5.1 Implementing zero emission transport

Progress towards implementing zero emission transport is improving, but needs to be further accelerated

Past progress: Progress towards implementing zero-emission transport improved in recent years: the share of zero emission vehicles (ZEVs) in the light- and heavy-duty vehicle stocks increased by nearly 60% and 140%, respectively, between 2017 and 2022, while the total number of recharging stations in the EU increased by over 190% per year between 2018 and 2023. Even though there has been real growth in zero and low emission vehicle and infrastructure deployment, the overall pace of progress was still far too slow in the assessed period: to achieve climate neutrality, ZEVs must account for 99% of the total passenger light-duty vehicle (LDV) stock and 70% of the total heavy-duty vehicle (HDV) stock in 2050 (EC, 2020g). To do so, the annual increase in ZEV uptake needs to occur 8 times faster for passenger vehicles and 444 times faster for heavy-duty vehicles. While 21.6% of new passenger car registrations were ZEVs in 2022, up by nearly 20% compared to 2018, the share is still increasing too slowly to reach the EU's 100% zero emission new passenger vehicles sales target by 2035. The EU's recharging network is expanding but is being developed too slowly to be compatible with climate neutrality; the rate of progress for recharging points must increase by 3.8 times.

Table 31: Progress towards implementing zero emission transport

Share of EVs in passenger car stock [%]	⚠
Share of ZEV in heavy-duty vehicle stock [%]	⚠
Share of ZEVs in new passenger car registrations [%]	!
Total number of recharging points [#]	⚠

Policy context: The EU strengthened the CO_2 emission performance standards in 2023 and, in doing so, effectively initiated the phase-out of ICE-based passenger vehicles by 2035. However, following Member State (MS) resistance, the standards may be amended to allow for carbon-neutral fuelled ICE vehicles after 2035. The EU reinforced the Alternative Fuels Infrastructure Regulation (AFIR) in 2023 to better coordinate recharging infrastructure development. MS have developed a diverse range of purchase subsidies, tax benefits, and behavioural incentives to support ZEV uptake and recharging infrastructure deployment. Even so, ZEV uptake is limited by upfront costs and insufficient recharging infrastructure, resulting in uneven progress across MS.

Areas of action: Progress could be made by strictly enforcing CO_2 emission standards for LDVs and formally adopting the proposal for more stringent standards for HDVs (EC, 2023ae). To improve affordability and access to ZEVs, Member States could expand fiscal policies that render ZEVs more cost competitive. The EU could encourage good fiscal policy practices to ensure equitable access to ZEVs across borders. Additional policy to support the accelerated development and deployment of heavy-duty ZEVs is necessary. Both EU- and MS-level policies could incentivise the production of more efficient, compact, and affordable ZEVs. Expediting stock turnover for ICEs and establishing the used ZEV market could be supported by national and EU-level policy.

A closer look at past progress

Achieving climate neutrality in the transport sector requires a fundamental shift away from ICE vehicles towards zero and low emission vehicles—particularly battery electric vehicles (BEVs) and fuel cell electric vehicles (FCEVs)—across both the light- and heavy-duty vehicle segments. The share of ZEVs in the existing stock contextualises the current state of decarbonisation in road transport, while the share of new ZEV registrations provides insight into the future makeup of the total vehicle stock. To support the diffusion of ZEVs, a robust and accessible recharging network across rural and urban settings is required.

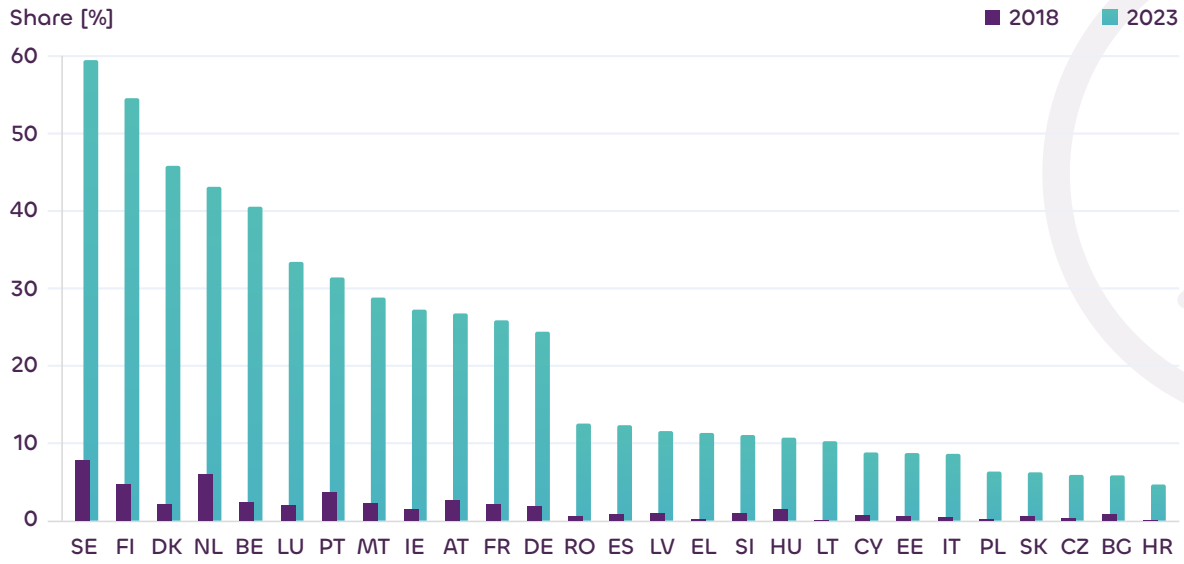
Share of ZEVs in new passenger car registrations [%]

Globally, Europe is a frontrunner in light-duty ZEV deployment; the continent accounts for 25% of global electric car sales and 30% of the global stock of EVs (IEA, 2023a). In 2022, 21.6% of new passenger vehicle registrations were ZEVs (EEA, 2023f). This share was increasing by 4.5%-points per year for the assessed period. However, this rate is still too slow to reach the 100% sales target in 2035 (assuming linear growth). New ZEV registrations must increase by at least 6%-points per year to achieve the 2035 target.

The European ZEV market is increasingly competitive (IEA, 2023a). New players, especially from China (ACEA, 2023c), are disrupting the European market with more affordable options and are putting pressure on legacy auto manufacturers to expand their electric offerings and reduce retail prices (Carey et al., 2024). Nevertheless, affordability remains a principal barrier to ZEV adoption (ACEA, 2023e). Currently, purchase prices for BEVs in the EU are still substantially higher than for ICE counterparts: in 2021, the average cost of a new BEV was just under EUR 50,000, while the average ICE retailed at EUR 30,000 (IEA, 2022b). What contributes to the higher purchase price is that a disproportionate share of new BEVs belongs to the high-price, premium vehicle segment (T&E, 2024a). The unaffordability of BEVs raises equity concerns: there exist vast differences in the share of ZEVs in Northwestern Member States in comparison to Central, Eastern, and Southern countries that link to differences in average incomes between countries (ACEA, 2023d). Although typically more expensive upfront, the reduced running costs of BEVs mean that the total cost of ownership for BEVs is at least equal to or cheaper than traditional ICE vehicles (Ellerbeck, 2023); the higher purchasing price can be fully recovered in as little as five years of ownership (Liu et al., 2021).

At the MS level, countries that reduced the purchase price of electric vehicles and offer other incentives had the highest registration shares of ZEVs (IEA, 2018). Additionally, both the EU and Member States are expanding recharging infrastructure and, in doing so, are removing a significant barrier to ZEV adoption. Across all Member States, the share of ZEVs in new passenger car registrations has grown substantially: between 2017 and 2022, registrations increased by nearly 67% per year. Spearheading the growth in new passenger ZEV registrations are Sweden and Finland, where over half of all new passenger vehicle registrations were ZEVs in 2022; the shares of ZEVs in new registrations are 59.5% and 54.6%, respectively. In Denmark, the Netherlands, and Belgium, new ZEV registrations account for over 40% of all 2023 LDV registrations (EAFO, 2024b). The variety in policy structure (see below), combined with the wide range of socioeconomic conditions and cultural preferences across the EU, results in diverse progress in ZEV uptake between Member States.

Figure 4: Past progress by Member States in increasing the share of ZEVs in new passenger vehicle registrations

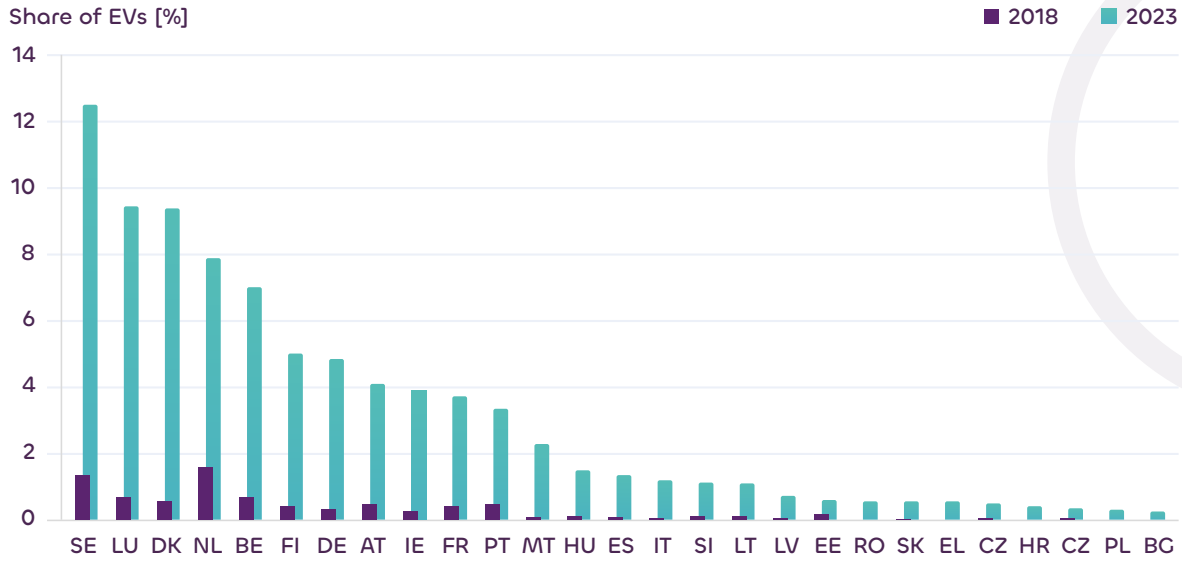


Source: EAFO (2024a). Note: ZEVs include EVs (including battery electric vehicles (BEVs), fuel cell electric vehicles (FCEVs) and plug-in hybrid vehicles (PHEVs)) as well as hydrogen combustion engine vehicles (H2-ICEVs).

Share of EVs in passenger car stock [%]

By 2050, ZEVs must make up 99% of the total share of passenger cars (EC, 2020g). In 2022, the share of EVs in the total passenger car stock amounted to only 2.3% and was increasing far too slowly. Between 2017 and 2022, the share of EVs increased by 0.4%-points annually. To reach a 99% share of ZEVs by 2050, the yearly increase in the share of EVs must happen at least 8 times faster. It is worth noting that this assessment assumes linear growth in EV deployment. However, EV deployment may increase exponentially and follow an S-curve pattern. Signs of exponential growth are already visible: despite only accounting for less than 3% of the total LDV stock in 2022, the EU's ZEV fleet size increased more than 10-fold in only five years (EAFO, 2024b). Several Member States dominate the overall EU trend. Sweden is the Union's clear frontrunner: ZEVs made up 12.6% of the total stock of passenger cars in 2023. To put the growth of the Swedish ZEV share in perspective, ZEVs only comprised 1.4% of the passenger car stock in 2018. The share of ZEVs in Luxembourg and Denmark accounted for approximately 9.4% of their respective car stocks in 2023, while the share of ZEVs hovered around 7.9% in the Netherlands. With about 2.4 million ZEVs in 2023, Germany boasts the greatest total number of ZEVs in the EU (EAFO, 2024b). The share of ZEVs in the overall vehicle stock is directly linked to the new registrations in the Member States. Therefore, the same tools that drive ZEV registrations—robust financial incentives and extensive recharging infrastructure—increase the share of ZEVs in the total passenger vehicle stock.

Figure 5: Past progress by Member States in increasing the share of EVs in passenger car stock

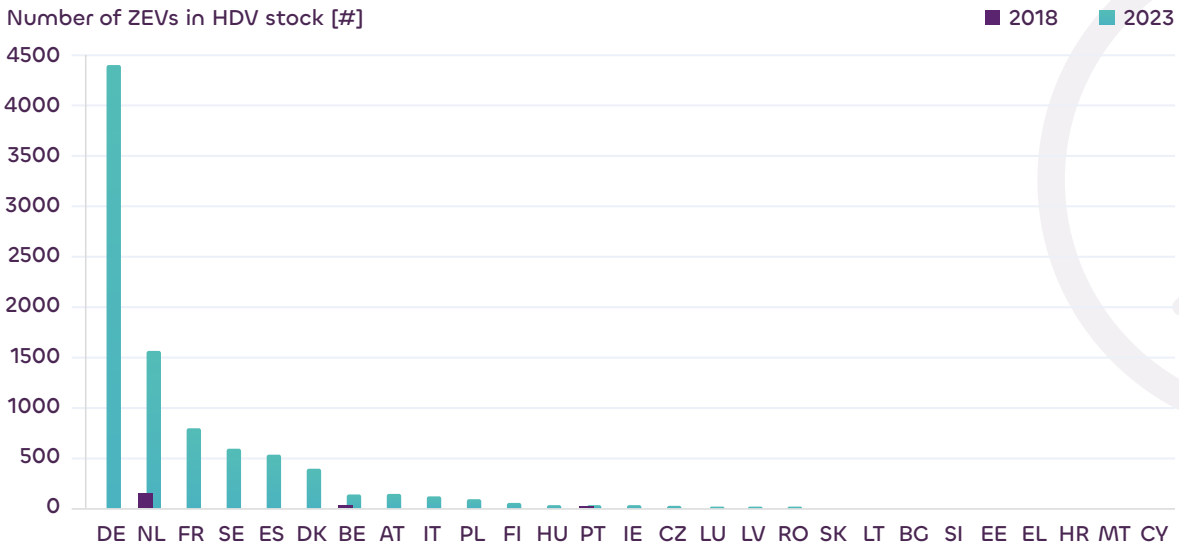


Source: EAFO (2024a).

Share of ZEVs in heavy-duty vehicle stock [%]

To align with the EU's climate neutrality target, the share of ZEVs in the heavy-duty vehicle stock needs to reach 70% by 2050 (EC, 2020g). It is important to note that the zero and low emission HDV segment is in a much earlier stage of development compared to the LDV sector: battery electric HDVs have only recently become commercially available (Lowell & Culkin, 2021), while hydrogen fuel cell HDVs are still in the early development phase (Collins, 2021). As a result, ZEVs only made up a total of 0.03% of the HDV stock in 2022, even though the share of ZEVs in the HDV stock increased by nearly 140% between 2017 and 2022 (IEA, 2023a). To reach a 70% share by 2050, the annual increase in ZEV uptake needs to occur 444 times faster (assuming a linear trajectory). To achieve the desired share by 2050, the EU and Member States could more proactively further research and development for zero and low emission HDVs and remove barriers to adoption. Germany is the clear frontrunner for deploying heavy-duty ZEVs. In 2023, over 4,400 heavy-duty ZEVs were registered in Germany. In comparison, only 11 such vehicles registered in the country in 2018. Driving this uptake were some of the largest financial incentives for operating commercial ZEVs in the EU (ACEA, 2023b).

Figure 6: Past progress by Member States in increasing the total number of ZEVs in heavy-duty vehicle stock

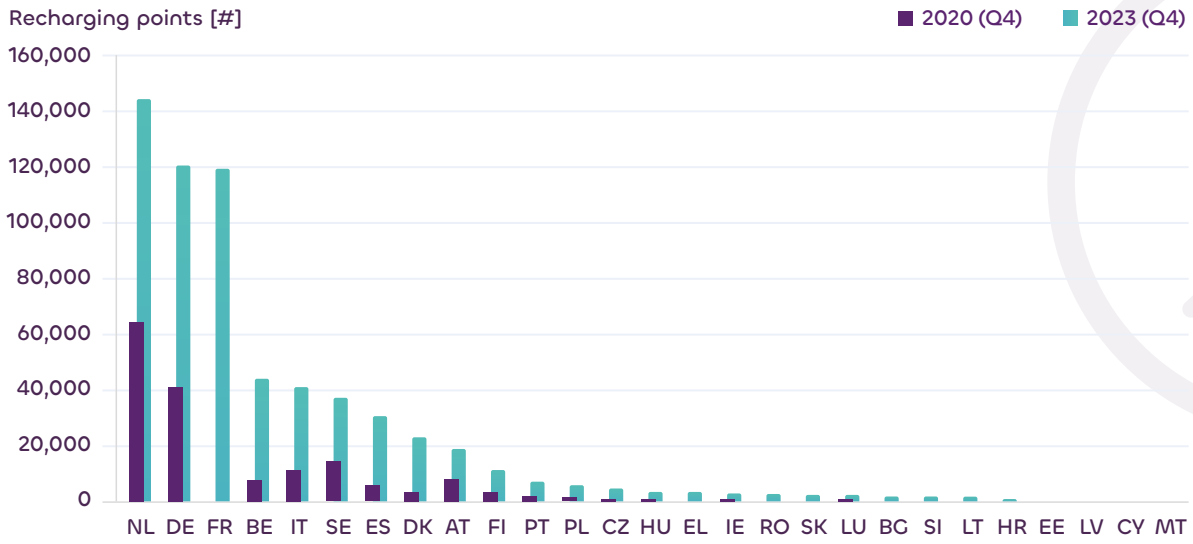


Source: EAFO (2024a).

Total number of recharging points [#]

The total number of recharging points in the EU increased by over 190% between 2018 and 2023. Nevertheless, the EU's recharging network is being built out far too slowly . Based on the EC's impact assessment for the revised AFIR, the EU needs 16,268,705 publicly accessible recharging points by 2050 to be compatible with the EU's climate neutrality target. In 2023, the EU only had 632,390 operational recharging stations. To reach the target number, the rate of progress needs to increase by 3.8 times relative to the current rate. So far, recharging infrastructure development has been disparate across Member States: in 2023, over 50% of all recharging points in the EU were located in the Netherlands, Germany, and France (Melissa, 2024). Overall, the Netherlands leads the EU in recharging point deployment. In the Netherlands, there are nearly 300 recharging points for every 100,000 residents, in comparison to an average of 92 points in the rest of Europe (GridX, 2023). In 2023, the country had over 140,000 operational recharging points (EAFO, 2024b). Already in 2022, Dutch recharging points accounted for 29.4% of all recharging points in the EU (ACEA, 2022). The robust expansion of the Dutch recharging network is the result of a clear national agenda and ambitious subnational action aimed at expanding access to recharging points (see below).

Figure 7: Past progress by Member States in increasing the the total number of recharging points



Source: EAFO (2024a); Note that no data was available for France in 2020.

EU and Member States policies

In the transport sector, EU- and MS-level policies reinforce each other. At the EU level, more stringent CO_2 emission standards are applying supply-side pressure on auto manufacturers to increase the number of ZEV offerings in their fleet. At the MS level, purchasing subsidies for ZEVs and fuel taxes on ICE vehicles are activating a demand-side response. Both EU- and MS-level initiatives are funding the development of recharging infrastructure and expanding coverage across borders and across urban, suburban, and rural settings. Policies at the subnational level, such as behavioural incentives, can further facilitate ZEV uptake (Wappelhorst et al., 2020).

EU policies

The EU's main policy lever for facilitating the uptake of ZEVs is its CO_2 emission performance standards for new vehicles. Emission standards play a central role in increasing ZEV sales worldwide (IEA, 2021a). In 2023, the EU strengthened the CO_2 emission performance standards for new light-duty cars and vans. The updated 2030 emission reduction target is now 55% for new passenger cars and 50% for vans compared to 2021 levels. For 2035, the emission reduction target is 100% for both cars and vans. While technically initiating the phase-out of ICE vehicles, there is some flexibility built into the legislation. A coalition of Member States successfully lobbied for the drafting of an amendment to the standards that would allow for the continued use of ICE vehicles that run on CO_2-neutral fuels after 2035 (Sims & Abnett, 2023; Wacket & Abnett, 2023). To qualify as a CO_2-neutral fuel or e-fuel, as defined in the RED III Directive, the fuel only needs to reduce its GHG emissions by 70% compared to traditional fossil fuels. This means that vehicles running on CO_2-neutral fuels are not zero emission and, instead, are estimated to emit 61 gCO_2e/km in 2035 (T&E, 2023a). The CO_2 emission standards also introduced a regulatory incentive mechanism that rewards auto manufacturers with less stringent CO_2 reduction targets if the manufacturers reach a 25% share of zero and low emission passenger vehicle sales.

Allowing low emission vehicles, and not only zero emission vehicles, to count towards reducing manufacturers' fleet-wide CO_2 targets, prolongs the production of CO_2-emitting, ICE-based plug-in hybrids and hinders a more rapid transition to battery- and hydrogen-based ZEVs. Nevertheless, five of the largest auto manufacturers in Europe, representing a 46% market share, have pledged to sell exclusively BEVs by 2030 (GridX, 2023).

The EU has proposed and nearly adopted updated CO_2 emission standards for HDVs (Eickhout, 2024). Raising ambition for HDV emission reductions is critical for achieving climate neutrality, as commercial vehicles have increasing and disproportionate effects on energy use, air pollution, and CO_2 emissions (IEA, 2021a). The proposed emission standards would mandate emission reductions of 45% in 2030, 65% in 2035, and 90% in 2040. The proposal introduces a separate emission reduction target of 100% for urban buses for 2035. Like the LDV emission standards, heavy-duty vehicles that use CO_2-neutral fuels will likely count towards the EU's emission reduction targets (Abnett & Wacket, 2024).

To further enable the uptake of ZEVs, the EU revised the Alternative Fuels Infrastructure Regulation (AFIR). The revision establishes distance-based targets for recharging infrastructure to address disparities in the recharging station development across Member States. The AFIR stipulates the construction of fast recharging stations for light-duty vehicles every 60 km along the TEN-T road network. For heavy-duty vehicles traveling on TEN-T routes, the AFIR sets targets for recharging vehicle stations for every 50 to 100 km, and every 200 km for hydrogen refuelling stations.

Member States policies

To increase the share of ZEVs in their domestic fleets, Member States use financial instruments to reduce vehicle upfront and operational costs. In 2023, all 27 Member States offered some form of tax benefit or purchase incentive for zero emission passenger vehicles (ACEA, 2023a). Tax benefits reduce value added taxes, registration fees, or ownership costs for individuals or companies. Purchase incentive schemes reduce the price gap between ZEVs and ICE equivalents by providing cash bonuses for buying ZEVs (IEA, 2021a). In some cases, purchase incentives also cover costs related to recharging. Some Member States additionally levy high taxes on petrol and diesel to further increase the cost competitiveness of ZEVs. A high tax differential—achieved by levying high taxes on polluting vehicles and low taxes on non-CO_2 emitting vehicles—correlates with higher uptake of zero and low emission passenger vehicles in the EU (T&E, 2022a). To reduce the fiscal burden of ZEV purchase subsidies, France's 'Bonus-Malus' system imposes a strict tax on emission-intensive vehicles and uses the tax revenue to finance bonus payments for electric vehicles (EUKI, 2019). The scope and structure of these fiscal policies, and the resulting tax burdens, differ substantially across Member States (T&E, 2022b). Purchase incentives range from EUR 1,500 in Hungary to upwards of EUR 12,000 in Cyprus (ACEA, 2023a). The level of registration and ownership tax deductions can be based on the level of CO_2 emission reduction, air pollution reduction, fuel type, vehicle weight, engine displacement, or year of production depending on Member State (Danielis, 2023). National fiscal policy is bolstered by subnational behavioural incentives. Urban access restrictions, parking benefits, public recharging points, electric vehicle awareness programs, and congestion charging discounts at the municipal level have been demonstrated to increase ZEV uptake in cities across the EU (Bernard et al., 2021).

Citing the increasing domestic price competitiveness of light-duty ZL (IEA, 2023a), **Sweden** entirely eliminated its state-sponsored acquisition subsidies for electric cars and plug-in hybrids in 2022 (EAFO, 2024b). The Swedish government previously offered strong economic incentives for zero and low emission vehicle adoption: between 2018 and 2022, the government provided up to approximately EUR 6,000 for new electric vehicles, while raising the vehicle tax for traditional ICEs (ITA, 2022; Kotilainen et al., 2019). Sweden, which features the highest share of ZEVs in its existing fleet and in new registrations of passenger vehicles in the EU, still reduces the annual road tax for zero emission cars and provides grants and tax deductions for installing at-home charging equipment (ACEA, 2023a).

In **Germany**, purchase incentives stimulated a tenfold increase in the share of electric vehicles in total LDV sales (IEA, 2023a), until Germany abruptly phased-out its purchase incentive scheme for passenger and commercial ZEVs in 2023 due to federal budgeting complications. Until the end of 2023, Germany provided significant financial incentives for zero and low emission HDVs (IEA, 2023a): 80% of additional vehicle costs and recharging infrastructure were subsidised (BMDV, 2021), and ownership taxes were absolved for a ten-year period (ACEA, 2023b). Germany is now shifting its focus towards increasing its financial support for infrastructure development (BMDV, 2024).

Poland is broadening and diversifying its purchase incentives and tax benefits for ZEVs. The Polish LDV market is one of the largest in the EU and is dominated by ICE vehicles (Kadiri, 2024a). However, the Polish government has set ambitious targets for ZEV sales and recharging infrastructure development. Since 2018, the government has been subsidising ZEV purchases and, in 2021, unlocked an additional EUR 115 million. In 2021, the government also implemented a novel subsidy scheme, 'My e-car', that reduces monthly lease payments for EVs (KPMG, 2021). The policy's implementation increased EV sales by 140% and 40,000 new EVs were registered in the first six months following the policy's adoption (Harper, 2022). In addition, BEVs are entirely exempt from sales taxes and qualify for a purchase subsidy of roughly EUR 4,000 (ACEA, 2023a). In 2023, Poland also began subsidising recharging infrastructure (IEA, 2023a).

The Netherlands features one of the densest recharging networks in the world (NAL, 2022) (see below). The government has developed a national strategy for developing ZEV recharging infrastructure: the Dutch National Charging Infrastructure Agenda. The Dutch agenda emphasises the importance of coverage and access, prioritising public, interoperable recharging stations across urban and rural areas (NAL, 2022). National ambition is complemented by progressive subnational policy. Cities are developing zero-emission zones in urban centres and municipal governments in Amsterdam, Rotterdam, and The Hague provide public recharging points for individuals and businesses in cases where private recharging is not possible (Bernard et al., 2021).

Portugal ranks seventh in the EU with its share of ZEVs in new light-duty vehicle registrations (EAFO, 2024b). Driving the zero and low emission LDV sales in Portugal is a combination of purchase and tax benefits and a highly accessible recharging network. Individuals receive a premium of EUR 3,000 to purchase a new BEV and are exempt from registration and ownership taxes (ACEA, 2023a). Portugal's recharging network, the Mobi.E Network, is characterised by digitalisation and interoperability (Kadiri, 2024b); over 4,500 public recharging points are operational and can be monitored in real time using a mobile app.

Areas of actions

The stricter CO_2 emission performance standards—which have been adopted for LDVs but have not been ratified for HDVs—will only have the desired supply-side effect if compliance is closely monitored and if non-compliance is penalised. If penalties are insufficient, legislation should be revised (Hu et al., 2021). Additionally, the potential classification of carbon-neutral-fuelled vehicles as zero-emission under the emission standards warrants careful consideration, as these ICE-based vehicles are not strictly zero-emission. Furthermore, the EU could accelerate progress by following through on its proposal to green corporate fleets; an important area of action, as corporate fleets accounted for nearly 60% of all new vehicle sales in the EU in 2022 (T&E, 2023b).

The EU could identify good practices at the MS level for supporting the uptake of ZEVs. Benefit structure and scale vary significantly between Member States for passenger ZEVs (ACEA, 2023a), resulting in highly varied diffusion rates. The link between EV adoption and GDP per capita in the EU (ACEA, 2021a) should be addressed, as Northwestern Member States with higher incomes have significantly higher EV shares (more than 30%) than those with lower average incomes in Central, Eastern, and Southern Europe (roughly 10%) (ACEA, 2023e). GDP and recharging point deployment are similarly correlated (ACEA, 2021b).

Member States could expand financial mechanisms that disincentivise ICE-based HDVs and incentivise zero-emission alternatives. Given that purchase costs are a key barrier, purchase incentives can be useful for HDVs (Sugihara et al., 2023). However, Member States offer notably fewer incentives for HDVs than for LDVs (ACEA, 2023b). The HDV segment also faces technical and logistical challenges regarding vehicle weight, as well as recharging frequency and duration, that do not apply to LDVs (Panayi, 2019).

EU- and MS-level policy could incentivise the production and uptake of compact, energy- and resource-efficient light-duty BEVs, as energy and resource efficiency are not considered in current legislation (ESABCC, 2024). While BEVs are more energy efficient than ICE vehicles, substantial differences in energy and resource efficiency exist between BEVs based on their size and weight: doubling the mass of a BEV results in a 40% increase in its real-world energy consumption (Weiss et al., 2020) and larger BEVs demand 75% more critical raw materials for their batteries relative to smaller BEVs (Lander & Grazia, 2023). The EU's emission standards do not explicitly prompt efficiency improvements for ZEVs; to the contrary, the standards use the average mass of sold vehicles per manufacturer to determine a manufacturer's progress in emission reduction (EC, 2023b), which may implicitly encourage the production of larger vehicles that are more energy and resource intensive (Thies et al., 2022). By incentivising the production of large BEVs, the

EU is also reducing access to BEVs because larger vehicles tend to be more expensive: in 2023, there was only one BEV for sale in Europe that retailed for under EUR 20,000. To address affordability and equity concerns, the EU could reconsider the design of the CO_2 emission standards and develop industrial policy that incentivises the production of affordable ZEVs (T&E, 2024a).

EU policy could further support the development of secondary ZEV markets. Increasing the sale of new BEVs will increase the supply of older, used BEV models (Morrison & Wappelhorst, 2024). However, BEVs face unique barriers to entry into the secondary market, such as the decline in battery capacity over time, that can be addressed through cost-effective battery swapping policies (IEA, 2023a). Additionally, the early retirement of older vehicles could be supported through 'cash-for-clunkers' programmes (Naumov et al., 2022).