market instruments, susceptibility to market shocks, risk appetite). For the former, measures that directly lead to significant reduction of financing costs and mitigate risk will be of particular importance.
- A wide range of instruments is available. Although investment co-financing has a significant impact on the total cost of ownership, the cost of the instrument is high, and its use should be limited to the first period of market development. It is worth not to neglect other available instruments, which, when used together, can provide significant support.
- Many instruments are consistent with the EU's strategic climate goals, which also include the decarbonization of transport. The implementation of such regulations in Poland will significantly change the operation of the transport sector. It is worth considering how to support and prepare the sector for these challenges. In many cases, regulatory implementation and specific parameters are at the discretion of individual Member States.
- In order for electrification to entail decarbonization, it is necessary to stimulate investment in the production of zero-emission green energy in Poland. Access to zero-carbon/renewable energy sources is increasingly becoming a prerequisite for making a decision on investing in a given country. Similarly, strategies of more and more companies include the goal of zero-carbon operations and progressive reduction of their carbon footprint along the entire value chain, including in transport.
- The costs of decarbonizing transport from a current viewpoint should be considered taking into account the costs of not following through with the investments. Failure to decarbonize the market means rising operating costs in the future, which translates into lower profitability. It could also damage competitiveness, which entails the risk that Polish transport companies may lose their markets. Transport decarbonization is a major challenge for the competitiveness of the sector due to the necessary expenditures. However, without planning and supporting the transition, we are ruining

[211] For the significance of climate change and regulatory pressures to the banking sector, see Łaszek A., Hołda P. Zmiany klimatyczne a sektor bankowy: Co rosnąca presja konsumentów i regulatorów oznacza dla banków. Bezpieczny Bank 4(89) 2022.

the prospects for the development of Polish transport companies in the coming years. Demand for non-zero-emission transport services will inevitably decline under customer pressure. The transition can also provide a new boost to the economy and help maintain jobs.

- It is worth taking advantage of synergies. A set of several measures focused on the same objective can produce a greater effect that the sum of the impacts of each instrument separately.
- From the point of view of public finances, it makes sense to use fiscally neutral solutions. This category will include solutions that simultaneously raise the cost of using internal combustion vehicles and lower that cost for zero-emission vehicles. Such instruments are consistent with the broad taxation of sources of greenhouse gas emissions (e.g. varying road tolls or taxes according to the level of vehicle emissions).
- Recycling of revenue. Part of the revenue from emission taxation may be used to finance other support instruments or support more vulnerable entities, e.g. owners of small fleets.
- Support is provided on a dynamically changing market. Therefore, constant monitoring of activities and utilization of the instruments is essential. It is also recommended to repeat the TCO analysis and review the effectiveness of instruments and program parameters every 2-3 years.
- In addition to domestic public funds, maximum use should be made of instruments to support the green transition, including the measures to implement the EU Green Deal strategy. It is also worth using trends in the financial sector - redirection of financing towards green and sustainable investments, in line with the EU Taxonomy.

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