# Global EV Outlook 2023

## Catching up with climate ambitions

International Energy Agency

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# Abstract

The Global EV Outlook is an annual publication that identifies and discusses recent developments in electric mobility across the globe. It is developed with the support of the members of the Electric Vehicles Initiative (EVI).

Combining historical analysis with projections to 2030, the report examines key areas of interest such as electric vehicle and charging infrastructure deployment, battery demand, electricity consumption, oil displacement, greenhouse gas emissions and related policy developments. The report includes analysis of lessons learned from leading markets to inform policy makers and stakeholders about policy frameworks and market systems for electric vehicle adoption.

This edition features analysis of the financial performance of EV-related companies, venture capital investments in EV-related technologies, and trade of electric vehicles. Finally, the report makes available two online tools: the Global EV Data Explorer and Global EV Policy Explorer, which allow users to interactively explore EV statistics and projections, and policy measures worldwide.

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# Executive summary

## Electric car sales break new records with momentum expected to continue through 2023

**Electric car markets are seeing exponential growth as sales exceeded 10 million in 2022.** A total of 14% of all new cars sold were electric in 2022, up from around 9% in 2021 and less than 5% in 2020. Three markets dominated global sales. China was the frontrunner once again, accounting for around 60% of global electric car sales. More than half of the electric cars on roads worldwide are now in China and the country has already exceeded its 2025 target for new energy vehicle sales. In Europe, the second largest market, electric car sales increased by over 15% in 2022, meaning that more than one in every five cars sold was electric. Electric car sales in the United States – the third largest market – increased 55% in 2022, reaching a sales share of 8%.

**Electric car sales are expected to continue strongly through 2023.** Over 2.3 million electric cars were sold in the first quarter, about 25% more than in the same period last year. We currently expect to see 14 million in sales by the end of 2023, representing a 35% year-on-year increase with new purchases accelerating in the second half of this year. As a result, electric cars could account for 18% of total car sales across the full calendar year. National policies and incentives will help bolster sales, while a return to the exceptionally high oil prices seen last year could further motivate prospective buyers.

**There are promising signs for emerging electric vehicle (EV) markets, albeit from a small base.** Electric car sales are generally low outside the major markets, but 2022 was a growth year in India, Thailand and Indonesia. Collectively, sales of electric cars in these countries more than tripled compared to 2021, reaching 80 000. For Thailand, the share of electric cars in total sales came in at slightly over 3% in 2022, while both India and Indonesia averaged around 1.5% last year. In India, EV and component manufacturing is ramping up, supported by the government's USD 3.2 billion incentive programme that has attracted investments totalling USD 8.3 billion. Thailand and Indonesia are also strengthening their policy support schemes, potentially providing valuable experience for other emerging market economies seeking to foster EV adoption.

## Landmark EV policies are driving the outlook for EVs closer to climate ambitions

**Market trends and policy efforts in major car markets are supporting a bright outlook for EV sales.** Under the IEA Stated Policies Scenario (STEPS), the global outlook for the share of electric car sales based on existing policies and firm objectives has increased to 35% in 2030, up from less than 25% in the previous outlook. In the projections, China retains its position as the largest market for electric cars with 40% of total sales by 2030 in the STEPS. The United States doubles its market share to 20% by the end of the decade as recent policy announcements drive demand, while Europe maintains its current 25% share.

**Projected demand for electric cars in major car markets will have profound implications on energy markets and climate goals in the current policy environment.** Based on existing policies, oil demand from road transport is projected to peak around 2025 in the STEPS, with the amount of oil displaced by electric vehicles exceeding 5 million barrels per day in 2030. In the STEPS, emissions of around 700 Mt $CO_2$-equivalents are avoided by the use of electric cars in 2030.

**The European Union and the United States have passed legislation to match their electrification ambitions.** The European Union adopted new $CO_2$ standards for cars and vans that are aligned with the 2030 goals set out in the Fit for 55 package. In the United States, the Inflation Reduction Act (IRA), combined with adoption of California's Advanced Clean Cars II rule by a number of states, could deliver a 50% market share for electric cars in 2030, in line with the national target. The implementation of the recently proposed emissions standards from the US Environmental Protection Agency is set to further increase this share.

**Battery manufacturing continues to expand, encouraged by the outlook for EVs.** As of March 2023, announcements on battery manufacturing capacity delivered by 2030 are more than sufficient to meet the demand implied by government pledges and would even be able to cover the demand for electric vehicles in the Net Zero Emissions by 2050 Scenario. It is therefore well possible that higher shares of sales are achievable for electric cars than those anticipated on the basis of current government policy and national targets.

## As spending and competition increase, a growing number of more affordable models come to market

**Global spending on electric cars exceeded USD 425 billion in 2022, up 50% relative to 2021.** Only 10% of the spending can be attributed to government support, the remainder was from consumers. Investors have also maintained confidence in EVs, with the stocks of EV-related companies consistently outperforming traditional carmakers since 2019. Venture capital investments in start-up firms developing EV and battery technologies have also boomed, reaching nearly USD 2.1 billion in 2022, up 30% relative to 2021, with investments increasing in batteries and critical minerals.

**SUVs and large cars dominate available electric car options in 2022**. They account for 60% of available BEV options in China and Europe and an even greater share in the United States, similar to the trend towards SUVs seen in internal combustion engine (ICE) car markets. In 2022, ICE SUVs emitted over 1 Gt $CO_2$, far greater than the 80 Mt net emissions reductions from the electric vehicle fleet that year. Battery electric SUVs often have batteries that are two- to three-times larger than small cars, requiring more critical minerals. However, last year electric SUVs resulted in the displacement of over 150 000 barrels of oil consumption per day and avoided the associated tailpipe emissions that would have been generated through burning the fuel in combustion engines.

**The electric car market is increasingly competitive.** A growing number of new entrants, primarily from China but also from other emerging markets, are offering more affordable models. Major incumbent carmakers are increasing ambition as well, especially in Europe, and 2022-2023 saw another series of important EV announcements: fully electric fleets, cheaper cars, greater investment, and vertical integration with battery-making and critical minerals.

**Consumers can choose from an increasing number of options for electric cars.** The number of available electric car models reached 500 in 2022, more than double the options available in 2018. However, outside of China, there is a need for original equipment manufacturers (OEMs) to offer affordable, competitively priced options in order to enable mass adoption of EVs. Today's level of available electric car models is still significantly lower than the number of ICE options on the market, but the number of ICE models available has been steadily decreasing since its peak in the mid-2010s.

## Focus expands to electrification of more vehicle segments as electric cars surge ahead

**Electrification of road transport goes beyond cars.** Two or three-wheelers are the most electrified market segment today; in emerging markets and developing economies, they outnumber cars. Over half of India's three-wheeler registrations in 2022 were electric, demonstrating their growing popularity due to government incentives and lower lifecycle costs compared with conventional models, especially in the context of higher fuel prices. In many developing economies, two/three-wheelers offer an affordable way to get access to mobility, meaning their electrification is important to support sustainable development.

**The commercial vehicle stock is also seeing increasing electrification**. Electric light commercial vehicle (LCV) sales worldwide increased by more than 90% in 2022 to more than 310 000 vehicles, even as overall LCV sales declined by nearly 15%. In 2022, nearly 66 000 electric buses and 60 000 medium- and heavy-duty trucks were sold worldwide, representing about 4.5% of all bus sales and 1.2% of truck sales. Where governments have committed to reduce emissions from public transport, such as in dense urban areas, electric bus sales reached even higher shares; in Finland, for example, electric bus sales accounted for over 65% in 2022.

**Ambition with respect to electrifying heavy-duty vehicles is growing**. In 2022, around 220 electric heavy-duty vehicle models entered the market, bringing the total to over 800 models offered by well over 100 OEMs. A total of 27 governments have pledged to achieve 100% ZEV bus and truck sales by 2040 and both the United States and European Union have also proposed stronger emissions standards for heavy-duty vehicles.

## EV supply chains and batteries gain greater prominence in policy-making

**The increase in demand for electric vehicles is driving demand for batteries and related critical minerals.** Automotive lithium-ion (Li-ion) battery demand increased by about 65% to 550 GWh in 2022, from about 330 GWh in 2021, primarily as a result of growth in electric passenger car sales. In 2022, about 60% of lithium, 30% of cobalt and 10% of nickel demand was for EV batteries. Only five years prior, these shares were around 15%, 10% and 2%, respectively. Reducing the need for critical materials will be important for supply chain sustainability, resilience and security, especially given recent price developments for battery material.

**New alternatives to conventional lithium-ion are on the rise**. The share of lithium-iron-phosphate (LFP) chemistries reached its highest point ever, driven primarily by China: around 95% of the LFP batteries for electric LDVs went into vehicles produced in China. Supply chains for (lithium-free) sodium-ion batteries are also being established, with over 100 GWh of manufacturing capacity either currently operating or announced, almost all in China.

**The EV supply chain is expanding, but manufacturing remains highly concentrated in certain regions, with China being the main player in battery and EV component trade**. In 2022, 35% of exported electric cars came from China, compared with 25% in 2021. Europe is China's largest trade partner for both electric cars and their batteries. In 2022, the share of electric cars manufactured in China and sold in the European market increased to 16%, up from about 11% in 2021.

**EV supply chains are increasingly at the forefront of EV-related policy-making to build resilience through diversification.** The Net Zero Industry Act, proposed by the European Union in March 2023, aims for nearly 90% of the European Union's annual battery demand to be met by EU battery manufacturers, with a manufacturing capacity of at least 550 GWh in 2030. Similarly, India aims to boost domestic manufacturing of electric vehicles and batteries through Production Linked Incentive (PLI) schemes. In the United States, the Inflation Reduction Act emphasises the strengthening of domestic supply chains for EVs, EV batteries and battery minerals, laid out in the criteria to qualify for clean vehicle tax credits. As a result, between August 2022 and March 2023, major EV and battery makers announced cumulative post-IRA investments of at least USD 52 billion in North American EV supply chains – of which 50% is for battery manufacturing, and about 20% each for battery components and EV manufacturing.

# Electric Vehicles Initiative

The Electric Vehicles Initiative (EVI) is a multi-governmental policy forum established in 2010 under the Clean Energy Ministerial (CEM). Recognising the opportunities offered by EVs, the EVI is dedicated to accelerating the adoption of EVs worldwide. To do so, it strives to better understand the policy challenges related to electric mobility, to help governments address them and to serve as a platform for knowledge-sharing among government policy makers. The EVI also facilitates exchanges between government policy makers and a variety of other partners on topics important for the transition to electric mobility, such as charging infrastructure and grid integration as well as EV battery supply chains. In 2022, Zero Emission Government Fleet Declaration was launched within the EVI, a strong commitment among government to move towards 100% zero emission vehicles in public procurement.

The International Energy Agency serves as the co-ordinator of the initiative. Governments that have been active in the EVI in the 2022-23 period include Canada, Chile, People's Republic of China (hereafter "China"), Finland, France, Germany, India, Japan, the Netherlands, New Zealand, Norway, Poland, Portugal, Sweden, United Kingdom and United States. Canada, China and the United States are the co-leads of the initiative.

The Global EV Outlook annual series is the flagship publication of the EVI. It is dedicated to tracking and monitoring the progress of electric mobility worldwide and to informing policy makers on how to best accelerate electrification of the road transport sector.

ELECTRIC VEHICLES INITIATIVE
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# Trends and developments in EV markets

## Electric light-duty vehicles

### Electric car sales continue to increase, led by China

Electric car sales[1] saw another record year in 2022, despite supply chain disruptions, macro-economic and geopolitical uncertainty, and high commodity and energy prices. The growth in electric car sales took place in the context of globally contracting car markets: total car sales in 2022 dipped by 3% relative to 2021. Electric car sales – including battery electric vehicles (BEVs) and plug-in hybrid electric vehicles (PHEVs) – exceeded 10 million last year, up 55% relative to 2021.[2] This figure – 10 million EV sales worldwide – exceeds the total number of cars sold across the entire European Union (about 9.5 million vehicles) and is nearly half of the total number of cars sold in China in 2022. In the course of just five years, from 2017 to 2022, EV sales jumped from around 1 million to more than 10 million. It previously took five years from 2012 to 2017 for EV sales to grow from 100 000 to 1 million, underscoring the exponential nature of EV sales growth. The share of electric cars in total car sales jumped from 9% in 2021 to 14% in 2022, more than 10 times their share in 2017.

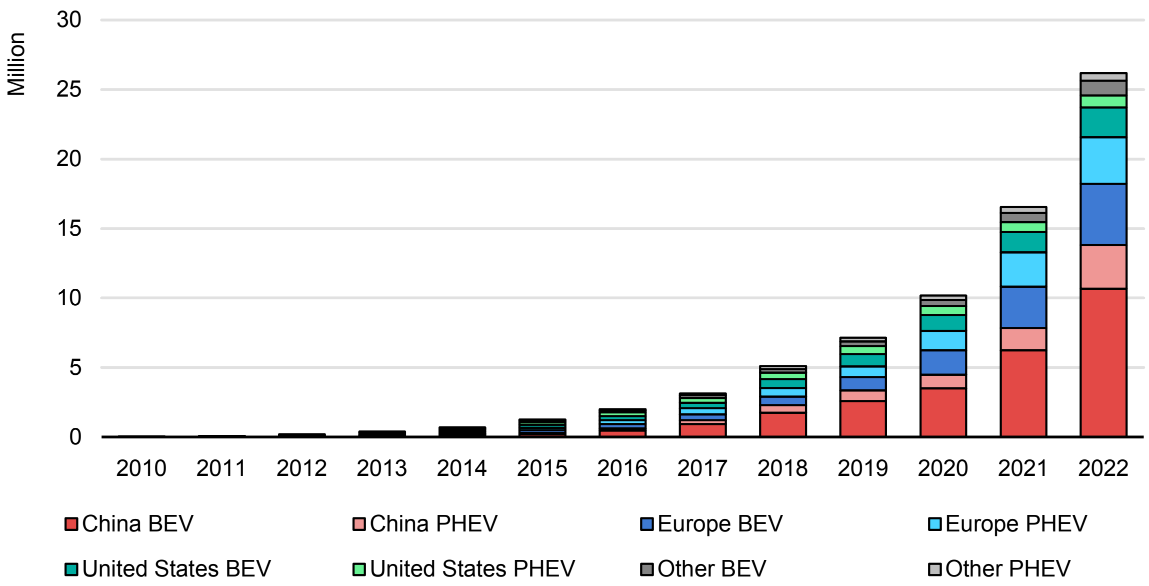
### Over 26 million electric cars were on the road in 2022, up 60% relative to 2021 and more than 5 times the stock in 2018

Increasing sales pushed the total number of electric cars on the world's roads to 26 million, up 60% relative to 2021, with BEVs accounting for over 70% of total annual growth, as in previous years. As a result, about 70% of the global stock of electric cars in 2022 were BEVs. The increase in sales from 2021 to 2022 was just as high as from 2020 to 2021 in absolute terms – up 3.5 million – but relative growth was lower (sales doubled from 2020 to 2021). The exceptional boom in 2021 may be explained by EV markets catching up in the wake of the coronavirus

[1] The term sales, as used in this report, represents an estimate of the number of new vehicles hitting the roads. Where possible, data on new vehicle registrations is used. In some cases, however, only data on retail sales (such as sales from a dealership) are available. See Box 1.2 for further details. The term car is used to represent passenger light-duty vehicles and includes cars of different sizes, sports utility-vehicles and light trucks.
[2] Unless otherwise specified, the term electric vehicle is used to refer to both battery electric and plug-in hybrid electric vehicles but does not include fuel cell electric vehicles. For a brief description of the trends related to fuel cell electric vehicles, see Box 1.3.

(Covid-19) pandemic. Seen in comparison to recent years, the annual growth rate for electric car sales in 2022 was similar to the average rate over 2015-2018, and the annual growth rate for the global stock of electric cars in 2022 was similar to that of 2021 and over the 2015-2018 period, showing a robust recovery of EV market expansion to pre-pandemic pace.

**Figure 1.1 Global electric car stock in selected regions, 2010-2022**






Notes: BEV = battery electric vehicle; PHEV = plug-in hybrid electric vehicle. Electric car stock in this figure refers to passenger light-duty vehicles. In “Europe”, European Union countries, Norway, and the United Kingdom account for over 95% of the EV stock in 2022; the total also includes Iceland, Israel, Switzerland and Türkiye. Main markets in “Other” include Australia, Brazil, Canada, Chile, Mexico, India, Indonesia, Japan, Malaysia, New Zealand, South Africa, Korea and Thailand.

The statistical data for Israel are supplied by and under the responsibility of the relevant Israeli authorities. The use of such data by the OECD is without prejudice to the status of the Golan Heights, East Jerusalem and Israeli settlements in the West Bank under the terms of international law.

Source: IEA analysis based on country submissions, ACEA, EAFO, EV Volumes and Marklines.

**Over 26 million electric cars were on the road in 2022, up 60% relative to 2021 and more than five times the stock in 2018.**

## Half of the world’s electric cars are in China

The increase in electric car sales varied across regions and powertrains, but remains dominated by the People’s Republic of China (hereafter “China”). In 2022, BEV sales in China increased by 60% relative to 2021 to reach 4.4 million, and PHEV sales nearly tripled to 1.5 million. The faster growth in PHEV sales relative to BEVs warrants further examination in the coming years, as PHEV sales still remain lower overall and could be catching up on the post-Covid-19 boom only now; BEV sales in China tripled from 2020 to 2021 after moderate growth over 2018-2020. Electric car sales increased even while total car sales dipped by 3% in 2022 relative to 2021.

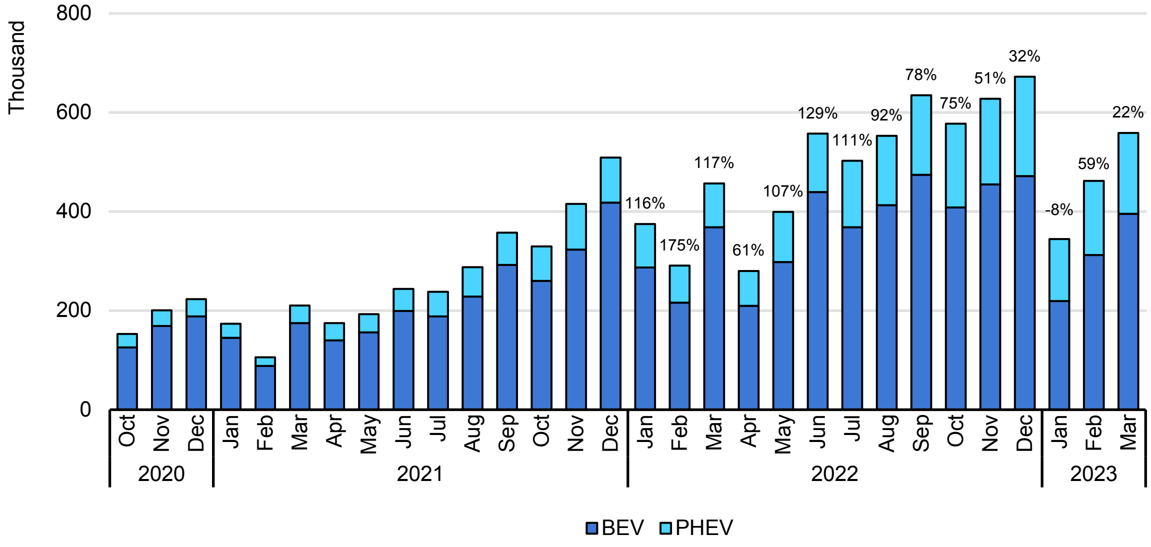
China accounted for nearly 60% of all new electric car registrations globally. For the first time in 2022, China accounted for more than 50% of all the electric cars on the world's roads, a total of 13.8 million. This strong growth results from more than a decade of sustained policy support for early adopters, including an extension of purchase incentives initially planned for phase-out in 2020 to the end of 2022 due to Covid-19, in addition to non-financial support such as rapid roll-out of charging infrastructure and stringent registration policies for non-electric cars.

In 2022, the share of electric cars in total domestic car sales reached 29% in China, up from 16% in 2021 and under 6% between 2018 and 2020. China has therefore achieved its 2025 national target of a 20% sales share for so-called new energy vehicles (NEVs)[3] well in advance. All indicators point to further growth: although the national NEV sales target is yet to be updated by China's Ministry of Industry and Information Technology (MIIT), which is responsible for the automotive industry, the objective of greater road transport electrification is re-affirmed in multiple strategy documents. China aims to reach a 50% sales share by 2030 in so-called "key air pollution control regions", and 40% across the country by 2030 to support the national action plan for carbon peaking. If recent market trends continue, China's 2030 targets may also be reached ahead of time. Provincial governments are also supporting adoption of NEVs, with 18 provinces to date having set NEV targets.

Support at the regional level in China has also helped to advance some of the world's largest EV makers. Shenzhen-based BYD has supplied most of the city's electric buses and taxis, and its leading position is also reflected in Shenzhen's ambition of reaching a 60% NEV sales share by 2025. Guangzhou, which has a 50% NEV sales share by 2025 target, facilitated the expansion of Xpeng Motors to become one of the national EV frontrunners.

[3] NEVs (China) include BEVs, PHEVs and fuel cell electric vehicles.

**Figure 1.2 Monthly new electric car registrations in China, 2020-2023**






Note: BEV = battery electric vehicle; PHEV = plug-in hybrid electric vehicle. Percentage labels in 2022-2023 refer to year-on-year growth rates relative to the same month in the previous year.
Source: IEA analysis based on EV Volumes.

**Electric car sales in China have been steadily increasing since 2020, but future trends will warrant further examination given that purchase incentives ended in 2022.**

Whether China's electric car sales share will remain significantly above the 20% target in 2023 remains uncertain, as sales may have been especially high in anticipation of incentives being phased out at the end of 2022. Sales in January 2023 plunged, and while this is in part due to the timing of the Chinese New Year, they were nearly 10% lower than sales in January 2022. However, electric car sales caught up in February and March 2023, standing nearly 60% above sales in February 2022 and more than 25% above sales in March 2022, thereby bringing sales in the first quarter of 2023 more than 20% higher than in the first quarter of 2022.

## Growth remained steady in Europe despite disruptions

In Europe,[4] electric car sales increased by more than 15% in 2022 relative to 2021 to reach 2.7 million. Sales grew more quickly in previous years: annual growth stood at more than 65% in 2021 and averaged 40% over 2017-2019. In 2022, BEV sales rose by 30% relative to 2021 (compared to 65% growth in 2021 relative to 2020) while PHEV sales dipped by around 3%. Europe accounted for 10% of global growth in new electric car sales. Despite slower growth in 2022, electric car

[4] Europe includes European Union countries, Iceland, Israel, Norway, Switzerland, Türkiye, and the United Kingdom.

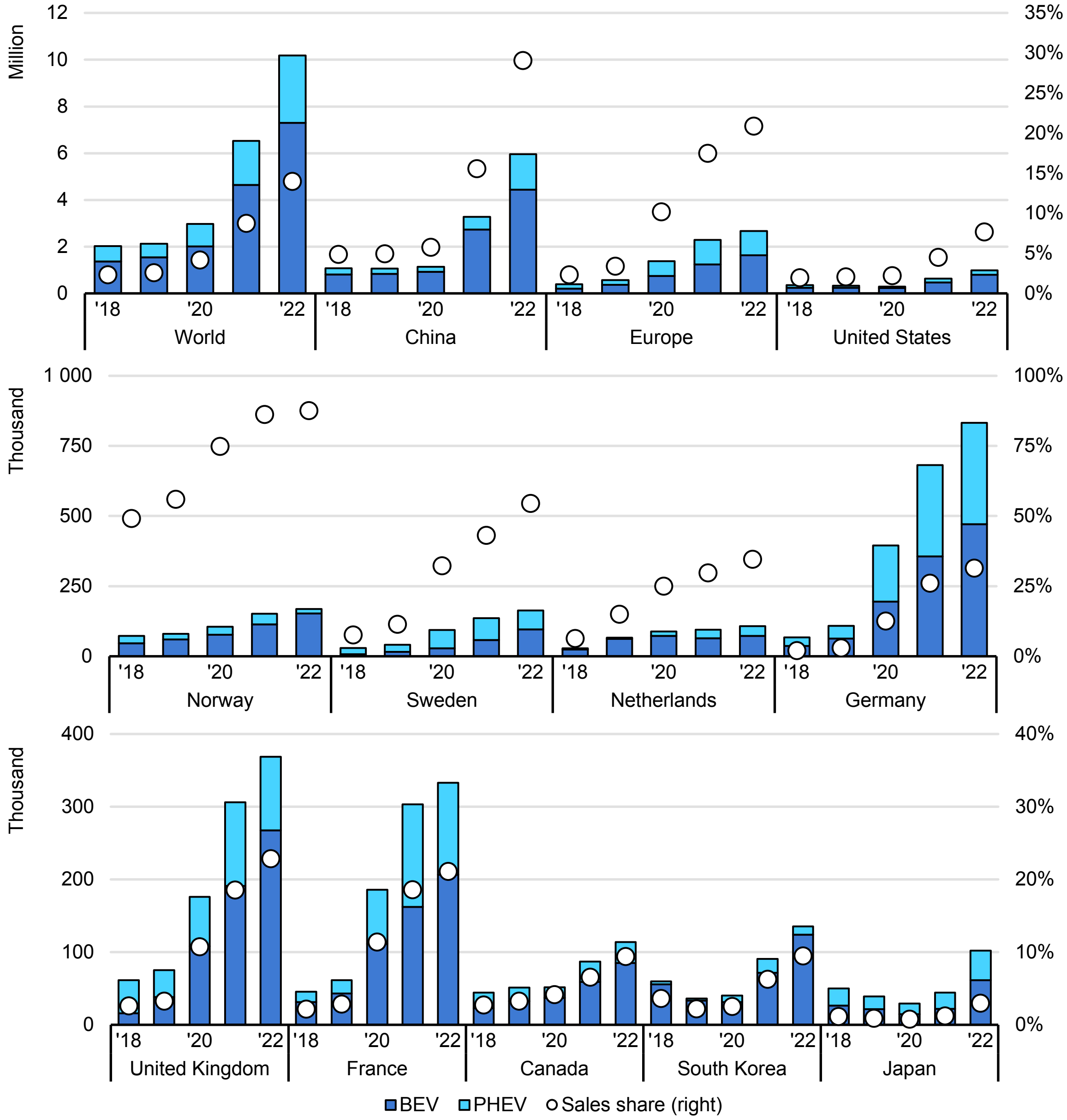
sales are still increasing in Europe in the context of continued contraction in car markets: total car sales in Europe dipped by 3% in 2022 relative to 2021.

The slowdown seen in Europe relative to previous years was, in part, a reflection of the exceptional growth in electric car sales that took place in 2020 and 2021 in the European Union, as manufacturers quickly adjusted corporate strategy to comply with the $CO_2$ emission standards passed in 2019. These standards covered the 2020-2024 period, with EU-wide emission targets becoming stricter only from 2025 and 2030 onwards.

High energy prices in 2022 had a mixed impact on the competitiveness of EVs relative to internal combustion engine (ICE) cars. Gasoline and diesel prices for ICE cars spiked, but residential electricity tariffs (with relevance for charging) also increased in some cases. Higher electricity and gas prices also increased manufacturing costs for both ICE and EV cars, with some carmakers arguing that high energy prices could restrict future investment for new battery manufacturing capacity.

Europe remained the world's second largest market for electric cars after China in 2022, accounting for 25% of all electric car sales and 30% of the global stock. The sales share of electric cars reached 21%, up from 18% in 2021, 10% in 2020 and under 3% prior to 2019. European countries continued to rank highly for the sales share of electric cars, led by Norway at 88%, Sweden at 54%, the Netherlands at 35%, Germany at 31%, the United Kingdom at 23% and France at 21% in 2022. In volume terms, Germany is the biggest market in Europe with sales of 830 000 in 2022, followed by the United Kingdom with 370 000 and France with 330 000. Sales also exceeded 80 000 in Spain. The share of electric cars in total car sales has increased tenfold in Germany since before the Covid-19 pandemic, which can in part be explained by increasing support post-pandemic, such as purchase incentives through the Umweltbonus, and a frontloading of sales in 2022 in expectation of subsidies being further reduced from 2023 onwards. However, in Italy, electric car sales decreased from 140 000 in 2021 to 115 000 in 2022, and they also decreased or stagnated in Austria, Denmark and Finland.

**Figure 1.3 Electric car registrations and sales share in selected countries and regions, 2018-2022**






Notes: BEV = battery electric vehicle; PHEV = plug-in hybrid electric vehicle. Passenger light-duty vehicles only. Major markets at the top. Other countries (middle, bottom) ordered by the share of electric car sales in total car sales. Y-axes do not have the same scale to improve readability.

Source: IEA analysis based on country submissions, ACEA, EAFO, EV Volumes and Marklines.

**Electric car sales exceeded 10 million in 2022, up 55% relative to 2021. Sales in China increased by 80% and accounted for 60% of global growth. Growth in Europe remained high (up 15%) and accelerated in the United States (up 55%).**

Sales are expected to continue increasing in Europe, especially following recent policy developments under the 'Fit for 55' package. New rules set stricter $CO_2$ emission standards for 2030-2034 and target a 100% reduction in $CO_2$ emissions for new cars and vans from 2035 relative to 2021 levels. In the nearer term, an incentive mechanism operating between 2025 and 2029 will reward manufacturers that achieve a 25% car sales share of zero- and low-emission cars (17% for vans). In the first two months of 2023, battery electric car sales were already up by over 30% year-on-year, while overall car sales increased by just over 10% year-on-year.

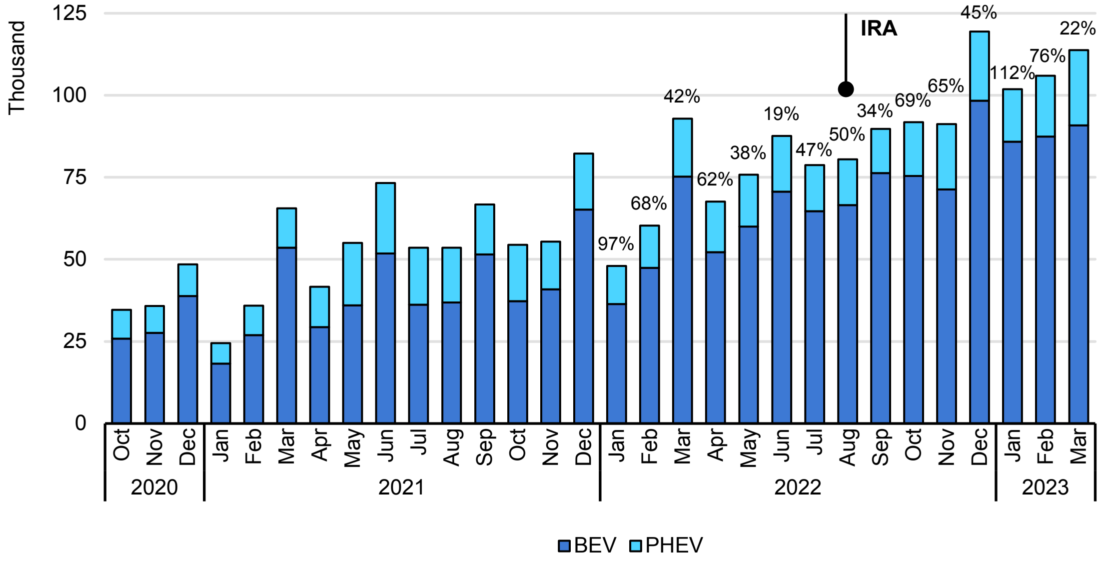
## The United States confirms return to growth

In the United States, electric car sales increased 55% in 2022 relative to 2021, led by BEVs. Sales of BEVs increased by 70%, reaching nearly 800 000 and confirming a second consecutive year of strong growth after the 2019-2020 dip. Sales of PHEVs also grew, albeit by only 15%. The increase in electric car sales was particularly high in the United States, considering that total car sales dropped by 8% in 2022 relative to 2021, a much sharper decrease than the global average (minus 3%). Overall, the United States accounted for 10% of the global growth in sales. The total stock of electric cars reached 3 million, up 40% relative to 2021 and accounting for 10% of the global total. The share of electric cars in total car sales reached nearly 8%, up from just above 5% in 2021 and around 2% between 2018 and 2020.

A number of factors are helping to increase sales in the United States. A greater number of available models, beyond those offered by Tesla, the historic leader, helped to close the supply gap. Given that major companies like Tesla and General Motors had already reached their subsidy cap under US support in previous years,[5] new models from other companies being available means that more consumers can benefit from purchase incentives, which can be as high as USD 7 500. Awareness is increasing as government and companies lean towards electrification: in 2022, a quarter of Americans expect that their next car will be electric, according to the American Automobile Association. Although charging infrastructure and driving range have improved over the years, they remain major concerns for US drivers given the typically long travel distances and lower popularity and limited availability of alternatives such as rail. However, in 2021 the Bipartisan Infrastructure Law strengthened support for EV charging, allocating USD 5 billion in total funding over the 2022-2026 period through the National Electric Vehicle Infrastructure Formula Program, as well as USD 2.5 billion in competitive grants over the same period through the Charging and Fueling Infrastructure Discretionary Grant Program.

[5] Manufacturer caps were still in place for sales taking place in 2022, with models by carmakers having sold over 200 000 EVs losing eligibility for the purchase incentive, even if they were manufactured in North America following requirements under the IRA. Caps were removed starting from 2023.

**Figure 1.4 Monthly new electric car registrations in the United States, 2020-2023**






Notes: BEV = battery electric vehicle; PHEV = plug-in hybrid electric vehicle; "IRA" refers to the Inflation Reduction Act. Percentage labels in 2022-2023 refer to year-on-year growth rates relative to the same month in the previous year.
Source: IEA analysis based on EV Volumes.

**Monthly sales of electric cars have been steadily increasing in the United States, with further growth expected in 2023 as a result of strengthened policy support.**

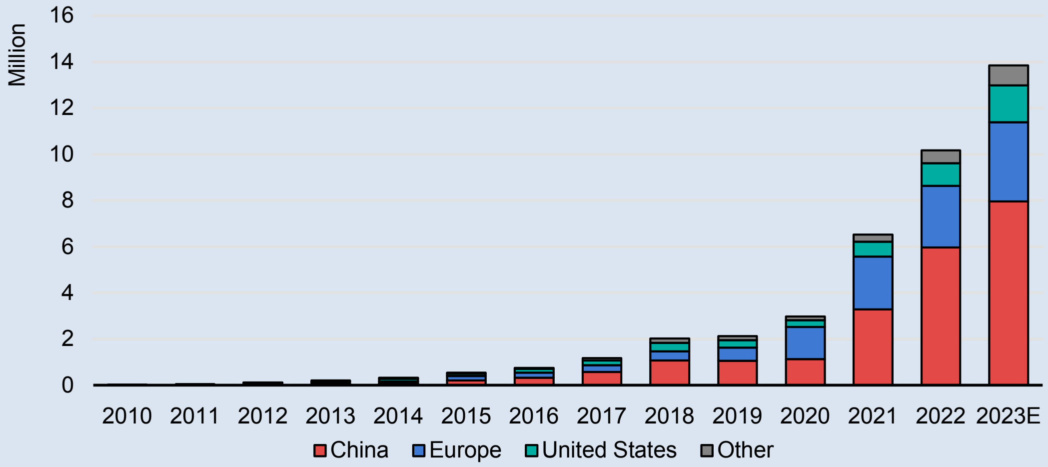
The acceleration in sales growth could continue in 2023 and beyond thanks to recent new policy support (see Prospects for electric vehicle deployment). The Inflation Reduction Act (IRA) has triggered a rush by global electromobility companies to expand US manufacturing operations. Between August 2022 and March 2023, major EV and battery makers announced cumulative post-IRA investments of USD 52 billion in North American EV supply chains, of which 50% is for battery manufacturing, and about 20% each for battery components and EV manufacturing. Overall, company announcements including tentative commitments for US investments for future battery and EV production add up to around USD 75-108 billion. As an example, Tesla plans to relocate its Berlin-based lithium-ion battery gigafactory to Texas, where it will work in partnership with China's CATL, and to manufacture next-generation EVs in Mexico. Ford also announced a deal with CATL for a battery plant in Michigan, and plans to increase electric car manufacturing sixfold by the end of 2023 relative to 2022, at 600 000 vehicles per year, scaling up to 2 million by 2026. BMW is seeking to expand EV manufacturing at its plant in South Carolina following the IRA. Volkswagen chose Canada for its first battery plant outside Europe, which will begin operations in 2027, and is also investing USD 2 billion in its plant in South Carolina. While these investments can be expected to lead to high growth in the years to come, the impact may only fully be seen from 2024 onwards as plants come online.

In the immediate term, the IRA has constrained eligibility requirements for purchase incentives, as vehicles need to be produced in North America in order to qualify for a subsidy. However, electric car sales have remained strong since August 2022 (Figure 1.4), and the first months of 2023 have been no exception: In the first quarter of 2023, electric car sales increased 60% compared to the same period in 2022, potentially boosted by the January 2023 removal of the subsidy caps for manufacturers, which means models by market leaders can now benefit from purchase incentives. In the longer-term, the list of models eligible for subsidies is expected to expand.

**Box 1.1 The 2023 outlook for electric cars is bright**

Early indications from first quarter sales of 2023 point to an upbeat market, supported by cost declines as well as strengthened policy support in key markets such as the United States. Globally, our current estimate is therefore for nearly 14 million electric cars to be sold in 2023, building on the more than 2.3 million already sold in the first quarter of the year. This represents a 35% increase in electric car sales in 2023 compared to 2022 and would bring the global electric sales share to around 18%, up from 14% in 2022.

**Electric car sales, 2010-2023**






Note: 2023 sales ("2023E") are estimated based on market trends through the first quarter of 2023.
Source: IEA analysis based on EV Volumes.

Electric car sales in the first three months of 2023 have shown strong signs of growth compared to the same period in 2022. In the United States, more than 320 000 electric cars were sold in the first quarter of 2023, 60% more than over the same period in 2022. Our current expectation is for this growth to be sustained throughout the year, with electric car sales reaching over 1.5 million in 2023, bringing the electric car sales share in the United States up to around 12% in 2023.

In China, electric car sales were off to a rough start in 2023, with January sales being 8% lower than in January 2022. The latest available data suggests a quick recovery: over the entire first quarter of 2023, electric car sales in China were more than 20% higher than in the first quarter of 2022, with more than 1.3 million electric cars being registered. For the remainder of 2023, we expect the generally favourable cost structure of electric cars to outweigh the effects of the phase-out of the NEV subsidy. As a result, our current expectation is for electric car sales in China to be more than 30% higher than in 2022 and reach around 8 million by the end of 2023, reaching a sales share of over 35% (from 29% in 2022).

Based on recent trends and tightening $CO_2$ targets not going into effect until 2025, the growth of electric car sales in Europe is expected to be the lowest of the three largest markets. In the first quarter of 2023, electric car sales in Europe increased by around 10% compared to the same period in 2022. For the full year, we currently expect electric car sales to increase by over 25%, with one-in-four cars sold in Europe being electric.

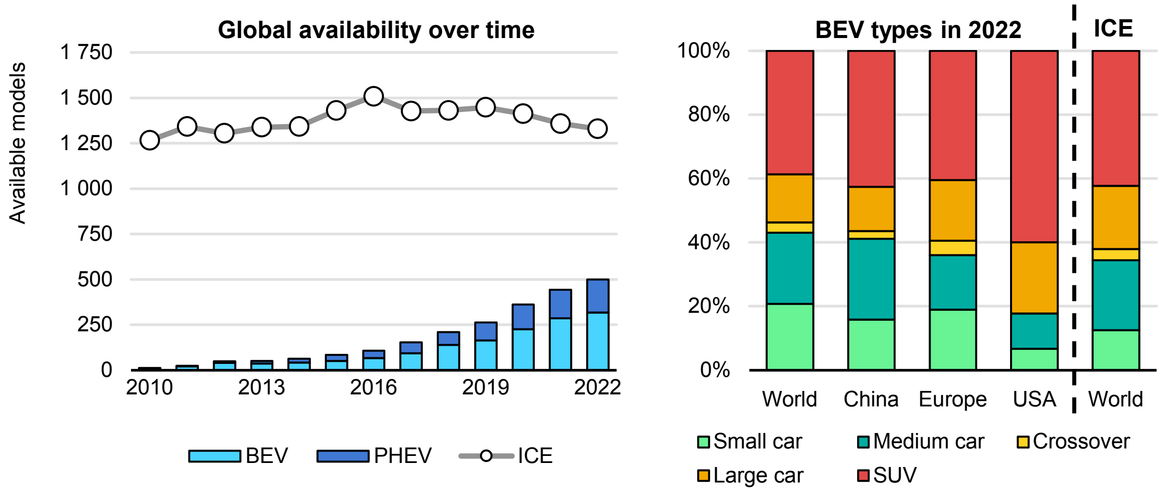
Outside of the major EV markets, electric car sales are expected to reach around 900 000 in 2023 – 50% higher than in 2022. Electric car sales in India in the first quarter of 2023 are already double what they were in the same period in 2022. In India and across all regions outside the three major EV markets, electric car sales are expected to represent 2-3% of car sales in 2023, a relatively small yet growing share.

There are, of course, downside risks to the 2023 outlook: a sluggish global economy and the phase-out of subsidies for NEVs in China could reduce 2023 growth in global electric car sales. On the upside, new markets may open up more quickly than anticipated, as persistent high oil prices make the case for EVs stronger in an increasing number of settings. And new policy developments, such as the April 2023 proposal from the US Environmental Protection Agency (EPA) to strengthen GHG emissions standards for cars, may send signals that boost sales even before going into effect.

## The number of electric car models rises, especially for large cars and SUVs, at the same time as it decreases for conventional cars

The race to electrification is increasing the number of electric car models available on the market. In 2022, the number of available options reached 500, up from below 450 in 2021 and more than doubling relative to 2018-2019. As in previous years, China has the broadest portfolio with nearly 300 available models, double the number available in 2018-2019, prior to the Covid-19 pandemic. This remains nearly twice as many as in Norway, the Netherlands, Germany, Sweden, France and the United Kingdom, which all have around 150 models available, more than three times as many as before the pandemic. In the United States, there were fewer than 100 models available in 2022, but twice as many as before the pandemic; and 30 or fewer were available in Canada, Japan and Korea.

**Figure 1.5 Car model availability by powertrain, 2010-2022 (left), and breakdown of available cars by powertrain and segment in 2022 (right)**





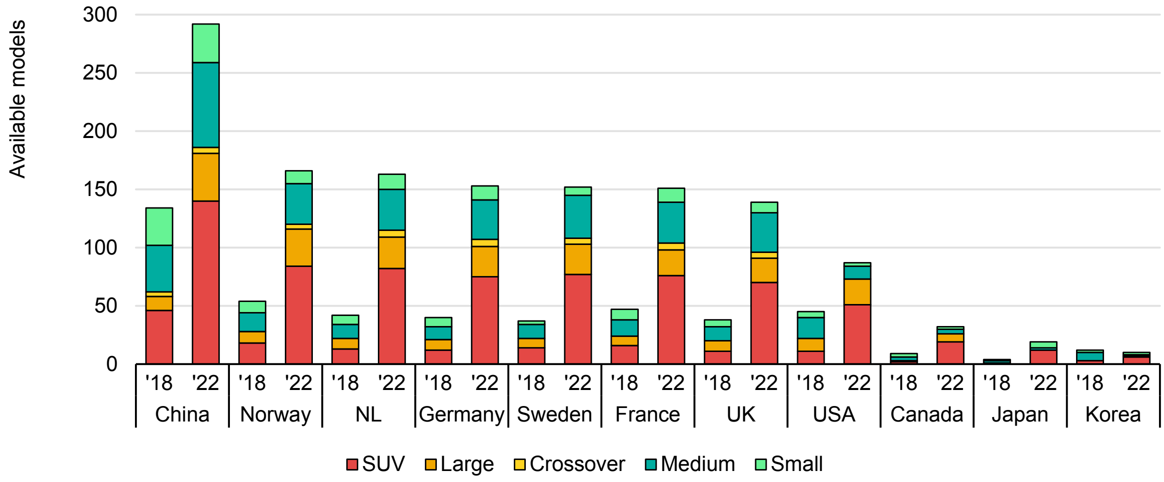

Notes: BEV = battery electric vehicle; PHEV = plug-in hybrid vehicle; ICE = internal combustion engine; SUV = sports utility vehicle; USA = United States. Analysis based on models for which there was at least one new registration in a given year; a model on sale but never sold is not counted, and as such actual model availability may be underestimated. In the chart on the right-hand side, distribution is based on the number of available models, not sales-weighted. Small cars include A and B segments. Medium cars include C and D segments. Crossovers are a type of sports utility vehicle (SUV) built on a passenger car platform. Large cars include E and F segments and multi-purpose vehicles.
Source: IEA analysis based on Marklines.

**The number of available electric car models reached 500 in 2022 but remains far below the number of ICE options. Large cars and SUVs still account for over half of available BEVs.**

The 2022 trend reflects the increasing maturity of EV markets and demonstrates that carmakers are responding to increasing consumer demand for electric cars. However, the number of electric car models available remains much lower than that of conventional ICE cars, which has remained above 1 250 since 2010 and peaked at 1 500 in the middle of the past decade. In recent years, the number of ICE models sold has been steadily decreasing, at a compound annual growth rate of minus 2% over the 2016-2022 period, reaching about 1 300 models in 2022. This dip varies across major car markets and is most pronounced in China, where the number of available ICE options was 8% lower in 2022 than in 2016, versus 3-4% lower in the United States and Europe over the same period. This could result from contracting car markets and a progressive shift towards EVs among major carmakers. Looking forward, the total number of ICE models available could remain stable, while the number of new models shrinks, if carmakers focus on electrification and keep selling existing ICE options rather than increasing budgets to develop new models.

In contrast to ICE models, EV model availability has been growing quickly, at a compound annual growth rate of 30% over the 2016-2022 period. Such growth is to be expected in a nascent market with a large number of new entrants bringing innovative products to the market, and as incumbents diversify their portfolios. Growth has been slightly lower in recent years: the annual growth rate stood at around 25% in 2021 and 15% in 2022. In the future, the number of models can be expected to continue to increase quickly, as major carmakers expand their EV portfolios and new entrants strengthen their positions, particularly in emerging markets and developing economies (EMDEs). The historic number of ICE models available on the market suggests that the current number of EV options could double, at least, before stabilising.

**Figure 1.6 Electric car model availability in selected countries by size, 2018-2022**






Notes: NL = the Netherlands; UK = United Kingdom; USA = United States; SUV = sports utility vehicle. Includes battery electric vehicles and plug-in hybrid electric vehicles. Countries are ordered by the number of available models in 2022. Analysis based on models for which there was at least one new registration in a given year; a model on sale but never sold is not counted, and as such actual model availability may be underestimated.
Source: IEA analysis based on Marklines.

**In 2022, 7 countries had around 150 EV models or more available for sale, up from 50 in 2018. The number of large models is increasing more quickly than that of small models.**

## SUVs and large car models dominate both EV and ICE markets

A major concern for global car markets – both EV and ICE – is the overwhelming dominance of SUVs and large models among available options. Carmakers are able to generate higher revenues from such models, given higher profit margins, which can cover some of the investments made in developing electric options. In certain cases, such as in the United States, larger vehicles can also benefit from less stringent fuel economy standards, hence creating an incentive for carmakers to slightly increase the vehicle size of a car for it to qualify as a light truck.

However, large models are more expensive, which poses significant affordability issues across the board, and all the more so in EMDEs. Large models also have implications for sustainability and supply chains, being equipped with larger batteries that require more critical minerals. In 2022, the sales-weighted average battery size of small battery electric cars ranged from 25 kWh in China to 35 kWh across France, Germany and the United Kingdom, and about 60 kWh in the United States. In comparison, the average for battery electric SUVs was around 70-75 kWh in these countries, and within the 75-90 kWh range for large car models.

Transitioning from ICE to electric is a priority for achieving net zero emissions targets, regardless of vehicle size, but mitigating the impacts of higher battery sizes will also be important. In France, Germany and the United Kingdom in 2022, the sales-weighted average weight of a battery electric SUV was 1.5 times higher than the average small battery electric car, requiring greater amounts of steel, aluminium and plastic; the battery in the SUV was twice as large, requiring about 75% more critical minerals. The $CO_2$ emissions associated with materials processing, manufacturing and assembly can be estimated at more than 70% higher as a result.

At the same time, in 2022, electric SUVs resulted in the displacement of over 150 000 barrels per day of oil consumption and avoided the associated tailpipe emissions that would have been generated through burning the fuel in combustion engines. Although electric SUVs represented roughly 35% of all electric passenger light-duty vehicles (PLDVs) in 2022, their share of oil displacement was even higher (about 40%), as SUVs tend to be driven more than smaller cars. Of course, smaller vehicles generally require less energy to operate and less materials to build, but electric SUVs certainly remain favourable to ICE vehicles.

In 2022, ICE SUVs emitted more than 1 Gt $CO_2$, far greater than the 80 Mt net emissions reductions from the electric vehicle fleet that year. While total car sales decreased by 0.5% in 2022, SUV sales increased by 3% relative to 2021, accounting for about 45% of total car sales, with noticeable growth in the United States, India and Europe. Of the 1 300 available options for ICE cars in 2022, more than 40% were SUVs, compared to fewer than 35% for small and medium cars. The total number of available ICE options went down from 2016 to 2022, but the drop was only for small and medium cars (down 35%) while large cars and SUVs increased (up 10%).

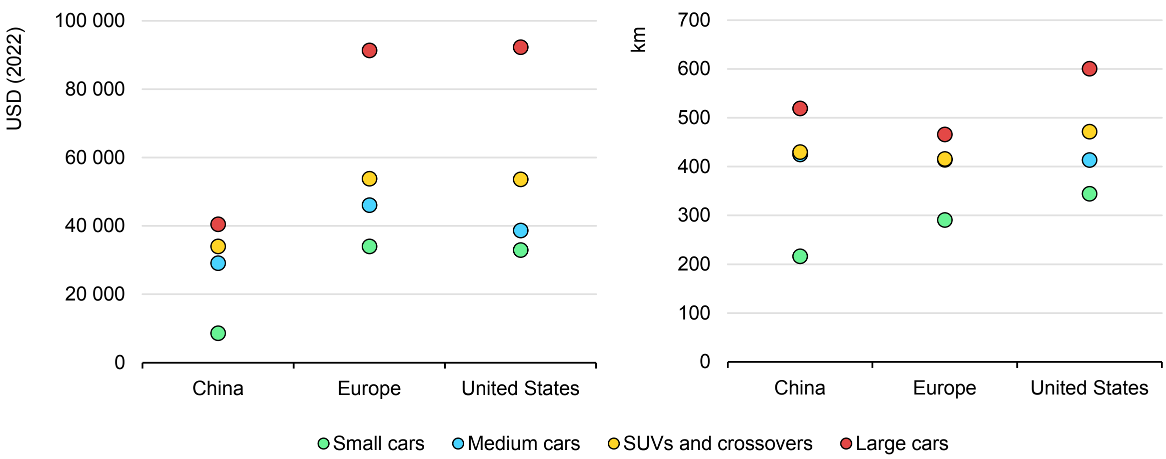
Similar trends are observed in EV markets. Around 16% of all SUVs sold were electric in 2022, which is above the overall market share of EVs and demonstrates consumer preferences for SUVs regardless of whether they are an ICE vehicle or EV. Nearly 40% of all BEV models available in 2022 were SUVs, which is equivalent to the shares of small and medium car options combined. Other large models accounted for more than 15%. Just 3 years before, in 2019, small and medium models accounted for 60% of all available models, and SUVs just 30%.

In China and Europe, SUVs and large models accounted for 60% of available BEV options in 2022, on par with the world average. As a comparison, ICE SUVs and large models accounted for about 70% of available ICE options in these regions, suggesting that electric cars currently remain somewhat smaller than their ICE equivalents. Announcements by some major European carmakers indicate that there could be a greater focus on smaller, more popular models in the years to come. For example, Volkswagen has announced the launch of a compact model for the European market under EUR 25 000 by 2025 and under EUR 20 000 by 2026-2027, as a means to appeal to a broader consumer base. In the United States, over 80% of available BEV options in 2022 were SUVs or large car models, which is greater than the share of ICE SUVs or large models at 70%. Looking ahead, more electric SUVs are to be expected in the United States, should recent policy announcements on expansion of IRA incentives to more SUVs be implemented. Following the IRA, the US Treasury has been revising vehicle classifications, and in 2023 changed the eligibility criteria for clean vehicle credits relevant to smaller SUVs, which are now eligible if priced under USD 80 000, up from the previous limit of USD 55 000.

## Electric cars remain much cheaper in China

The growth in electric car sales in China has been underpinned by sustained policy support, but also cheaper retail prices. In 2022, the sales-weighted average price of a small BEV in China was below USD 10 000. This is significantly less than the prices of small BEVs found in Europe and the United States, where the sales-weighted average price exceeded USD 30 000 in the same year.

**Figure 1.7 Sales-weighted average retail price (left) and driving range (right) of BEV passenger cars in selected countries, by size, in 2022**






Notes: BEV = battery electric vehicle; SUV = sports utility vehicle. 'Europe' is based on data only from France, Germany and the United Kingdom. Retail prices collected in 2022-2023, before subsidy.
Source: IEA analysis based on EV Volumes.

**In 2022, BEV passenger cars remained much cheaper in China, which explains in part higher adoption rates there.**

In China, the best-selling electric cars in 2022 were the Wuling Mini BEV, a small model priced at under USD 6 500, and BYD's Dolphin, another small model, below USD 16 000. Together, these two models accounted for nearly 15% of Chinese BEV passenger car sales, illustrating the appetite for smaller models. To compare, the best-selling small BEVs across France, Germany and the United Kingdom – Fiat's 500, Peugeot's e-208 and Renault's Zoe – were all priced above USD 35 000. Few small BEVs were sold in the United States, limited mainly to Chevrolet's Bolt and the Mini Cooper BEV, which are priced around USD 30 000. Tesla's Y Model was the best-selling BEV passenger car in both the selected European countries (priced at more than USD 65 000) and the United States (more than USD 50 000).[6]

Chinese carmakers have focused on developing smaller and more affordable models in advance of their international peers, cutting down costs following years of tough competition domestically. Hundreds of small EV manufacturers have entered the market since the 2000s, benefitting from a variety of public support schemes, including subsidies and incentives for both consumers and manufacturers. The majority of these firms went bankrupt due to competition as subsidies were gradually phased out, and the market has since consolidated around a dozen frontrunners, which have succeeded in developing small and cheap electric cars for the Chinese market. Vertical integration of battery and EV supply chains from mineral processing to battery and EV manufacturing, as well as cheaper labour, manufacturing and access to finance across the board, have also contributed to developing cheaper models.

Meanwhile, carmakers in Europe and the United States – both early developers such as Tesla and incumbent major manufacturers – have mostly focused on larger or more luxurious models to date, hence offering few options affordable for mass-market consumers. However, the small options available in these countries typically offer greater performance than those in China, such as longer driving range. In 2022, the sales-weighted average range of small BEVs sold in the United States was nearly 350 km, while in France, Germany and the United Kingdom it was just under 300 km, compared to under 220 km in China. For other segments, the differences are less significant. The broader availability of public charging points in China may, in part, explain why consumers there have been more willing to opt for lower driving ranges than their European or American counterparts.

In 2022, Tesla heavily reduced the price of its models on two occasions as competition increased, and many carmakers have also announced cheaper options in the coming years. While these announcements warrant further examination, this trend could indicate that the price gap between small electric cars and incumbent ICE options could progressively close during this decade.

[6] However, Tesla has decreased car prices several times since the publication of the IRA in the United States, in part to boost sales as competition gets tougher (see section on corporate strategy and finance).

## Emerging markets see encouraging growth

China, Europe and the United States – the three major markets for electric cars – accounted for about 95% of global sales in 2022. Emerging market and developing economies (EMDEs) outside China account for only a fraction of the global electric car market. Demand for electric cars has increased in recent years, but sales remain low.

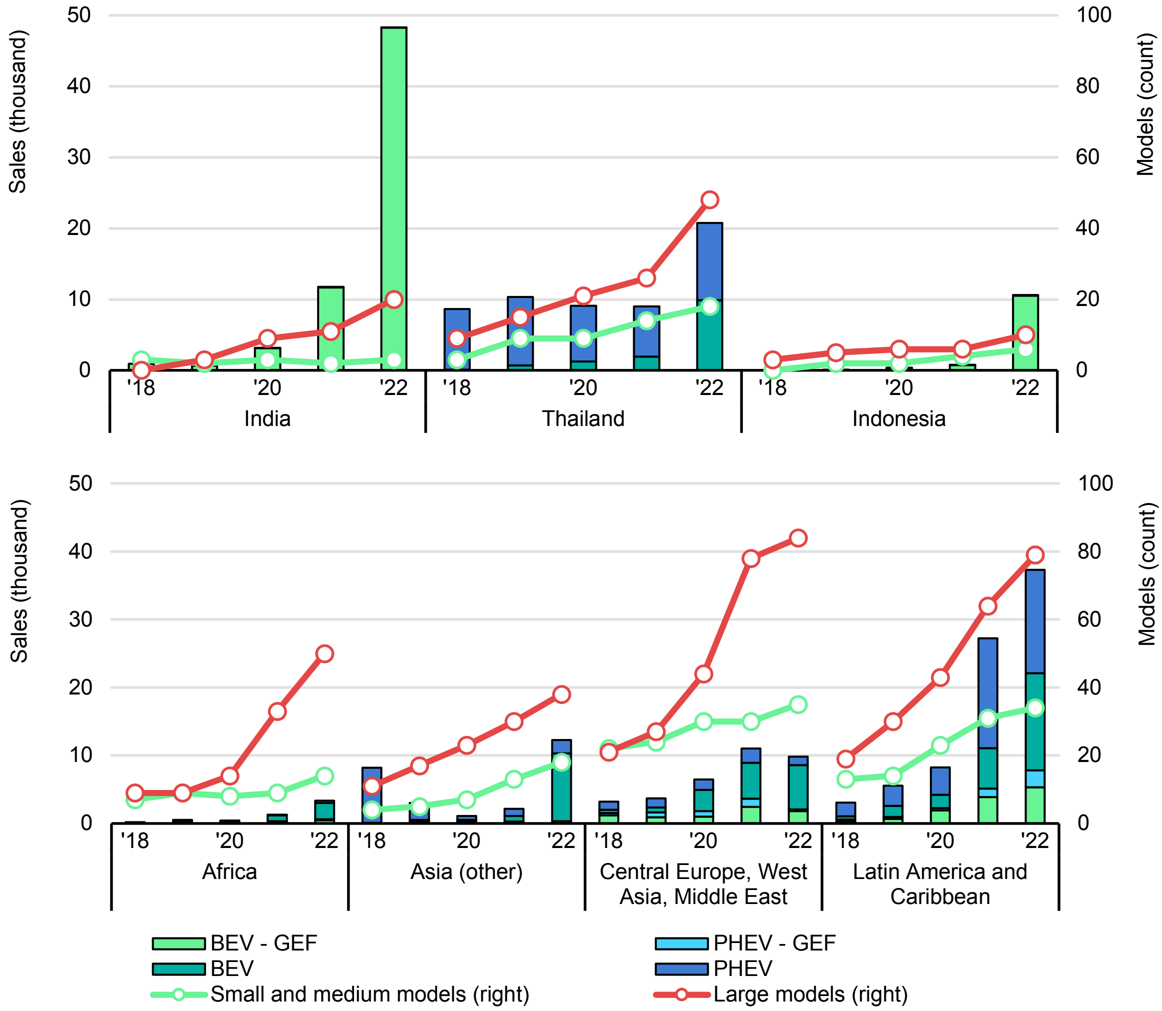
While EMDEs often quickly adopt low-cost emerging technology products (e.g. smartphones, computers and connected devices), electric cars remain typically too expensive for the majority of the population. According to a recent survey, over 50% of Ghanaian respondents would prefer to purchase an EV to an ICE vehicle, but more than half of those potential consumers would not be willing to spend more than USD 20 000 for an electric car. Lack of access to reliable and affordable charging can be a barrier, as can limited access to EV servicing, maintenance and repair. In most EMDEs, road transport remains largely based on smaller mobility solutions in urban centres, such as two- and three-wheelers, which have seen much greater success in terms of electrification, as well as shared mobility for regional commutes. Purchasing behaviour is also different, with lower personal car ownership rates and more common purchase of used cars. Looking forward, while sales of electric cars – both new and used – can be expected to increase in EMDEs, it is likely that many countries will continue to rely primarily on two- and three-wheelers (see subsequent section on these vehicles in this report).

There was a notable boom in electromobility in 2022 in India, Thailand and Indonesia. Collectively, sales of electric cars in these countries more than tripled relative to 2021, reaching nearly 80 000. Sales in 2022 were 7 times higher than in 2019, before the Covid-19 pandemic. In contrast, sales in other EMDEs were lower.

In India, BEV sales reached nearly 50 000 in 2022, 4 times more than in 2021, while total car sales increased by just below 15%. Leading domestic manufacturer Tata accounted for over 85% of BEV sales, including through sales of its small BEV Tigor/Tiago, which quadrupled. Indian PHEV sales remained close to zero. Burgeoning electromobility companies are now betting on the government's Production Linked Incentive (PLI) scheme – with around USD 2 billion in subsidy programmes – to ramp up EV and component manufacturing. This scheme has attracted investments totalling USD 8.3 billion.

The Indian market, however, currently remains geared towards shared and smaller mobility. In 2022, 25% of electric car purchases in India were by fleet operators, such as for taxis. In early 2023, Tata secured a large order from Uber for 25 000 electric cars. Furthermore, while 55% of three-wheelers sold were electric, fewer than 2% of cars sold were EVs. Ola, India's top EV company by revenue, does not yet offer electric cars. Ola is instead concentrating on smaller mobility and aims to double its electric two-wheeler manufacturing capacity to 2 million by the end of 2023, and to reach an annual production capacity of 10 million between 2025 and 2028. The company also seeks to build lithium-ion battery manufacturing facilities, initially at 5 GWh capacity, scaling up to 100 GWh by 2030. Ola aims to start marketing electric cars for its taxi business by 2024 and to make its fleet of taxis fully electric by 2029, while launching its own electric car business for both the high-end and mass markets. It announced over USD 900 million of investments for battery and EV manufacturing in Southern India, and an increase in annual production from 100 000 to 140 000 vehicles.

**Figure 1.8 Electric car sales by powertrain (columns) and available models by car size (lines) in selected regions, 2018-2022**






Notes: BEV = battery electric vehicle; PHEV = plug-in hybrid electric vehicle. “GEF” refers to the Global Environment Facility’s Global E-Mobility Programme, which was launched in 2019 and supports 27 countries in their shift to electromobility. In Africa, GEF includes Burundi, Côte d'Ivoire, Madagascar, Seychelles, Sierra Leone, South Africa, Togo, and Tunisia. In Asia, GEF includes Bangladesh, India, Indonesia, Maldives, Philippines, and Sri Lanka, but India and Indonesia are shown separately. In Central Europe, West Asia and Middle East, GEF includes Albania, Armenia, Jordan, Ukraine and Uzbekistan. In Latin America and Caribbean, GEF includes Antigua and Barbuda, Chile, Costa Rica, Ecuador, Grenada, Jamaica, Peru and St Lucia. Other countries in Africa include: Algeria, Egypt, Ethiopia, Ghana, Kenya, Mauritius, Morocco, Nigeria, Rwanda, Zambia and Zimbabwe. Other countries in Asia include: Cambodia, Fiji, Laos, Malaysia, Mongolia, Nepal, Pakistan, Thailand and Viet Nam. Other countries in Central Europe, West Asia, Middle East include Azerbaijan, Bahrain, Belarus, Bosnia, Georgia, Iraq, Kazakhstan, Kosovo, Kuwait, Lebanon, Moldova, North Macedonia, Oman, Qatar, Russia, Saudi Arabia, Serbia and the United Arab Emirates. Other countries in Latin America and Caribbean include Argentina, Bahamas, Bolivia, Brazil, Colombia, Dominican Republic, Panama, Paraguay and Uruguay. The number of available models refers to unique models across the selected sample of countries. The number of available models includes BEVs and PHEVs.

Source: IEA analysis based on EV Volumes.

**Electric car sales continue to increase in emerging markets with a notable boom in India, but they remain low relative to major markets, and model availability is still an issue.**

In Thailand, electric car sales doubled to 21 000, equally distributed between BEVs and PHEVs. The emerging presence of Chinese carmakers has accelerated EV adoption in the country. In 2021, Chinese original equipment manufacturer (OEM) Great Wall Motors launched its Ora Good Cat BEV model in the Thai market, and in 2022 it became the most sold electric car in Thailand, with nearly 4 000 sales. The second and third best-selling cars were also Chinese, manufactured by Shanghai Automotive Industry Corporation (SAIC), none of which were sold in the country in 2020. Chinese automakers were able to undercut EV prices from foreign competitors also present in the Thai market, such as BMW and Mercedes, thereby appealing to a broader consumer base. In addition, the Thai government offers various financial incentives for electric cars, including subsidies, excise duty waivers and import tax reductions, which have contributed to making electric cars more attractive. Tesla is planning to enter the Thai market in 2023 along with building Superchargers.

In Indonesia, BEV sales multiplied by more than 14, exceeding 10 000, while PHEV sales remained close to zero. In March 2023, Indonesia announced new incentives to support sales of electric two-wheelers, cars and buses, with the aim of strengthening domestic capacity in EV and battery manufacturing through local component requirements. The government aims to subsidise the sale of 200 000 electric two-wheelers and 36 000 electric cars in 2023, reaching a sales share of 4% and 5% respectively. The new subsidies could reduce the price of an electric two-wheeler by 25-50% to help compete against ICE equivalents. Indonesia plays an important role in EV and battery supply chains, in particular given its abundant raw mineral resources and status as the world's largest nickel miner. This has attracted investment from global companies, and Indonesia could become the largest manufacturing hub in the region for batteries and components.

Model availability remains an issue in EMDEs, with many of the options on sale heavily geared towards the higher end, such as SUVs, large and luxury models. While the trend for SUVs is global, purchasing power is more limited in EMDEs, making such vehicles largely unaffordable. Across the different regions considered in this section of the report, for a total of more than 60 EMDEs, including those which receive support from the Global Environment Facility's (GEF) Global E-Mobility Programme, there were two to six times more large models available than small ones in 2022.

In Africa, the best-selling electric car model in 2022 was the Hyundai Kona, a crossover BEV, and there were about as many recorded sales of Porsche's large and expensive Taycan BEV as there were of Nissan's medium-sized Leaf BEV. There were also eight times more sales of electric SUVs than of the Mini Cooper SE BEV and Renault Zoe BEV combined, the two best-selling small electric cars. In India, the best-selling electric car model was Tata's crossover Nexon BEV, with over 32 000 sales, or three times more than the second best-selling model, Tata's small Tigor/Tiago BEV. Across all of the EMDEs considered here, sales of electric SUVs reached 45 000, which is more than the sales of small (23 000) and medium (16 000) electric cars combined. In Costa Rica, the leading country in Latin America in terms of BEV sales share, only 4 models in the top 20 were not SUVs, and nearly a third were luxury models. The future of mass-market electrification in EMDEs relies on the development of smaller, more affordable electric cars, alongside two- and three-wheelers.

**Box 1.2 On the distinction between vehicle registrations and vehicle sales**

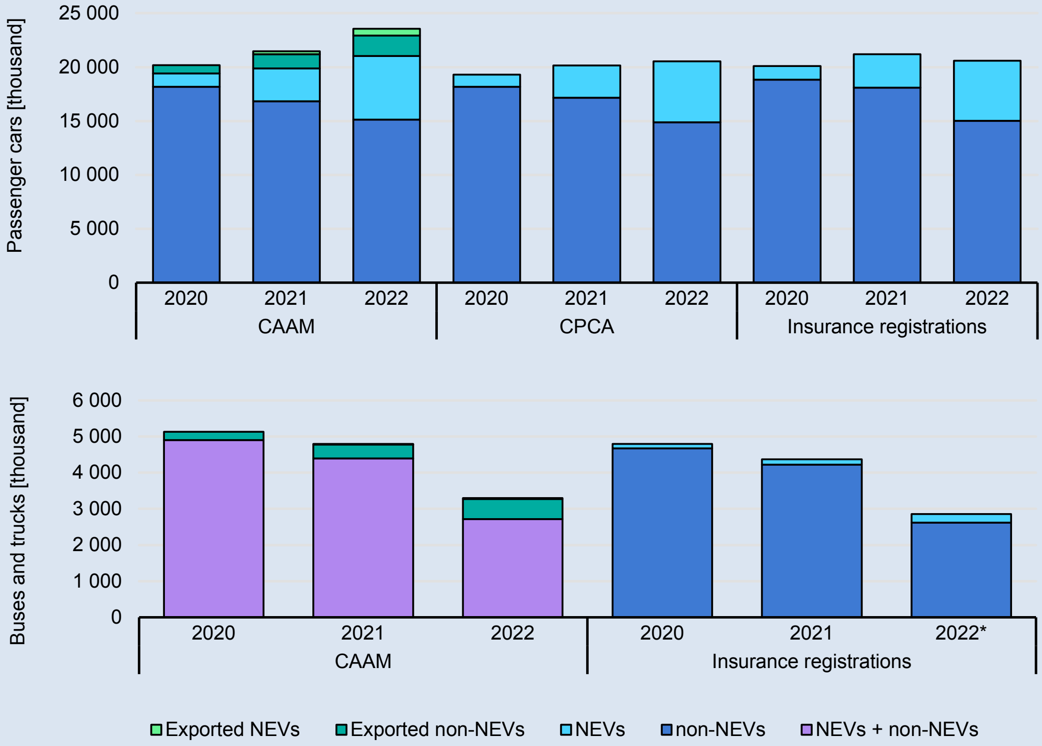
An important distinction for assessing the evolution of vehicle markets is the difference between registrations and sales. New registrations represent the number of vehicles that have been officially registered for the first time with the relevant government ministry or insurance agency, including domestically produced and imported vehicles. Sales can either refer to vehicles sold by dealers or agencies (retail sales), or to vehicles sold to dealers by vehicle manufacturers (factory shipments, i.e. including exports). The choice of metric can make a significant difference when analysing vehicle markets. For consistency in accounting across all countries, and to avoid double-counting at a global level, in this report vehicle market sizes are based on new vehicle registrations, where available, and retail sales otherwise, not on factory shipments.

China's vehicle market trends in 2022 are a good illustration of why this matters. In 2022, an increase of 7 to 10% in factory shipments (reported as sales) for the Chinese passenger car market was reported, while insurance registrations showed a stagnation of the domestic market in the same year. This increase was observed in data from the China Association of Automobile Manufacturers (CAAM), which is the official data source for China's car industry. CAAM data is collected from car manufacturers and represents factory shipments. Another widely referenced source is the China Passenger Car Association (CPCA), a non-governmental organisation that provides wholesale, retail sales and exports for passenger cars, but is not qualified to provide national statistics, and it does not cover all OEMs, whereas CAAM does. The China Automotive Technology and Research Center (CATARC) is a state-owned think tank, and collects car production numbers from vehicle identification numbers and car sales numbers from vehicle insurance registrations. In China, vehicle insurance is registered for the vehicle itself and not for the individual driver, and is therefore useful for tracking the number of vehicles on the road, including imports. The main differences between CATARC data and the other sources stem from exports and military or other cars that do not get registered, and inventory stocks of vehicle manufacturers.

In 2022 the total exports of passenger cars increased rapidly, making the differences between these data sources more apparent. In 2022 the export of passenger vehicles increased by almost 60%, exceeding 2.5 million, while the imports of passenger vehicles decreased by almost 20% (950 000 to 770 000).

Similar discrepancies between factory shipments and insurance registrations are apparent in the Chinese bus and truck (commercial vehicle) market. In both 2021 and 2022, total volumes of factory shipments were substantially higher than insurance registrations, implying net export shares of commercial vehicles of about 9% in 2021 and more than 13% in 2022.

**Number of passenger car (top) and commercial vehicle (bottom) sales and registrations in China reported by various sources, 2020-2022**






*Insurance registrations of commercial vehicles from EV100 and from EVI member country data submissions. Note: CAAM = China Association of Automobile Manufacturers; CPCA = China Passenger Car Association; NEV = new energy vehicle.
Sources: IEA analysis based on sales data from CAAM and CPCA and insurance registrations of new passenger vehicles from Dongchedi. CAAM: Includes exports, exclude imports (CAAM, 2023), CPCA: Excludes exports and imports (CPCA, 2023).

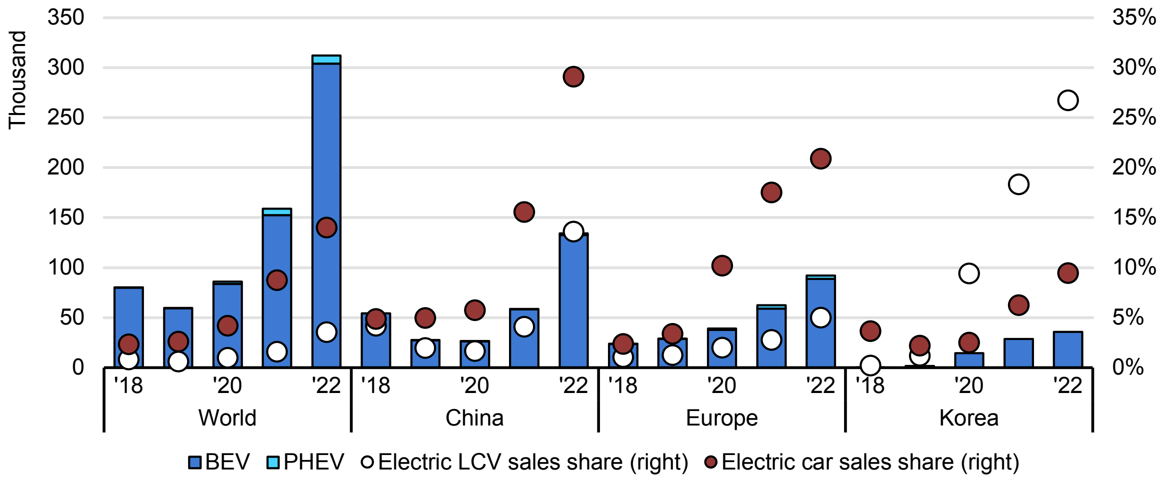
## Sales of electric light commercial vehicles continue to increase, catching up with electric car sales

Electric light commercial vehicle (LCV) sales worldwide nearly doubled in 2022 relative to 2021 to more than 310 000 vehicles, even as overall LCV sales declined by more than 10% (Figure 1.9). At a global level, the electric LCV sales share is

3.6%, about one-quarter that of passenger cars. Current trends indicate that the electric LCV market is catching up with that of electric cars, suggesting that the gap in terms of EV sales shares could narrow in the future. For the first time in 2022, the increase in the share of electric LCVs outpaced that of electric passenger cars (albeit from a low base). This demonstrates that once a critical tipping point in terms of favourability of total cost of ownership (TCO) has been achieved, commercial vehicle purchasers are likely to respond more rapidly to economic fundamentals than private consumers. Commercial vehicle owners typically use their vehicles more intensively, and as they have an imperative to maximise profit, EVs provide an opportunity to considerably reduce operating costs. The experience of commercial owners can also provide learnings for the private consumers segment: better fleet and charging management could help address concerns over range limitations.

The share of PHEVs in LCVs has remained very low; around 98% of both electric LCV sales and stock in 2022 were BEVs. It is likely that this reflects the economic favourability of the battery electric powertrain – as opposed to plug-in hybrids – in commercial operations characterised by intensive usage, regularity and predictability (in terms of driving range, geographic extent, and return-to-base for overnight charging), as well as the lower maintenance and service costs of battery electric LCVs. Battery electric LCV adoption may also be spurred on by the continuing expansion of low- and zero-emission zones.

**Figure 1.9 Electric light commercial vehicle sales and sales shares, 2018-2022**






Notes: BEV = battery electric vehicle; PHEV = plug-in hybrid vehicle; LCV = light commercial vehicle. Electric car sales shares are provided as a point of comparison.

**Sales of electric LCVs nearly doubled in 2022, reaching 3.5% of total LCV sales, led by Korea, Norway and China.**

In 2022, China led in terms of overall electric LCV sales with over 130 000 units sold, and nearly 15% of LCVs sold being electric.[7] Subsidies for battery electric and fuel cell trucks and vocational vehicles (including LCVs) have decreased in recent years, but overall zero-emission commercial truck sales have been growing since 2020, even as subsidies per vehicle have declined, indicating the increasing commercial competitiveness of electric trucks.

In terms of market share, Korea continued to lead in 2022 with 27% of LCV sales being electric (36 000 vehicles), but sales growth in 2022 slowed to half its level in the previous year. This may be due to changes to the subsidy scheme for LCVs and to the repealing in April 2022 of a policy that made obtaining commercial registration permits easier for electric LCVs than ICE models (see Policy developments and corporate strategy).

Light commercial EV sales shares also grew substantially in the Nordic countries, with Norway reaching 25%, Iceland 16%, and Sweden 13%. In all other key European and North American national markets, shares are lower than 10%, and typically less than the global average of 3.5%, but the rate of growth in market share for electric LCVs was higher than for passenger light-duty vehicles (PLDVs) (albeit from a lower baseline) across most leading EV markets, including the United States, Japan, and the European Union.

## Electric two-wheeler sales declined in China while global electric three-wheeler sales continued to rise

Global electric two-wheeler sales totalled about 9.2 million in 2022, a drop of nearly 18% from 2021 (Figure 1.10). This drop is almost entirely attributable to the dip in sales of electric mopeds and motorcycles in China, which fell from 10.2 million in 2021 to under 7.7 million in 2022, even as the overall two-wheeler market there continued to grow. Supply chain challenges stemming from China's pandemic-related restrictions in 2022 hit the electric two-wheeler market particularly hard, and in spite of growth in sales of premium domestic and imported two-wheelers (e.g. from BMW, Ducati and others), the overall sales share of electric two-wheelers dipped back below 50%.[8] Despite the decline in sales, China

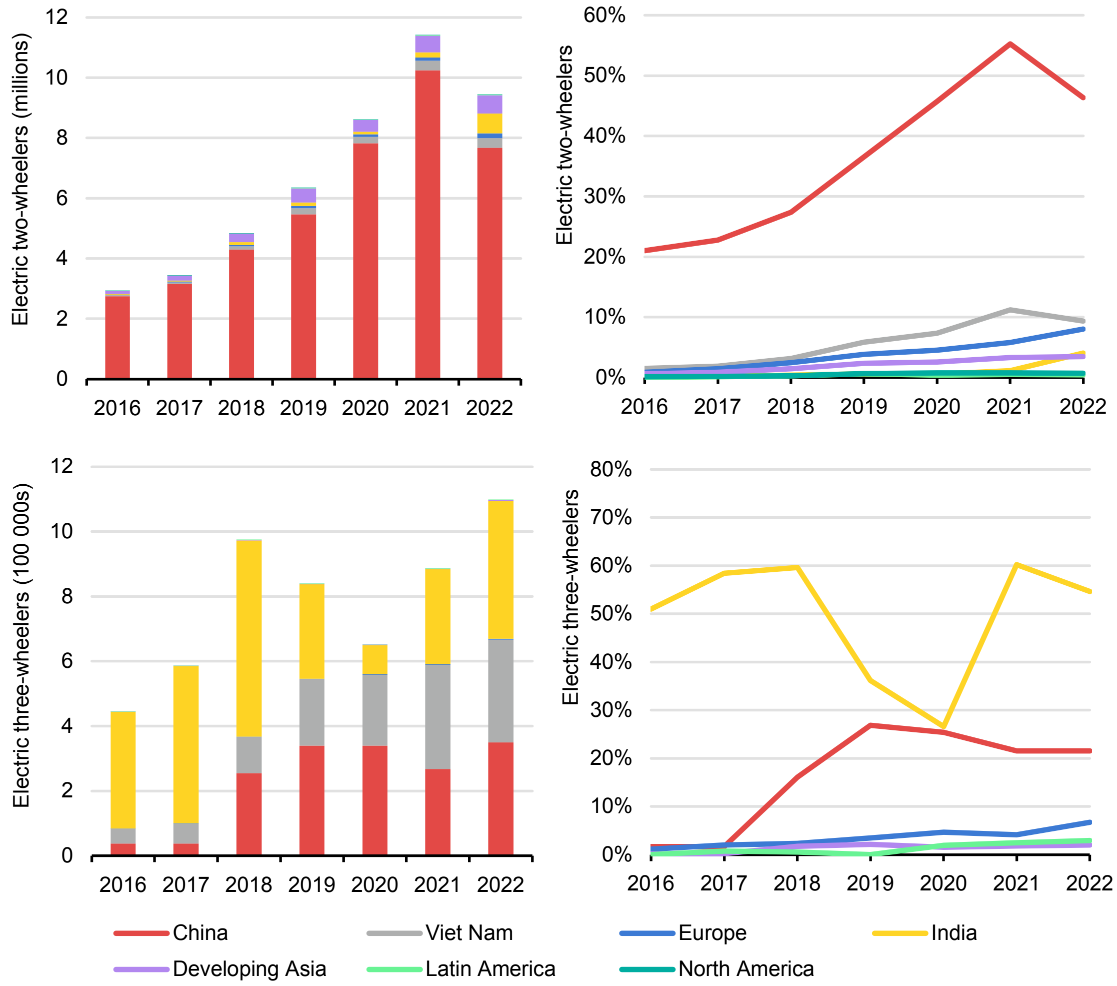
[7] Commercial truck sales in China are reported according to four gross vehicle weight (GVW) bins: less than 1.8 tonnes, 1.8-6 tonnes, 6-14 tonnes, and greater than 14 tonnes. These are reallocated to categories based on other external data sources to match IEA's harmonised global definitions of light commercial vehicles (less than 3.5 tonnes GVW), medium trucks (3.5-15 tonnes), and heavy trucks (15 tonnes GVW and above).

[8] As with other vehicle types, tracking new two-wheeler registrations ("sales") in China is difficult, as the official data source, CAAM, tracks factory shipments, and hence reports volumes that include exported vehicles. Tracking is particularly difficult in the case of electric two-wheelers, however, as many data sources include pedal-electric bicycles and other small electric mopeds (see, for instance, a recent industry report from Honda). Chinese data sources give vehicle sales of electric two-wheelers at around 50 million in 2021, and 60 million in 2022, of which about 7.6 million are classified as motorcycles (China Chamber of Commerce for Motorcycles). Some of these attain top speeds of less than 50 km/hour, and so are excluded from the above figures. In India, electric bicycles and mopeds with a top speed of less than 50 km/hour made up more than 80% of the market in 2021 and 2022. The accounting here includes only vehicles with a minimum top speed of 50 km/hr and that fit the UNECE definition of L1 or L3, based on data provided by MotorcyclesData.com.

continued to dominate the electric two-wheeler market in terms of size, accounting for nearly 85% of global sales.

Electric two-wheelers also lost market share in Viet Nam, despite sales shares of domestically produced electric two-wheelers having increased considerably in recent years. In terms of absolute volumes, sales grew in most Asian markets outside China and Viet Nam.

**Figure 1.10 Electric two- and three-wheeler sales and sales share by region, 2016-2022**






Source: IEA analysis based on country submissions and data from MotorcyclesData.com.

**China leads global electric two-wheeler sales, despite a 25% drop in 2022. Battery leasing business models and stronger manufacturing boost Indian electric three-wheeler sales.**

## India leads on sales of electric three-wheelers thanks to policy support and innovative business models

Sales of electric three-wheelers, which play an important role in urban mobility in India for both cargo and passenger services, soared to 425 000 units in 2022. Sales have been strong in India for a number of years, with hundreds of thousands of electric three-wheelers sold every year since 2012, with the exception of 2020, when the Covid-19 pandemic reduced sales volumes to 30% of the previous year.

Over half of India's three-wheeler registrations in 2022 were electric, demonstrating their growing popularity due government incentives and lower lifecycle costs compared with conventional models, as well as higher fuel prices. IEA analysis on the TCO in India suggests that electric three-wheelers are already 70% cheaper than their gasoline-power ICE equivalents over their lifetime (IEA, forthcoming).

Policies including the purchase incentives under FAME II, supply-side incentives under the PLI scheme, tax benefits and India's Go Electric campaign all contributed to reducing the higher upfront costs (see Policy developments and corporate strategy for a detailed discussion of these and other policies). A total of 15 Indian states have already adopted EV policies to promote stronger EV deployment (and many more are drafting them), the majority of which include additional demand incentives. Bulk procurement schemes, the emergence of the battery-as-a-service (BaaS) business model and India's draft battery swapping policy all give further impetus to the rapidly rising sales of electric three-wheelers.

China followed India in terms of electric three-wheeler sales, with nearly 350 000 units sold in 2022. Together, China and India accounted for nearly 99% of global electric three-wheeler sales.

### Box 1.3 Korea continues to lead fuel cell electric car growth

In 2022, the stock of fuel cell electric vehicles (FCEVs) increased 40% compared to 2021, reaching over 72 000 vehicles globally. About 80% of the FCEVs are cars, 10% trucks and almost 10% buses. In 2022, the fuel cell truck segment grew at a faster rate than cars and buses, increasing 60%.

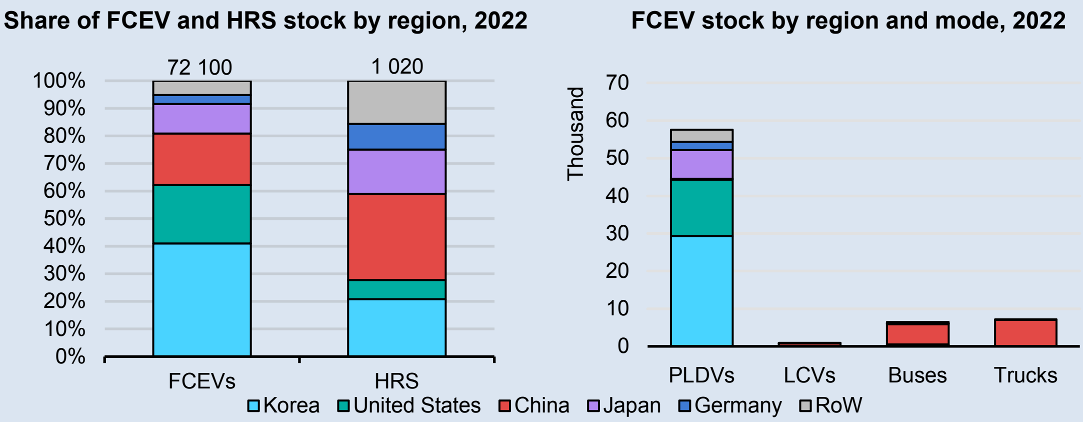
Korea is now home to over half of all fuel cell cars globally. Two-thirds of the additional 15 000 fuel cell cars that hit the road in 2022 were in Korea. This can be attributed in part to a policy landscape that supports FCEV production and sales, which has also led to Hyundai being the top fuel cell automaker.

The United States holds the second largest FCEV stock, with over 15 000 FCEVs. Most of these are fuel cell cars, with a little more than 200 fuel cell buses. In 2022, the stock of FCEVs in the United States increased more than 20%, which is much less than the 60% growth in China, which has the third largest FCEV stock.

Historically, China has dominated the heavy-duty fuel cell vehicle segments (trucks and buses). This is still the case in 2022, with China home to over 95% of the global fuel cell truck fleet and almost 85% of the global fuel cell bus fleet. However, in 2022, China added over 200 fuel cell cars to its FCEV fleet after years of only deploying buses and trucks.

For further details on the status of FCEVs and other hydrogen-based applications, see the IEA Global Hydrogen Review report series.

**Fuel cell electric vehicle and hydrogen refuelling station stock by region, 2022**






Notes: FCEVs = fuel cell electric vehicles; HRS = hydrogen refuelling station; PLDVs = passenger light-duty vehicles; LCVs = light commercial vehicles; RoW = rest of the world.
Source: IEA analysis based on the data submission of the Advanced Fuel Cells Technology Collaboration Program.

# Electric heavy-duty vehicles

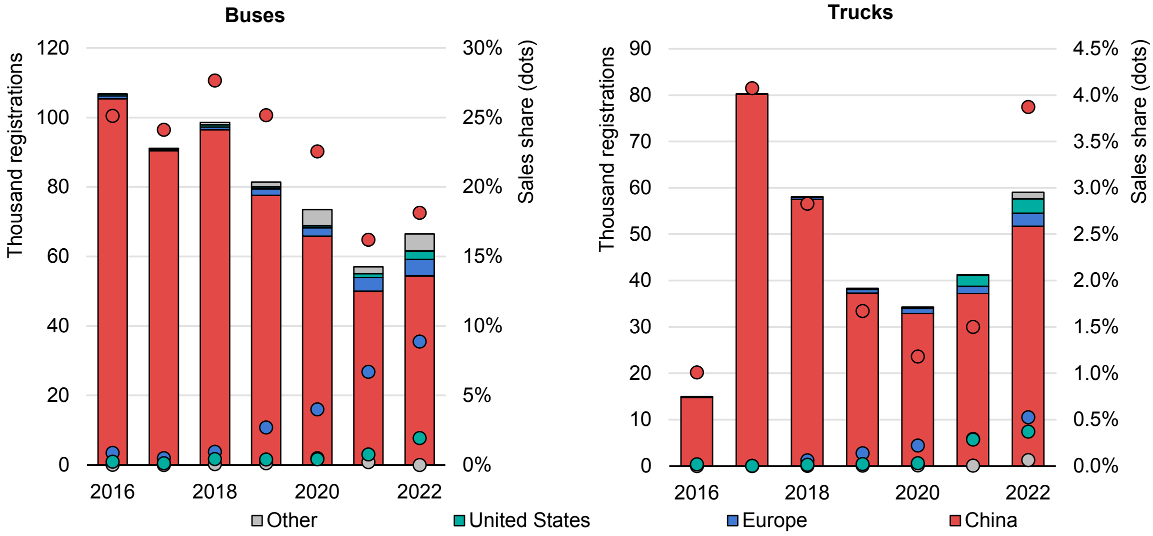
## Electric truck and bus sales shares

In 2022, nearly 66 000 electric buses and 60 000 medium- and heavy-duty trucks were sold worldwide, representing about 4.5% of all bus sales and 1.2% of truck sales worldwide. China continues to dominate production and sales of electric (and fuel cell) trucks and buses. In 2022, 54 000 new electric buses and an estimated 52 000 electric medium- and heavy-duty trucks[9] were sold in China, representing 18% and 4% of total sales in China and about 80% and 85% of global

[9] Commercial truck sales in China are reported according to four GVW bins: less than 1.8 tonnes, 1.8-6 tonnes, 6-14 tonnes, and greater than 14 tonnes. These are reallocated to categories based on other external data sources to match IEA's harmonised global definitions of light commercial vehicles (less than 3.5 tonnes GVW), medium trucks (3.5-15 tonnes), and heavy trucks (15 tonnes GVW and above).

sales, respectively. In addition, many of the buses and trucks being sold in Latin America, North America and Europe are Chinese brands.

**Figure 1.11 Electric bus and truck registrations and sales share by region, 2015-2022**






Source: IEA analysis based on country submissions and data from EV100 and vehicle insurance registration data.

**China continues to account for about 80% of global electric bus sales and 85% of electric truck sales, as well as exporting large volumes of both.**

Within Europe, the sales share for electric buses was highest in Finland, where electric buses made up two-thirds of sales in 2022, Norway and the Netherlands, where they made up nearly half of sales, and Denmark, where they made up nearly one-third. Sales shares were also high in Sweden, Switzerland and Israel.

Electric trucks sales shares remain low across most major markets. With the exception of China, cumulative electric medium- and heavy-duty truck ("truck") sales to date number in the hundreds in most countries (just under 2 000 electric trucks were sold across the entire European Union in 2022). Sales shares generally remain well under 1% in medium- and heavy-duty segments, with major shipping logistics companies running demonstrations of electric trucks in regional and long-haul electric operations.

The average declared range of electric trucks produced in China exceeded 300 km, and that of electric buses 400 km. A growing number of electric buses have ranges that enable intercity operations; the vast majority of electric buses in China (and elsewhere) are currently used in urban public transit operations, but official statistics show that at least 8% of new energy buses are operating on intercity routes.

The majority of electric trucks sold in China are box trucks,[10] and 90% of electric truck sales were under 4.5 tonnes in gross vehicle weight (GVW), with the majority of these being between 3.5-4.5 tonnes. Electric truck sales for tractor-trailers and garbage trucks in China have also grown rapidly from a low base.

Until the past few years, the production and sales volumes of electric buses and trucks ebbed and flowed based on subsidies. The central government introduced subsidies totalling nearly CNY 30 billion (Chinese Yuan renminbi) (USD 4.3 billion) in 2016 and 2017, the vast majority of which went to electric buses; BYD buses alone received about CNY 10 billion (USD 1.5 billion). Despite a progressive reduction in subsidies from 2018 onwards (total subsidies from 2018-2021 were less than CNY 20 billion [USD 2.9 billion]), electric bus and truck sales began increasing in 2021 and grew again in 2022, a promising sign that they have reached cost and performance metrics that make them increasingly competitive without government support. Cost reductions are also being driven by market consolidation and economies of scale. Indeed, China's commercial electric truck sales (including both LCVs and medium- and heavy-duty trucks – see section above on electric LCVs) dipped from a high of nearly 150 000 in 2017 (immediately following the adoption of the subsidy) to a low point in 2020, at 59 000; before rebounding to reach 186 000 total electric truck sales in 2022, despite declining subsidies on a per-vehicle basis in both 2021 and 2022.

## Zero-emission vehicle model availability expanded in 2022 in the medium- and heavy-duty truck segments

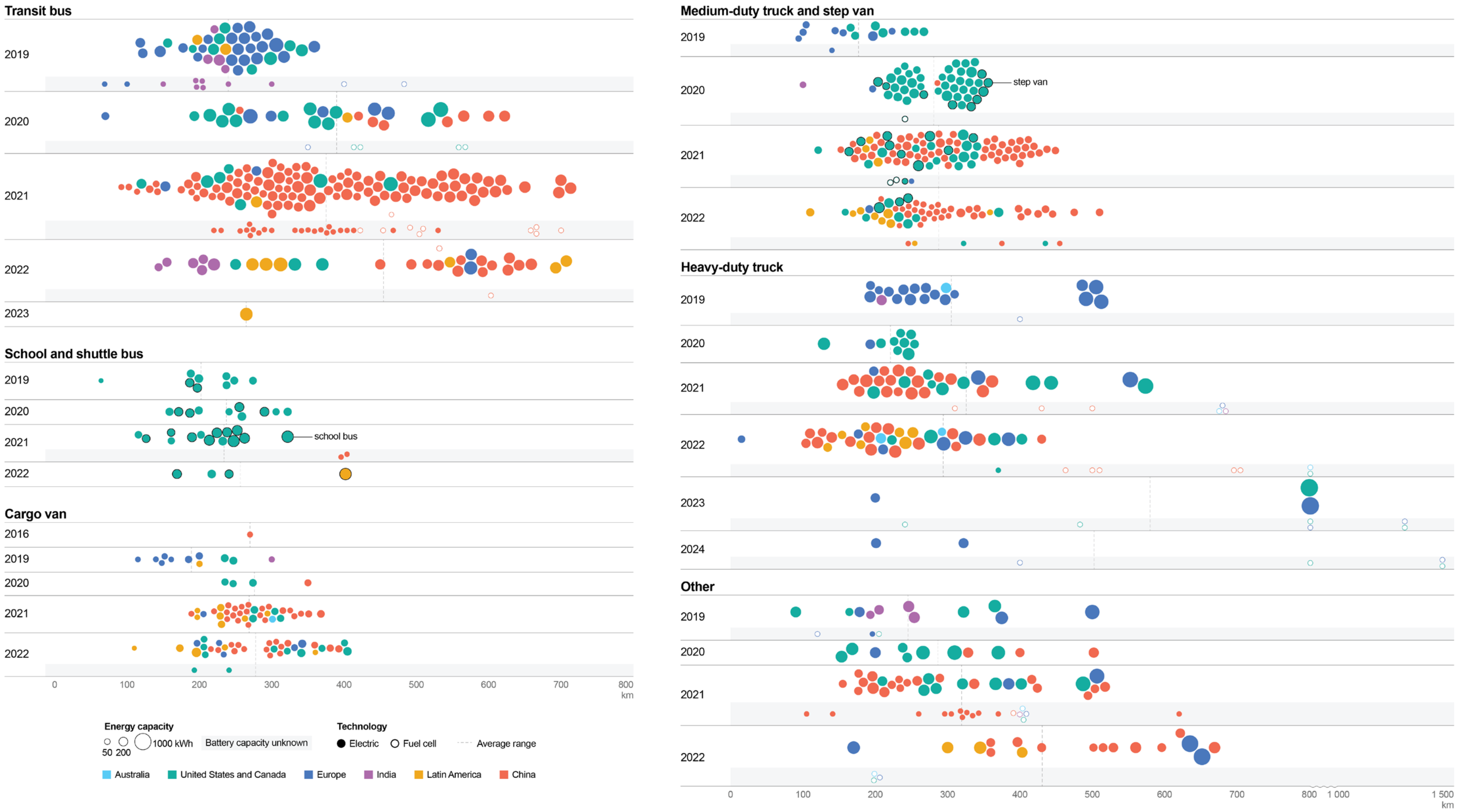
The number of models on offer for zero-emission trucks has continued to expand in 2022, with nearly 840 current and announced medium- and heavy-duty vehicle models in the Global Drive to Zero Emission Technology Inventory (ZETI) database.

The trend of new model development has shifted from buses to medium- and heavy-duty trucks. Of the 220 models that became available in 2022, more than half were either medium-duty trucks (over 60 models) or heavy-duty trucks (over 50 models), reflecting the fact that truck manufacturers are increasingly gaining confidence in supplying larger, heavier zero-emission models with greater payloads. The majority (over 90%) of the already available medium-duty and heavy-duty trucks models are battery electric; 12 models of fuel cell heavy-duty trucks are currently available – and another 8 are due to become available in 2023-24.

Of commercially available bus and truck models in 2022, 60% (over 500 models) were produced by OEMs headquartered in China. Another 20% (over 170 models) were produced by North American OEMs, and 15% (over 120 models) by European OEMs.

[10] Box trucks are light commercial and medium-duty chassis cab trucks with an enclosed box-shaped cargo space in the back.

**Figure 1.12 Current and announced zero-emission commercial vehicle models by type, release date and range, 2019-2023**






Notes: Although the inventory is continuously updated, this snapshot may not be fully comprehensive due to new model announcements and small manufacturers not yet captured in the inventory. Zero-emission vehicles (ZEVs) include battery electric vehicles (BEVs), plug-in hybrid electric vehicles (PHEVs) and fuel cell electric vehicles (FCEVs). "Other" includes garbage, bucket, concrete mixer, mobile commercial and street sweeper trucks. The heavy-duty truck and transit bus figures include announced models for 2023-2024.

Source: IEA analysis based on the Global Drive to Zero ZETI tool database.

## China dominates heavy-duty battery production

European and North American electric bus and truck makers rely heavily on Asian battery makers. Given their dominance in lithium iron phosphate (LFP) battery chemistries, China's CATL produces the vast majority of batteries for trucks. However, spurred on by industrial policies – the European Union's Green Industrial Plan and the United States' IRA – truck makers have already begun to build or are announcing investments in new production facilities for heavy-duty battery packs (such as Volvo's 2.7 GWh plant, which opened in Sweden in 2022). Truck makers have also entered collaborations with major cell makers, seeking to secure further opportunities for vertical integration.

More than 95% of heavy-duty trucks produced in China were equipped with LFP cathode chemistries in 2021. The durability and lower cost of LFP batteries make them the preferred choice not only because of the high lifetime mileage needed for commercial operations, but also because price is a concern for bus and truck buyers: over half of truck purchases are leases or rely on loans.

The battery capacity of currently available commercial and announced models included in the ZETI database within a given vehicle type generally correlates with declared vehicle range (Figure 1.12). Table 1 shows how average battery capacity has generally increased across most bus categories from 2019 to 2022. However, no such clear trend is apparent across coaches or truck categories.

**Table 1.1 Average battery capacity in medium- and heavy-duty vehicle models**

| Vehicle Category | Average Battery Capacity (kWh) | | | | |
|---|---|---|---|---|---|
| | 2019 | 2020 | 2021 | 2022 | Change 2019-2022 |
| Transit bus | 264 | 322 | 225 | 345 | *31%* |
| School bus | 155 | 141 | 207 | 137 | *-12%* |
| Shuttle bus | 104 | 119 | 120 | 150 | *45%* |
| Coach | 316 | 347 | 233 | 266 | *-16%* |
| Cargo van | 69 | 90 | 57 | 60 | *-13%* |
| Medium-duty step van | -- | 134 | 155 | 163 | *22%** |
| Medium-duty truck | 124 | 139 | 99 | 92 | *-26%* |
| Heavy-duty truck | 293 | 232 | 372 | 311 | *6%* |
| Yard tractor | 150 | 184 | 160 | 197 | *31%* |

* Change from 2020 to 2022 average, as no medium-duty step vans were sold in 2019.
Source: IEA analysis based on the Global Drive to Zero ZETI tool database.

Actual vehicle range depends on the loaded vehicle weight, duty cycle, aerodynamics and drivetrain efficiency, as well as environmental factors such as temperature. In addition, as no harmonised test procedure currently exists to measure electric range for medium- and heavy-duty vehicles in any of the major markets where deployment of electric trucks has begun, manufacturers can determine their own methods to declare the electric range of the commercially available and announced models. However, any standardised test procedure would need to consider complicated issues of non-motive energy consumption (e.g. heating ventilation and air conditioning in buses, cooling in refrigerated trucks), as well as the potential for buses and trucks to be used in vehicle-to-grid applications (as has been demonstrated, for instance, with electric school buses in the United States). In light of such considerations, a first regulatory step could be to mandate that electric medium- and heavy-duty vehicle makers measure and disclose the usable battery energy according to a yet-to-be-developed standardised measurement procedure.

# Charging infrastructure

## Public charging points are increasingly necessary to enable wider EV uptake

While most of the charging demand is currently met by home charging, publicly accessible chargers are increasingly needed in order to provide the same level of convenience and accessibility as for refuelling conventional vehicles. In dense urban areas, in particular, where access to home charging is more limited, public charging infrastructure is a key enabler for EV adoption. At the end of 2022, there were 2.7 million public charging points worldwide, more than 900 000 of which were installed in 2022, about a 55% increase on 2021 stock, and comparable to the pre-pandemic growth rate of 50% between 2015 and 2019.

### Slow chargers

Globally, more than 600 000 public slow charging points[11] were installed in 2022, 360 000 of which were in China, bringing the stock of slow chargers in the country to more than 1 million. At the end of 2022, China was home to more than half of the global stock of public slow chargers.

Europe ranks second, with 460 000 total slow chargers in 2022, a 50% increase from the previous year. The Netherlands leads in Europe with 117 000, followed by around 74 000 in France and 64 000 in Germany. The stock of slow chargers

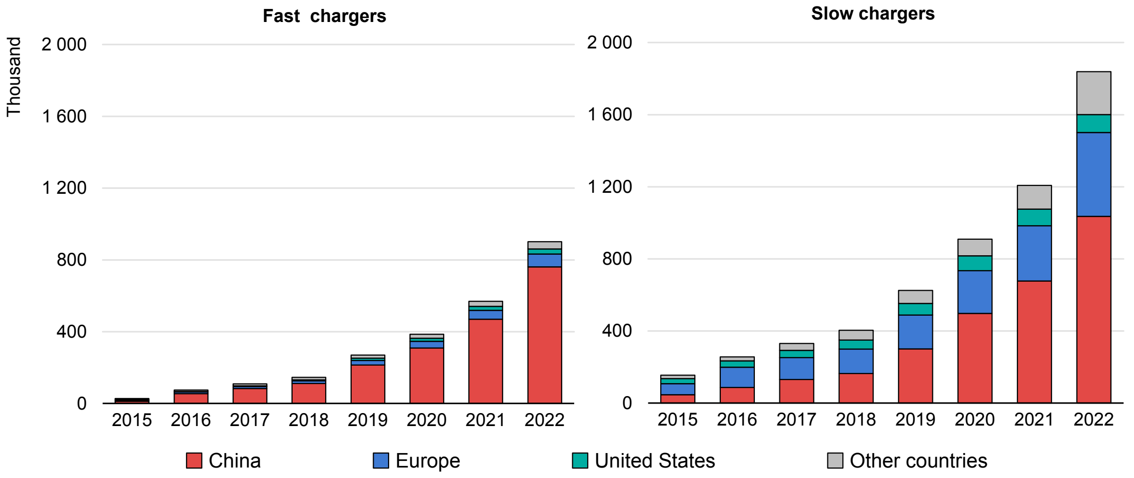
[11] Slow chargers have power ratings less than or equal to 22 kW. Fast chargers are those with a power rating of more than 22 kW and up to 350 kW. "Charging points" and "chargers" are used interchangeably and refer to the individual charging sockets, reflecting the number of EVs that can charge at the same time. ''Charging stations" may have multiple charging points.

in the United States increased by 9% in 2022, the lowest growth rate among major markets. In Korea, slow charging stock has doubled year-on-year, reaching 184 000 charging points.

## Fast chargers

Publicly accessible fast chargers, especially those located along motorways, enable longer journeys and can address range anxiety, a barrier to EV adoption. Like slow chargers, public fast chargers also provide charging solutions to consumers who do not have reliable access to private charging, thereby encouraging EV adoption across wider swaths of the population. The number of fast chargers increased by 330 000 globally in 2022, though again the majority (almost 90%) of the growth came from China. The deployment of fast charging compensates for the lack of access to home chargers in densely populated cities and supports China's goals for rapid EV deployment. China accounts for total of 760 000 fast chargers, but more than 70% of the total public fast charging pile stock is situated in just ten provinces.

**Figure 1.13 Installed publicly accessible light-duty vehicle charging points by power rating and region, 2015-2022**






Note: Values shown represent number of charging points.
Source: IEA analysis based on country submissions.

**Installed publicly accessible charging points have increased by around 55%, with accelerated deployment led by China and Europe.**

In Europe the overall fast charger stock numbered over 70 000 by the end of 2022, an increase of around 55% compared to 2021. The countries with the largest fast charger stock are Germany (over 12 000), France (9 700) and Norway (9 000). There is a clear ambition across the European Union to further develop the public charging infrastructure, as indicated by provisional agreement on the proposed

Alternative Fuels Infrastructure Regulation (AFIR), which will set electric charging coverage requirements across the trans-European network-transport (TEN-T).[12] An agreement between the European Investment Bank and the European Commission will make over EUR 1.5 billion available by the end of 2023 for alternative fuels infrastructure, including electric fast charging.

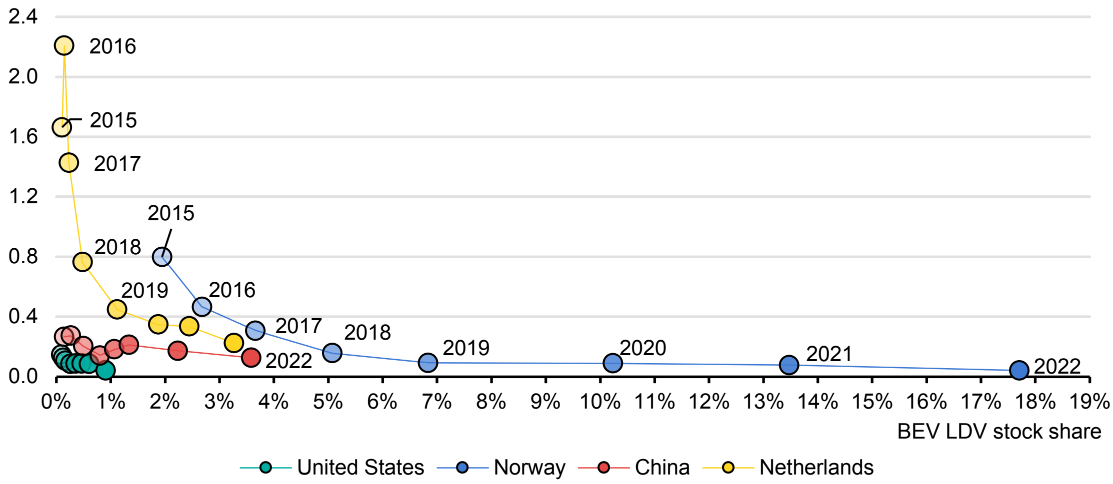
The United States installed 6 300 fast chargers in 2022, about three-quarters of which were Tesla Superchargers. The total stock of fast chargers reached 28 000 at the end of 2022. Deployment is expected to accelerate in the coming years following government approval of the National Electric Vehicle Infrastructure Formula Program (NEVI). All US states, Washington DC, and Puerto Rico are participating in the programme, and have already been allocated USD 885 million in funding for 2023 to support the build-out of chargers across 122 000 km of highway (see Policy support for EV charging infrastructure). The US Federal Highway Administration has announced new national standards for federally funded EV chargers to ensure consistency, reliability, accessibility and compatibility. As a result of the new standards, Tesla has announced it will open a portion of its US Supercharger (where Superchargers represent 60% of the total stock of fast chargers in the United States) and Destination Charger network to non-Tesla EVs.

## Ratio of electric LDVs per public charger

Deployment of public charging infrastructure in anticipation of growth in EV sales is critical for widespread EV adoption. In Norway, for example, there were around 1.3 battery electric LDVs per public charging point in 2011, which supported further adoption. At the end of 2022, with over 17% of LDVs being BEVs, there were 25 BEVs per public charging point in Norway. In general, as the stock share of battery electric LDVs increases, the charging point per BEV ratio decreases. Growth in EV sales can only be sustained if charging demand is met by accessible and affordable infrastructure, either through private charging in homes or at work, or publicly accessible charging stations.

[12] Previously a directive, the proposed AFIR, once formally approved, would become a binding legislative act, stipulating, among other things, a maximum distance between chargers installed along the TEN-T, the primary and secondary roads within the European Union.

**Figure 1.14 Public charging points per battery electric light-duty vehicle ratio in selected countries against battery electric light-duty vehicle stock share, 2015-2022**





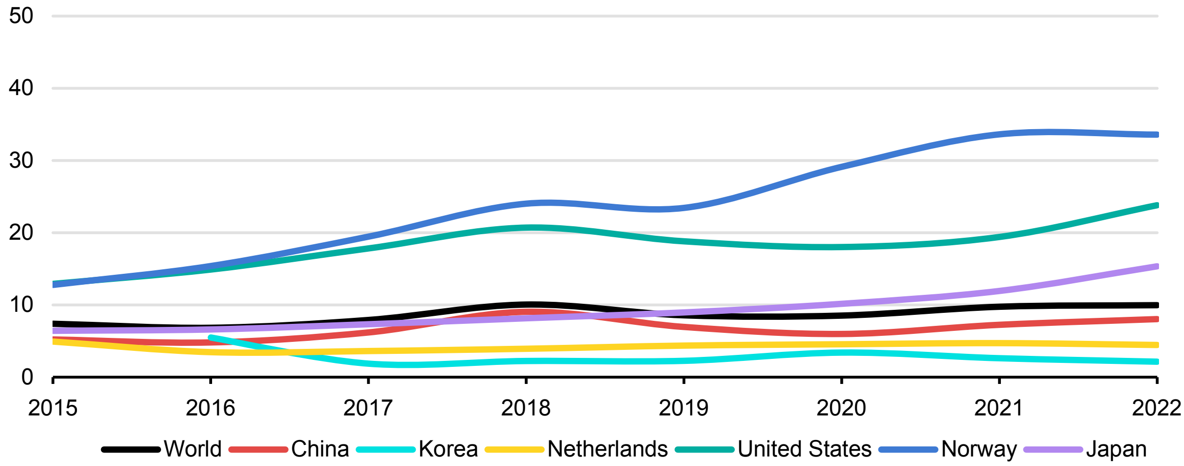

Notes: BEV = battery electric vehicle; LDV = light-duty vehicle. Charging points include only publicly available chargers, both fast and slow. Shading grows darker each year.
Source: IEA analysis based on country submissions.

**In many advanced markets, as the stock share of battery electric LDVs increased, the charging point per BEV ratio has decreased.**

While PHEVs are less reliant on public charging infrastructure than BEVs, policy-making relating to the sufficient availability of charging points should incorporate (and encourage) public PHEV charging. If the total number of electric LDVs per charging point is considered, the global average in 2022 was about ten EVs per charger. Countries such as China, Korea and the Netherlands have maintained fewer than ten EVs per charger throughout past years. In countries that rely heavily on public charging, the number of publicly accessible chargers has been expanding at a speed that largely matches EV deployment.

However, in some markets characterised by widespread availability of home charging (due to a high share of single-family homes with the opportunity to install a charger) the number of EVs per public charging point can be even higher. For example, in the United States, the ratio of EVs per charger is 24, and in Norway is more than 30. As the market penetration of EVs increases, public charging becomes increasingly important, even in these countries, to support EV adoption among drivers who do not have access to private home or workplace charging options. However, the optimal ratio of EVs per charger will differ based on local conditions and driver needs.

**Figure 1.15 Electric light-duty vehicle per public charging point, 2010-2022**





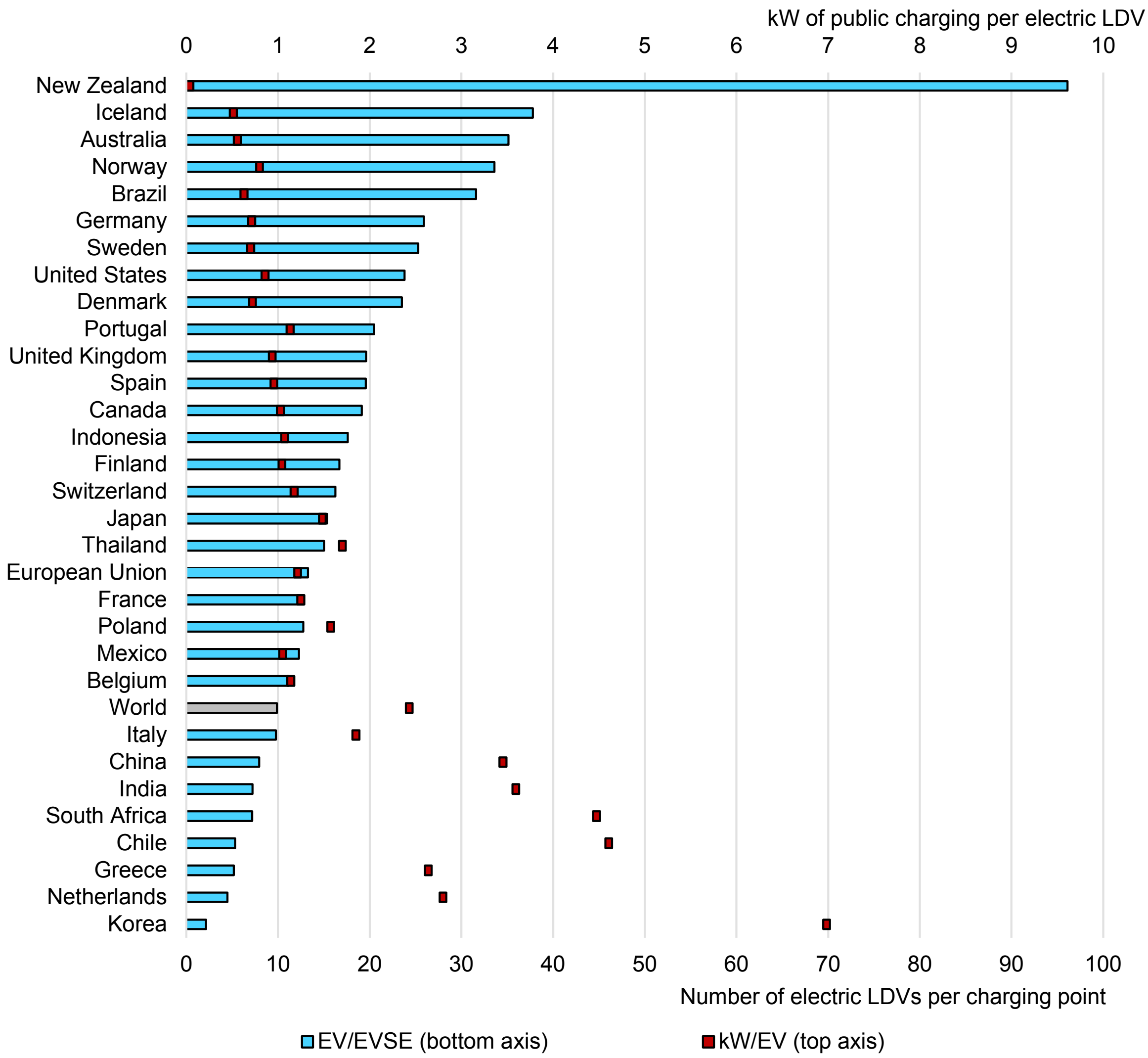

Note: Charging points include only publicly available chargers, both fast and slow.
Source: IEA analysis based on country submissions.

**Countries show different speeds in public charging deployment as the number of EVs on the road increases.**

Perhaps more important than the number of public chargers available is the total public charging power capacity per EV, given that fast chargers can serve more EVs than slow chargers. During the early stages of EV adoption, it makes sense for available charging power per EV to be high, assuming that charger utilisation will be relatively low until the market matures and the utilisation of infrastructure becomes more efficient. In line with this, the European Union's provisional agreement on the AFIR includes requirements for the total power capacity to be provided based on the size of the registered fleet.

Globally, the average public charging power capacity per electric LDV is around 2.4 kW per EV. In the European Union, the ratio is lower, with an average around 1.2 kW per EV. Korea has the highest ratio at 7 kW per EV, even with most public chargers (90%) being slow chargers.

**Figure 1.16 Number of electric light-duty vehicles per public charging point and kW per electric light-duty vehicle, 2022**






Notes: EV = electric vehicle; EVSE = electric vehicle supply equipment; LDV = light-duty vehicle. Kilowatts per EV are estimated assuming 11 kW for slow and 50 kW for fast chargers. Official national metrics might differ from these values as they can rely on more granular data.
Source: IEA analysis based on country submissions.

**The number of electric light-duty vehicles per public EV charging point varies dramatically between countries, ranging from about 2 vehicles per charging point in Korea to almost 100 in New Zealand.**

## Charging needs for heavy-duty vehicles

In the regions where electric trucks are becoming commercially available, battery electric trucks can compete on a TCO basis with conventional diesel trucks for a growing range of operations, not only urban and regional, but also in the heavy-duty tractor-trailer regional and long-haul segments. Three parameters that determine the time at which TCO parity is reached are tolls; fuel and operations costs (e.g. the difference between diesel and electricity prices faced by truck operators, and reduced maintenance costs); and CAPEX subsidies to reduce the gap in the upfront vehicle purchase price. Since electric trucks can provide the same operations with lower lifetime costs (including if a discounted rate is applied), the time horizon in which vehicle owners expect to recuperate upfront costs is a key factor in determining whether to purchase an electric or conventional truck.

The economics for electric trucks in long-distance applications can be substantially improved if charging costs can be reduced by maximising "off-shift" (e.g. night-time or other longer periods of downtime) slow charging, securing bulk purchase contracts with grid operators for "mid-shift" (e.g. during breaks), fast (up to 350 kW), or ultra-fast (>350 kW) charging, and exploring smart charging and vehicle-to-grid opportunities for extra income.

Electric trucks and buses will rely on off-shift charging for the majority of their energy. This will be largely achieved at private or semi-private charging depots or at public stations on highways, and often overnight. Depots to service growing demand for heavy-duty electrification will need to be developed, and in many cases may require distribution and transmission grid upgrades. Depending on vehicle range requirements, depot charging will be sufficient to cover most operations in urban bus as well as urban and regional truck operations.

The major constraint to rapid commercial adoption of electric trucks in regional and long-haul operations is the availability of "mid-shift" fast charging. Although the majority of energy requirements for these operations could come from "off-shift" charging, fast and ultra-fast charging will be needed to extend range such that operations currently covered by diesel can be performed by battery electric trucks with little to no additional dwell time (i.e. waiting). Regulations that mandate rest periods can also provide a time window for mid-shift charging if fast or ultra-fast charging options are available en route: the European Union requires 45 minutes of break after every 4.5 hours of driving; the United States mandates 30 minutes after 8 hours.

Most commercially available direct current (DC) fast charging stations currently enable power levels ranging from 250-350 kW. The European Union's Alternative Fuels Infrastructure Regulation (AFIR) aims to enable mid-shift charging across the EU's core TEN-T network, which covers 88% of total long-haul freight activity, and along other key freight corridors. The provisional agreement reached by the European Council and Parliament includes a gradual process of infrastructure deployment for electric heavy-duty vehicles starting in 2025. Recent studies of power requirements for regional and long-haul truck operations in the United States and Europe find that charging power higher than 350 kW, and as high as 1 MW, may be required to fully recharge electric trucks during a 30- to 45-minute break.

Recognising the need to scale up fast or ultra-fast charging as a prerequisite for making both regional and, in particular, long-haul operations technically and economically viable, in 2022 Traton, Volvo, and Daimler established an independent joint venture, Milence. With EUR 500 million in collective investments from the three heavy-duty manufacturing groups, the initiative aims to deploy more than 1 700 fast (300 to 350 kW) and ultra-fast (1 MW) charging points across Europe.

Multiple charging standards are currently in use, and technical specifications for ultra-fast charging are under development. Ensuring maximum possible convergence of charging standards and interoperability for heavy-duty EVs will be needed to avoid the cost, inefficiency, and challenges for vehicle importers and international operators that would be created by manufacturers following divergent paths.

In China, co-developers China Electricity Council and CHAdeMO's "ultra ChaoJi" are developing a charging standard for heavy-duty electric vehicles for up to several megawatts. In Europe and the United States, specifications for the CharIN Megawatt Charging System (MCS), with a potential maximum power of 4.5 MW, are under development by the International Organization for Standardization (ISO) and other organisations. The final MCS specifications, which will be needed for commercial roll-out, are expected for 2024. After the first megawatt charging site offered by Daimler Trucks and Portland General Electric (PGE) in 2021, at least twelve high-power charging projects are planned or underway in the United States and Europe, including charging of an electric Scania truck in Oslo, Norway, at a speed of over 1 MW, Germany's HoLa project, and the Netherlands Living Lab Heavy-Duty and Green Transport Delta Charging Stations, as well as investments and projects in Austria, Sweden, Spain and the United Kingdom.

Commercialisation of chargers with rated power of 1 MW will require significant investment, as stations with such high-power needs will incur significant costs in both installation and grid upgrades. Revising public electric utility business models and power sector regulations, co-ordinating planning across stakeholders and smart charging can all help to manage grid impacts. Direct support through pilot projects and financial incentives can also accelerate demonstration and adoption in the early stages. A recent study outlines some key design considerations for developing MCS rated charging stations:

- Planning charging stations at highway depot locations near transmission lines and substations can be an optimal solution for minimising costs and increasing charger utilisation.
- "Right-sizing" connections with direct connections to transmission lines at an early stage, thereby anticipating the energy needs of a system in which high shares of freight activity have been electrified, rather than upgrading distribution grids on an

ad-hoc and short-term basis, will be critical to reduce costs. This will require structured and co-ordinated planning between grid operators and charging infrastructure developers across sectors.

- Since transmission system interconnections and grid upgrades can take 4-8 years, siting and construction of high-priority charging stations will need to begin as soon as possible.

Alternative solutions include installing stationary storage and integrating local renewable capacity, combined with smart charging, which can help reduce both infrastructure costs related to grid connection and electricity procurement costs (e.g. by enabling truck operators to minimise cost by arbitraging price variability throughout the day, taking advantage of vehicle-to-grid opportunities, etc.).

Other options to provide power to electric heavy-duty vehicles (HDVs) are battery swapping and electric road systems. Electric road systems can transfer power to a truck either via inductive coils[13] in a road, or through conductive connections between the vehicle and road, or via catenary (overhead) lines. Catenary and other dynamic charging options may hold promise for reducing the uncertainty of system-level costs in the transition to zero-emission regional and long-haul trucks, competing favourably in terms of total capital and operating costs. They can also help to reduce battery capacity needs. Battery demand can be further reduced, and utilisation further improved, if electric road systems are designed to be compatible not only with trucks but also electric cars. However, such approaches would require inductive or in-road designs that come with greater hurdles in terms of technology development and design, and are more capital intensive. At the same time, electric road systems pose significant challenges resembling those of the rail sector, including a greater need for standardisation of paths and vehicles (as illustrated with trams and trolley buses), compatibility across borders for long-haul trips, and appropriate infrastructure ownership models. They provide less flexibility for truck owners in terms of routes and vehicle types, and have high development costs overall, all affecting their competitiveness relative to regular charging stations. Given these challenges, such systems would most effectively be deployed first on heavily used freight corridors, which would entail close co-ordination across various public and private stakeholders. Demonstrations on public roads to date in Germany and Sweden have relied on champions from both private and public entities. Calls for electric road system pilots are also being considered in the China, India, the United Kingdom and the United States.

[13] Inductive solutions are further from commercialisation and face challenges to deliver sufficient power at highway speeds.

## Recent developments in battery swapping

Battery swapping entails switching a drained vehicle battery with a fully charged battery at a swapping station. In general, battery swap-enabled vehicles can also be charged via conventional plug-in charging infrastructure.

Battery swapping offers advantages in terms of purchase price parity with ICE vehicles and recharging times. In particular, offering the battery as a service – for example based on a monthly subscription fee – reduces upfront investment for vehicle owners. In addition, drivers can choose a right-sized battery for daily commuting and then upgrade to a larger battery ahead of a long journey.

Battery swapping also has the potential to improve battery management (e.g. to extend battery lifetime through controlled charging), co-ordinate charging to reduce the impact on the grid, increase utilisation of renewable electricity, and even provide grid services that can generate revenue. Specifically, battery swapping stations can leverage the aggregation of batteries in order to provide grid services. In traditional cases in which battery ownership and utilisation remain at individual vehicle level, more extensive communication and control measures are required to allow for the provision of grid services.

However, battery swapping presents some disadvantages compared to conventional charging. Firstly, more than one battery is required per vehicle to ensure sufficient availability at swap stations, with some companies currently averaging about two batteries per vehicle. This could affect critical material demand and the associated environmental impacts, though given that battery capacity per vehicle may decrease, the net impact is uncertain. Furthermore, the capital investment required for a battery swap station can be high, given the cost of the spare batteries in addition to the infrastructure cost. Additional costs may also be incurred if batteries are damaged during the swapping process. Estimates for the costs for a single battery swap station range from USD 390 000 to USD 1.4 million, including the structure, land requirement, labour, maintenance, electricity and stored batteries. From a customer perspective, the lower resale value of an electric vehicle that does not include a battery may be a deterrent. Finally, battery swapping either requires a degree of standardisation (see Policy incentives for battery swapping in China and India), or for battery swap stations to be tailored to certain vehicle makes or models. The success of battery swapping will likely depend on regional conditions, such as supportive policies and standards, vehicle market structure, and vehicle applications.

Various battery swapping business models, including battery leasing and BaaS business models, are particularly interesting for commercial vehicles. Battery swapping is seeing growing adoption within the LDV sector, including two/three-wheelers, used for delivery or ride-hailing services. In particular, battery swapping for two/three-wheelers is growing in Asian markets. The deployment of battery swapping for trucks, however, is thus far limited to China, where the market is growing. China introduced buses with swappable batteries for the 2008 Beijing Olympics, but the technology has not developed as much as for other vehicle segments. However, a number of projects in India focus on battery swapping for electric buses, especially for intercity operations. Ashok Leyland (now Switch Mobility), one of India's largest commercial vehicle manufacturers, set up the first electric bus battery-swapping station in 2019.

## Two/three-wheelers

International Council on Clean Transportation (ICCT) analysis suggests that battery swapping for electric two-wheelers in taxi services (e.g. bike taxis) offers the most competitive TCO compared to point charging BEV or ICE two-wheelers. In the case of last-mile delivery via a two-wheeler, point charging currently has a TCO advantage over battery swapping, but with the right policy incentives and scale, swapping could become a viable option under certain conditions. In general, as the average daily distance travelled increases, the battery electric two-wheeler with battery swapping becomes more economical than point charging or gasoline vehicles. In 2021, the Swappable Batteries Motorcycle Consortium was founded with the aim to facilitate battery swapping of light-weight vehicles, including two/three-wheelers, by working together on common battery specifications.

Battery swapping of electric two/three-wheelers is particularly gaining momentum in India. There are currently over ten different companies in the Indian market, including Gogoro, a Chinese Taipei-based electric scooter and battery swapping technology leader. Gogoro claims its batteries power 90% of electric scooters in Chinese Taipei, and the Gogoro network has more than 12 000 battery swapping stations to support over 500 000 electric two-wheelers across nine countries, mostly in the Asia Pacific region. Gogoro has now formed a partnership with India-based Zypp Electric, which runs an EV-as-a-service platform for last-mile deliveries; together, they are deploying 6 battery swapping stations and 100 electric two-wheelers as part of a pilot project for business-to-business last-mile delivery operations in the city of Delhi. At the beginning of 2023, they raised USD 25 million, which they will use to expand their fleet to 200 000 electric two-wheelers across 30 Indian cities by 2025. Sun Mobility has a longer history of battery swapping in India, with over 210 swapping stations across the country for electric two- and three-wheelers, including e-rickshaws, with partners such as Amazon India. Thailand is also seeing corporate interest in battery swapping services for motorcycle taxi and delivery drivers.

While most prevalent in Asia, battery swapping for electric two-wheelers is also spreading to Africa. For example, Rwandan electric motorbike start-up Ampersand operates battery swap stations, with a focus on serving motorcycle taxi operations that require long daily ranges. Ampersand has built ten battery swap stations in Kigali and three in Nairobi, Kenya. These stations perform close to 37 000 battery swaps a month.

## Trucks

For trucks in particular, battery swapping can have major advantages over ultra-fast charging. Firstly, swapping can take as little as 3-5 minutes, which would be difficult and expensive to achieve through cable-based charging, requiring an ultra-fast charger connected to medium- to high-voltage grids and expensive battery management systems and battery chemistries. Avoiding ultra-fast charging can also extend battery capacity, performance and cycle life.

Battery-as-a-service (BaaS), separating the purchase of the truck and the battery, and establishing a lease contract for the battery, substantially reduces the upfront purchase cost (by as much as 50%). In addition, since trucks tend to depend on lithium iron phosphate (LFP) battery chemistries, which are more durable than lithium nickel manganese cobalt oxide (NMC) batteries, they are well-suited for swapping in terms of safety and affordability.

However, the cost of building a station will likely be higher for truck battery swapping given the larger vehicle size and heavier batteries, which require more space and specialised equipment to perform the swap. Another major barrier is the requirement that batteries be standardised to a given size and capacity, which truck OEMs are likely to perceive as a challenge to competitiveness as battery design and capacity is a key differentiator among electric truck manufacturers.

China is at the forefront of battery swapping for trucks due to significant policy support and use of technology designed to complement cable charging. In 2021, China’s MIIT announced that a number of cities would pilot battery swapping technology, including HDV battery swapping in three cities. Almost all major Chinese heavy truck manufacturers, including FAW, CAMC, Dongfeng, Jiangling Motors Corporation Limited (JMC), Shanxi Automobile, and SAIC, have now launched a battery swapping-enabled model of their battery electric trucks. In 2022 alone, more than 12 000 battery swapping-enabled electric trucks were sold in China.

## Cars

China is also the leader in battery swapping for passenger cars. Across all modes, the total number of battery swapping stations in China stood at almost 2 000 at the end of 2022, 50% higher than at the end of 2021. NIO, which produces battery swapping-enabled cars and the supporting swapping stations, runs more than 1 300 battery swapping stations in China, reporting that the network covers more than two-thirds of mainland China. Half of their swapping stations were installed in 2022, and the company has set a target of 4 000 battery swap stations globally by 2025. The company claims their swap stations can perform over 300 swaps per day, charging up to 13 batteries concurrently at a power of 20-80 kW.

NIO also announced plans to build battery swap stations in Europe as their battery swapping-enabled car models became available in European markets towards the end of 2022. The first NIO battery swap station in Sweden was opened in November 2022, and by the end of 2022, ten NIO battery swap stations had been opened across Norway, Germany, Sweden and the Netherlands. In contrast to NIO, whose swapping stations service NIO cars, the Chinese battery swapping station operator Aulton's stations support 30 models from 16 different vehicle companies.

Battery swapping could also be a particularly attractive option for LDV taxi fleets, whose operations are more sensitive to recharging times than personal cars. US start-up Ample currently operates 12 battery swapping stations in the San Francisco Bay area, mainly serving Uber rideshare vehicles.

# Batteries

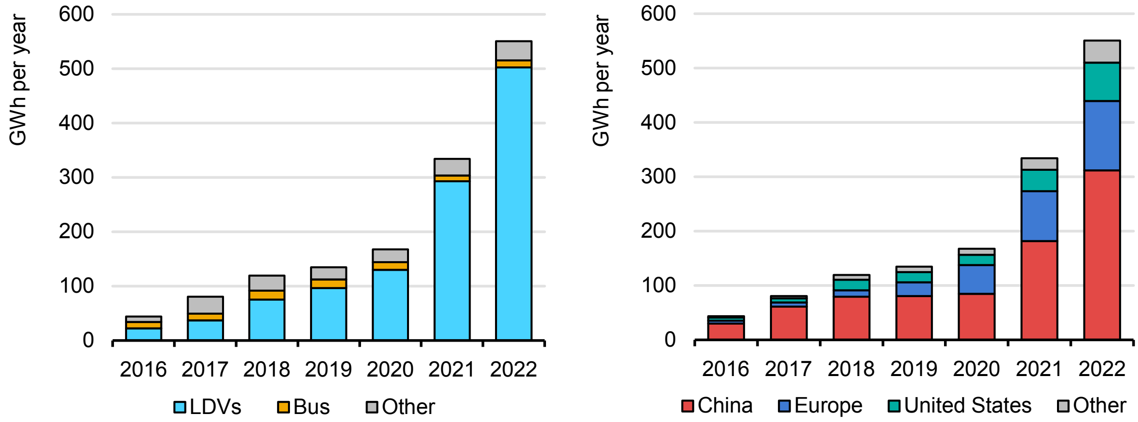
## Battery demand for EVs continues to rise

Automotive lithium-ion (Li-ion) battery demand increased by about 65% to 550 GWh in 2022, from about 330 GWh in 2021, primarily as a result of growth in electric passenger car sales, with new registrations increasing by 55% in 2022 relative to 2021.

In China, battery demand for vehicles grew over 70%, while electric car sales increased by 80% in 2022 relative to 2021, with growth in battery demand slightly tempered by an increasing share of PHEVs. Battery demand for vehicles in the United States grew by around 80%, despite electric car sales only increasing by around 55% in 2022. While the average battery size for battery electric cars in the United States only grew by about 7% in 2022, the average battery electric car battery size remains about 40% higher than the global average, due in part to the higher share of SUVs in US electric car sales relative to other major markets,[14] as well as manufacturers' strategies to offer longer all-electric driving ranges. Global sales of BEV and PHEV cars are outpacing sales of hybrid electric vehicles (HEVs), and as BEV and PHEV battery sizes are larger, battery demand further increases as a result.

[14] For more information on the climate impact of SUVs, refer to the IEA's 27 February 2023 commentary on the subject.

**Figure 1.17 Battery demand by mode and region, 2016-2022**





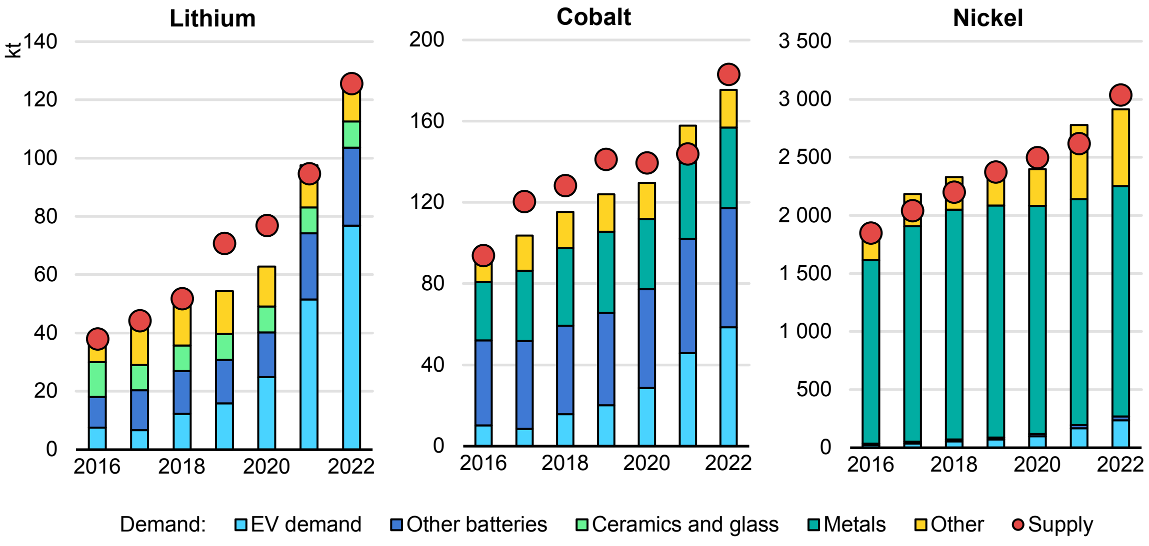

Notes: LDVs = light-duty vehicles, including cars and vans; In the left chart, "Other" includes medium- and heavy-duty trucks and two/three-wheelers. Battery demand refers to automotive lithium-ion batteries. This analysis does not include conventional hybrid vehicles.
Source: IEA analysis based on EV Volumes.

**Global battery demand increased by 65% in 2022, mainly as a result of electric car sales in China.**

The increase in battery demand drives the demand for critical materials. In 2022, lithium demand exceeded supply (as in 2021) despite the 180% increase in production since 2017. In 2022, about 60% of lithium, 30% of cobalt and 10% of nickel demand was for EV batteries. Just five years earlier, in 2017, these shares were around 15%, 10% and 2%, respectively. As has already been seen for lithium, mining and processing of these critical minerals will need to increase rapidly to support the energy transition, not only for EVs but more broadly to keep up with the pace of demand for clean energy technologies.[15] Reducing the need for critical materials will also be important for supply chain sustainability, resilience and security. Accelerating innovation can help, such as through advanced battery technologies requiring smaller quantities of critical minerals, as well as measures to support uptake of vehicle models with optimised battery size and the development of battery recycling.

[15] For more information on the future of supply and demand of critical minerals, refer to the Energy Technology Perspective 2023 report.

**Figure 1.18 Overall supply and demand of battery metals by sector, 2016-2022**






Note: EV = electric vehicle. The metals category includes alloying applications. Supply refers to refinery output and not mining output.
Source: IEA analysis based on Mineral Commodity Summary 2022 by USGS, lithium and cobalt global supply-demand balance (January 2023) and nickel global supply-demand balance (January 2023) from S&P Global and World Metal Statistics Yearbook by the World Bureau of Metal Statistics.

**In 2022, supply of nickel and cobalt exceeded demand, while lithium demand outpaced supply by a small margin.**

# Battery chemistries are diversifying

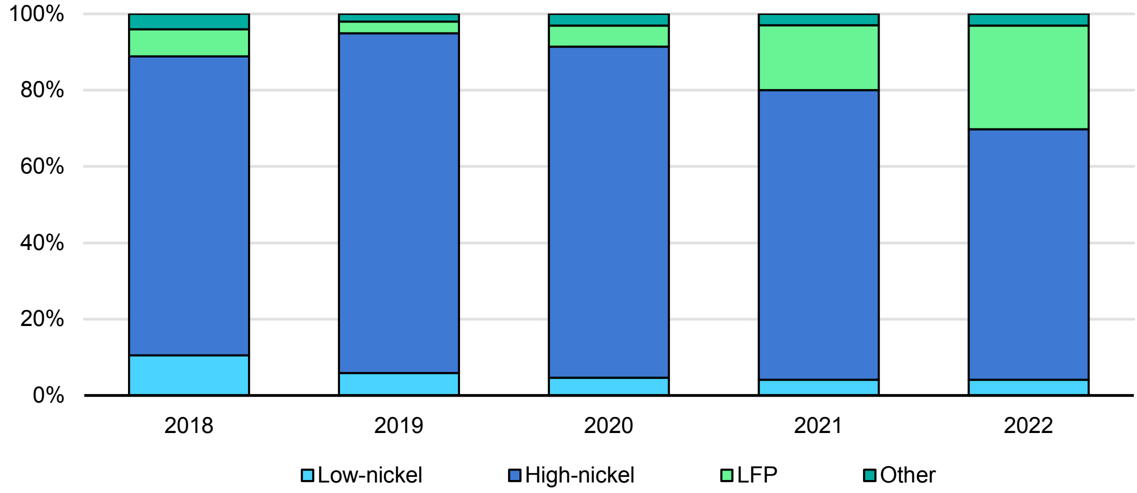
## New alternatives to conventional lithium-ion are on the rise

In 2022, lithium nickel manganese cobalt oxide (NMC) remained the dominant battery chemistry with a market share of 60%, followed by lithium iron phosphate (LFP) with a share of just under 30%, and nickel cobalt aluminium oxide (NCA) with a share of about 8%.

Lithium iron phosphate (LFP) cathode chemistries have reached their highest share in the past decade (Figure 1.19). This trend is driven mainly by the preferences of Chinese OEMs. Around 95% of the LFP batteries for electric LDVs went into vehicles produced in China, and BYD alone represents 50% of demand. Tesla accounted for 15%, and the share of LFP batteries used by Tesla increased from 20% in 2021 to 30% in 2022. Around 85% of the cars with LFP batteries manufactured by Tesla were manufactured in China, with the remainder being manufactured in the United States with cells imported from China. In total, only around 3% of electric cars with LFP batteries were manufactured in the United States in 2022.

LFP batteries contrast with other chemistries in their use of iron and phosphorus rather than the nickel, manganese and cobalt found in NCA and NMC batteries. The downside of LFP is that the energy density tends to be lower than that of NMC. LFP batteries also contain phosphorus, which is used in food production. If all batteries today were LFP, they would account for nearly 1% of current agricultural phosphorus use by mass, suggesting that conflicting demands for phosphorus may arise in the future as battery demand increases.

**Figure 1.19 Electric light-duty vehicle battery capacity by chemistry, 2018-2022**



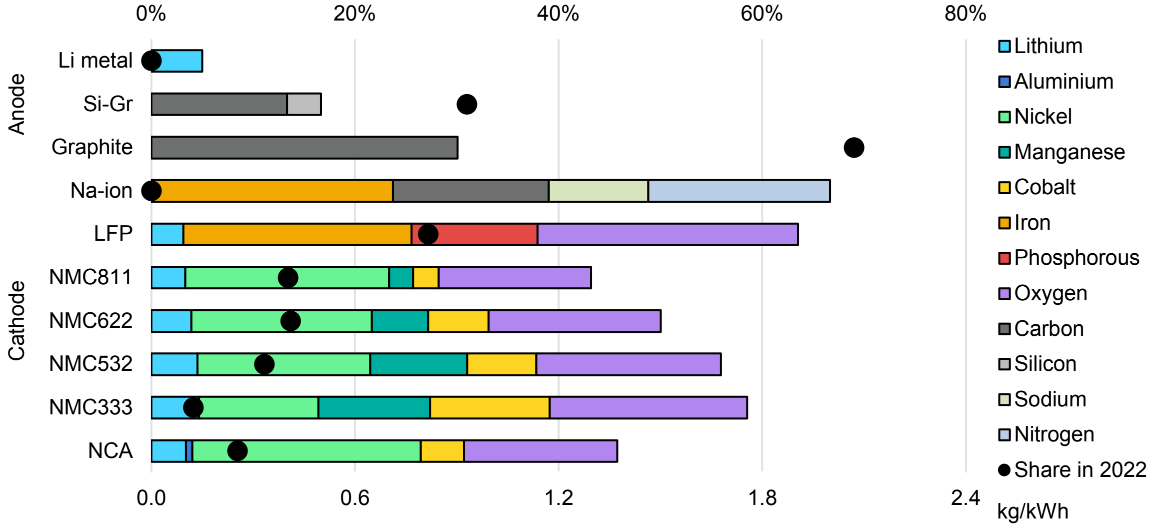



Notes: LFP = Lithium iron phosphate. Low-nickel includes: NMC333. High-nickel includes: NMC532, NMC622, NMC721, NMC811, NCA and NMCA. Cathode sales share is based on battery capacity.
Source: IEA analysis based on EV Volumes.

**The share of lithium iron phosphate reached its highest ever point, accounting for almost 30% of new electric LDV battery capacity in 2022.**

With regards to anodes, a number of chemistry changes have the potential to improve energy density (watt-hour per kilogram, or Wh/kg). For example, silicon can be used to replace all or some of the graphite in the anode in order to make it lighter and thus increase the energy density. Silicon-doped graphite already entered the market a few years ago, and now around 30% of anodes contain silicon. Another option is innovative lithium metal anodes, which could yield even greater energy density when they become commercially available (Figure 1.20).

**Figure 1.20 Material content in different anode and cathodes**






Notes: Li metal = Lithium metal anode; Si-Gr = Silicon-graphite anode; Graphite = Pure graphite anode; Na-ion = Sodium-ion; LFP = Lithium iron phosphate; NMC = Lithium nickel manganese cobalt oxide; NCA = Lithium nickel cobalt aluminium oxide. Materials composing the battery casing and the electrolyte are excluded. Chemistry shares are based on demand. The share of NCA battery includes every NCA type and Si-Gr includes every degree of silicon-graphite mix. Carbon covers the graphite composing anodes. The Na-ion cathode shown is the Prussian white.

Source: IEA analysis based on Lithium-Ion Batteries: State of the Industry 2022 by BNEF, BatPaC v4 by Argonne Laboratory and Sodium-ion batteries: disrupt and conquer? by Wood Mackenzie.

**Lithium iron phosphate cathodes do not rely on nickel, manganese or cobalt, which has contributed to their increased market share.**

In recent years, alternatives to Li-ion batteries have been emerging, notably sodium-ion (Na-ion). This battery chemistry has the dual advantage of relying on lower cost materials than Li-ion, leading to cheaper batteries, and of completely avoiding the need for critical minerals. It is currently the only viable chemistry that does not contain lithium. The Na-ion battery developed by China's CATL is estimated to cost 30% less than an LFP battery. Conversely, Na-ion batteries do not have the same energy density as their Li-ion counterpart (respectively 75 to 160 Wh/kg compared to 120 to 260 Wh/kg). This could make Na-ion relevant for urban vehicles with lower range, or for stationary storage, but could be more challenging to deploy in locations where consumers prioritise maximum range autonomy, or where charging is less accessible. There are nearly 30 Na-ion battery manufacturing plants currently operating, planned or under construction, for a combined capacity of over 100 GWh, almost all in China. For comparison, the current manufacturing capacity of Li-ion batteries is around 1 500 GWh.

Multiple carmakers have already announced Na-ion electric cars, such as the Seagull by BYD, which has an announced range of 300 km and is sold for USD 11 600 (with possible discounts bringing the price down to USD 9 500), and the Sehol EX10, produced by the VW-JAC joint venture, with a 250 km range.

While these first models are likely to be slightly more expensive than the cheapest small BEV models in China – such as the Wuling Mini BEV, sold for as little as USD 5 000 to 6 500 – they are still cheaper than equivalent options with similar driving range. To compare, the Wuling Mini BEV's range stands at 170 km, but BYD's Dolphin BEV, the second best-selling small BEV in China in 2022, with a similar range to the announced Na-ion cars, can cost more than USD 15 000. BYD plans to progressively integrate Na-ion batteries into all its models below USD 29 000 as battery production ramps up. These announcements suggest that electric vehicles powered by Na-ion will be available for sale and driven for the first time in 2023-2024, hence bringing the technology to a readiness level (TRL[16]) of 8-9, between first-of-a-kind commercial and commercial operation in the relevant environment. In 2022, it was assessed at TRL 6 (full prototype at scale) in the IEA Clean Technology Guide, compared to only TRL 3-4 (small prototypes) in the assessment from 2021, highlighting quick technological progress.

## Critical mineral prices can have an impact on chemistry choice

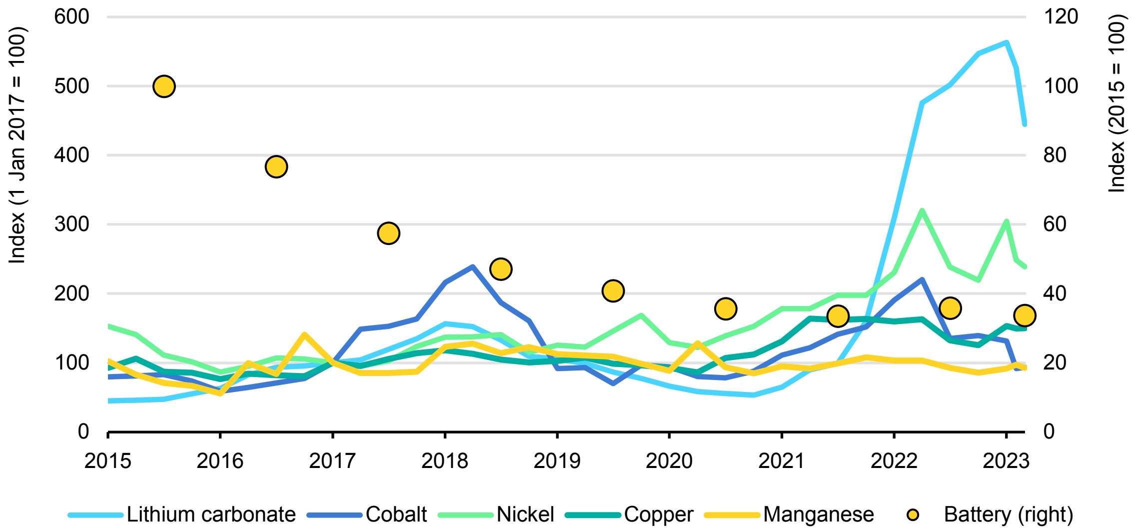
The variability in price and availability of critical minerals can also explain some of the developments in battery chemistry from the last few years (Figure 1.21). NMC chemistries using an equal ratio of nickel, manganese, and cobalt (NMC333 or NMC111) were popular until 2015. Since then, cobalt price increases and concerns affecting public acceptance of cobalt mining have contributed to a shift towards lower-cobalt ratios, such as NMC622, and then NMC811, which are nevertheless more difficult to manufacture. In 2022, the price of nickel increased, reaching a peak twice as high as the 2015-2020 average. This created incentives to use chemistries that are less reliant on nickel, such as LFP, despite their lower energy density.

Lithium carbonate prices have also been steadily increasing over the past two years. In 2021, prices multiplied four- to five-fold, and continued to rise throughout 2022, nearly doubling between 1 January 2022 and 1 January 2023. At the beginning of 2023, lithium prices stood six times above their average over the 2015-2020 period. In contrast to nickel and lithium, manganese prices have been relatively stable. One reason for the increase in prices for lithium, nickel and cobalt was the insufficient supply compared to demand in 2021 (Figure 1.18). Although nickel and cobalt supply surpassed demand in 2022, this was not the case for lithium, causing its price to rise more strongly over the year. Between January and March 2023, lithium prices dropped 20%, returning to their late 2022 level. The combination of an expected 40% increase in supply and slower growth in demand, especially for EVs in China, has contributed to this trend. This drop – if sustained – could translate into lower battery prices.

[16] Technology Readiness Level (TRL) provides a snapshot of the maturity of a given technology. It has 11 steps ranging from initial idea at step 1 to proof of stability reached at step 11. For more information, refer to the IEA Clean Technology Guide.

Beyond those materials, global commodity prices have surged in the last few years, as a result of supply disruptions in the wake of the Covid-19 pandemic, rising demand as the global economy started to recover, and Russia's invasion of Ukraine in February 2022, among other factors.

**Figure 1.21 Price of selected battery materials and lithium-ion batteries, 2015-2023**






Notes: Data until March 2023. Lithium-ion battery prices (including the pack and cell) represent the global volume-weighted average across all sectors. Nickel prices are based on the London Metal Exchange, used here as a proxy for global pricing, although most nickel trade takes place through direct contracts between producers and consumers. The 2023 battery price value is based on cost estimates for NMC 622.

Source: IEA analysis based on material price data by S&P, 2022 Lithium-Ion Battery Price Survey by BNEF and Battery Costs Drop as Lithium Prices in China Fall by BNEF.

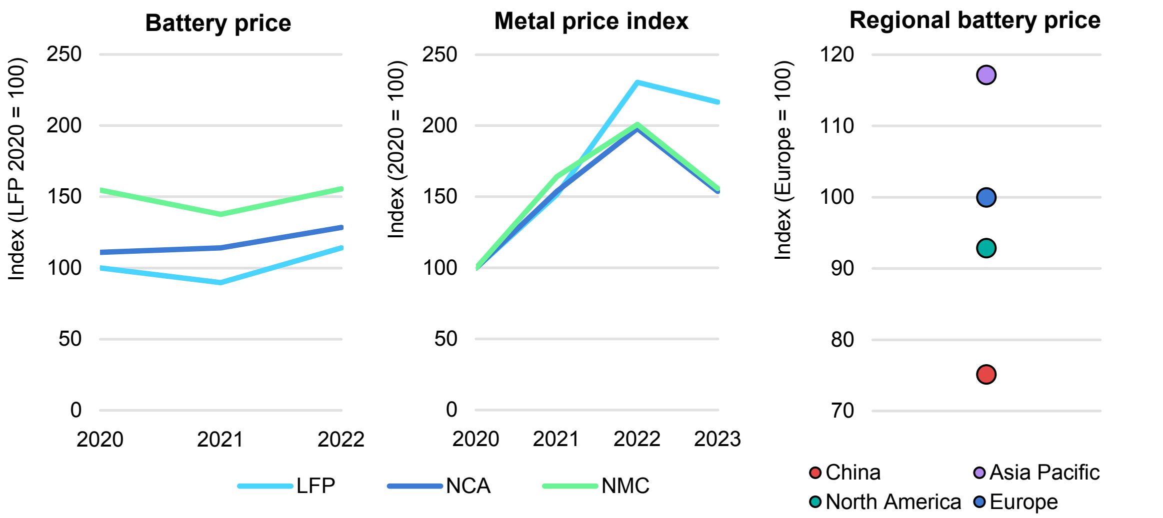
**From 2021 to the end of 2022, the price of critical materials such as lithium, cobalt and nickel increased dramatically, putting pressure on historical Li-ion battery price decreases.**

In 2022, the estimated average battery price stood at about USD 150 per kWh, with the cost of pack manufacturing accounting for about 20% of total battery cost, compared to more than 30% a decade earlier. Pack production costs have continued to decrease over time, down 5% in 2022 compared to the previous year. In contrast, cell production costs increased in 2022 relative to 2021, returning to 2019 levels. This can be explained in part by the increasing prices of materials, which account for a significant portion of cell price, and of electricity, which affects manufacturing costs, whereas efficiency gains in pack manufacturing help decrease costs. Bloomberg New Energy Finance (BNEF) sees pack manufacturing costs dropping further, by about 20% by 2025, whereas cell production costs decrease by only 10% relative to their historic low in 2021. This warrants further analysis based on future trends in material prices.

The effect of increased battery material prices differed across various battery chemistries in 2022, with the strongest increase being observed for LFP batteries (over 25%), while NMC batteries experienced an increase of less than 15% (Figure 1.21). Since LFP batteries contain neither nickel nor cobalt, which are relatively expensive compared to iron and phosphorus, the price of lithium plays a relatively larger role in determining the final cost. Given that the price of lithium increased at a higher rate than the price of nickel and cobalt, the price of LFP batteries increased more than the price of NMC batteries. Nonetheless, LFP batteries remain less expensive than NCA and NMC per unit of energy capacity.

The price of batteries also varies across different regions, with China having the lowest prices on average, and the rest of the Asia Pacific region having the highest (Figure 1.21). This price discrepancy is influenced by the fact that around 65% of battery cells and almost 80% of cathodes are manufactured in China.

**Figure 1.22 Price index for selected battery chemistries, regions and metal price, 2020-2023**






Note: LFP = Lithium iron phosphate; NMC = Lithium nickel manganese cobalt oxide; NCA = Lithium nickel cobalt aluminium oxide. The metal price index is based on the price evolution of four commodities (lithium carbonate, cobalt, nickel and copper) weighted by their use in each battery chemistry. For this metal price index, NMC uses the NMC622 chemistry. The 2023 value of the metal price index covers only the first 3 months of the year. Asia Pacific excludes China. Regional battery (pack) price refers to 2022.

Source: IEA analysis based on material price data by S&P, 2022 Lithium-Ion Battery Price Survey by BNEF, BatPaC v4 by Argonne Laboratory and Lithium-Ion Batteries: State of the Industry 2022 by BNEF.

**Despite a higher relative increase in price compared to other battery chemistries, LFP batteries remain the lowest price per kWh.**

# Policy developments and corporate strategy

## Overview

Global electric vehicle (EV) markets today differ widely, shaped by different levels of policy support, corporate activity, consumer preference and awareness, driving patterns and cultural specificities. The role of policy has been particularly significant in steering corporate strategy towards electrification and enabling consumer uptake.

In today's major EV markets – including China, Europe and the United States – early adoption was jump-started in many cases by policies to spur demand, such as vehicle purchase incentives. Direct incentives for carmakers were also used in China. Many of these countries and regions are now seeing EV markets maturing, especially for cars, for which sales shares are increasing rapidly. More developed markets such as China and several European countries are now progressively decreasing or phasing out incentive schemes for electric cars and shifting focus towards other segments such as heavy transport and charging.

At the same time, some governments in major markets have increased their targets for EV adoption further and are working to address other parts of EV supply chains, such as through policy support for vehicle and battery manufacturing and critical mineral supply chains. Many other countries outside the major markets have also started to introduce policy to support EV adoption in recent years, for the first time in some cases. Overall, global spending by governments and consumers on electric cars has significantly increased in the past few years, exceeding USD 400 billion in 2022.

For companies, policy requirements were an important driver for electrification in the early years of EV adoption. With the exponential growth of electric car sales, however, it has become increasingly important for major incumbent carmakers to offer EVs as a key part of their portfolios in order to capture market share and maintain a competitive edge. Competition is increasing, with a growing number of new entrants, particularly from China but also from other emerging market and developing economies (EMDEs), pushing the entire industry to accelerate decarbonisation. Overall, corporate strategy among major carmakers is shifting, and – as in recent years – 2022-2023 saw a series of important EV announcements: fully electric fleets, cheaper cars, more investments, and integration with battery making and critical minerals.

This section of the Outlook provides information on selected policy developments announced between April 2022 and March 2023, since the last edition of the IEA Global Electric Vehicle Outlook in 2022.[1]

As in recent years, most policies supporting EVs target the electric light-duty vehicle (LDV) segment, for which market maturity is most advanced and vehicle availability greatest. In 2022, more than 90% of global sales of LDVs were covered by policy that encourages EV uptake. Typical policies include fuel economy and pollutant standards; zero-emission vehicle mandates; economic and budgetary regulation for fuels and vehicles, such as through fiscal regimes and taxation; purchase incentives and subsidies; and bans on internal combustion engine (ICE)-only vehicles.

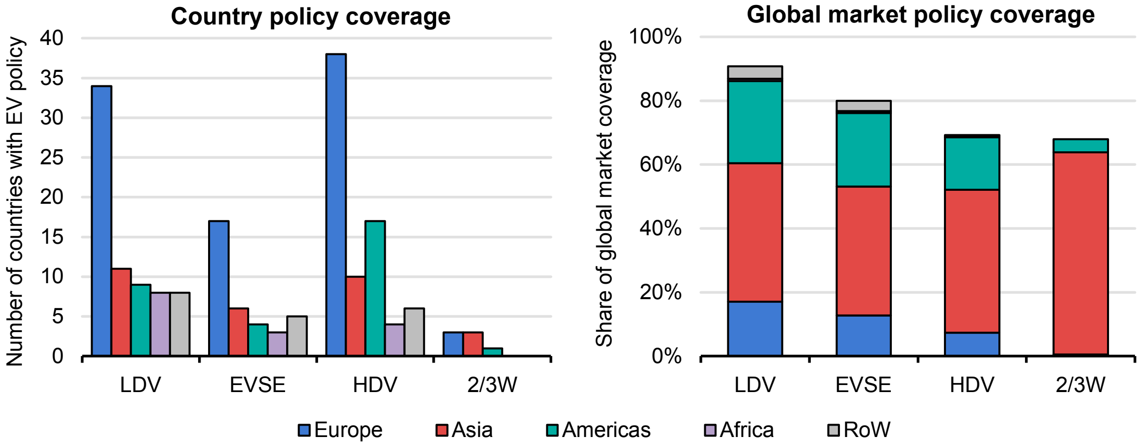
There is an increasing policy focus on the heavy-duty vehicle (HDV) segment, including medium freight trucks, heavy freight trucks and buses, and almost 70% of global HDV sales are now covered by EV policies. Countries are increasing funding, committing to zero-emission vehicle[2] (ZEV) deployment targets and enacting HDV-specific policies for the first time. In 2022, 11 countries signed on to the Global Memorandum of Understanding (MoU) on Zero-Emission Medium- and Heavy-Duty Vehicles, bringing the total number of signatories to 27. These countries aim for 100% zero-emission new truck and bus sales by 2040.

Policies are also shifting towards electric vehicle supply equipment (EVSE), or charging, and currently almost 80% of global EV sales (LDV and HDV) are covered by EVSE-related policy. Countries are increasingly dedicating funds to EVSE deployment, acknowledging that lack of charging infrastructure can be a critical barrier to EV adoption.

The 2022-2023 period was notable for the announcement of policies in the European Union and United States – new $CO_2$ standards and the Inflation Reduction Act (IRA), respectively – which are expected to have a significant impact on the pathway to zero-emission road transport. In addition, several EMDEs outside China have developed specific industrial policy to support battery and EV production, seeking to capitalise on opportunities to strengthen domestic manufacturing capacity.

[1] More comprehensive policy coverage and analysis, both regionally and prior to 2022-2023, can be found online in the interactive IEA Global EV Policy Explorer. The explorer now includes policies and targets from around 90 countries, covering the majority of the annual global sales shares of LDVs (over 90%), HDVs (70%), and two/three-wheelers (almost 70%) respectively. In particular, new entries for EMDEs have been added. The explorer provides information on government policies, ambitions and targets encouraging EV adoption across all road transport segments. It covers vehicle deployment targets, financial incentives, manufacturing policies, as well as targets and financial support for charging infrastructure.
[2] Includes battery, plug-in, and fuel cell electric vehicles.

**Figure 2.1. Countries with EV-related policy, and subsequent market coverage by category, 2022**





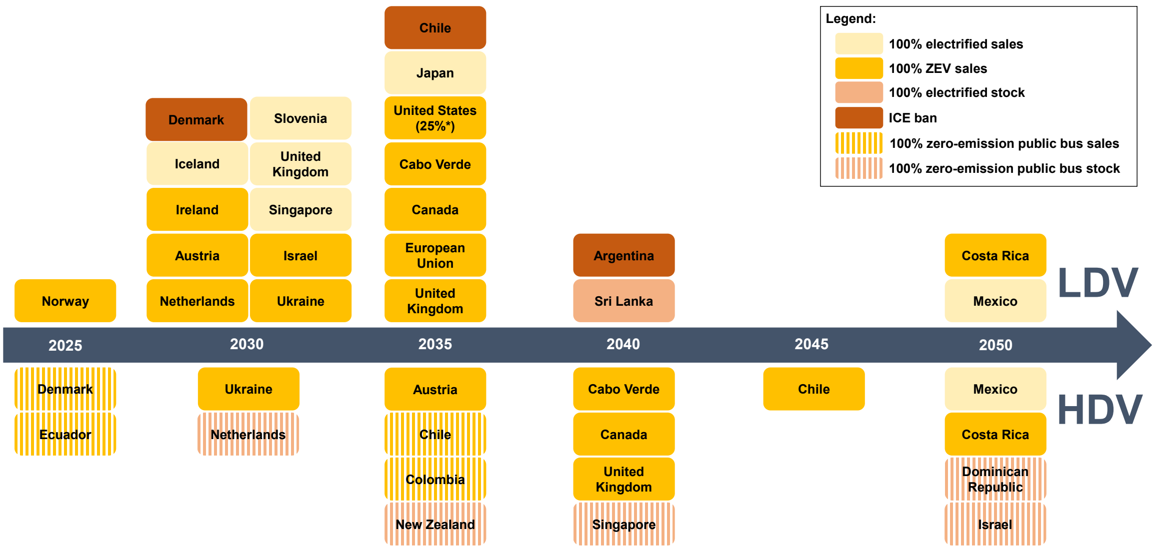

Notes: EV = electric vehicle; LDV = light-duty vehicle; HDV = heavy-duty vehicle; 2/3W = two/three-wheeler; EVSE = electric vehicle supply equipment; RoW = rest of the world. Countries are counted when they have at least one EV-supportive policy in a given category, for example a purchase incentive, a national target for sales shares, or favourable taxation. The share of global market coverage then represents the share of the vehicle market that countries with policies account for. Coverage of EVSE-related policies is based on LDV and HDV sales.

Source: IEA analysis based on announced policies; see the Global EV Policy Explorer for further details.

**As of 2022, more countries have EV-related policies than do not, accounting for more than 90% of global LDV sales and around 70% of HDV and two/three-wheeler sales.**

Zero-emission vehicle targets are a cornerstone of policy for transport decarbonisation, and almost all such targets, with respect to market coverage, have relatively short- to medium-term implementation dates. For LDVs, around half of annual global sales are covered by targets for 2035 or earlier, increasing only slightly to 55% by 2050. While the vast majority of this coverage comes from China, the European Union and the United States, there are promising increases in ambition in other markets.

**Figure 2.2. Global zero-emission vehicle mandates and internal combustion engine bans**






* Refers to the share of passenger light-duty vehicle sales accounted for by Advanced Clean Cars II (ACC II) signatories or proposed signatories.

Notes: ICE = internal combustion engine; ZEV = zero-emission vehicle; "electrified" includes hybrid electric vehicles (HEVs) in addition to electric vehicles (EVs) and fuel cell electric vehicles. European Union countries with LDV targets earlier than the EU 2035 target are included separately. Only countries that have legislated or proposed an ICE ban or 100% electrification target have been included. The proposed EU heavy-duty vehicle $CO_2$ standards include a 100% emission reduction target only for urban buses, and are thus not included in the chart. The Global Memorandum of Understanding (MoU) on Zero-Emission Medium- and Heavy-Duty Vehicles is a pledge and is therefore also not included.

Source: IEA analysis based on announced policies; see the Global EV Policy Explorer for further details.

**Zero-emission vehicle targets are now in place in an increasing number of countries, including in emerging markets and developing economies.**

# Policy to develop EV supply chains

## Policy increasingly aims to boost manufacturing, not just deployment

Several of the policies announced in 2022 and early 2023 relate to the development of EV manufacturing in addition to EV deployment.

In China, the largest market for electric cars, supporting EV manufacturers and companies through direct incentives along EV supply chains to ramp up domestic production is not a new phenomenon. The past decade has seen a sustained use of supply- and demand-side incentives for domestic firms, as well as joint ventures with international carmakers. Support has been particularly prevalent at the local level in China, thereby stimulating national uptake and the development of several major EV companies. Regions and cities have also recently announced targets for manufacturing, such as Chongqing's goal to produce and sell more than 10% of

China's new energy vehicles (NEVs),[3] and Jilin's aim to reach an annual production capacity of around 1 million NEVs, both by 2025, supported by policies focusing on EV manufacturing.

There were also notable announcements in other major markets, such as the IRA in the United States, and the Green Deal Industry Plan in the European Union. In India, the aims of the national Production Linked Incentive (PLI) scheme to encourage domestic EV manufacturing have also been supported by subnational government, such as in Tamil Nādu, where updated policy encourages local EV manufacturing. A number of other examples in EMDEs further demonstrate this trend, such as in Indonesia, which has introduced policy to invest in battery manufacturing, and Ethiopia, which is offering tax exemptions for locally assembled EVs in order to attract investment. In July 2022, Morocco announced plans to build a large EV battery factory, and the country marked the completion of its first domestically produced battery electric vehicle (BEV) in December 2022 following the reduction of tariffs on lithium-ion cells in 2021 to encourage assembly.

## United States: Inflation Reduction Act

The Inflation Reduction Act (IRA), passed in August 2022, includes various tax incentives and funding programmes to meet the aim of building a clean energy economy. Part of the Act concentrates on accelerating EV adoption, with dedicated funding drawn from the USD 369 billion allocated for climate investments.

The Clean Vehicle Tax Credit introduces a new set of conditions for EV models to qualify for incentives. From 2023 onwards, these conditions stipulate that final assembly must occur in North America, and that vehicles must have a 7 kWh battery or greater (to exclude low-range plug-in hybrid electric vehicles [PHEVs]), be under 6.35 t gross vehicle weight (GVW), and have a suggested retail price of less than USD 80 000 for vans, SUVs and pickup trucks, or USD 55 000 for other vehicles. In order to qualify for the incentive, the EV buyer's household income must be below the limit set by the US Internal Revenue Service. These conditions open eligibility for an incentive of up to USD 7 500 per vehicle: USD 3 750 if the battery meets the critical mineral requirement, and another USD 3 750 if it meets the component requirement.[4] Furthermore, from 2025, vehicles with any critical minerals from "foreign entities of concern" will not be eligible for the credit, and vehicles with battery components from such entities will be ineligible from 2024.

[3] The policy specifically refers to "Intelligent and Connected New Energy Vehicles", and therefore may not necessarily mean 10% of total NEV sales in China.
[4] This requirement stipulates that: 1) in 2023, 40% or more of the battery critical minerals must be extracted or processed in the United States or a US free trade country, or have been recycled in North America, gradually increasing to 80% in 2027 and beyond; and 2) in 2023, 50% of the value of the components in the battery must be manufactured or assembled in North America, gradually increasing to 100% in 2029 and beyond.

Several of the major US automotive manufacturers have submitted a list of specific models that comply with the new requirements, and removing the manufacturer sales cap of 200 000 means GM and Tesla can participate in the scheme. Of the 37 models listed, 4 are PHEVs and 33 are BEVs. The average listed retail price for the eligible PHEVs and BEVs is just below the USD 55 000 and USD 80 000 limit for cars and SUVs, respectively, indicating original equipment manufacturer (OEM) corporate strategy to meet the eligibility criteria of the IRA, even if this implies cutting prices in some cases. The Act also commits USD 1 billion to incentives and infrastructure projects for HDVs between now and 2031.[5] For vehicles from approved manufacturers, with 15 kWh or more of battery capacity, the tax credits are up to USD 40 000 per vehicle.

In addition to demand-side credits for vehicle purchase, the IRA includes supply-side Advanced Manufacturing Production Tax Credits. Under this scheme, the US government provides subsidies for domestic battery production of up to USD 35 per kWh, plus another USD 10 per kWh for module assembly. Assuming average battery prices in 2022 are around USD 150 per kWh, these new US production incentives could account for nearly a third of total battery price.

Finally, in addition to confirming that countries with existing free trade agreements have preferred status as suppliers, the United States signed an MoU with the Democratic Republic of Congo and Zambia in January 2023, committing to support development of a productive supply chain from mining to assembly.

## European Union: Green Deal Industry Plan

In February 2023, the European Union presented the Green Deal Industrial Plan, which has four pillars related to progress on net zero-related projects: faster permitting, financial support, enhanced skills, and open trade. The plan also includes provision for the creation of a Critical Raw Materials Act, the proposal for which was issued in March 2023, with a focus on security of supply, extraction and environmental standards, as well as recycling.

The faster permitting for facilities, including battery production, will be formalised via the proposed Net Zero Industry Act, providing simplified and predictable planning approvals. As well as loosening rules on state aid until 2025, the financial support package of the plan attempts to allow faster access to essential subsidies and loans, to compensate businesses for high energy prices, to help ensure liquidity, and to reduce electricity demand. The plan also aims to reskill workers affected by the green transition, and to establish Net Zero Industry Academies. Lastly, the trade element focuses on improving the resilience of the EU's supply chains, opening trade with new partners and attracting private investment.

[5] Also included in the budget is provision of "workforce development and training, and planning and technical activities".

In March 2023, the European Union proposed the Net Zero Industry Act, which aims to meet 40% of the European Union's needs for strategic net zero technologies with EU manufacturing capacity by 2030. These technologies explicitly include battery and storage technologies, and for batteries the aim is for nearly 90% of the European Union's annual battery demand to be met by EU battery manufacturers, with a combined manufacturing capacity of at least 550 GWh in 2030, in line with the objectives of the European Battery Alliance. These announcements came just as $CO_2$ standards for car sales over 2030-2035 tightened under the Fit for 55 package.

## India: Production Linked Incentives (PLI)

The Indian PLI on Advanced Chemistry Cell (ACC) Battery Storage was announced in late 2021 with the aim of boosting domestic battery manufacturing with a budget of INR 181 billion (Indian rupees) (USD 2.2 billion). Specifically, the government aimed to reach a cumulative 50 GWh in domestic manufacturing capacity by allocating funding to companies based on the sales of batteries manufactured in India, disbursed over five years, and dependent on meeting a domestic value-add of at least 25% in year 1, increasing to 60% in year 5. This is particularly ambitious given that there is currently no significant domestic battery cell manufacturing in India, and the 50 GWh figure is 50% greater than anticipated domestic demand as projected in the IEA Stated Policies Scenario (STEPS) in 2025. The scheme attracted 10 bids with cumulative capacity of 128 GWh in early 2022, and by July 2022, the government had assigned funding to 3 companies – Reliance, Ola and Rajesh – for a total of at least 30 GWh of battery manufacturing capacity with the remainder to be allocated to the next highest placed bidder(s). Other private companies are expected to establish an additional 95 GWh.

The Automobile and Auto Component PLI scheme has two parts: the Champion OEM incentive scheme, which grants incentives for sales of advanced automotive technology vehicles (battery electric and hydrogen fuel cell vehicles) across all vehicle segments; and the Component Champion scheme, which provides incentives for sales of certain components for both ICE and electric vehicles. The budgetary outlay is INR 260 billion (USD 3.2 billion) over five years, and the scheme has been successful in attracting investments worth INR 677 billion (USD 8.3 billion), which will be spent over a period of five years. A total of 95 applicants had been approved under this scheme as of March 2022. In both schemes, the minimum domestic value-add requirement is 50%.

## Leveraging critical mineral resources to build domestic manufacturing

Recognition of the vital role of critical minerals in the EV transition has also catalysed policy action. As carmakers and battery manufacturers around the world race to secure supply as EV demand increases, governments are seeking to position themselves in global supply chains, with a focus on increasing domestic capacity. It will be important to ensure these new supply chains for critical minerals are ethical and environmentally sustainable into the future.

The European Union's December 2022 proposed revisions to the EU Battery Directive introduce new rules for the production, recycling, and repurposing of batteries. The European Union also proposed the Critical Raw Materials Act in March 2023, which aims, by 2030, to achieve extraction capacity of 10% of the European Union's annual consumption of strategic raw materials; processing capacity for 40%; and recycling capacity for 15%. Objectives also include diversifying the origin of imported materials to increase supply chain security and resilience, and improving the environmental sustainability of mineral-related activities.

In the United States, the importance of critical minerals and the preference for developing domestic capacity has been underlined by the stipulation under the IRA that half of the vehicle subsidy is dependent on meeting the critical mineral requirement.

Initiatives to stimulate domestic manufacturing and ensure supply of critical minerals are also underway in many other countries. Australia is aiming to accelerate lithium production for both export and domestic downstream processing. Recent policy developments have included a consultation on the Australian Made Battery Plan, which sets out an AUD 100 million (Australian dollars) (USD 65 million) budget proposal for domestic battery manufacturing projects in Queensland, and on a new Critical Minerals Strategy. Like Chile, Australia has a free trade agreement with the United States, meaning greater synergy with the IRA than in countries not covered by such agreements. Argentina sees an opportunity to build a battery manufacturing industry that would create 2 500 jobs by 2030, and is considering the introduction of a domestic market quota of 5%, potentially increasing to 20%, to guarantee domestic industry access to lithium. Japan aims to increase domestic production of vehicle batteries to 100 GWh by 2030 under the Green Growth Strategy. In 2022, Japan earmarked JPY 331.6 billion (Japanese yen) (USD 2.5 billion) to develop materials for magnets and batteries to reduce the dependency on rare earth elements and lithium, including those used for EV applications. In Mexico, a decentralised public body, Lithium for Mexico, was created in August 2022, recognising lithium as strategic mineral and nationalising the value chain, with a target that 50% of vehicles produced in Mexico will be ZEVs by 2030. Russia is aiming to leverage minerals to develop a battery industry, and for no less than 10% of car production to be EVs in 2030.

In 2020-2021, India imported lithium-ion cells worth USD 1 billion, more than 95% of which were from Hong Kong and China, according to trade data. To reduce dependency on imports, in 2022 India issued Battery Waste Management Rules, which aim at recycling or refurbishing all types of batteries, including those of EVs. The rules also set the goal of increasing the recycled content of EV batteries to 20% by 2030, including for imported products. In February 2023, India announced its first inferred lithium deposits of 5.9 Mt.[6] If confirmed, this may become a game-changer for India and for global cell manufacturing.

Other countries are also positioning themselves as potential players in the EV supply chain: In 2023, Iran claimed to have identified lithium reserves, which if confirmed could amount to 8.5 Mt, or the second largest such reserves in the world.

### Box 2.1 Promoting electric vehicle adoption beyond targets and subsidies

**Expansion of Low-Emission Zones or similar policies**

Low-Emission Zones (LEZs) are increasingly common, particularly in Europe, and they may encourage EV adoption in the future, provided they are able to address acceptance and equity issues. London and Milan provide examples of LEZs that have been in place for several years. In London, the Ultra-Low Emission Zone introduced in 2021 will expand across all boroughs from August 2023 onwards: a vehicle driving in the area without meeting the emissions standards will face a daily charge of up to GBP 12.5 (USD 15.5). Milan has banned older petrol and diesel vehicles (based on the engine's Euro classification) from entering the city during weekdays, subject to a fine, with only the cleanest vehicles permitted by 2030.

In France, the scope of existing LEZs expanded in 2022 and 2023, with the government requiring the adoption of LEZs in all municipalities with more than 150 000 inhabitants by 2024, eventually covering municipalities in more than 40 regions. Similarly, Spain has mandated LEZs in municipalities with more than 50 000 inhabitants, covering 70% of Spanish cities. In the Netherlands, Amsterdam is extending its LEZs in 2025 with the goal of emission-free traffic by 2030, as is Utrecht, and the government aims for at least 30 cities to have implemented a zero-emission zone for logistics by 2030 (e.g. delivery, vans). In Scotland, a LEZ will be introduced in Glasgow in June 2023, with three other cities following in 2024. In order to facilitate the change, a scrappage scheme for people living in affected areas has been launched. Similarly, in Belgium, the LEZs that came into force at the start of 2023 were paired with a scrappage scheme. Elsewhere, China has created national pilot ecological civilisation zones, which are regions for air pollution

[6] The total viable resource will be significantly lower than the inferred resource.

prevention and control with associated targets for NEV deployment. Although the regulations pertaining to the restrictions applied are not yet all fully defined, they are expected to have an impact on EV sales.

**Interest-free or low-interest loans**

Affordability can be a barrier to EV adoption, particularly among lower-income households, and some governments have sought to facilitate greater uptake by providing low-interest loans. In 2022, Scotland offered a suite of interest-free loans to both individuals and businesses for both new and used BEVs and PHEVs. The current round of funding is fully subscribed. In Australia, the Australian Capital Territory offers interest-free loans of up to AUD 15 000 (more than USD 10 000), with a repayment period of up to 10 years, to help bridge potential price premiums relative to ICE equivalents. From 2023 in France, as a two year-trial, interest-free loans will be offered to lower-income households in LEZs who would like to change to an EV. Since 2022, the Canada Infrastructure Bank has offered low- or zero-interest loans for the purchase of zero-emission buses, with repayments sourced from savings generated by the lower operating costs. Slovenia offers subsidised loans to people wishing to purchase an EV as part of an Eco Fund.

# Policy support for electric light-duty vehicles

## More ambitious policy-making sets course for zero-emission driving

### New EU standards introduce deadlines and increase targets

Over the past year there has been substantial progress towards adopting legislation in line with reducing emissions in the European Union by at least 55% by 2030, as outlined in the Fit for 55 package. In March 2023, the European Union adopted new $CO_2$ standards for cars and vans requiring a 55% and 50% reduction in emissions of new cars and vans by 2030 (compared to 2021), and 100% for both by 2035. As stated in the regulation, the Commission will also submit a proposal to allow for the registration of vehicles running exclusively on $CO_2$-neutral e-fuels after 2035.

In June 2022, the European Parliament also called for amendments to regulations regarding the default utility factor for PHEVs, which represents the share of distance travelled using the battery compared to the distance travelled using the ICE. Consequently, from 2025 the utility factor (with its effect on vehicle emissions) will be based on the 2022 ICCT-Fraunhofer study of real-world data rather than estimates, substantially increasing the assumed emissions. This is expected to significantly decrease the incentive for carmakers to use PHEVs to meet European fleet targets. As of 2027, the updated methodology will be based on an even split of private and company cars, as the latter have been responsible for an even greater gap between assumed and actual performance. Furthermore, it is proposed that from January 2027 the utility factor will be changed to reflect the latest results of on-board fuel consumption monitoring devices.

## Tighter Euro 7 regulations expand coverage of emissions

In November 2022, the European Commission proposed new Euro 7 emissions standards for cars, vans, trucks and buses. The proposed emission standards are intended to be more reflective of real driving conditions, particularly city driving, and regulate not just tailpipe emissions, but also emissions from brakes and tyres – including for EVs. The standards are also intended to reinforce new stricter air quality standards proposed in October 2022.

As with the United Nations regulations (see "Globally harmonised technical regulations for safer and cleaner electric vehicle deployment"), the Euro 7 emissions standards would introduce minimum performance standards for LDV battery durability of 80% by year 5 or 100 000 km, and 70% from years 5 to 8 or 160 000 km.[7] Also included are nitrogen oxide ($NO_x$) emissions reductions of 35% for LDVs and 56% for HDVs, and tailpipe particle emissions reductions of 13% for LDVs and 39% for HDVs. These limits cannot be exceeded before 200 000 km or 10 years of driving, double the previous requirements. They represent an anticipated cost increase of EUR 90 to 150 (USD 95 to 160) for LDVs, and EUR 2 600 (USD 2 750) for HDVs compared to Euro 6/VI.

**Box 2.2 Globally harmonised technical regulations for safer and cleaner electric vehicle deployment**

**Technical regulations and safety**

In addition to fiscal policies, technical regulations are key enablers of mass adoption, by ensuring safe, clean and sustainable operation, and thereby increasing consumer confidence. Alongside representatives from governments, industry and civil society, the World Forum for Harmonization of Vehicle Regulations, hosted by the United Nations Economic Commission for Europe (UNECE), develops legally binding technical regulations on vehicle design and construction.

In 2018, the UN introduced performance-oriented requirements to address potential safety risks of EVs in both LDVs and HDVs. The requirements are divided into in-

[7] These limits apply to M1 vehicles (passenger cars with up to 8 seats). The limits for N1 vehicles (vans less than 3.5 t) are 75% and 65% respectively.

use (occupant protection, charging, safety of the rechargeable energy storage system), and post-crash (electrical isolation, battery integrity etc.) categories.

EV-specific occupant protections have also been included in the five other UN Regulations dealing with vehicle collisions. Work to improve the 2018 regulation is ongoing, with experts considering the flammability, toxicity and corrosiveness of vented gas, energy storage system vibration profile, water immersion, and thermal propagation. Thermal propagation is of particular importance in light of recent instances of EV fires, which are extremely difficult to extinguish. The second phase of this work is expected to culminate in the adoption of an amendment in 2024.

**Environmental performance**

Similar regulatory activities to aid clean deployment of EVs are ongoing, with 27 countries[8] committed to transposing minimum battery durability requirements in HEVs, PHEVs, and BEVs into their national legislation after the requirements were adopted by the UN in April 2022. The new provisions require manufacturers to certify that the batteries will lose less than 20% of their initial capacity over 5 years or 100 000 km, and less than 30% over 8 years or 160 000 km. They are equal to the provisions in the proposed Euro 7 regulations, but less stringent than the provisions adopted in California. The scope of the work is now extending to HDVs, a sector expected to electrify rapidly in the coming years.

Such initiatives are crucial for increasing the environmental performance of EVs beyond their low emissions output, easing the pressure on in-demand critical raw materials needed for their production, and reducing waste from used batteries. A procedure to measure brake particulate emissions has also been developed at the UN and has already been included into the Euro 7 proposal. Elsewhere, following the forthcoming development of a harmonised procedure to determine the carbon footprint of all vehicle types, a draft proposal from the UN on automotive Life Cycle Assessment (LCA) is expected to be adopted in 2025.

## Greater ambition for US states under Advanced Clean Cars II

In November 2022, the California Air Resources Board approved the Advanced Clean Cars II (ACC II) rule, which sets a minimum ZEV sales shares for passenger LDVs ranging from 35% in 2026 to 100% in 2035.[9] Any vehicle sold from 2035 onwards must be a zero-emission vehicle or PHEV. This follows sustained support for low- and zero-emission vehicles in California in the past decades, such as through the zero-emission vehicle credits. While the regulation can only take effect after a waiver is granted to California by the US Environmental Protection Agency,

[8] Australia, Canada, China, European Union (representing Cyprus, Finland, France, Germany, Hungary, Italy, Lithuania, Luxembourg, Netherlands, Romania, Slovakia, Slovenia, Spain, and Sweden), India, Japan, Malaysia, Norway, Korea, Russia, South Africa, Tunisia, United Kingdom and United States.

[9] Includes passenger cars, SUVs, and pickup trucks, but not LCVs, which accounted for 6% of US LDV sales in 2022.

other states have already followed California's lead. Vermont, Washington, Oregon and New York have all adopted ACC II, altogether representing about 20% of US passenger LDV sales. Currently, Massachusetts, Delaware and Colorado have also either begun the process to adopt ACC II or have announced intentions to do so, which would bring the share of sales covered by the rule to almost 25%.

## National plans in many countries pave the way for zero-emission car transport

In 2022-2023, more and more countries proposed policy to accelerate electric car adoption, either by strengthening existing plans or introducing a support mechanism for the first time.

In Europe, the United Kingdom brought forward the date to end the sale of fully ICE cars and vans to 2030, five years earlier than previously announced, with a full transition to 100% ZEV sales by 2035.[10] In March 2023, the government laid out proposed ZEV sales share trajectories for cars and vans to reach the 2035 target.

Greece, which had a previous target of 30% ZEV sales share by 2030, strengthened its policy to only allow the sale of zero-emission LDVs from then onwards. In Switzerland a target first established in 2018 for a 15% electric car sales share by 2022 has been surpassed, reaching 25% in 2022, building on strong collaboration and investment across around 50 leading organisations through the Electromobility Roadmap. The new target stands at 50% electric car sales share by 2025. Italy's subsidy scheme has also been renewed with a focus on scrapping older, more polluting ICEs, similar to a scheme in Singapore. Spain has a similar focus on scrappage, accompanied by support for lower-income individuals. In Denmark, changes to taxation aim to make EV company cars more attractive, while in Finland, import and annual taxes for EVs have been significantly reduced. Austria renewed its EV subsidy in 2023, applying the same rates as the previous year.[11] Croatia and Cyprus[12] both began subsidising EV purchase in 2022.

[10] Between 2030 and 2035, new cars and vans can be sold if they have significant zero-emission capability, which would include some plug-in and hybrid electric vehicles. The definition of significant zero-emission capability will be consulted on later this year.
[11] Rates for commercial applicants have reduced between 2022 and 2023.
[12] Note by the Republic of Türkiye: The information in this document with reference to "Cyprus" relates to the southern part of the Island. There is no single authority representing both Turkish and Greek Cypriot people on the Island. Türkiye recognises the Turkish Republic of Northern Cyprus (TRNC). Until a lasting and equitable solution is found within the context of the United Nations, Türkiye shall preserve its position concerning the "Cyprus issue". Note by all the European Union Member States of the OECD and the European Union: The Republic of Cyprus is recognised by all members of the United Nations with the exception of Türkiye. The information in this document relates to the area under the effective control of the Government of the Republic of Cyprus.

In 2022, Canada increased its national ambition for LDV deployment, with current goals to achieve a zero-emission sales share of 20% by 2026, 60% by 2030 and 100% by 2035. On the provincial level, British Columbia has increased its 2030 target to 90%.

Having funded a charging infrastructure programme since 2020, in February 2022 Australia also started providing competitive grant funding supporting the purchase of EVs (both light- and heavy-duty) for commercial use. The total funding amounts to AUD 128 million (USD 89 million) and is a component of the expanded AUD 500 million (USD 346 million) Future Fuels Fund. In May 2022, New Zealand published its first comprehensive emissions reduction plan. It aims for 30% of the LDV stock to be ZEVs by 2035. Electric cars accounted for over 10% of new sales in 2022, despite New Zealand only introducing a purchase subsidy in mid-2021. This also covers imports of used vehicles, given their prevalence in the country, as well as several non-purchase related incentives.

Japan's Green Growth Strategy, announced in 2021, sets targets to reach 100% electrification of LDV by 2035, and the 2023 Act on the Rational Use of Energy tracks and accelerates the targets set under the Strategy.

In EMDEs, governments are also increasing ambition. EVs are viewed as an opportunity to reduce air pollution, mitigate climate impacts and decrease reliance on energy imports. The EV policies being introduced commonly take the form of tax exemptions for EVs, equipment and parts, as well as purchase incentives, mandates, and deployment targets.

In Indonesia, government vehicles have been required to be electric since 2022, and EV purchase subsidies have been put in place from 2023. In Seychelles, the aim is for 30% of new vehicles sales to be electric by 2030 and the forthcoming National Electric Mobility Strategy will contain a target of 100% of buses to be electric by 2050. In Panama, 40% of the stock of selected public vehicles are to be EVs by 2030. Viet Nam has introduced a net zero emissions target for the transport sector in 2050, aiming to use vehicles powered by 100% electricity and green energy, with a ban on the production, assembly and import of fossil fuel-powered vehicles in 2040. Ghana's recently released strategy contains a target that 4%, 16%, and 32% of new sales are to be EVs in 2025, 2030, and 2050, respectively. In addition, countries recently proposing tax-related policies include Angola, Brazil (following previous tax exemptions for imports of electric cars dating back to 2015), Ecuador, Pakistan, Trinidad and Tobago, Tunisia, Uzbekistan, and Viet Nam.

# Purchase incentives are being adjusted in more advanced markets

## China: local action ramps up as national subsidies phase out

In China, December 2022 saw the end of the national NEV subsidy scheme, originally aimed for phase-out two years earlier, and following a gradual reduction of national subsidies for NEV purchases since 2017. Meanwhile, with a sales share of almost 30% in 2022, China's NEV market has surpassed the country's target of a 20% sales share by 2025. The extended vehicle purchase tax exemption for NEVs will remain as the main national-level financial incentive until the end of 2023.

Moreover, road transport electrification is stated as a goal in multiple guiding strategies. To reduce air pollution, China aims to reach a 50% NEV sales share by 2030 in its "key air pollution control regions", which combined account for nearly 80% of China's car market. In addition, China's national action plan to reach carbon peaking before 2030 sets out a target for the sales share of NEVs to reach around 40% by 2030.

Meanwhile, targets and favourable policies at the regional level continue to play an important role. In line with the country's national action plan, 18 Chinese provinces currently have explicit NEV targets as part of carbon peaking policies, aiming for 40% of NEV sales share by 2030, with Tianjin at 50%. Regional sectoral strategies and local 14th Five-Year Plans also set more ambitious targets in some cases, such as Shenzhen's aim to achieve a 60% NEV sales share by 2025, and Shanghai's BEV sales share target of 50% by 2025. Several regional governments announced local incentives at the beginning of 2023; for example, Zhengzhou and Wuxi are providing vouchers for NEV purchases, while Beijing and Shanghai both announced incentives to replace an ICE vehicle with a NEV.

## The focus and level of incentives are changing as markets mature

In addition to China, many other countries in which EV markets are maturing are now also reducing or changing the nature of purchase incentives:

- In 2023, Norway reintroduced value-added tax (VAT) on EVs costing more than NOK 500 000 (Norwegian kroner) (USD 52 000), meaning only the most expensive models would see price increases. Norway proposed to replace the VAT exemption with a new subsidy scheme, though few details have been released to date. Other advantages and incentives have also been gradually reduced.

- In the United Kingdom, subsidies for electric cars ended in 2022, having exceeded a 20% sales share, after the available grant was gradually reduced between 2016 and 2021.[13] Subsidies remain in place for electric taxis, vans and trucks, as well as for company cars with new tax exemptions, and the focus on charging is also increasing.
- Germany and Ireland both lowered purchase incentive levels in 2023.
- The Netherlands has been reducing premiums year-on-year, with a EUR 400 (USD 420) reduction between 2022 and 2023.
- Sweden had first planned to tighten the cap on purchase incentives for electric cars from SEK 70 000 (Swedish kronor) (USD 7 000) in 2022 to SEK 50 000 (USD 5 000) in 2023, following an increase from SEK 60 000 (USD 6 000) in early 2021. Then, in light of closer price parity between electric and ICE cars, Sweden announced that the purchase incentive would expire from November 2022 onwards.
- After increasing the incentive in order to boost sales during the Covid-19 pandemic, France reduced incentives from EUR 7 000 (USD 7 400) in 2021 to EUR 6 000 in 2022 (USD 6 300) and EUR 5 000 in 2023 (USD 5 300). However, the purchase incentive for lower-income households was increased from EUR 6 000 (USD 6 300) in 2022 to EUR 7 000 (USD 7 400) in 2023 in order to improve equity of access to EVs.
- In Korea, the government promotes EVs by applying higher subsidy amounts to vehicles with greater fully electric range. The maximum passenger car incentives slightly decreased from KRW 7 million (Korean won) (USD 5 400) to KRW 6.8 million (USD 5 300) in 2023, though consumers can benefit from local subsidies as well. For electric LCVs, the incentives per vehicle decreased from KRW 14 million (USD 10 800) to KRW 12 million (USD 9 300) in 2023. However, with around 30% more passenger cars and commercial vehicles subsidised, total government funding for electric LDV subsidies increased from KRW 1 561 billion (USD 1.2 billion) in 2022 to KRW 1 676 billion (USD 1.3 billion) in 2023. Additionally, in April 2022, Korea ended their policy of free light commercial vehicle (LCV) registration, yet has remained a leader in electric LCV deployment in 2022, averaging 27% of sales over the year.
- In 2022, Japan increased their EV subsidy scheme to JPY 70 billion (USD 530 million) – doubling support for BEV purchases up to JPY 850 000 (USD 6 500) and JPY 550 000 (USD 4 200) for PHEV.

## Stronger policy preference for fully battery electric options

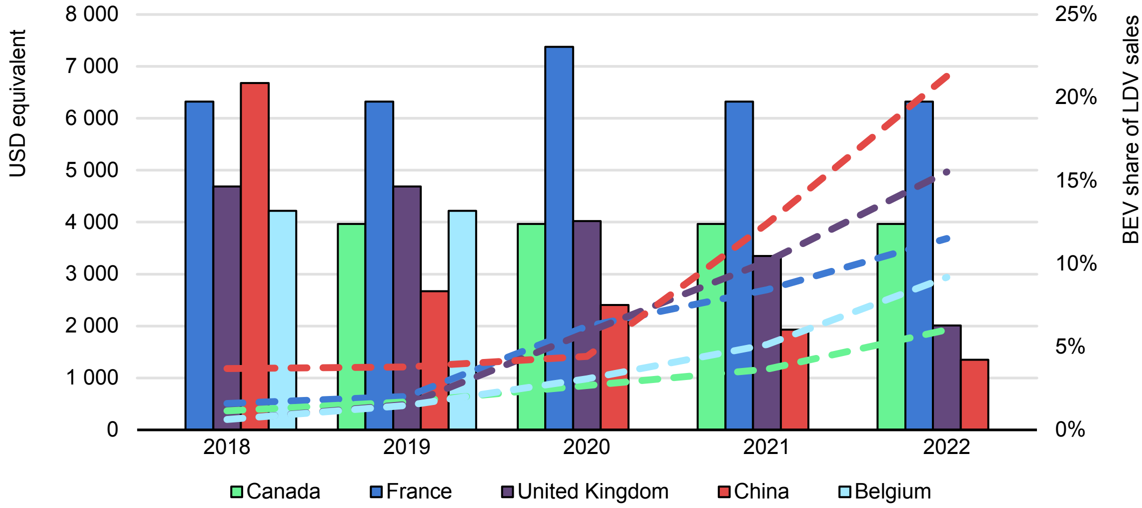
Recent developments indicate possible strengthening of policy support for battery electric cars over PHEVs. In Europe, for example, Belgium, Finland, the Netherlands, Portugal and the United Kingdom supported BEVs over the 2019-

[13] The grant was first available in 2011 and capped at 25% of the vehicle cost (to a maximum of GBP 5 000 (USD 6 170)); this was then set to GBP 4 500 (USD 5 550) in 2016, reducing between GBP 500 and GBP 1 000 (USD 620 and 1 230) per year thereafter.

2022 period, but not PHEVs. In 2022, Ireland decided to end subsidies for PHEVs, followed in 2023 by Germany.

In China, Shanghai offers purchase subsidies for BEVs but not for PHEVs, and several Indian states have set BEV-specific targets without including PHEVs. The United States and Canada have maintained the same level of support for PHEVs since 2019. In California, however, a 40 mile (65 km) minimum fully electric range is being introduced for PHEVs. The IRA is now also stipulating a minimum of 7 kWh battery capacity to qualify for subsidies, thereby excluding low-range PHEVs.

**Figure 2.3. Battery electric vehicle incentives and the battery electric vehicle share of light-duty vehicle sales, 2018 - 2022**






Note: USD = US dollar; BEV = battery electric vehicle; LDV = light-duty vehicle. The dashed lines represent the battery electric LDV sales share in each country. Subsidy values are representative of a vehicle with a 350 km range with a purchase price less the upper limit designated by the national scheme. The incentive level shown does not include scrappage bonuses or bonuses based on individual financial circumstances. Values are not adjusted for inflation or currency fluctuations. In France and the United Kingdom, the subsidy schemes were adjusted during the calendar year, with the UK subsidy ending in June 2022; the values shown represent the subsidy level at the beginning of the year. For Belgium, only the subsidy in Flanders is represented.
Source: IEA analysis based on announced policies.

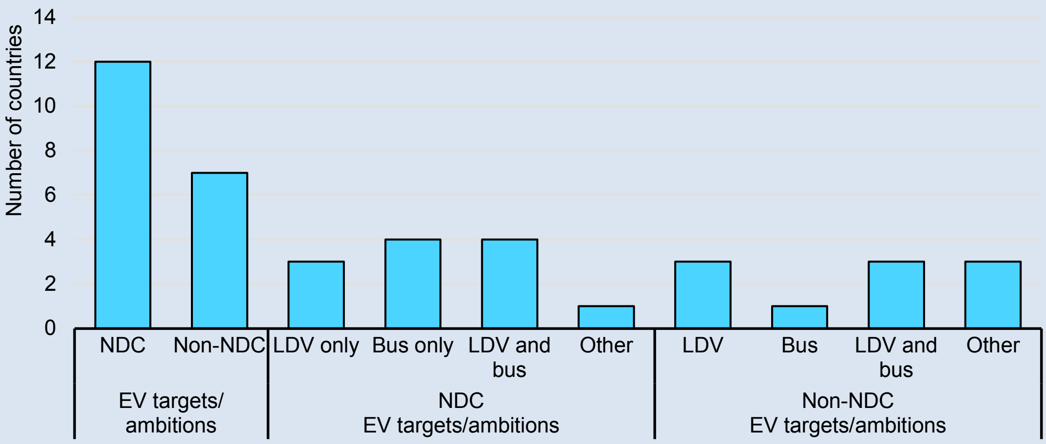
**China, the United Kingdom, and Belgium have all reduced and/or ended private passenger car subsidy schemes and still see shares continue to grow. Canada and France have maintained subsidies to encourage further adoption.**

### Box 2.3 Emerging markets and developing economies (EMDEs) target electrification of transport in their Nationally Determined Contributions

Nationally Determined Contributions (NDCs) generally contain aspirational language and few quantitative or qualitative targets. Including specific targets demonstrates a degree of confidence in a country's ability to meet its stated goal. In 2022, 19 parties updated their NDCs ahead of a UN synthesis report in October 2022.[14] It showed that 41% of NDCs, for around 80 countries, included electrification of road transport as a mitigation measure.

In this context, NDC submissions from 50 key EMDE markets were analysed to ascertain if - and to what extent - electrification of transport has become part of EMDEs' mitigation strategies. Collectively, these EMDEs account for over 40% of global LDV sales and almost 90% of LDV sales in all EMDEs.

**Electric vehicle ambitions and targets in emerging markets and developing economies**






Note: NDC = Nationally Determined Contribution; EV = electric vehicle; LDV = light-duty vehicle.
Source: IEA analysis based on announced policies.

Analysis of the NDC content shows that only Trinidad & Tobago and Nicaragua have specific transport sector emission reduction targets, but a further 12 countries spread across Latin America, Central America, Africa, and Asia, making up about 0.9 million annual LDV sales, have specific EV targets or ambitions. Of these, four countries have EV ambitions or targets for both LDVs and buses, three countries have LDV targets only, and four others only have bus targets. In addition, two African countries (Mauritius and Rwanda), while not having any specific EV target, have identified vehicle electrification as a key strategy and are monitoring adoption metrics.

[14] 13 more countries have updated their NDCs since the synthesis report of 23 September 2022.

Seven countries (contributing about 31% of global LDV sales), including China, Mexico and Indonesia, have EV targets and ambitions set outside of their NDCs as part of separate national EV plans.

# Policy support for electric heavy-duty vehicles

## New EU $CO_2$ standards for trucks and buses could be a step-change

The European Commission released proposed revisions of the regulation on HDV emissions in February 2023. The scope of the proposed regulation includes smaller trucks, city buses, long-distance buses, and trailers, to cover 95% of sectoral emissions, up from about 70% currently. This demonstrates a step-up in ambition: the International Council on Clean Transportation (ICCT) estimates that the new regulations could achieve sectoral emissions reduction of over 75% by 2050 relative to 2020.

The revisions would increase targets for $CO_2$ emissions reductions to 45% by 2030 relative to 2019, 65% by 2035, and 90% by 2040. Furthermore, all city buses should be ZEVs by 2030. Compliance will be measured separately for passenger (bus and coach) and freight vehicles via a system of credits and debts settled at the end of five-year periods between 2025 and 2040. Additionally, the definition of ZEV applied is changing, increasing from 1 $gCO_2$ per vehicle-km to 5 $gCO_2$ per tonne-km (tkm) to allow for dual fuel. Trading between economically linked entities (e.g. between brands at the same parent company) is allowed to help meet targets. The minimum range of long-haul trucks is defined as 350 km, and financial penalties are applied for non-compliance.

Several European Union member countries are strengthening support for zero-emission heavy transport in national plans. Germany has among the highest truck purchase subsidies in Europe, with 80% of additional costs of the vehicle and/or the charging infrastructure covered. Ireland's updated Climate Action Plan includes a target of 700 low-emission heavy-duty trucks by 2025, a 30% zero-emission heavy-duty truck sales share by 2030, and provisions for HDVs. Ireland also introduced its first electric bus target: 300 by 2025. In Denmark, from 2025 onwards, taxes on trucks will be based on $CO_2$ emissions, sending a clear policy signal to operators. In April 2022, Italy made subsidies available for trucks between 3.5 and 12 t, and in the same month, the Netherlands introduced a wide-ranging scheme covering vehicles from small trucks up to tractor units (4.25-18+ t). Croatia implemented a scheme with a similarly wide scope in June.

In total, ten European countries now also have a subsidy scheme for HDVs, five of which were introduced in 2022/23.

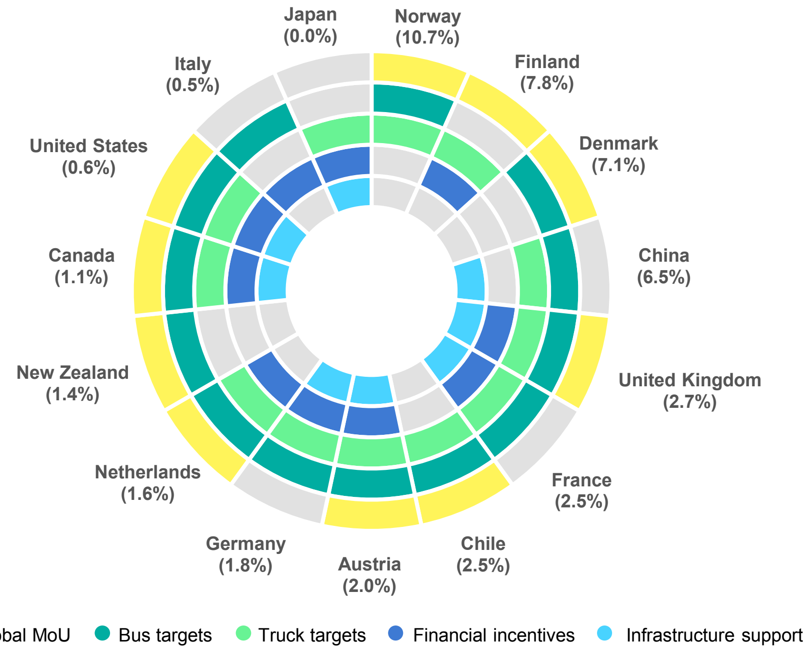
## Increasing inclusion of HDVs in targets and policy incentives

In the United States, the IRA provides USD 1 billion for vehicles and infrastructure specifically for HDVs, including subsidies, and the state of California's funding package for charging infrastructure will see 70% of funds dedicated to charging for HDVs. In the United Kingdom, HDVs remain included in subsidy schemes even though support for electric cars has been phased out. Similarly, Australia's subsidy scheme under the Future Fuels Program specifically targets HDVs and HDV charging with dedicated funding that is not available for LDVs.

Several countries have specific targets for zero- or low-emission heavy transport. In New Zealand, the aim is to reduce emissions from freight transport by 35% by 2035. Norway aims for virtually zero-emission goods distribution by 2030 in the biggest urban centres. Tianjin (China), aims to have 80% NEVs in public transport, rental, logistics and delivery vehicle sales by 2025, while Viet Nam's net zero transport by 2050 goal includes HDVs. Japan aims to introduce 5 000 electric HDVs by 2030, with a JPY 13.6 billion (USD 120 million) plan to electrify HDVs and taxis. Some countries are also introducing financial support for electric truck purchases for the first time. In July 2022, Canada's Incentives for Medium- and Heavy-duty Zero-Emission Vehicles (iMHZEV) programme began to offer incentives up to CAD (Canadian dollars) 200 000 (USD 160 000) towards the purchase or lease of ZEV trucks of various categories.

With respect to electric buses, overall model availability is higher and cost-competitiveness better than trucks, making them generally more affordable. Indeed, several EMDEs have begun including ambitious deployment targets for electric buses in national plans, often ahead of LDV targets. For example, in April 2022, Panama announced the aim of transitioning towards electric public transport, reaching a 10% share by 2025, 20% by 2027, and 33% by 2030. In February 2023, Tamil Nādu in India also introduced a target for 30% of their bus fleet to be electric by 2030 as part of a broad strategy to promote EVs and supporting infrastructure. In advanced economies, grants for electric buses have been introduced in Canada. The United States also provides substantial funding towards the purchasing or leasing of electric buses: up to 85% of vehicle costs and up to 90% of infrastructure costs.

**Figure 2.4. Heavy-duty vehicle policy coverage in selected key countries**






Note: Numbers in parentheses are the electric HDV (bus and truck) sales shares in each country in 2022. Grey sections indicate that a country does not have policy or commitment addressing this specific area. HDV targets are separated as it is common for countries to have explicit targets for one category and not both. A country is considered to have infrastructure policy only where HDV charging is explicitly mentioned. Similarly, "truck targets" refers to explicit targets for either vehicle sales/stock volumes or shares.

**Countries are supporting deployment of electric trucks and buses, from less firm commitments such as signing pledges, all the way to funding dedicated charging infrastructure.**

# Policy support for EV charging infrastructure

## Support is gradually shifting from vehicles to charging in some markets

In countries where electromobility is more well developed, focus is shifting towards supporting charging infrastructure and moving away from more expensive private vehicle subsidisation. In the United Kingdom, for example, in June 2022 the government announced its intention to refocus on charging, after winding down the electric car subsidy programme. Almost GBP 1.6 billion (USD 2.1 billion) of government funding has been committed to supporting the EV Infrastructure Strategy, which set an expectation of 300 000 public chargers being installed by 2030. The UK government is also working to increase the availability of on-street chargers, particularly in residential areas where off-street parking is not available.

With charging identified as the top consideration for consumers in China, Guangdong, Hunan and Shanghai, among other regions, have implemented subsidies for the deployment of charging points. Shenzhen is targeting 43 000 fast chargers and 790 000 slow chargers by 2025, and Chongqing 240 000 chargers.

Germany, which is also winding down its vehicle subsidy scheme, has at the same time supplemented the budget for fast chargers. In Switzerland, the government extended its Electromobility Roadmap in 2022, with the goal of achieving 20 000 public charging stations by 2025 to support the 50% EV sales share target. Having launched a vehicle subsidy scheme in 2021, Poland is now also subsiding charging infrastructure. Finland and Denmark have recently committed to greater support of charger roll-out, as has Ireland, which released a revised ZEV plan that focuses on public charging.

## Additional support for charging infrastructure aims to service different road transport segments in more settings

Some countries are choosing to fund infrastructure development in advance of large-scale adoption of EVs. One notable example is Australia, which has had grants to fund charging prior to 2020 and a dedicated infrastructure funding programme since 2020, and began to provide support for electric HDVs in 2022, in conjunction with charging.[15] The first period of Viet Nam's strategy includes building a charging network, without a focus on subsidising vehicles. Similarly, Bulgaria's efforts to promote EVs are starting with charging. In India, targets and incentives are being developed at the state level to supplement national ambitions, with the Tamil Nādu government set to subsidise the installation of 750 chargers. Under the Green Growth Strategy, Japan plans to construct 150 000 publicly accessible charging stations by 2030: 30 000 of which will be fast charging.

In the United States, more than USD 1.5 billion has been approved under the National Electric Vehicle Infrastructure (NEVI) Formula Program to help build EV chargers covering approximately 75 000 miles of highway across the country. National standards to qualify for the funding were adopted in 2023 with the aim of creating a convenient, affordable, reliable, and equitable network of chargers throughout the country. These standards will harmonise payments and pricing information for charging, and aim to ensure minimum numbers and types of chargers, including fast charging, to support achievement of the target of installing 500 000 chargers no more than 80 km apart along major routes by 2030. In addition, under the IRA, as of January 2023, vehicle charging infrastructure installations are eligible for a tax credit of up to USD 100 000, and consumers who

[15] This funding specifically excludes private vehicles and cannot be used to fund direct costs for LDVs.

purchase a home charger can receive a tax credit of up to USD 1 000. California, often a front-runner in EV policy development, committed additional funding of USD 1 billion of funding to charging infrastructure in November 2022. Both at a national level and under California's funding scheme, there is financial support to build out medium- and heavy-duty truck charging stations.

Canada recently increased funding available through the Zero Emission Vehicle Infrastructure Program by an additional CAD 400 million (USD 310 million) to extend the programme through March 2027. The programme supports the deployment of public and private chargers, including at multi-unit residential buildings and workplaces, as well as funding strategic infrastructure projects for urban delivery and fleet applications. Furthermore, the Canada Infrastructure Bank announced in 2022 that it will invest CAD 500 million (USD 385 million) in large-scale charging infrastructure. This is all to support the government's target of 84 500 chargers deployed by 2029.

In 2021, the European Commission proposed the Alternative Fuels Infrastructure Regulation (AFIR) in place of the 2014 Directive. As of March 2023, the European Council and European Parliament have a provisional agreement for the AFIR, which includes requirements for total power capacity based on the size of the light EV fleet, and coverage requirements for the trans-European network-transport (TEN-T) with respect to light- and heavy-duty vehicles. An agreement between the European Investment Bank and the European Commission will make over EUR 1.5 billion available by the end of 2023 for alternative fuels infrastructure, including for EV charging. Grants to support EVSE deployment are also available from the Connecting Europe Facility (CEF) for Transport programme.

## Policy incentives for battery swapping in China and India

Battery swapping policies are gaining popularity, as the technology offers a potential solution to concerns about range, charging times, and upfront costs faced by EV owners. The two countries most actively pursuing battery swapping are China and India. In China, battery swapping is being used for passenger cars and more recently has also been used for trucks. In India, battery swapping focuses on two- and three-wheelers and is most often proposed for the e-commerce and hyper-local delivery services sector in which variable routes and high daily mileages are a concern. However, widespread implementation is still hindered by high start-up costs and a lack of standardisation.

The first Chinese standard was published in 2021, and later that year 11 cities were chosen for technology demonstration pilots, with the goal of refining the standards, but this has not yet been completed. The relevance of battery swapping in China is further evidenced by its inclusion in the national strategy for the NEV industry. Cities and provinces such as Shanghai, Beijing and Chongqing also provide financial support for battery swapping, often as a part of their NEV promotion plans or subsidy schemes for charging infrastructure. Chongqing, for example, aims to build over 200 battery swapping stations and deploy more than 10 000 battery swapping-enabled EVs by 2023, while Beijing aims to have 310 by 2025. At the end of 2022, China had almost 2 000 battery swapping stations.

In order to promote battery swapping, India first amended the demand incentive scheme (FAME II) to allow the sale of vehicles and batteries separately to electric two- and three-wheelers, with the aim of reducing upfront costs. However, this resulted in ambiguity around subsidy disbursement and eligibility, and incidentally increased the applicable tax rate. To resolve these issues, in 2022 India announced a draft battery swapping policy that stipulates the minimum technical and operational requirements, as well as clarifications on financial issues. A number of state governments in India have also announced support for battery swapping. For example, the Delhi government stipulates an even distribution of subsidy between the vehicle owner and energy operator and an allocation of land for the establishment of swap points with favourable conditions. Other states are providing up to 25% capital subsidy for stations that meet certain eligibility criteria. The national government envisages the roll-out of the swapping stations in two phases. In Phase 1, all metropolitan cities with a population of more than 4 million will be prioritised, followed by Tier-II cities (with a population greater than 0.5 million) in Phase 2.

# A multiplying number of international initiatives and pledges

The number of multilateral initiatives and pledges focusing on electromobility has increased rapidly in the last decade. This reflects government appetite around the world to accelerate the transition to zero-emission transport, and is an encouraging sign that international collaboration has a strong role to play in global decarbonisation. The multiplication of multilateral initiatives is a phenomenon also observed in other segments of the clean energy sector, such as hydrogen and renewables. To increase the impact of such initiatives, it is important for member countries to ensure that the schemes complement each other and to identify where specifically in the EV value chain they should focus.

## Accelerating to Zero

The overarching goal of the Accelerating to Zero (A2Z) coalition launched at the Conference of the Parties (COP 27) is for all sales of new cars and vans globally to be ZEVs by 2040, and by no later than 2035 in leading markets. The coalition builds on the Zero-Emission Vehicles Declaration, which received some 130 signatures on launch at COP26, and now has 223 signatories. These include

30 governments in advanced economies,[16] 11 governments in EMDEs,[17] 73 local/regional governments, 14 automotive manufacturers, 47 fleet owners and operators, 15 investors with shareholdings in automotive manufacturing, 2 financial institutions and 31 other signatories. The 40 governments together accounted for almost a quarter of annual LDV sales worldwide, and close to 20% of electric LDV sales in 2022. Some subnational government or non-governmental signatories have also set specific, more ambitious goals, such as regional or city authorities and fleet owners and operators aiming to electrify their fleets by as early as 2030.

## Zero-Emission Government Fleet Declaration

In 2022, recognising the catalytic role that national governments can have via demand signals and leadership, a group of nine countries[18] committed to the Zero-Emission Government Fleet Declaration. They aim to reach 100% zero-emission cars and vans in government fleets, with an additional aspiration of 100% zero-emission trucks and buses, by no later than 2035. Exact timelines vary by country. For example, 75% and 100% of acquisitions should be electric by 2025 in Australia[19] and Israel, respectively; 100% of acquisitions by 2027 in the United States; and 100% of the LDV stock should be zero-emission by 2030 in Canada.

## Zero-emission Vehicle Emerging Markets Initiative

In 2022, at COP27, the World Business Council for Sustainable Development (WBCSD), the United States and the United Kingdom launched the Zero-Emission Vehicle Emerging Markets Initiative. It aims to enhance co-operation between public and private actors in EMDEs to accelerate the transition to zero-emission road transport. Specifically, the initiative opened a dialogue between governments and corporates on public support and private investment to achieve ZEV deployment targets in EMDEs, with the view to facilitate and announce agreements at COP28. It gathers companies that have announced a combined USD 50 billion in investment and committed to deploy over 2 million EVs in EMDEs by 2030. In February 2023, the first dialogue of the series took place in India, launching a country pilot programme there.

[16] Austria, Azerbaijan, Belgium, Cabo Verde, Canada, Chile, Croatia, Cyprus, Denmark, El Salvador, Finland, France, Greece, Iceland, Ireland, Israel, Liechtenstein, Lithuania, Luxembourg, Malta, Netherlands, New Zealand, Norway, Poland, Slovenia, Spain, Sweden, the Holy See, and the United Kingdom.

[17] Armenia, Dominican Republic, Ghana, India, Kenya, Mexico, Morocco, Paraguay, Rwanda, Türkiye, and Ukraine.

[18] Australia, Canada, Germany, Israel, Netherlands, New Zealand, Norway, Sweden, and the United States.

[19] Includes leases.

## Global Memorandum of Understanding on Zero-Emission Medium- and Heavy-Duty Vehicles

In 2021, the Dutch government and Drive to Zero programme launched the Global Memorandum of Understanding (MoU) on Zero-Emission Medium- and Heavy-Duty Vehicles, through which signatories commit to work together to achieve 100% ZEV bus and truck sales by 2040, with an interim goal of 30% by 2030. In 2022, Aruba, Belgium, Croatia, Curaçao, Dominican Republic, Ireland, Liechtenstein, Lithuania, Sint Maarten, Ukraine, and the United States all signed the MoU. This brings the total number of countries and territories among the signatories to 27,[20] accounting for over 15% of total annual sales of new medium- and heavy-duty vehicles worldwide. The MoU also has endorsements from regional government, manufacturing, fleet owners and operators, among others.

## Greening Corporate Fleets

The European Commission committed to promote commercial use of zero-emission vehicles through a Greening Corporate Fleets initiative in 2023. In an open letter to the Commission shared by Transport & Environment, a campaign group, 30 private and state-owned companies, as well as industry groups, called for the Commission's initiative to include a binding target that by 2030 all new corporate LDVs should be ZEVs. The companies include fleet owners and operators and EV infrastructure developers.

The letter was also signed by the EV100 campaign, which itself now has 130 member companies. EV100 aims by 2030 to switch all fleet vehicles under 7.5 t to EVs and to install charging infrastructure for employees and customers. In total, EV100 members have now committed to electrify nearly 725 000 vehicles in their own fleets, and over 5 million leased vehicles.

## EV100+

The EV100+ campaign was launched in 2022 by the Climate Group, the originators of the EV100 aimed at LDVs. Signatories of the EV100+ campaign commit to transition their fleet of vehicles over 7.5 t to zero-emission by 2040 in OECD markets, China and India. Founding members include a few corporate fleet owners or users.

Recent actions included setting up a broader coalition of truck makers, transport operators, shippers and retailers, energy providers and infrastructure operators and calling for ambitious targets in the (then upcoming) EU HDV $CO_2$ regulations,

[20] Previous signatories are Austria, Canada, Chile, Denmark, Finland, Luxembourg, Netherlands, New Zealand, Norway, Portugal, Scotland, Switzerland, Türkiye, United Kingdom, Uruguay, and Wales.

such as a binding ZEV target for 2035 with only limited exceptions, and interim targets of 30% emissions reduction by 2027, and 65% by 2030. The call was also signed by CALSTART. EV100+ also signed a similar open letter by Transport & Environment, demonstrating their alignment on the issue.

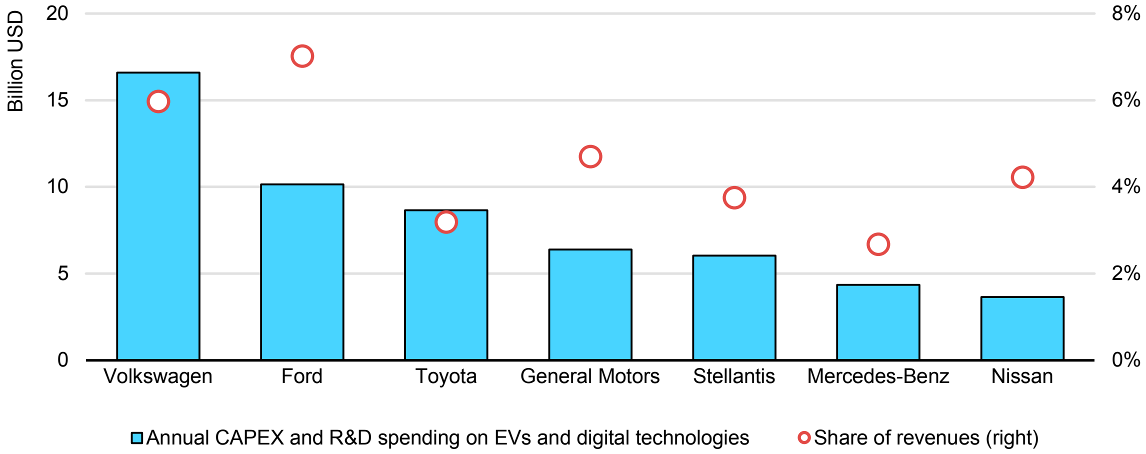
# Electrification plans by original equipment manufacturers (OEMs)

Voluntary announcements of EV targets have become increasingly common across the automotive industry. Targets may be formulated in terms of total sales volumes, as sales shares, or as an ambition to transition all sales of the company or of a certain brand to all-electric. As shown in Prospects for electric vehicle deployment, these targets often exceed not only regulatory requirements (as reflected in the Stated Policies Scenario), but also government ambitions (as reflected in the Announced Pledges Scenario).

However, manufacturers' targets are non-binding and still often focus only on leading EV markets. Indeed, it is probably no coincidence that the most ambitious targets are for the European market, where the newly amended $CO_2$ emission standards would mean that all new cars and vans will be zero-emission by 2035. Major new OEM announcements have been made at the global level and regionally in 2022-2023. Several Chinese OEMs recently announced EV targets; in contrast with OEMs based in the rest of the world, Chinese car manufacturers' targets are generally shorter-term and tend to be well within reach of current NEV market shares.

In addition, automakers continue to invest increasing sums in electrification and digital technologies. Just seven automakers, which were collectively responsible for nearly half of LDV sales in 2022, have capital expenditures of more than USD 55 billion on emerging automotive technologies since 2019, including for manufacturing facilities.

**Figure 2.5. Annual CAPEX and R&D spending commitments on EVs and digital technologies by selected automakers, 2019-2022**






Notes: CAPEX = Absolute capital expenditures. R&D = Research and development expenditures. Estimates based on company commitments for CAPEX and R&D spending and average spending over 2019-2022.
Source: IEA analysis based on data from BNEF and Bloomberg.

**Major carmakers are committing up to 50-70% of CAPEX and R&D budgets to electric vehicles and digital technologies.**

**Table 2.1 Automakers' electrification targets for LDV since 2022**

| Automaker | Target | Region | Group / Brand |
|---|---|---|---|
| Ford | 600 000 BEV sales by 2026 | Europe | Group |
| General Motors | 400 000 EV sales from 2022-24; 1 million EV production capacity in 2025 | North America | Group |
| Volkswagen | Targets fully electric production by 2033 (brought forward by two years) | Europe | Brand |
| Toyota | 1 500 000 BEV sales; introduce 10 additional models by 2026; committed to a multi-pathway approach to reduce $CO_2$, including continuing development of FCEVs and PHEVs | Global | Group |
| Mazda | Expects at least 25% of sales globally to be BEV in 2030 | Global | Group |
| Honda | Aims to launch 30 EV models globally by 2030, with production volume of more than 2 million units annually | Global | Group |
| Nissan | Updated global target to 44% EV sales by 2026 (with regional subtargets for Europe, Japan, China, and the United States) and to 55% EV sales by 2030 | Global | Group |
| Mitsubishi | Plans for 100% of EV sales by 2035 and 50% EV sales by 2030 in their Environmental Targets 2030 | Global | Group |

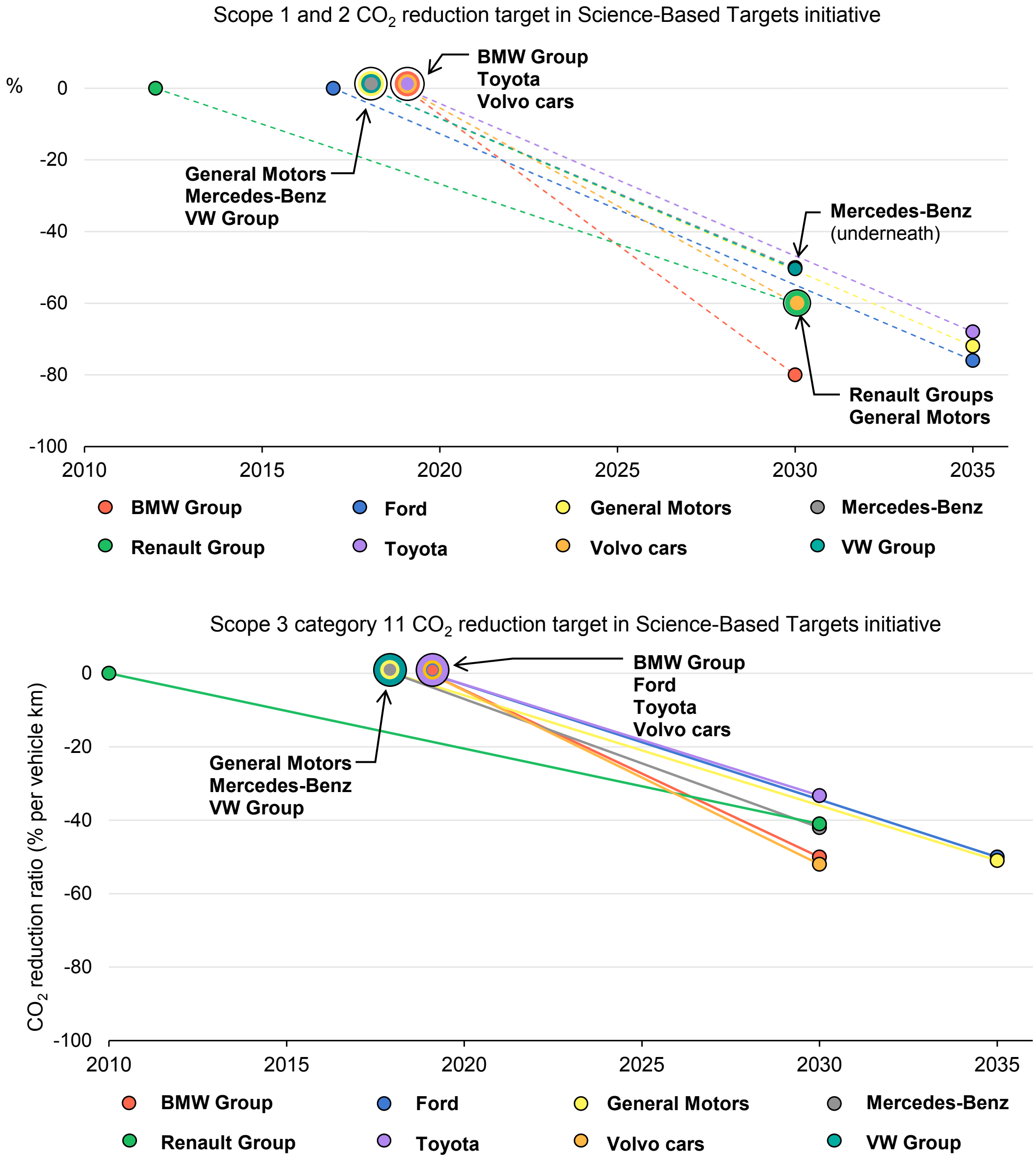
| Automaker | Target | Region | Group / Brand |
|---|---|---|---|
| Porsche | 80% of sales to be electric by 2030 | Europe | Brand |
| BMW Group | Cumulative sales of over 2 million EVs by the end of 2025; EV sales shares of 30% by 2025, 50% by 2030 | Global | Group |
| Mini and Rolls-Royce | Aims to have fully electric line-up by 2030 | Global | Brand |
| Lancia | All new model launches from 2026 to be electric; to sell 100% EVs by 2028 | Global | Brand |
| Jaguar | Aims to go all-electric by 2025 | Global | Brand |
| Land Rover | Aims to go all-electric by 2036 | Global | Brand |
| BYD | Ceased ICE vehicle production; has produced only EVs since March 2022 | Global | Brand |
| Geely | 600 000 EV sales over this year | Global | Group |
| SAIC-GM-Wuling | Annual sales of 1 million NEVs by 2023 including small EVs; 40% NEVs in total sales by 2025 | China | Group |
| BAIC Group | NEVs to make up 1 million of 3 million in total sales in 2025 | China | Group |
| FAW Group | Half of its total 1 million sales target by 2025 to be NEVs; 1.5 million vehicles (mostly NEVs) sold by 2030 | China | Group |

## Automakers aim to reduce emissions throughout the supply chain

In addition to goals to electrify vehicle production and sales, major automotive groups have set corporate decarbonisation targets.

Eight major automotive groups that collectively accounted for more than 40% of LDV sales in 2022 – BMW Group, Ford, General Motors, Mercedes-Benz, Renault Group, Toyota, Volvo Cars, and VW Group – have joined the Science-Based Targets initiative, which defines a common framework and path to reduce emissions in line with the Paris Agreement. The automotive groups have set targets for LDVs to reduce Scope 1 and 2 GHG emissions (i.e. coming from sources controlled or owned by an organisation, and indirect emissions associated with the purchase of electricity, steam, heat, or cooling) by 50%-80%, relative to recent benchmarks, as well as certain Scope 3 emissions by 30%-50%, all in the 2030-2035 timeframe (Figure 2.8). Within Scope 3, the most commonly set targets include only category 11 emissions, which covers those incurred in the fuel supply chain and use of fuel to power vehicles produced by the car company.

**Figure 2.6. Automakers' commitments under the Science-Based Targets initiative**



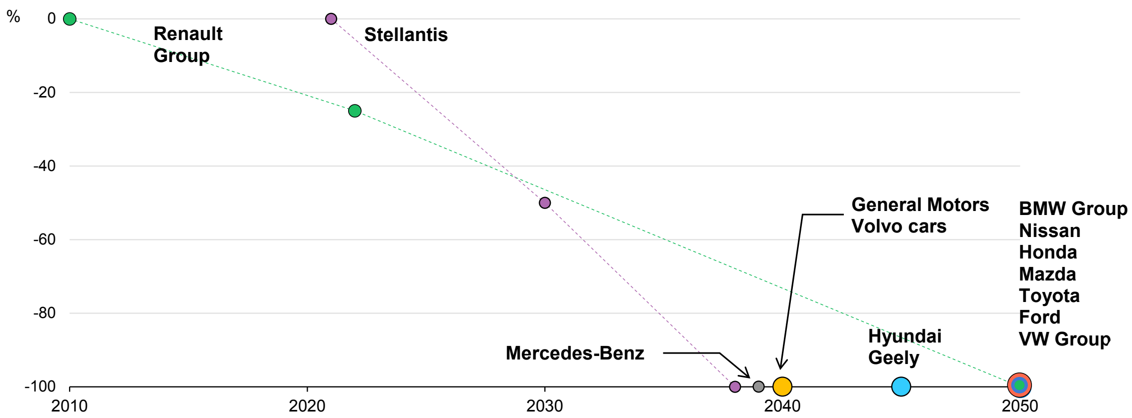



Note: Double or triple circles show overlapping dots; Mercedes-Benz Group's Scope 1 and 2 targets align closely with those of VW Group and their Scope 3 targets align closely with Renault Group's targets. BMW Group, General Motors, and Toyota all include biogenic emissions and removals from bioenergy feedstocks in their targets. Toyota's target includes LCVs.

**Eight major automotive groups, collectively accounting for more than 40% of light-duty vehicle sales, have committed to decarbonisation targets through the Science-Based Targets initiative. Commitments include Scope 1 and 2 as well as Scope 3 emissions.**

Automakers are also announcing their own corporate net zero pathways. BMW Group, Ford, Geely, General Motors, Honda, Hyundai, Mazda, Mercedes-Benz, Nissan, Renault Group, Stellantis, Toyota, Volvo Cars, and VW Group have set targets for carbon neutrality from 2038 through 2050. Collectively, these companies accounted for around 60% of global light-duty vehicle (LDV) sales in 2022. These corporate ambitions differ in terms of scope, reporting, and the degree to which they are incorporated into corporate governance, strategy, and financial decisions.

**Figure 2.7. Automakers' emissions reductions for Scope 1, 2, and 3 emissions and corporate net zero emissions targets**






Note: Dots on the y-axis indicate dates of corporate net zero emissions targets, and so do not necessarily reflect accounting across scopes 1, 2, and 3.
Source: IEA analysis based on official company announcements.

**Various automakers, collectively comprising around 60% of the light-duty vehicle market, have announced emission reduction targets.**

# Global spending on electric cars continues to increase

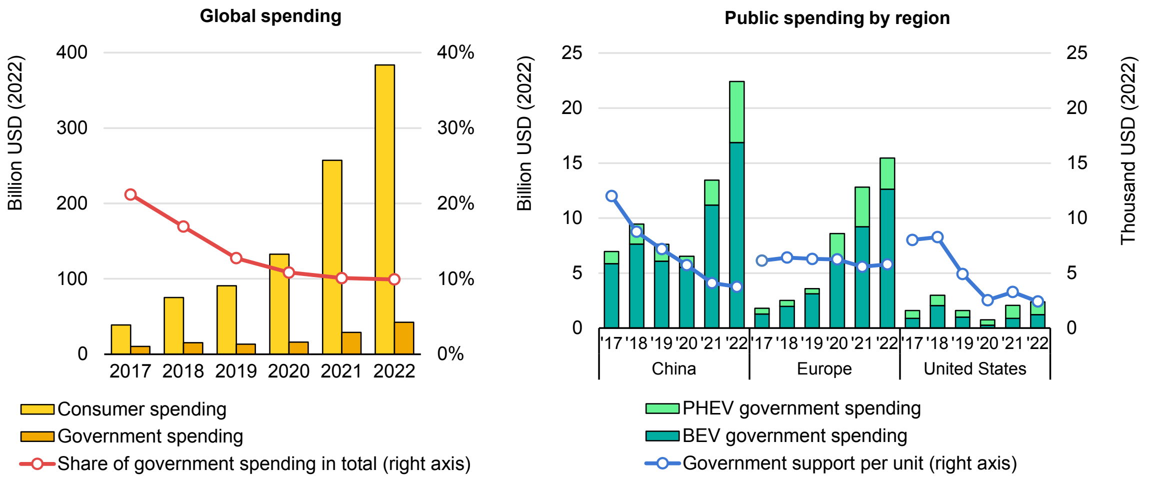
Global spending on electric cars was up 50% in 2022 relative to 2021, reaching about USD 425 billion. Most of this was directly spent by consumers when buying a vehicle, while governments spent around USD 40 billion through direct purchase incentives. These include subsidies and tax deductions such as VAT exemption, and bonuses related to weight, $CO_2$ emissions or range. The increase in global spending on electric cars means that carmakers – including incumbents – are generating more revenues from EV sales, and particularly from SUVs and large car models, thereby progressively helping to reduce reliance on ICE sales to finance EV manufacturing, R&D and new model development. While there is still a long way to go, this is an important step for EV growth and the transition to fully electrified road transport.

Over the 2017-2022 period, the share of government spending in total spending decreased from over 20% to just under 10%. On a per-vehicle basis, government spending decreased from around USD 9 000 per electric car in 2017 to USD 4 000 in 2022, as sales increased more quickly than government spending. In 2023 and beyond, governments in major EV markets are gradually phasing out subsidies for electric cars, suggesting government spending will decrease in those markets. However, incentives in markets where adoption has been lower to date, including in EMDEs such as India, Indonesia and Thailand, could push overall government spending up.

In both China and Europe, government spending has increased significantly since 2017, especially in the wake of the Covid-19 pandemic. In China, government spending dipped in 2019-2020 but caught up quickly afterwards: it doubled between 2020 and 2021, and increased by nearly 70% in 2022 relative to 2021, exceeding USD 22 billion. In Europe, government spending boomed in 2020 and continued increasing through 2021 (up 50% year-on-year) and 2022 (up 20%), totalling more than USD 15 billion in 2022. In China, purchase incentives, which are based on driving range, have been decreasing. Although the average range of electric cars sold in China has been increasing, and accordingly more models have become eligible for subsidies, per-unit government support has been steadily decreasing, standing at around USD 4 000 in 2022. The majority of public support for electric cars comes from the vehicle purchase tax exemption rather than the subsidy. In Europe, per-unit support by governments has remained steady at around USD 6 000 over the 2017-2022 period, but could drop in 2023 and future years as subsidies decrease in major markets such as Germany, the United Kingdom and France.

Meanwhile, federal government spending in the United States has remained much lower than that in other major markets in the past few years, especially as major carmakers – mostly Tesla and General Motors – reached the cap on further subsidies. However, it increased from below USD 1 billion in 2020 to almost USD 2.5 billion in 2022 as more electric cars that are eligible to subsidies were sold than in previous years. While aggregate public support increased significantly, the IRA changed eligibility requirements for sales taking place between mid-August and end-2022. The IRA aims to promote EV manufacturing in North America, and as such the list of vehicles qualifying for subsidies shrank in the second half of 2022. Furthermore, while carmaker caps have been removed in 2023, they remained in place throughout 2022. As a result, public spending on a per-unit basis dropped from more than USD 3 000 in 2021 to USD 2 500 in 2022. The trend could be reversed in 2023 and beyond as the list of qualifying vehicles grows.

**Figure 2.8. Consumer and government spending on electric cars, 2017-2022**






Note: Government spending is the sum of direct central government spending through purchase incentives and foregone revenue due to taxes waived specifically for new electric cars. Only central government purchase support policies for electric cars are taken into account. Spending on charging is not included. Consumer spending is the total expenditure based on model price, minus government incentives. Excludes incentives for company cars. Values and trends may change slightly relative to previous publications following methodology improvements and better coverage of government support schemes.

Source: IEA analysis based on EV Volumes and country policy documents.

**Total global spending on electric cars stood at USD 425 billion in 2022, increasing by 50% relative to 2021, with government support accounting for a stable 10% share of the total.**

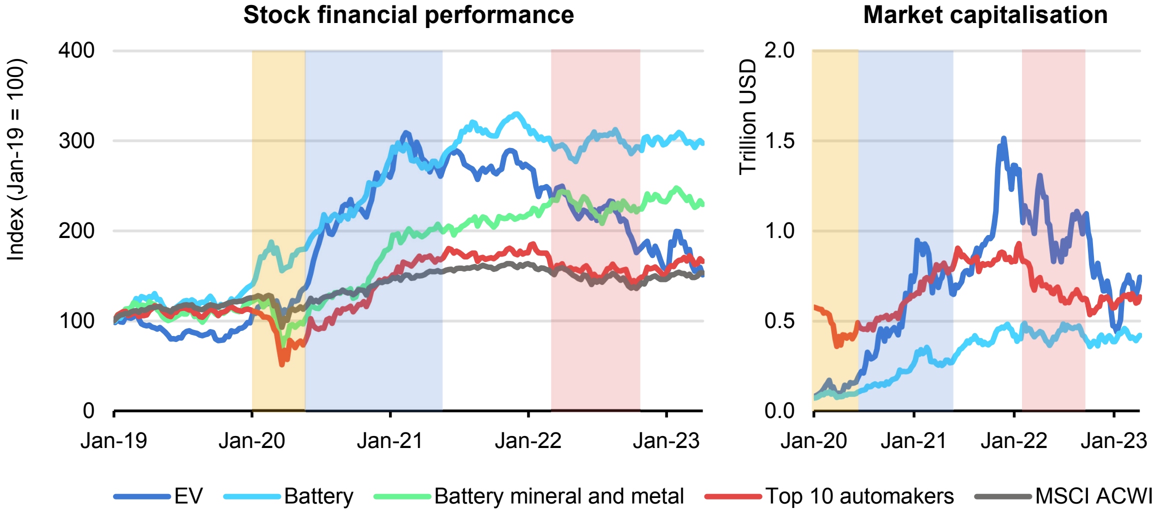
# Finance, venture capital and trade

## Financial performance of EV-related company stocks

### Competition is getting tougher for electric cars

While financial markets and investors have maintained confidence in the future of transport being electric, 2022 was a difficult year for EV companies. The stocks of EV-related companies had seen extraordinary growth in the past few years, including through the Covid-19 pandemic, consistently outperforming traditional carmakers since 2019. However, growth stalled in 2022 and financial markets were rationalised in the context of increased market maturity and tougher competition (especially in China with a downward price war for electric cars), and as a result of increased risks, geopolitical shocks, supply chain disruptions and higher inflation rates. The gap between pure-play EV companies and incumbent carmakers has narrowed accordingly.

**Figure 2.9. Performance of major car, battery and mining companies and market capitalisation, 2019-2023**





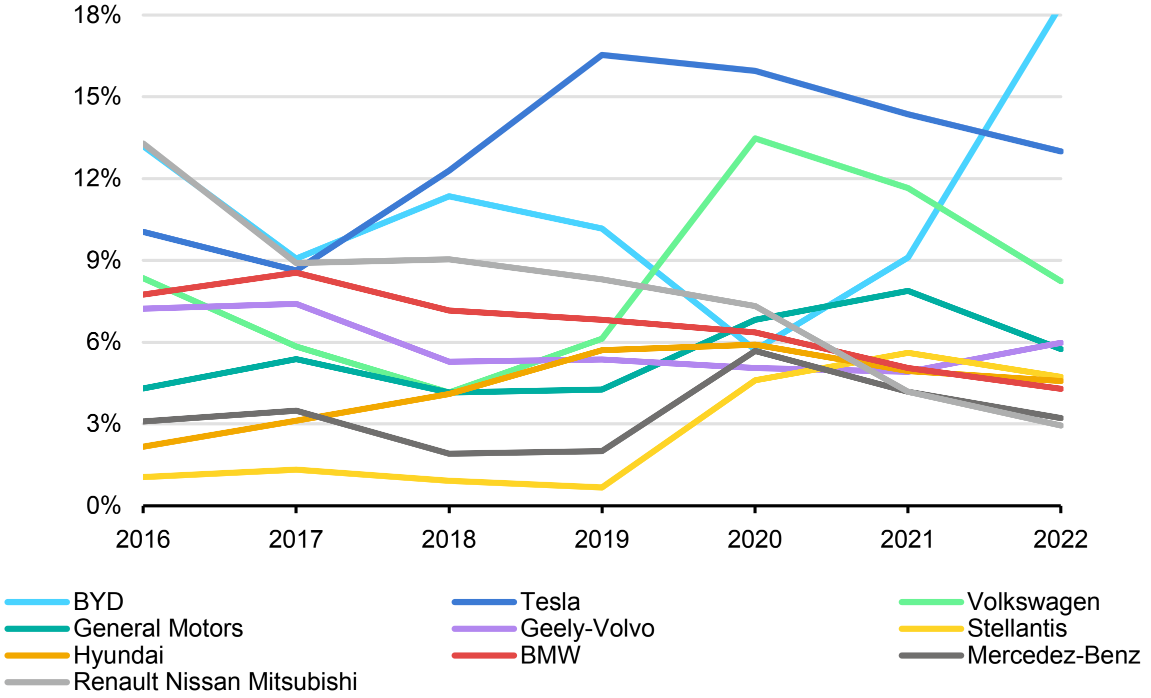

Notes: Data through Q1 2023 included. Performance is measured via arithmetic returns, which refer to the sum of quarterly returns on a given stock (capital gains and dividends). The area highlighted in yellow represents a credit crisis, and in blue, a recovery period for capital markets followed by the pandemic-induced credit shock in Q1 2020. The red highlight shows the months following Russia's invasion of Ukraine. Weekly financial performance of selected EV, battery and battery mineral and metal companies are plotted against the top 10 carmakers and the broader public equity market benchmark, MSCI All Country World Index (ACWI), at an index level. All indices except MSCI ACWI and for battery minerals and metals are equal-weighted, giving equal importance to each constituent company regardless of market capitalisation or share. The EV index consists of 14 pure-play EV companies (Tesla, Lucid, Rivian, NIO, Li Auto, XPeng, Fisker, Nikola, Arrival, Proterra, Lion Electric, Hyzon, Canoo, Hyliion) and the battery index of 7 battery manufacturing companies (LG Energy Solution, BYD, Contemporary Amperex Technology, Samsung SDI, Gotion High-tech, Eve Energy, Farasis Energy). The battery mineral and metal index includes more than 40 companies selected in the S&P Global Core Battery Metals Index. The top 10 carmakers include Toyota, Volkswagen, Kia Hyundai, General Motors, Ford, Nissan, Stellantis, Renault, and Mercedes-Benz. Financial performance and market capitalisation do not necessarily reflect actual profits or losses, but rather investor expectations of future returns.

Source: IEA analysis based on data from Bloomberg.

**Stocks of EV-related companies have outperformed those of incumbent car makers since 2019, but supply chain disruptions, increasing competition and market rationalisation are closing the gap.**

In 2022 the market capitalisation of EV companies shrank dramatically, falling from an all-time high at the end of 2021. This drop is almost entirely due to Tesla: the company's market capitalisation decreased from its peak at the end of 2021 to early 2023 by about USD 870 billion, which is more than the combined valuation of the selected top 10 incumbent carmakers early 2023. The company also heavily reduced vehicle prices repeatedly in 2023 to boost sales, with discounts of up to USD 34 000. However, Tesla remains the highest valued EV firm and the eighth most highly valued company in the world, with strong investor confidence. It ranks far ahead of competitors such as BYD, Li Auto and NIO, and other companies such as Rivian, Lucid Motors and XPeng, which struggled in 2022, as well as smaller players such as VinFast and truckmaker Lordstown Motors. As an example of a company that had difficulties in 2022, Rivian halted plans to produce electric vans with Mercedes-Benz in Europe, weakening confidence.

**Figure 2.10. Share of global electric car markets by selected carmakers, 2016-2022**






Notes: Market share in terms of electric car sales. Includes battery electric and plug-in hybrid electric cars.
Source: IEA analysis based on EV Volumes.

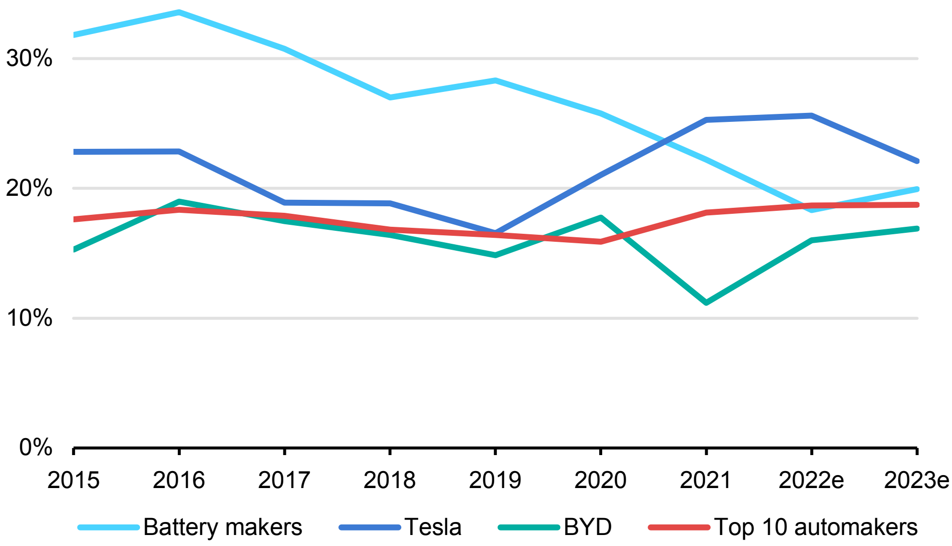
**In 2022, BYD and Tesla accounted for over 30% of global EV markets. BYD overtook Tesla in terms of sales, while competition remains fierce among incumbent automakers.**

Increasing competition in EV markets is also influencing investor confidence and financial performance. Incumbent carmakers are diversifying their fleets in order to comply with strengthened policies, such as $CO_2$ standards, or to reach new consumers, yet are struggling to catch up with EV companies. New market entrants – especially from China – that aim to capture a share of booming EV markets are also increasing pressure on incumbent carmakers. Carmakers that do not have sufficiently attractive electric car offerings are likely to face issues in the growing EV market in the near future.

In 2022, the world's largest carmakers in terms of ICE car sales (Volkswagen, General Motors, Toyota, Stellantis, Honda, Renault-Nissan-Mitsubishi, Ford, Hyundai-Kia, Geely, Mercedes-Benz and BMW) accounted for 40% of global electric car sales. In 2015, the same companies accounted for 55%. Over the same period, the combined market share of just two companies, Tesla and BYD, increased from 20% to over 30%. In 2015, Chinese carmakers accounted for 35% of global EV sales, and this share increased to 45% in 2022, led by BYD (18%), Geely (6%), and a number of other firms including SAIC, Chery, Changan, Dongfeng, Hozon, CHJ, Great Wall, NIO, Xiaopeng and Leap. Geely, for example, saw revenue increase by nearly 50% in 2022 relative to 2021, and net income by

10%, with expectations of a 15% growth in electric car sales in 2023. Incumbent Chinese carmakers are also adapting their strategies, such as Great Wall Motor, which in March 2023 announced a new strategy focusing on EVs, after sales dropped in 2022 by nearly 20% relative to 2021.

**Figure 2.11. Gross margin of selected companies, 2015-2023**






Notes: Gross margin refers to gross profits as a share of revenues. Battery makers include LG Energy Solution, CATL, Samsung SDI, Gotion Hi-Tech and Eve Energy, each having equal weight in the sample. Data for 2022 and 2023 are based on company and financial analyst expectations.
Source: IEA analysis based on Bloomberg data.

**EV battery company margins have been steadily decreasing since 2015. On average, Tesla has been outperforming incumbent automakers.**

## Companies seek value upstream in batteries and critical minerals

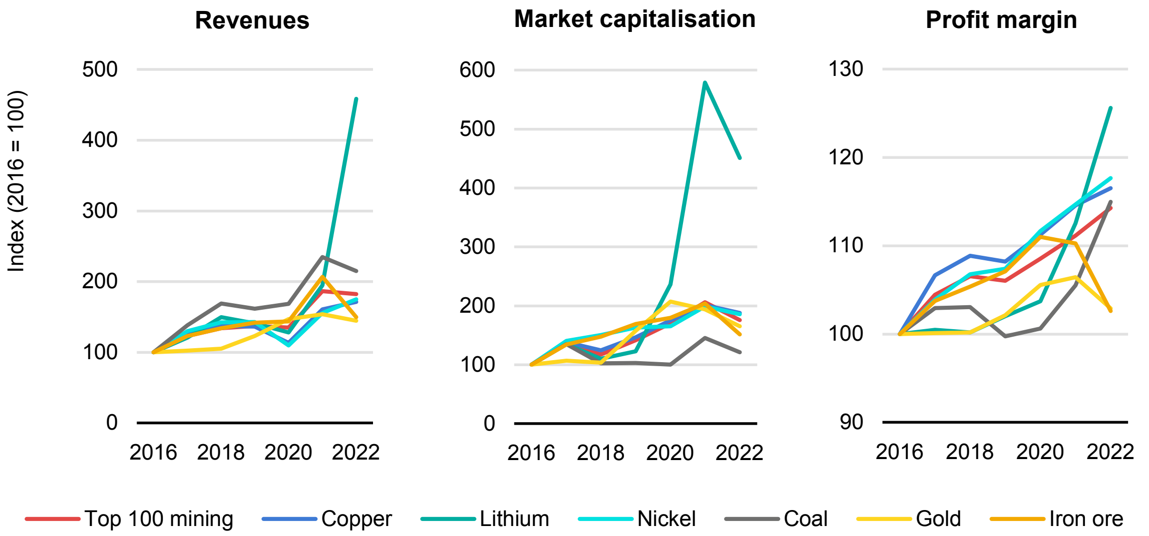
As battery demand continues to increase, battery makers are seeing strong financial stock performance, outperforming that of EV makers in 2022, in spite of supply chain disruptions and critical mineral price volatility. Their market capitalisation has also been steadily increasing since 2020, suggesting strong investor confidence in future returns and growth. In 2022, CATL, which accounts for nearly 40% of the world's market for EV cells, far ahead of LG Energy and BYD, saw net income nearly double relative to 2021 as EV sales increased. Financial analysts suggest that the market for lithium-ion batteries could boom from USD 90 billion in 2022 to USD 250 billion in 2030.

However, growth in market capitalisation was slower and financial performance not as high in 2022 as it was over 2020-2021. The gross profit margin of major battery makers has been steadily decreasing from more than 30% in 2015 to about 20% in

2022. This is due not only to increasing competition in the market, but also to higher raw material and commodity prices (e.g. for lithium, cobalt and nickel), which tend to boost the profits of firms involved in extraction while putting pressure on the firms purchasing the materials for refining and to manufacture products such as batteries.

As carmakers compete to secure battery supplies, they are increasing investments for in-house battery production for increased vertical integration. For example, Tesla is increasing its focus on battery manufacturing, and introducing innovative concepts expected to cut costs. Toyota, GM, Hyundai and Ford are investing USD 2.5 billion, USD 6.6 billion, USD 5.5 billion and USD 11.4 billion respectively in EV and battery manufacturing sites in the United States alone. To secure supply of critical minerals needed for batteries, carmakers are also partnering with mining companies or even directly investing in mining operations. Ford partnered with Vale and Huayou to build a processing plant in Indonesia with capacity to process 120 kt of nickel per year; Stellantis invested EUR 50 million (USD 55 million) in the German lithium producer Vulcan, and Tesla signed agreements with mining companies such as Albemarle, for lithium, and Prony Resources, for nickel.

**Figure 2.12. Key financial indicators of top mining companies, 2016-2022**






Notes: Top 100 mining refers to companies with the highest market capitalisation in 2022 and with a share of revenues from mining of more than 70% of total revenues. The same rules apply to selected top coal companies. For copper, lithium and nickel mining, each sample contains about 15-20 companies, and 30 for iron ore, with over 50% of revenues from corresponding mining activities. Revenues and market capitalisation are respectively cumulative over the sample of companies, in current US dollars. Three-year moving non-weighted averages over the sample of companies are used for profit margin, excluding single outlier data points.

Source: IEA analysis based on Bloomberg data.

**Market capitalisation, revenues and profit margin of major critical mineral companies are increasing rapidly, especially in lithium, often outperforming conventional mining companies.**

The past two years have been very profitable for the mining industry. The revenues of the top 40 mining companies increased by 30% between 2020 and

2021, and their net profit by 130%. In the context of the energy transition, critical mineral demand is of particular interest for the mining sector. In 2021, the combined value of critical minerals used for clean technologies was around USD 75 billion. Assuming prices stay constant, by 2050, the needs of the energy transition could increase this value fivefold in the Net Zero by 2050 Scenario. This prospect makes the critical mineral sector especially attractive for investors. Indeed, the market capitalisation of lithium, copper and nickel mining companies grew by 350%, 90% and 85% respectively between 2016 and 2022, compared with 20% for coal producers and 75% for the top 100 mining companies over the same period. This reflects increasing appetite for critical metal mining and confidence in future returns. There are also new entrants in this sector, just as in other steps of the EV supply chain. In March 2023, Lithium Royalty Corp., a Canadian company established in 2018, raised USD 109 million in the biggest initial public offering (IPO) in the country since May 2022.

Competition is pushing some mining companies to also seek vertical integration: downstream in mineral processing for miners, and upstream in mining for refiners. Albemarle and Covalent Lithium, for example, are building processing sites in Australia to turn the spodumene they extract into lithium hydroxide. In total, lithium processing projects have received USD 5 billion in Western Australia alone over the past three years. As a result of mining companies expanding operations downstream, refiners are under pressure, with profit margins shrinking, especially in China where there is historic reliance on Australian spodumene. As a result, some refiners are moving upstream as a means to secure raw materials, but lead times to develop new mines can be long.

Looking to the future, vertical integration on both sides of EV supply chains – from miners downstream and from carmakers upstream – could help decrease manufacturing costs and prices for consumers accordingly, but could also lead to greater market concentration.

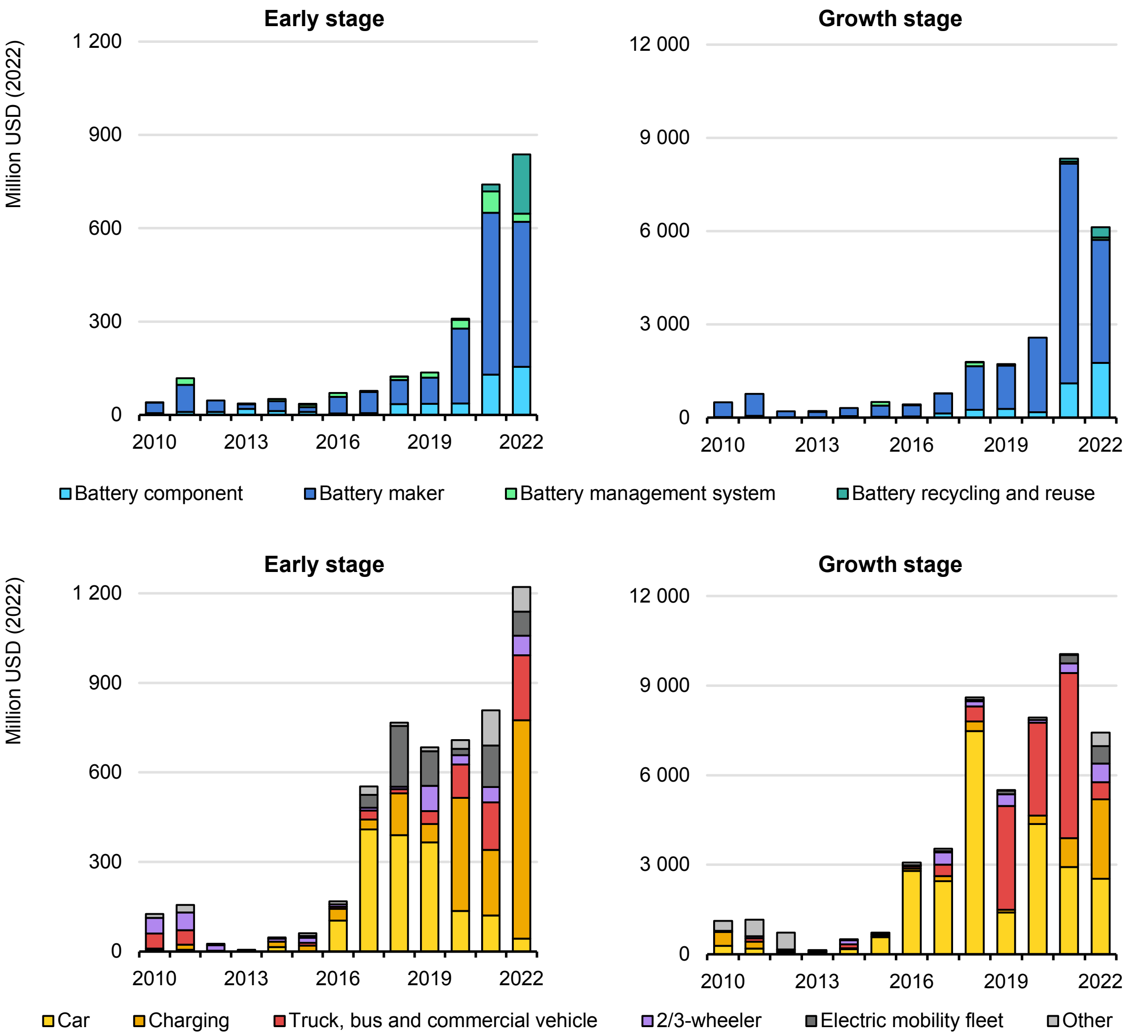
## Venture capital investments in EV start-ups

In the past decade, venture capital (VC) funding for clean energy start-ups has boomed, particularly in electromobility. Financial investors such as banks and VC or private equity funds see in EV start-ups a potential for future returns with high exit values. Many companies, including major incumbent carmakers, also provide funding to start-ups through corporate VC to develop new technology or to acquire concepts developed by new entrants, as a means to maintain a competitive edge and secure their own positioning in car markets. While in the past century most major carmakers typically developed ICE technology in-house, through R&D and manufacturing innovation, investing in start-ups is now a notable trend, illustrating a new way of innovating, and the need to catch up with quickly evolving markets and regulatory environments.

In 2022, VC investments in early-stage start-ups (i.e. seed and series A, referring to the first rounds of financing and the earlier stages of start-up development) developing battery technologies increased by 15% relative to 2021 to nearly

USD 850 million. VC investments in start-ups producing vehicles and charging technologies increased by 50% to USD 1.2 billion. The increase was particularly high in the charging segment, which saw an all-time high among early-stage funding at USD 730 million. There was also a notable increase in funding for battery recycling and reuse, which stood at USD 200 million, an eightfold increase relative to 2021.

**Figure 2.13. Early-stage (left) and growth-stage (right) venture capital investments in batteries (top) and electric mobility (bottom) start-ups, by technology, 2010-2022**





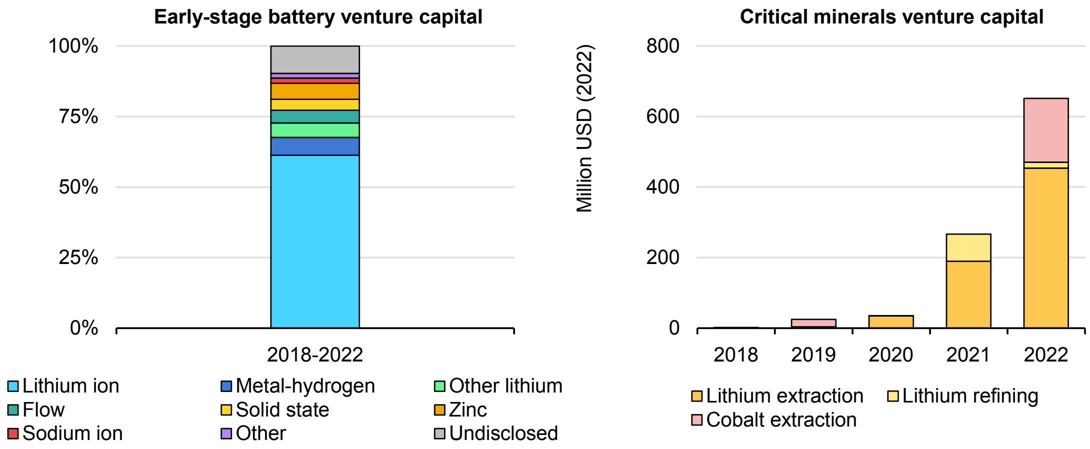

Notes: Early-stage deals refer to seed and series A, growth-stage to series B and growth equity deals. “Other” includes electric vehicle components and manufacturing (excluding electric motors that are not specific to road transport), digital and software products otherwise excluded, hybrid car makers, EV project development and operation, and EV finance.
Source: IEA analysis based on Cleantech Group i3 database.

**Early-stage VC investments in battery and EV charging start-ups have boomed in the last three years, as electric car maker companies mature and attract growth-stage funding.**

Meanwhile, early-stage electric car manufacturers are raising less and less money as EV markets mature. Start-ups developing new electric cars were the first beneficiaries of booming EV VC in around 2015, but less and less capital is provided to new entrants as competition increases and major incumbents accelerate electrification. The 2015-2020 period also saw major VC activity in China, but this has now declined as the market consolidates around frontrunners – many of which were start-ups less than a decade ago.

Early-stage investors are instead looking for new investment opportunities in the value chain, either upstream (such as batteries or critical minerals) or downstream (such as charging or recycling). Companies developing lithium-ion batteries still dominate, accounting for 60% of early-stage VC investments in the battery segment over 2018-2022, but new chemistries are on the rise, both lithium- and non-lithium-based. Critical minerals VC is also booming as metal demand surges, standing at around USD 650 million in 2022 from close to zero in 2018-2019, before the Covid-19 pandemic.

**Figure 2.14. Venture capital investments in start-ups developing battery technologies, by chemistry, 2015-2022**





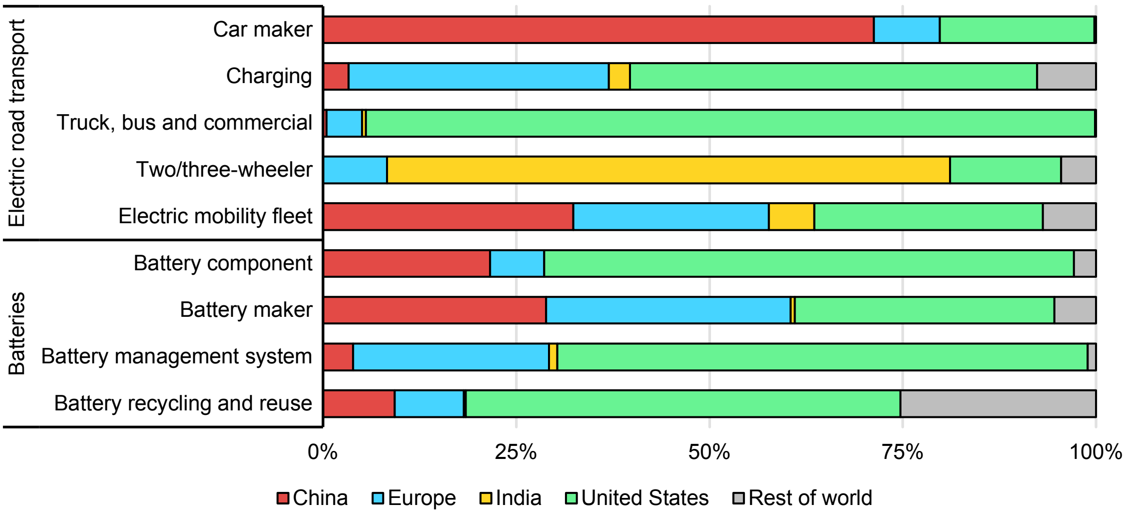

Notes: "Other lithium" includes lithium metal-based and lithium-sulphur batteries. "Flow" includes redox flow (including vanadium-based) as well as other flow batteries (e.g. iron-based, hydrogen-bromine). "Other" includes lead acid, metal-air, organic materials and polymer batteries. Critical minerals venture capital is not exclusive to electric mobility applications.
Source: IEA analysis based on Cleantech Group i3 database.

**Lithium-ion makes up 60% of early-stage battery venture capital, but many alternative chemistries are in development. Critical minerals venture capital is booming as metal demand surges.**

One notable development in 2022 was the drop in growth-stage investments (i.e. series B and growth equity, which refers to the later rounds of financing as start-ups increase activity). These fell by 25% relative to 2021 both for batteries, to USD 6.1 billion, and for vehicles and charging, to USD 7.4 billion, due to lower investments in battery and truck manufacturers. Putting things into perspective, 2021 was an exceptional year for batteries, as investments caught up following the Covid-19 pandemic; and 2022 was still twice as high as ever before. As such, the downward trend in 2022 might not be of immediate concern. For trucks, the 2019-2021 period was a fruitful one in growth equity VC markets, but investor appetite may be drying up following concerns over the performance of leading companies.

Over the 2018-2022 period, China accounted for 70% of VC investments in electric car start-ups, while the United States led in investments in charging, trucks and battery components. Funding for battery making start-ups was evenly distributed across China, Europe and the United States. India had a strong lead in two-wheelers, the only EMDE beyond China with a significant presence in global EV VC.

**Figure 2.15. Share of total cumulative venture capital investment in electric mobility technology areas by country or region, 2018-2022**





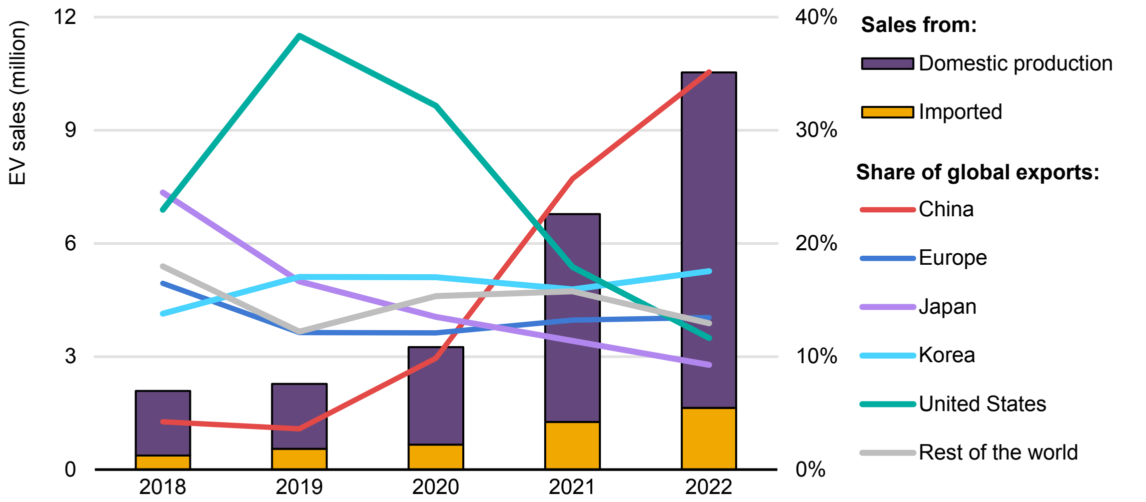

Notes: Includes both early- and growth-stage deals. The country or region is determined based on company headquarters and not the origin of investors. "Europe" includes European Union countries, Norway, Switzerland and the United Kingdom.
Source: IEA analysis based on Cleantech Group i3 database.

**Global venture capital markets are often regionally concentrated, such as in China for electric cars, in the United States for heavy-duty vehicles and batteries, and in India for two/three-wheelers.**

## Trade in EV-related goods

Given that China is the largest electric car market, it comes as no surprise that it is also the largest producer of EVs: China imports under 1% of the electric cars sold in the country. The focus of China's EV policy on domestic sales has also attracted international car manufacturers to set up production in China. Around 25% of all the electric cars manufactured in China in 2022 were made by foreign carmakers, and since EV production costs in China are relatively low, those carmakers, as well as domestic ones, also export part of their Chinese output. China is therefore a leading exporter of electric cars, representing over 35% of electric car exports, as well as of batteries. In 2022, the share of global battery manufacturing capacity located in China was around 75%.

**Figure 2.16. Global electric car sales and share of selected regions in global trade, 2018-2022**



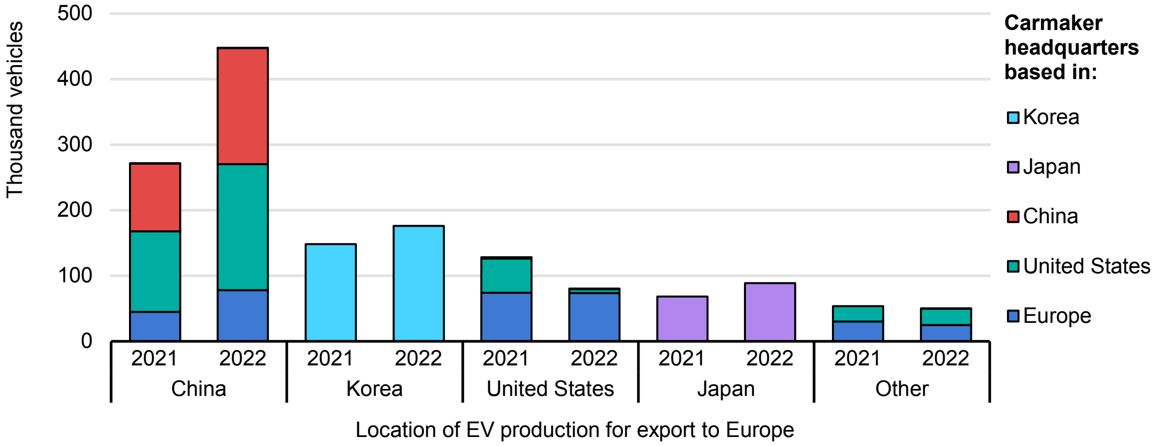



Note: The share of global exports represents the volume of exported electric cars from a region divided by the global exported volume. EV sales between countries within the same regional group (i.e. Europe and rest of the world) are considered domestic production.
Source: IEA analysis based on EV Volumes.

**Around 15% of electric vehicles are traded internationally, with China being the largest exporter.**

Europe is China's largest trade partner for both electric cars and their batteries. Indeed, over the past year the share of electric cars sold in the European market coming from China increased from about 11% in 2021 to about 16% in 2022. However, almost 20% of the electric cars shipped from China for sale in Europe were manufactured by European OEMs with plants in China; another 40% were American cars produced in China.

**Figure 2.17. Electric car imports to Europe by country of production and manufacturer headquarters, 2021-2022**





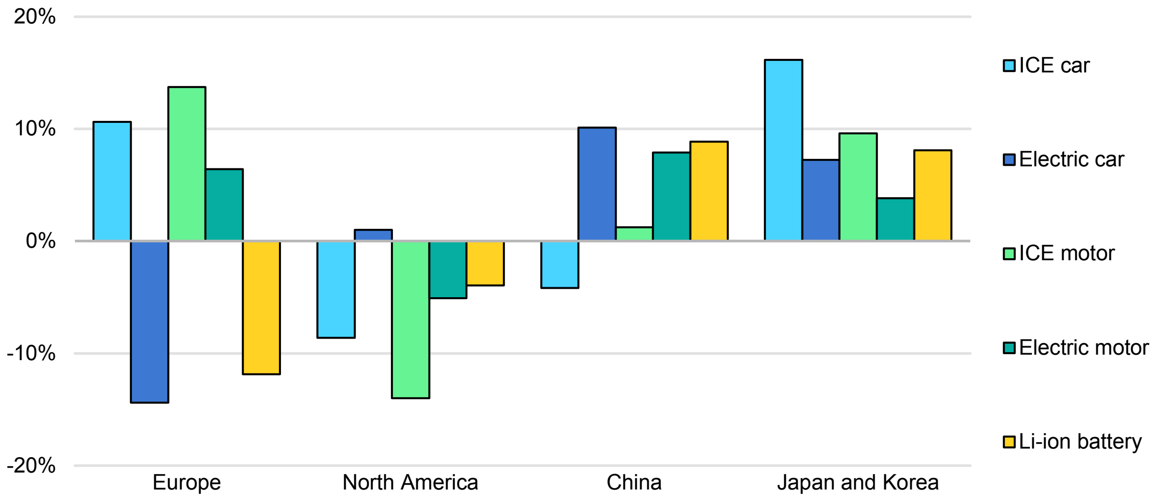

Source: IEA analysis based on EV Volumes.

**European imports of electric cars manufactured in China have increased by almost 175 000 over the past year, though only 40% of these come from Chinese OEMs.**

Over the past five years, the share of global electric car exports coming from China has increased more than eightfold, with China becoming the largest exporter in 2021 and the gap further widening in 2022. The share of electric car exports from the United States peaked in 2019 and has since fallen below the levels exported from China, Korea and Europe. While the number of electric cars traded globally has continued to increase over time, the share of exports out of total electric car sales has decreased over the past four years.

The transition to electric mobility is shifting and will continue to shift trade balances. Historically, Europe has been a net exporter of ICE cars (by value), while China has been a net importer. However, with the transition to electric cars, the size of the ICE car market is expected to shrink over time, while the EV market grows. China, Japan and Korea are all net exporters of electric cars, electric motors and Li-ion batteries, and are well positioned to benefit from a growing electric car market. Nonetheless, these battery-exporting countries are also strongly dependent on the import of critical minerals, such as lithium, cobalt and nickel.

**Figure 2.18. Trade balance along car supply chains in selected countries/regions, 2021**






Notes: ICE = internal combustion engine. Trade balance here is the net export divided by global trade in monetary value of a given commodity, a negative value meaning that the region is a net importer. Trade inside a region is excluded. The Harmonized System codes used for each value are as follows - ICE car: 870321, 870322, 870323, 870324, 870331, 870332 and 870333; EV car: 870380; ICE motor: 840734; Electric motor: 850153; Li-ion battery: 850650. Note that those motors and batteries may not be exclusively used as car components.

Source: IEA analysis based on BACI international trade database.

**The transition to electric vehicles is changing the trade balance along the supply chain for cars.**

# Prospects for electric vehicle deployment

Several pathways to electrify road transport in the period to 2030 are explored in this section. First, deployment of electric vehicles (EVs) is projected by region and road segment for the Stated Policies and Announced Pledges scenarios, and globally by segment for the Net Zero Emissions by 2050 Scenario. These projections are then compared to announcements by original equipment manufacturers (OEMs). Then the corresponding battery demand is projected, followed by roll-out requirements for charging infrastructure. Finally, the impacts of EV deployment are assessed, including increased electricity demand, oil displacement, implications for tax revenues, and net well-to-wheels GHG emissions.

## Outlook for electric mobility

### Scenarios

A scenario-based approach is used to explore road transport electrification and its impact, based on the latest market data, policy drivers and technology perspectives. Two IEA scenarios – the Stated Policies and Announced Pledges scenarios – inform the outlooks, which are examined in relation to the Net Zero Emissions by 2050 Scenario at the global level.[1] These scenarios are based on announced policies, ambitions and market trends through the first quarter of 2023.

The purpose of the scenarios is to assess plausible futures for global EV markets and the implications they could have. The scenarios do not make predictions about the future. Rather, they aim to provide insights to inform decision-making by governments, companies and stakeholders about the future of EVs.

These scenario projections incorporate GDP and population assumptions from the International Monetary Fund (2022) and United Nations (2022), respectively.

#### Stated Policies Scenario

The Stated Policies Scenario (STEPS) reflects existing policies and measures, as well as firm policy ambitions and objectives that have been legislated by

[1] The projections in the Stated Policies and Announced Pledges scenarios are based on historical trends through the end of 2022 as well as stated policies and ambitions as of the end of March 2023. The Net Zero Emissions by 2050 Scenario is consistent with the World Energy Outlook 2022 publication.

governments around the world. It includes current EV-related policies, regulations and investments, as well as market trends based on the expected impacts of technology developments, announced deployments and plans from industry stakeholders. The STEPS aims to hold up a mirror to the plans of policy makers and illustrate their consequences.

## Announced Pledges Scenario

The Announced Pledges Scenario (APS) assumes that all announced ambitions and targets made by governments around the world are met in full and on time. With regards to electromobility, it includes all recent major announcements of electrification targets and longer-term net zero emissions and other pledges, regardless of whether these have been anchored in legislation or in updated Nationally Determined Contributions (NDCs). For example, the APS assumes that countries that have signed on to the Conference of the Parties (COP 26) declaration on accelerating the transition to 100% zero emissions cars and vans will achieve this goal, even if there are not yet policies or regulations in place to support it. In countries that have not yet made a net zero emissions pledge or set electrification targets, the APS considers the same policy framework as the STEPS. Non-policy assumptions for the APS, including population and economic growth, are the same as in the STEPS.

The difference between the APS and the STEPS represents the "implementation gap" that exists between the policy frameworks and measures required to achieve country ambitions and targets, and the policies and measures that have been legislated.

## Net Zero Emissions by 2050 Scenario

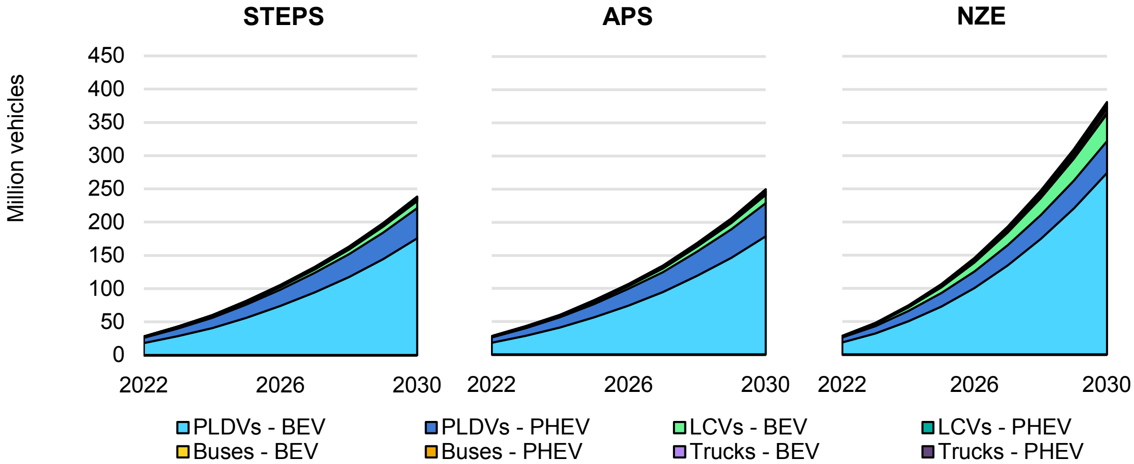
The Net Zero Emissions by 2050 Scenario (NZE Scenario) is a normative scenario that sets out a narrow but achievable pathway for the global energy sector to achieve net zero $CO_2$ emissions by 2050. The scenario is compatible with limiting the global temperature rise to 1.5°C with no or limited temperature overshoot, in line with reductions assessed by the Intergovernmental Panel on Climate Change in its Special Report on Global Warming of 1.5°C. There are many possible paths to achieve net zero $CO_2$ emissions globally by 2050 and many uncertainties that could affect them. The NZE Scenario is therefore *a* path and not *the* path to net zero emissions.

The difference between the NZE Scenario and the APS highlights the "ambition gap" that needs to be closed to achieve the goals under the 2015 Paris Agreement.

# Electric vehicle fleet to grow by a factor of eight or more by 2030

The total fleet of EVs (excluding two/three-wheelers) grows from almost 30 million in 2022 to about 240 million in 2030 in the Stated Policies Scenario (STEPS), achieving an average annual growth rate of about 30%. In this scenario, EVs account for over 10% of the road vehicle fleet by 2030. Total EV sales reach over 20 million in 2025 and over 40 million in 2030, representing over 20% and 30% of all vehicle sales, respectively.

**Figure 3.1. Electric vehicle stock by mode and scenario, 2022-2030**



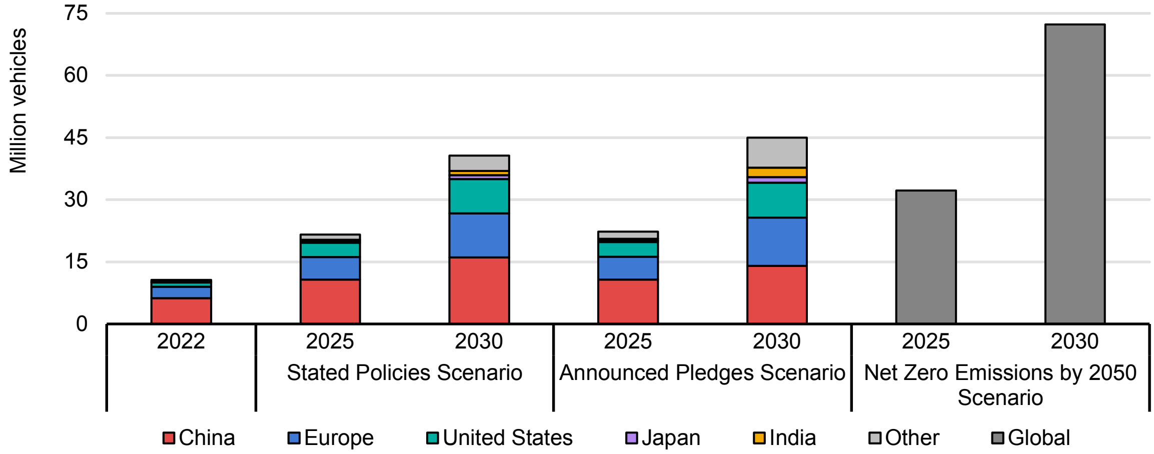



Notes: STEPS = Stated Policies Scenario; APS = Announced Pledges Scenario; NZE = Net Zero Emissions by 2050 Scenario; BEV = battery electric vehicle; PHEV = plug-in hybrid electric; PLDV = passenger light-duty vehicle; LCV = light commercial vehicle.

**EV deployment commensurate with government pledges is only 5% above what stated policies would imply by 2030.**

In the Announced Pledged Scenario (APS), based on announced government targets and pledges that go beyond existing policies, the global EV fleet reaches almost 250 million in 2030, around 5% higher than in the STEPS. The average annual growth rate in the APS is nearly 35%, with the result that one in seven vehicles on the road is an EV in 2030. Total EV sales reach 45 million in 2030, representing over 35% of all vehicle sales.

**Figure 3.2. Electric vehicle sales by region, 2022-2030**

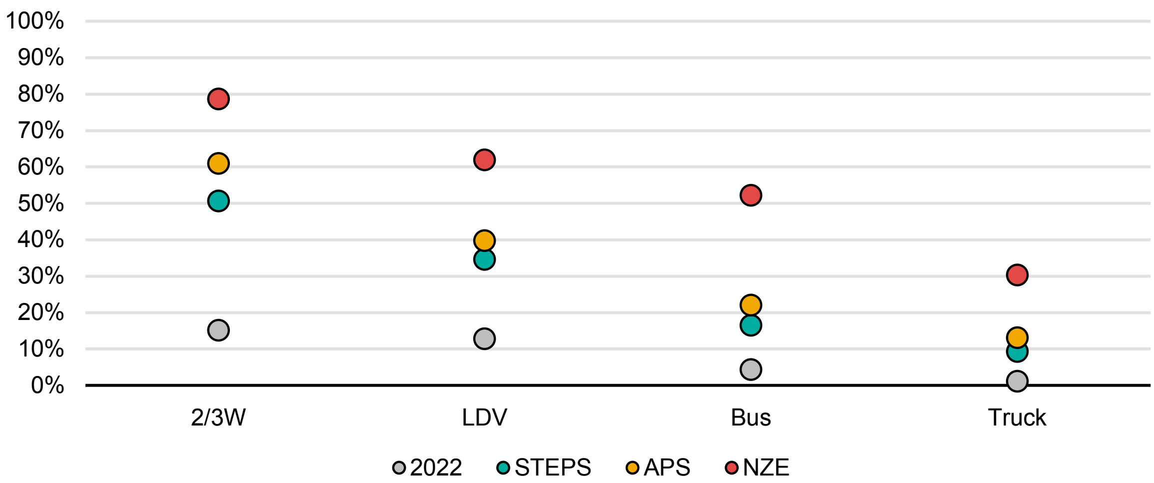





**Global EV sales increase around fourfold from 2022 to 2030 under both stated policies and announced ambitions.**

The global EV sales share in 2030 in the STEPS is about half that in the NZE Scenario, in which the fleet of EVs grows more rapidly, at an average annual rate of around 40%, reaching 380 million EVs on the road in 2030. Electric vehicle sales reach over 30 million in 2025 and over 70 million in 2030, a total of approximately 30% and 60% of all vehicle sales, respectively.

**Figure 3.3. Electric vehicle sales shares by mode and scenario, 2030**






Notes: 2/3W = two/three-wheeler; LDV = light-duty vehicle; STEPS = Stated Policies Scenario; APS = Announced Pledges Scenario; NZE = Net Zero Emissions by 2050 Scenario.

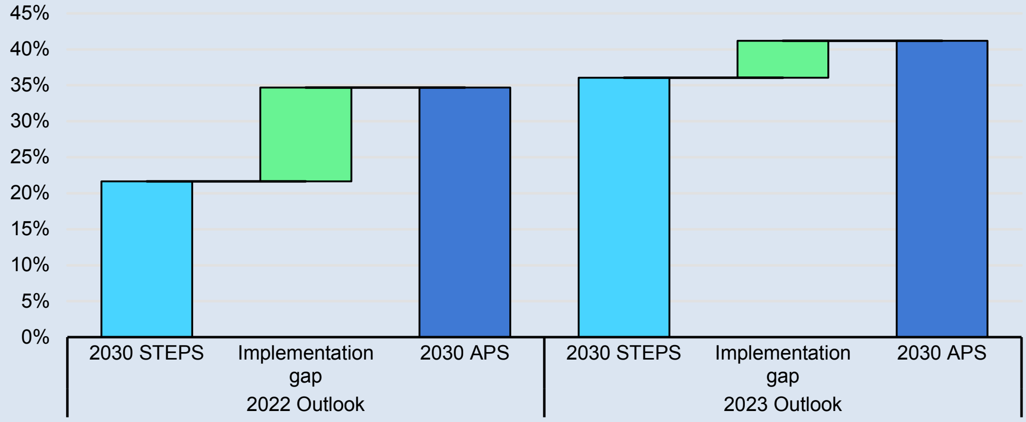
**Existing policies are projected to yield market shares almost in line with country pledges across all modes of transport.**

**Box 3.1 Closing the implementation gap: how EV policy is catching up with targets**

Targets and ambitions for clean energy technology deployment are generally more easily formulated than they are achieved, but in the case of EVs, the momentum is clearly on the side of achievement. Strong market uptake in 2022, combined with major policy announcements over the past year, have led to a significant upward revision of EV deployment to 2030 in the STEPS presented in this edition of the Global EV Outlook compared to the 2022 edition. The projected sales shares of EVs based on stated policies and market trends are now coming close to country stated ambitions for EVs, meaning that the policy implementation gap – the difference between country deployment ambitions and the policies currently in place – in the 2023 Outlook is much smaller than in the 2022 edition.

This is most notable for light-duty vehicles, where recent policies such as the US Inflation Reduction Act (IRA) and new EU $CO_2$ standards for cars and vans have resulted in a significantly higher EV sales share in 2030 in the STEPS. In this year's Outlook, under announced ambitions, the electric car sales share exceeds 40% in 2030 compared to 35% under stated policies: this gap has more than halved in the past year. For trucks and buses, the EV sales share in 2030 in the STEPS also increased faster than ambition. As a result, the gap between ambition and legislated policies for HDVs is half of what it was in the 2022 Outlook.

**Electric car sales share implementation gap, 2030**






Realising the potential of EVs to support government climate (as well as energy security) ambitions is thus almost in reach under current policy frameworks. In particular, the gap between policy and ambition has closed in three of the largest EV markets: the European Union, the United States and China. At the global level, oil displacement by EVs reaches 1.8 million barrels per day in 2025 (over 5 mb/d in 2030) under stated policies. As a result, global demand for oil-based road transport fuels will peak by 2025.

The momentum seen over the past year in terms of increasing EV sales and new supportive policies being introduced, along with funding designated for the necessary infrastructure (for example, the USD 5 billion allocated in the US IIJA to support EV charger installation), have also led industry players to invest more in EV supply chains. Notably, planned EV battery manufacturing expansions are set to increase capacity more than fourfold, reaching 6.8 TWh/year of production capacity in 2030, 65% higher than is needed to enable the level of EV deployment in the APS. Taken together, this suggests that even higher EV deployment than is implied by the APS is achievable by 2030 if policy efforts are sustained and critical potential bottlenecks (such as around recharging infrastructure and mining) are addressed early on.

## Light-duty vehicles

Light-duty vehicles (LDVs), including passenger light-duty vehicles (PLDVs) and light commercial vehicles (LCVs), continue to make up the majority of electric vehicles (excluding two/three-wheelers). This is a result of strong policy support, including light-duty vehicle fuel economy or $CO_2$ standards, the availability of EV models, and the size of the LDV market. In the STEPS, electric LDV sales are projected to reach over 20 million in 2025, doubling the number of sales in 2022, and to quadruple to 40 million in 2030. The sales share of electric LDVs thus increases from 13% in 2022 to over 20% in 2025 and around 35% in 2030. The stock of electric LDVs reaches about 230 million in 2030, meaning that about one in every seven LDVs on the road is electric.

In the APS, the fleet of electric LDVs reaches over 240 million in 2030, a 15% stock share. Of these, 230 million are electric PLDVs, with only 6% being LCVs. Sales of electric LDVs reach almost 45 million in 2030 in the APS, representing a sales share of 40%. These results reflect government electrification ambitions and net zero pledges, including the 2021 COP 26 declaration target to achieve 100% zero-emission LDV sales by 2040, and by 2035 in leading markets, which 40 national governments have committed to.

In the NZE Scenario, the sales share of electric LDVs reaches 30% in 2025, four years earlier than in the STEPS. In 2030, the sales share is over 60%, about 80% higher than in the STEPS and 55% higher than in the APS.

## Buses

Governments have made significant progress in electrifying public bus fleets. In 2022, there were more than 800 000 electric buses on the road, representing over 3% of all buses. As such, buses are the most electrified road segment, excluding two/three-wheelers. In the STEPS, the electric bus fleet reaches 1.4 million in 2025 and 2.7 million in 2030, at which point around one in ten buses will be electric. In the near term, electrification is expected to progress most rapidly within the publicly owned urban bus fleet, which is covered by government procurement regulations and, in some cases, government funding. For example, Canada is aiming to put 5 000 electric public and school buses on the road by the end of 2025 via the CAD 2.75 billion Zero Emission Transit Fund.

In the APS, the electric bus fleet exceeds 3 million in 2030, reaching a stock share of over 10%. In 2030, about a quarter of buses sold are electric, which is about 35% higher than the sales share in the STEPS. In part, this increase is due to the proposed EU heavy-duty vehicle $CO_2$ standards, which would require 100% zero-emission city bus sales from 2030. In the NZE Scenario, the electrification of buses is even more rapid, with one in two buses sold in 2030 being electric.

## Medium- and heavy-duty trucks

Medium- and heavy-duty trucks are more difficult to electrify than other road segments, due in part to the size, weight and cost of the batteries needed to fully electrify this segment. However, progress is being made: around 320 000 electric trucks were on the road in 2022. By 2030, the fleet of electric trucks reaches almost 3.5 million in the STEPS, over 3% of the total truck fleet.

In the APS, the stock of electric trucks exceeds 4 million in 2030, a stock share of 4%. Electric truck sales increase from a negligible share today to over 9% in the STEPS in 2030 and 13% in the APS. The increased sales in the APS are driven in particular by the Global Memorandum of Understanding (MoU) on Zero-Emission Medium- and Heavy-Duty Vehicles, through which 27 countries have now pledged to reach 30% zero-emission medium- and heavy-duty vehicle[2] sales by 2030 and 100% by 2040. In addition, the European Union has proposed HDV $CO_2$ standards that would require a 45% reduction in emissions in 2030 compared to 2019 levels.

In the NZE Scenario, electric trucks reach 30% of sales in 2030, which is aligned with the Global MoU on Zero-Emission Medium- and Heavy-Duty vehicles. However, this sales share is still two-and-a-half times that in the APS, and over three times that in the STEPS.

## Two/three-wheelers

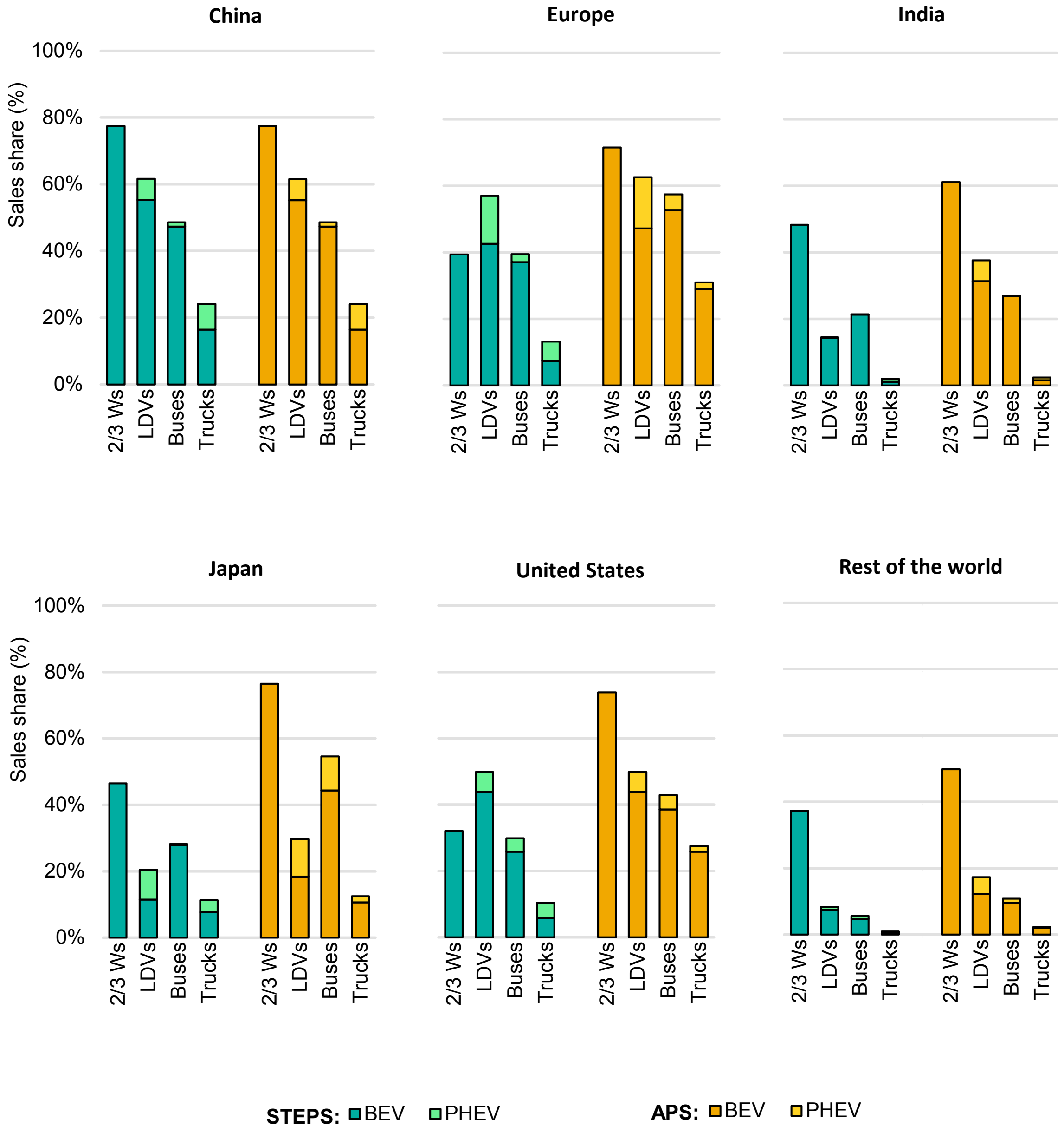
Two/three-wheelers are currently the most electrified road transport segment. Given the vehicles' light weight and limited daily driving distance, battery electrification is relatively easy and makes economic sense on a total cost of ownership basis in many regions. In 2022, the electric two/three-wheeler fleet totalled over 50 million, reaching a stock share of around 7%.

In the STEPS, the fleet of electric two/three-wheelers reaches 220 million in 2030, or a quarter of the total two/three-wheeler fleet. In the APS, the stock grows to 280 million, and almost 30% of all two/three-wheelers are electric. The electric sales share in 2030 reaches 50% in the STEPS and 60% in the APS. In the NZE Scenario, the electric two/three-wheeler sales share reaches almost 80% in 2030.

[2]Includes buses.

# The implementation gap between stated policies and country ambitions is shrinking in most major electric vehicle markets

**Figure 3.4. Electric vehicle sales shares by mode and region in the Stated Policies and Announced Pledges scenarios, 2030**






Notes: STEPS = Stated Policies Scenario; APS = Announced Pledges Scenario; 2/3Ws = two/three-wheelers; LDVs = light-duty vehicles; BEV = battery electric vehicle; PHEV = plug-in hybrid electric vehicle. The countries included in Europe are listed in documentation related to IEA's Global Energy and Climate Model. Regional projected EV sales and sales shares data can be explored in the interactive Global EV Data Explorer.

**With two/three-wheelers continuing to reign in EV markets around the world, announced pledges are pushing EV market shares for LDVs and buses above the 40% mark by 2030 in almost all major markets.**

## China

China once again exceeded expectations for electric car sales in 2022, reaching a sales share of around 29%. As such, the government's target of 20% new energy vehicle sales in 2025 was comfortably met three years ahead of time. China has gradually reduced its purchase subsidies for EVs since 2017, but electric car sales have continued to increase strongly. It is expected that sales will continue to grow due, in part, to the increasing availability of affordable EV models, despite 2023 being the first year without any subsidy.

The sales share of electric cars and vans reaches almost 45% by 2025 in the STEPS, and over 60% in 2030. Given that the government's electrification targets have already been met, and that 60% electric light-duty vehicle sales in 2030 is on track with China's carbon neutrality by 2060 pledge, the electric LDV sales shares to 2030 in the APS are the same as in the STEPS. In fact, 60% electric LDV sales in 2030 is in line with the global share in the Net Zero Emissions by 2050 Scenario.

China is the global leader in terms of electric share of the two/three-wheeler fleet, with more than one-third of all two/three-wheelers being electric. In both the STEPS and APS, China is expected to remain the leader in electric two/three-wheeler sales. In the STEPS, the sales share of electric two/three-wheelers reaches almost 80% in 2030. The APS follows the same trends to 2030.

China also has one of the highest stock shares of electric buses, reaching nearly 15% in 2022 and totalling over 750 000 (>95% of the global stock). In 2030, the sales share of electric buses increases to 50% in both scenarios, up from 18% in 2022. While electric sales of medium- and heavy-duty trucks are significantly lower than other road modes, China also led in electric truck stock in 2022, with over 95% of the world's electric trucks. Electric truck sales are projected to reach a sales share of nearly one-quarter in 2030 in both scenarios. Given that other countries have announced truck electrification targets, China's lack of announced ambitions means that other countries achieve higher sales shares in the APS.

The sales share of EVs across all road transport modes (excluding two/three-wheelers) reaches around 60% in 2030 in both scenarios. Across all modes, the current market dynamics, and the policy landscape as considered in the STEPS to 2030, is sufficient to bring EV sales shares high enough to be in line with China's ambition of climate neutrality by 2060, as well as with provincial electrification targets. As such, in China there is no gap between what current policy frameworks have legislated for and what the targets are.

## Europe

Europe maintains its status as one of the most advanced EV markets in the STEPS through 2030 in light of recent market trends and a supportive policy landscape. The 2023 adoption of stricter $CO_2$ standards for cars and vans in the European Union has significantly increased electric LDV sales shares in the STEPS. To meet the 2030 target of 55% emissions reduction for cars and 50% reduction for vans (compared to 2021 levels), the electric LDV sales share in the European Union increases from around 20% in 2022 to almost 65% in 2030. For Europe as a whole, electric LDV sales increase from 19% in 2022 to almost 60% in 2030. Given that the European Union has now legislated to the level of ambition laid out in the Fit for 55 package, there is no implementation gap for the European Union with respect to LDVs. The electric LDV sales share in 2030 for Europe, however, is slightly higher in the APS than the STEPS, reaching almost 65% in the APS. This is primarily driven by additional EV sales based on the United Kingdom's proposed ZEV mandate trajectory, which has the overall ambition to reach 100% zero-emission sales in 2035, as well as the eight non-EU countries in Europe[3] that have joined the Accelerating to Zero Coalition.

For buses and trucks, the EU Clean Vehicles Directive sets minimum requirements for the procurement of "clean" public buses and trucks that vary by member state, with average minimum sales of 33-65% clean buses and 7-15% clean trucks from 2026 to 2030. A number of European countries also offer financial incentives for electric buses and trucks in the form of tax exemptions, purchase subsidies and funding to support heavy-duty charging infrastructure. In the STEPS, the sales shares of electric buses and trucks reach 40% and 10% respectively in 2030. Within the European Union the sales shares reach 55% and around 13% in 2030. The APS takes into account the European Union's proposed heavy-duty vehicle (HDV) $CO_2$ standards, which would require 100% of city bus sales to be zero-emission from 2030, and other heavy-duty vehicles to reduce $CO_2$ emission by 45% from 2030 compared to 2019 levels. In addition, the APS includes the ambitions of 18 European national governments[4] who have signed the Global Memorandum of Understanding (MoU) on Zero-Emission Medium- and Heavy-Duty Vehicles to reach 30% zero-emission HDV sales shares in 2030 and 100% in 2040.

In Europe, the EV sales share across all modes (excluding two/three-wheelers) is 55% in 2030 in the STEPS. In the APS, Europe has a combined EV sales share of over 60% in 2030 (for electric LDVs, buses and trucks), which is in line with the global trajectory in the NZE Scenario. Last year, the implementation gap in Europe in terms of EV sales share in 2030 was about 15 percentage points. This has now

[3] Here, we refer to the Europe regional definition in the IEA's Global Energy and Climate (GEC) Model, which includes Türkiye and Israel.
[4] As Wales, Scotland and the United Kingdom are listed separately as signatories, each is counted in the European total.

shrunk to six percentage points, with greater increases in EV sales shares in the STEPS, due to new regulations and market trends, than in the APS due to the additional signatories to zero-emission vehicle (ZEV) initiatives and the proposed EU HDV $CO_2$ standards. For the European Union, the implementation gap in 2030 across all modes (excluding two/three-wheelers) has closed from over 10 percentage points in the 2022 Outlook to 1 percentage point.

## United States

With a supportive policy landscape, sales of electric cars and vans are expected to accelerate over the remainder of this decade in the United States, reaching the government target of 50% in 2030. With the foundation of stricter US fuel economy standards for 2024-26 legislated in 2021,[5] a slate of new measures are expected to promote uptake of electric LDVs, namely: financial incentives for electric cars included in the Inflation Reduction Act (IRA), allocated funding for EV charging infrastructure in the Infrastructure Investment and Jobs Act (IIJA), and growing adoption of California's Advanced Clean Cars II (ACC II) regulations by a number of states. The implementation gap between the STEPS and APS LDV sales in 2030 has fully closed due to the passing of the IRA and adoption of the ACC II regulations in 2022.

The IRA also includes a tax credit for the purchase of zero-emission medium- and heavy-duty trucks, as well as for the installation of EV chargers. In the STEPS, the sales share of electric trucks reaches 10% in 2030. In 2022, the United States signed the Global Memorandum of Understanding (MoU) on Zero-Emission Medium- and Heavy-Duty Vehicles, with a 2030 target of 30% zero-emission vehicles sales across buses and trucks. As such, the electric truck sales share reaches slightly less than 30% (which is balanced by higher bus sales shares to achieve the overarching target) in 2030 in the APS. The electric bus sales share reaches more than 40% in 2030 in the APS, compared to about 30% in the STEPS.

In the United States the EV sales share across all modes (excluding two/three-wheelers) reaches almost 50% in both the STEPS and APS. Thus, the implementation gap for EV sales shares in the United States shrank from around a 30 percentage points difference in 2030 last year to a negligible difference in this year's Outlook.

[5] The U.S. Environmental Protection Agency proposed new GHG emissions standards for light- and medium-duty vehicles in April 2023, which are expected to further promote EV sales. As this was announced after the first quarter of 2023, the proposal is not reflected in the scenario projections.

## Japan

In Japan, the sales share of electric cars and vans increases from 3% in 2022 to 20% in 2030 in the STEPS, in part to comply with the 2030 fuel economy standards for passenger cars. In the APS, electrification of LDVs increases more rapidly to reach 30% in 2030, which is in line with the government's target of 20-30% EV sales for passenger light-duty vehicles and 20-30% electrified vehicle sales for light commercial vehicles.

Japan also has fuel efficiency standards for heavy-duty vehicles, which state that efficiency must improve by around 13% for trucks and 14% for buses by the fiscal year 2025 compared to 2015. In 2030, in the STEPS, the electric bus sales share reaches almost 30% and the electric truck sales share reaches over 10%. Japan's Green Growth Strategy also sets targets for commercial vehicles, including that 100% of new commercial vehicle sales should be electrified or suitable for the use of decarbonised fuels by 2040. In the APS, sales of electric trucks amount to almost 15% in 2030, while the electric bus sales share reaches about 55%.

In Japan, the EV sales share across all modes (excluding two/three-wheelers) is 20% in 2030 in the STEPS and about 30% in the APS. The "implementation gap" has remained the same over the past year, as no new policies or ambitions for EVs were announced.

## India

India is one of the largest two-wheeler markets in the world, and both the national and local governments are promoting electric two-wheelers. For example, modifications to the FAME-II scheme in 2021 increased purchase incentives for electric two-wheelers to cover up to 40% of the price. The sales share of electric two/three-wheelers in India increases from around 7% in 2022 to almost 50% in 2030 in the STEPS. In addition, various Indian states have sales or stock targets for electric two- and/or three-wheelers, including Assam, Gujarat, Karntaka and Maharashtra. In the APS, the sales share of electric two/three-wheelers reaches over 60% in 2030.

The rate of electrification of buses and LDVs is lower, reaching about 20% and 15% respectively in 2030 in the STEPS. In the APS, electric buses reach a sales share of more than 25% and electric cars and vans a share of more than 30% in 2030. The APS reflects India signing the COP 26 declaration to transition to 100% zero-emission LDV sales by 2040. While there is no national target for electric buses, four Indian states (containing around 15% of India's population) aim to reach 100% electric bus sales by 2030 or earlier.

The EV sales share across all modes (including two/three-wheelers) in India is about 40% in 2030 in the STEPS (and closer to 14% if two/three-wheelers are excluded). In the APS, EV sales shares in India scale up to over 50% in 2030 across all road vehicle modes (30% excluding two/three-wheelers). The “implementation gap” in India, in terms of EV sales shares, is therefore about 15 percentage points.

### Other regions

The number of countries around the world that have not yet developed a clear vision for electromobility or set targets is declining over time. In emerging and developing economies in particular, adoption of EVs can be hindered by a lack of fiscal incentives, limited availability of charging infrastructure and purchase price hurdles, but the Global Electric Mobility Programme is working with governments in low- and middle-income countries to advance deployment of EVs.

In the STEPS, the average EV sales share across regions and countries other than those listed above is about 8% for LDVs, 6% for buses and 1% for trucks in 2030. In the APS, sales across these other regions reach over 15% of LDVs, 10% of buses and 2% of trucks. The countries that have adopted EV-related policies and set ambitions tend to have higher EV sales shares than these averages. For example, Canada and Korea both have fuel economy standards for light-duty vehicles and purchase incentives for electric LDVs, and as such the electric LDV sales shares reach over 30% in both Canada and Korea in 2030 in the STEPS, which increase to around 60% for both in the APS.

## Manufacturers’ targets versus scenario projections

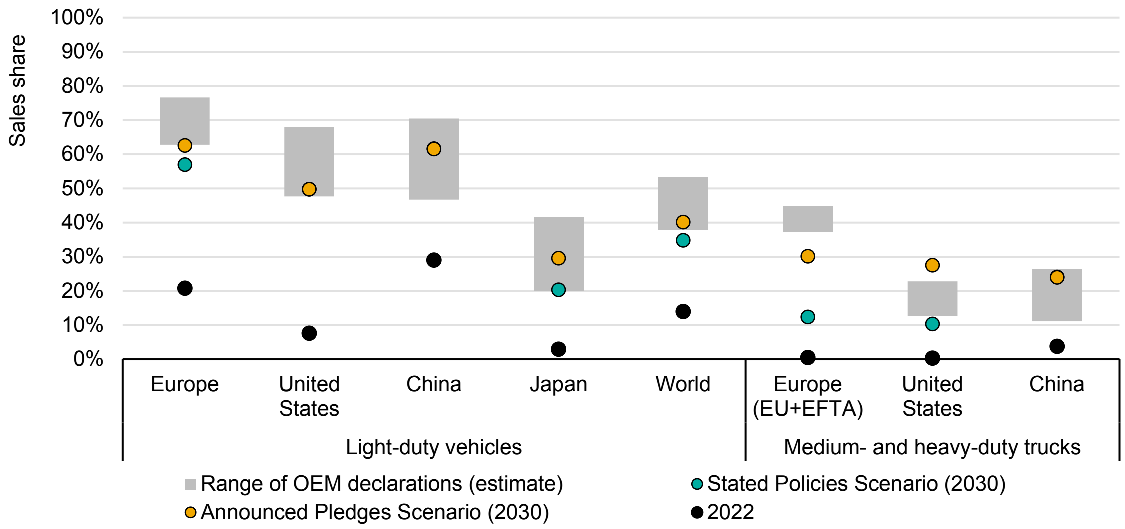
In most regions, the combined EV sales shares targeted by OEMs are either in step with or more ambitious than government pledges in the APS.

In addition to the new targets that OEMs have outlined for zero-emission and electric vehicle sales for LDVs (see Electrification plans by original equipment manufacturers), several announcements were made by heavy-duty OEMs in the past year. In the United States, Navistar announced targets of 50% zero-emission new vehicle sales by 2030 and 100% by 2040. In China, carbon neutrality (rather than new energy vehicle [NEV] sales shares) targets of heavy-duty OEMs have typically been at the group or brand level; Dongfeng, BAIC Group, FAW, and SAIC have set targets for carbon peaking, carbon neutrality or net zero emissions, or some combination of the three.

In the LDV market, OEM announcements are most ambitious in Europe, and roughly equally ambitious in the United States and China. The corporate targets in all three markets have followed announcements of policy ambition and commitments to transition to net zero emissions by 2050 in the United States and the European Union and by 2060 in China (Figure 3.5), showing how policy ambitions can spur corporate announcements.

In contrast, pivotal policies passed over the past year in the United States (including the IRA) have thus far not translated into OEMs in North America raising their announced level of ambition for electric cars and vans (with the exception of GM's near-term EV sales targets). However, the new legislation has encouraged OEMs to make massive investments in EV batteries and production facilities based in North America.

**Figure 3.5. Original Equipment Manufacturer targets and sales shares in the Stated Policies and Announced Pledges scenarios, 2030**






Notes: OEM = original equipment manufacturer. For medium- and heavy-duty trucks, OEM pledges cover the European Union and the European Free Trade Association (EFTA) whose members are Iceland, Liechtenstein, Norway and Switzerland. The figure compares OEM targets for heavy-duty vehicles (HDVs) (which, for some OEMs, include buses) relative to IEA projections for zero-emission medium- and heavy-duty truck sales (including fuel cell electric vehicles). Since annual sales of trucks substantially outnumber sales of buses, achieving HDV targets will require selling zero-emission trucks, which is currently more challenging than selling electric buses. The regional average market share in 2030 is calculated by collating announcements that explicitly mention ZEV market shares or ZEV sales by the top 10-25 OEMs in each region. Electric bus and truck registrations and stock data can be interactively explored via the Global EV Data Explorer.

Sources: IEA analysis based on country submissions, complemented by ACEA; EAFO; EV Volumes.

**Zero-emission vehicle announcements by manufacturers tend to follow major policy announcements, often surpassing policy ambitions as articulated in the Announced Pledges Scenario.**

## China

In a market where EV sales shares currently exceed government targets, projected sales in the STEPS and APS are well aligned with OEM ambitions. New targets were announced by Geely, SAIC-GM-Wuling, BAIC Group and FAW Group in 2022, and BYD ended production of conventional internal combustion engine (ICE) vehicles in early 2022 (see Electrification plans by original equipment manufacturers).

### Europe

The electrification plans of OEMs anticipated the adoption of the new EU $CO_2$ standards for cars and vans, with the result that combined OEM ambitions roughly match or exceed the 2030 electric LDV sales share in the STEPS. New LDV electrification ambitions in the European market have been announced by Ford, Volkswagen, and BMW (see Electrification plans by original equipment manufacturers). Heavy-duty vehicle makers are most ambitious about the European market, with targets reaching around 40% zero-emission vehicles sales in 2030. This exceeds what is projected in the STEPS and APS, despite the European Commission's proposal for a 100% zero-emission target for city buses for 2030, and a 90% $CO_2$ reduction target for trucks for 2040.

### United States

In the US LDV market, OEM ambitions match or exceed the government's target of 50% EV sales by 2030. However, OEM ambitions in the heavy-duty sector lag behind what is projected in the APS, despite the targets announced by Navistar in 2022. In part this is due to the United States becoming one of eleven new country signatories to the Global MoU on Zero-Emission Medium- and Heavy-Duty Vehicles in the past year, which recently increased ambition.

# Battery demand

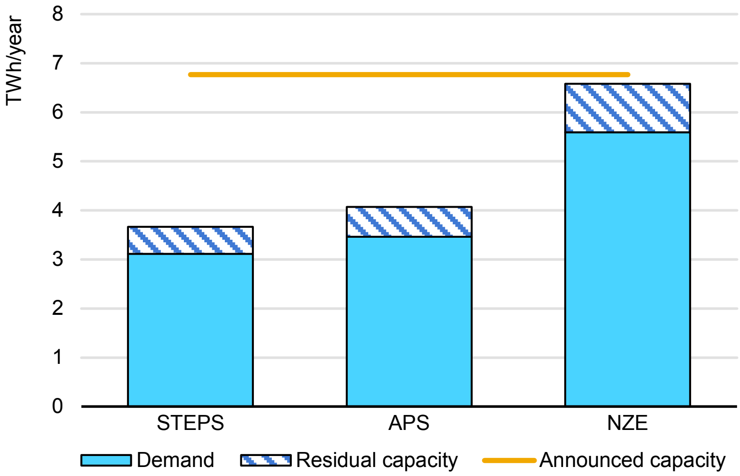
## Global battery demand continued to grow in 2022

Global EV battery demand increased by about 65% in 2022, reaching around 550 GWh, about the same level as EV battery production. The lithium-ion automotive battery manufacturing capacity in 2022 was roughly 1.5 TWh for the year, implying a utilisation rate of around 35% compared to about 43% in 2021.

Battery demand is set to increase significantly by 2030, reaching over 3 TWh in the STEPS and about 3.5 TWh in the APS. To meet that demand, more than 50 gigafactories (each with 35 GWh of annual production capacity) would be needed by 2030 in the STEPS in addition to today's battery production capacity. This increases to close to 65 new gigafactories to meet 2030 demand in the APS. According to Benchmark Mineral Intelligence (as of March 2023), the announced battery production capacity by private companies for EVs in 2030 amounts to 6.8 TWh, plenty sufficient to meet demand in both the STEPS and APS. In the NZE Scenario, battery demand reaches over 5.5 TWh in 2030. Assuming an average utilisation rate of battery production facilities of 85%,[6] announced capacity in 2030 narrowly covers what is needed in the NZE Scenario.

[6] In 2022, battery manufacturer CATL averaged a capacity utilisation rate of 83.4% for the year.

**Figure 3.6. Required and announced expansions of battery manufacturing capacity by scenario, 2030**





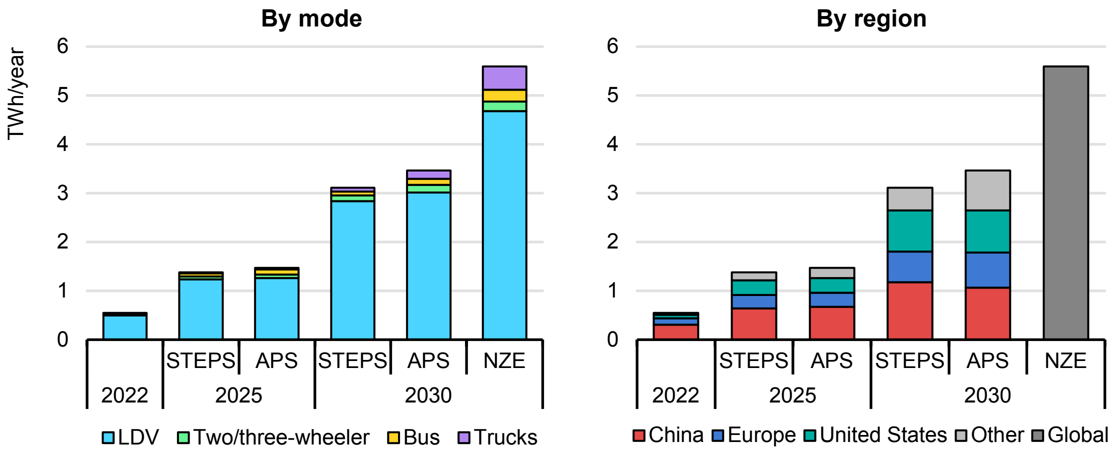

Notes: STEPS = Stated Policies Scenario; APS = Announced Pledges Scenario; NZE = Net Zero Emissions by 2050 Scenario. Announced capacity includes Tier 1 and Tier 2 battery manufacturers. Manufacturing capacity needed to meet projected demand is estimated using a utilisation rate of 85%. Residual capacity therefore represents the manufacturing capacity that would remain unused on average.

Source: Announced capacity based on data available as of March 2023 from Benchmark Mineral Intelligence.

**Announced battery manufacturing capacity in 2030 narrowly covers what would be required to fulfil demand for EV batteries in the Net Zero Scenario.**

China is expected to dominate demand for EV batteries up to 2025, in both the STEPS and the APS. However, in the APS, China's share of EV battery demand declines to about 35% in 2030, from over 55% in 2022, due to significant growth in EV sales in the United States, Europe and other markets.

**Figure 3.7. Projected battery demand by mode and region, 2022-2030**






Notes: STEPS = Stated Policies Scenario; APS = Announced Pledges Scenario; NZE = Net Zero Emissions by 2050 Scenario; LDV = light-duty vehicle.

**Battery demand increases more than sixfold from 2022 to 2030 in the Announced Pledges Scenario and tenfold in the Net Zero Scenario.**

Electric cars and vans are expected to continue to dominate total battery demand for EVs, accounting for around 90% of demand in both scenarios. In the APS, battery demand is projected to reach 120 GWh for buses and 160 GWh for two/three-wheelers in 2030. Battery demand for trucks increases significantly, reaching about 80 GWh in the STEPS and 170 GWh in the APS by 2030.

# Charging infrastructure

The projected deployment of charging infrastructure is underpinned by two main trends. The first is that home or depot charging is the preferred option for EV charging, as it tends to be slow charging (which is more affordable than fast charging) and because these locations are conducive to overnight charging. Slow home or depot charging is also compatible with smart charging and vehicle-to-grid operations, and generally puts less strain on the grid than faster charging. As such, it is assumed most LDV charging occurs at home, if the owner has access to residential charging, and that electric HDV fleet owners will install depot charging for all buses or trucks with driving schedules that allow for overnight depot charging. However, access to home charging and suitability of depot charging vary across regions and over time.

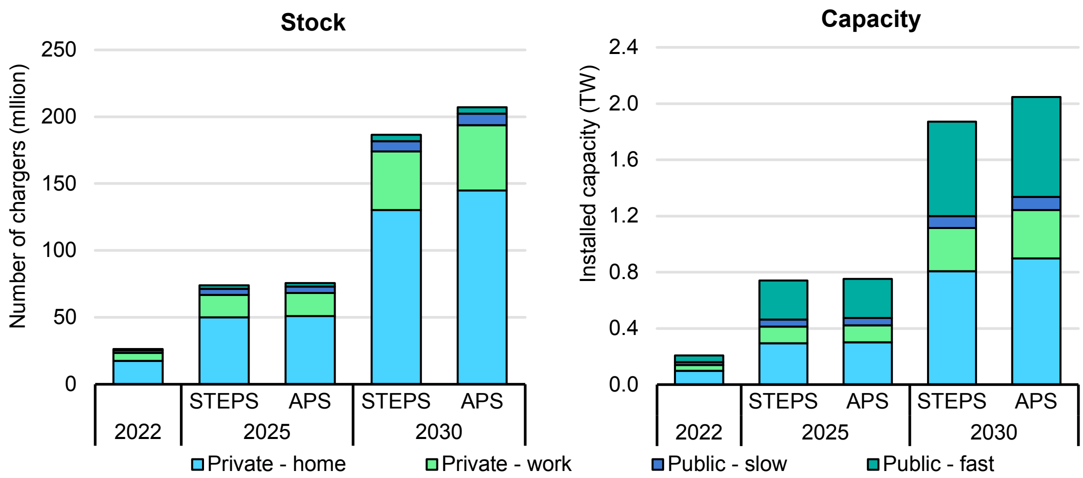
Secondly, it is assumed that public and opportunity chargers will gain more importance over time as EV adoption increases. For LDVs, it is assumed that as the stock of electric cars increases, a smaller proportion of owners will have access to home charging. For HDVs, it is assumed that as technologies mature, more electric HDVs will be used on longer-range routes. The deployment of public charging should anticipate and enable electrification of these segments.

## Requirements for light-duty vehicle charging

Today, the majority of electric car and van charging relies on private chargers, mainly at the driver's residence. Early adopters of electric cars and vans have tended to live in single-family detached homes, where home charging is more convenient and more affordable than using public chargers. For example, around 80% of EV owners in the United States live in single-family homes. Assuming that access to home charging covers 50-80% of the electric LDV fleet, varying according to the share of population residing in dense urban areas, there were an estimated 17.5 million home chargers in 2022. The stock of home chargers increases to 135 million in 2030 in the STEPS and 145 million in the APS.

To strengthen EV adoption across population segments that live in multi-unit dwellings, where charger availability may be limited, access to public and workplace charging becomes increasingly important. The stock of workplace chargers increases about eightfold by 2030 across the scenarios, while the number of public chargers increases around fivefold.

**Figure 3.8. Light-duty vehicle charger installations by number and capacity, 2022-2030**





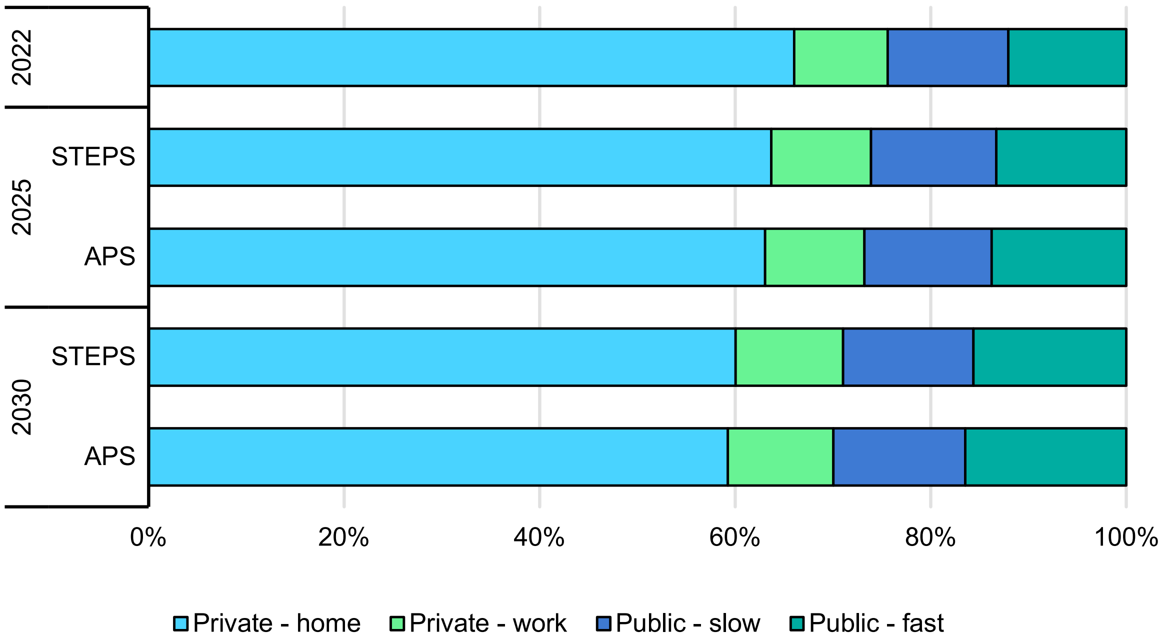

Notes: STEPS = Stated Policies Scenario; APS = Announced Pledges Scenario; LDV = light-duty vehicle. Regional projected electric vehicle supply equipment (EVSE) stock data can be interactively explored via the Global EV Data Explorer.

**By 2030, public charging points represent fewer than 10% of charging points for light-duty vehicles, but 40% of charging capacity.**

By 2030, the total installed LDV charger capacity grows more than ninefold to 1.9 TW in the STEPS, and to more than 2 TW in the APS. For reference, the total installed capacity of solar PV worldwide in 2021 stood at less than 1 TW. The capacity of public fast chargers grows at the fastest rate, increasing fifteen-fold by 2030 in the APS, despite the stock of public fast chargers increasing only around fivefold. In 2030, the average capacity of fast chargers is about 13 times that of public slow chargers and over 20 times that of private (home and workplace) slow chargers.

In 2030, less than 20% of the LDV stock is electric in the APS in most countries. As a result, it is expected that the majority of EV owners in 2030 will continue to have access to residential chargers, and the majority (around 60%) of electricity delivered to electric cars and vans will come from these home chargers. Public chargers provide about 30% of the electricity needed to power the electric LDV fleet worldwide in 2030.

**Figure 3.9. Electricity delivered to electric light-duty vehicles by charger type, 2022-2030**






Notes: STEPS = Stated Policies Scenario; APS = Announced Pledges Scenario. Home and workplace chargers are slow chargers that provide power less than or up to 22 kW. Fast chargers provide more than 22 kW.

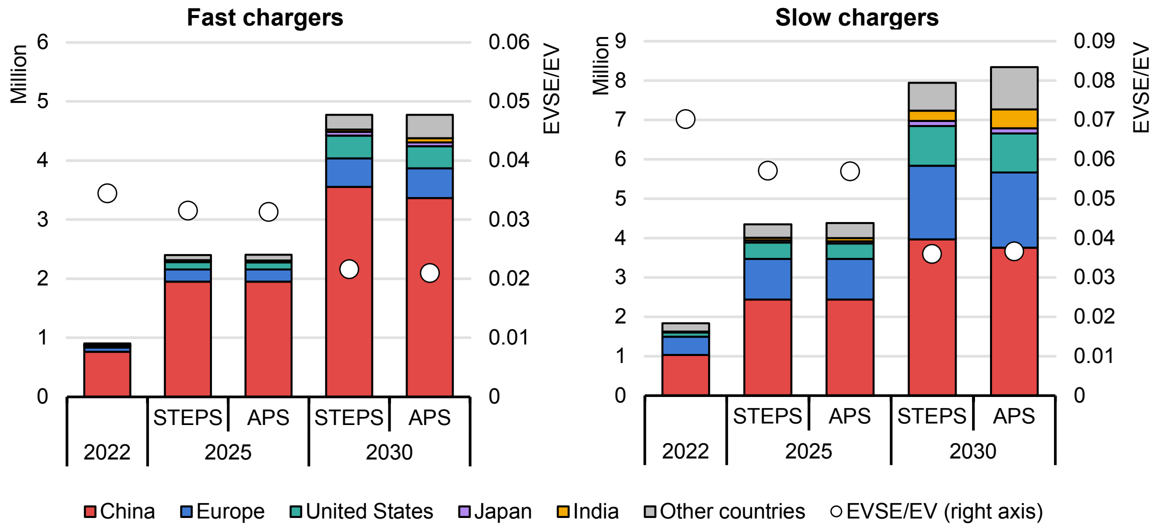
**The share of electricity for electric cars and vans delivered by public chargers increases to 30% by 2030.**

## Regional trends in public charging infrastructure for cars and vans

Public charging projections are based on the general trend of a decreasing ratio of charging points per EV over time as the market matures and the system is optimised, while maintaining reasonable charging capacity per EV.

At the end of 2022, China accounted for about 50% of the electric LDV stock and 65% of public LDV chargers. China is expected to remain a leader in public charger deployment to 2030, in part due to limited home charger access. In 2030, the stock of public LDV fast chargers reaches almost 5 million in the APS from less than 1 million in 2022, and China's share reduces from about 85% of public fast chargers to 70%, as other regions build out their network to keep pace with EV deployment targets. The number of public slow chargers remains higher than fast chargers in both scenarios, increasing from about 1.8 million in 2022 to 8 million in 2030 in the STEPS and over 8.2 million in the APS.

**Figure 3.10. Number of public light-duty vehicle chargers installed by region, 2022-2030**






Notes: STEPS = Stated Policies Scenario; APS = Announced Pledges Scenario; EVSE = electric vehicle supply equipment. Regional projected EVSE stock data can be interactively explored via the Global EV Data Explorer.

**The number of publicly accessible light-duty vehicle chargers increases from about 3 million in 2022 to around 13 million in 2030 in the Announced Pledges Scenario.**

The total number of public chargers needed to support LDV electrification in China in 2030 is estimated to be around 7.5 million, with a fairly even split between fast and slow chargers. In 2025, the stock of electric vehicle supply equipment already exceeds 4 million charging points. In terms of targets, the China National Development and Reform Commission has said that charging infrastructure should be sufficient to meet the needs of more than 20 million EVs by 2025. However, in both scenarios, the projected stock of electric cars and vans in China in 2025 is over 40 million. In the IEA scenarios there is therefore a ratio of over nine electric LDVs per public charging point in 2025, slightly higher than the eight electric LDVs per public charging point witnessed in 2022.

In Europe, the stock of public LDV chargers increases to around 2.4 million in 2030 in both the STEPS and APS, up from about half a million in 2022. In both scenarios, about 80% of the European public charging stock is in the European Union, or around 2 million chargers in 2030.

In March 2023, the European Parliament and Council provisionally agreed to the proposed Alternative Fuels Infrastructure Regulation (AFIR), which sets requirements for the total power capacity to be provided by public charging infrastructure based on the size of the registered fleet and coverage requirements for the trans-European network-transport (TEN-T). In the APS, the stock share of electric LDVs reaches over 10% for BEVs and 5% for PHEVs, while the public charging capacity averages about 1.6 kW per EV.

The United Kingdom has announced a strategy to deliver the charging infrastructure to support a 2030 phase-out of the sale of new petrol and diesel cars and vans, which includes the target of at least 300 000 public chargers by 2030 and a minimum of 6 000 fast chargers by 2035. In the APS, the stock of public chargers reaches around 280 000 in 2030, of which about 80 000 are fast chargers. This means that the share of fast chargers in the total public electric vehicle supply equipment stock increases to around 30%, from 20% in the past few years. The number of electric LDVs per charging point is around 35 and the charging capacity is around 1.5 kW per EV.

In the United States, the National Electric Vehicle Infrastructure Formula Program, established by the IIJA of 2021, will distribute up to USD 5 billion in funds from 2022-2026 to support the development of an EV charging network, with a target of 500 000 chargers. In the APS, this level of public electric vehicle supply equipment deployment is required before the end of 2025, and the number of chargers reaches over 1.3 million in 2030. In 2030, there are about 30 electric LDVs per charging point.

Japan's Green Growth Strategy sets a target of installing 150 000 charging points by 2030, including 30 000 fast chargers, with the goal of achieving the same level of convenience as refuelling gasoline vehicles. In the APS, the stock of LDV charging points reaches over 200 000 in 2030, of which about 70 000 are fast chargers. Such a ratio increases the share of fast chargers only a few percentage points, from about 30% in 2022 to 34% in 2030.

In India, FAME II provides financing and sets objectives for charging infrastructure, for example that chargers be established every 25 km along major highways. In March 2023, the Ministry of Heavy Industries also announced financial assistance for upstream electric vehicle supply equipment infrastructure. In the APS, the stock of public electric LDV charging points reaches 550 000 in 2030, meaning there are fewer than 15 electric LDVs per charging point.

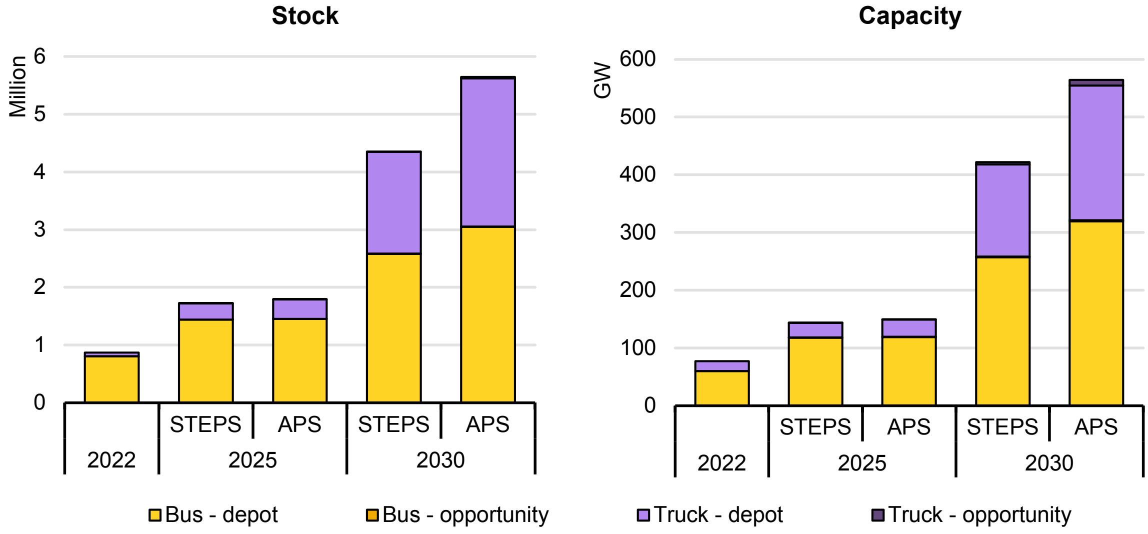
## Requirements for heavy-duty vehicle charging

In general, slow charging of EVs is cheaper than fast or ultra-fast charging. For HDVs, overnight charging at bus and truck depots is the most convenient way to charge at rates of less than 350-400 kW, which would require close to a one-to-one ratio of depot chargers per electric HDV.

Battery electric trucks and buses with daily ranges that exceed what can be provided from an overnight charge will also need to charge during the day. This daytime charging can take place at the depot or at an opportunity charger (either at public or semi-public charging stations, or at destinations). Destination chargers can be installed at locations where the vehicle has planned idle time, such as distribution centres where trucks are parked for loading and unloading, or at terminal bus stops. For long-distance applications, such as intercity bus routes and long-haul trucking, some charging will likely need to take place along highways during breaks.

Through the remainder of this decade, the adoption of electric HDVs is expected to centre on city buses and urban and regional delivery applications with short range routes (under 200 km/day), so that operations do not need to depend on opportunity charging. However, as the electrification of HDV segments that travel longer daily distances increases over time, opportunity chargers – especially highway charging – will be required. High-voltage connections that may be required for HDV opportunity chargers have long lead times, and so planning is needed in the short-term to ensure adequate availability in the medium- to long-term.

**Figure 3.11. Heavy-duty vehicle charger stock and capacity by type, 2022-2030**






Notes: HDV = heavy-duty vehicle; STEPS = Stated Policies Scenario; APS = Announced Pledges Scenario; EVSE = electric vehicle supply equipment. Charger stock in 2022 is estimated based on the number of electric buses and trucks.

**The stock of charging points for heavy-duty vehicles increases more than sixfold from 2022 to 2030 in the Announced Pledges Scenario.**

In the STEPS, the number of bus depot chargers increases from about 800 000 in 2022 to 2.5 million in 2030, reaching a total capacity of around 250 GW. The number of opportunity chargers needed for buses in 2030 is relatively low, assuming that buses travelling on short routes are electrified first; the stock of opportunity bus chargers reaches around 5 000, with an installed capacity of just over 1.2 GW. In the APS in 2030, the stock of depot bus chargers is around 3 million, reaching a capacity of about 315 GW, while the number of opportunity bus chargers is only slightly more than 6 500 (1.6 GW of capacity).

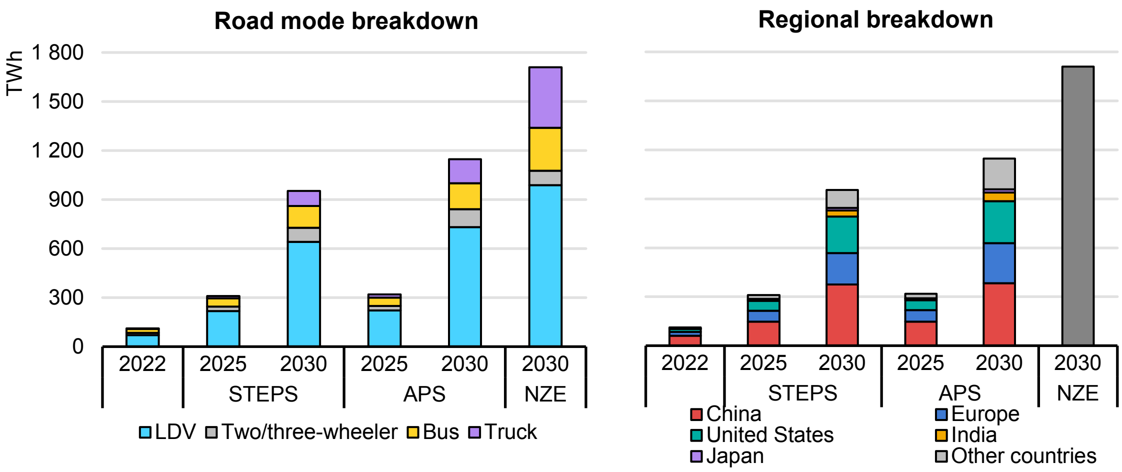
To power the growing stock of electric trucks, the number of depot chargers increases from around 300 000 today to 3.5 million in 2030 in the STEPS and 4.2 million in the APS. The installed capacity of truck depot chargers is about 310 GW in the STEPS and 380 GW in the APS in 2030. As with buses, the number of depot chargers needed in 2030 is far greater than the number of opportunity chargers. In the STEPS, the number of opportunity truck chargers is about 13 500 (6.5 GW installed capacity), increasing to 25 000 (13 GW installed capacity) in the APS in 2030.

# Impact on energy demand and emissions

## Electricity demand

The global EV fleet consumed about 110 TWh of electricity in 2022, which equates roughly to the current total electricity demand in the Netherlands. Almost a quarter of the total EV electricity consumption was for electric cars in China, and a fifth for electric buses in the same country. Electricity demand for EVs accounts for less than half a percent of current total final electricity consumption worldwide, and still less than one percent of China's final electricity consumption.

**Figure 3.12. Electricity demand by mode and region, 2022-2030**






Notes: STEPS = Stated Policies Scenario; APS = Announced Pledges Scenario; NZE = Net Zero Emissions by 2050 Scenario; LDV = light-duty vehicle; RoW = rest of the world. The analysis is carried out for each region in the transport model within the IEA's Global Energy and Climate Model (GEC-Model) separately and then aggregated for global results. For the Net Zero Emissions by 2050 Scenario, only global values are reported. Regional data can be interactively explored via the Global EV Data Explorer.

**Electricity demand for EVs accounts for only a minor share of global electricity consumption in 2030 in the Announced Pledges Scenario.**

Electricity demand for EVs is projected to reach over 950 TWh in the STEPS and about 1 150 TWh in the APS in 2030. Notably, electricity demand in the APS is about 20% higher than in the STEPS, despite the stock of EVs only being about 15% higher. This is in part due to higher rates of electrification in many high-average vehicle mileage markets such as the United States, but also to greater electrification in the truck and bus segments, which contribute incrementally to vehicle stock, but have a high electricity demand per vehicle. In addition, it is assumed that in countries with net zero pledges, a larger share of energy consumption in PHEVs is provided by electricity (as opposed to gasoline or diesel). This is particularly relevant for cars and vans, which account for about two-thirds of demand in both scenarios.

By 2030, electricity demand for EVs accounts for less than 4% of global final electricity consumption in both scenarios. As shown in the World Energy Outlook 2022, in 2030 the share of electricity for EVs is relatively small compared to demand for industrial applications, appliances or cooling and heating.

**Table 3.1 Share of electricity consumption from electric vehicles relative to final electricity demand by region and scenario, 2022 and 2030**

| Country/region | 2022 | Stated Policies Scenario 2030 | Announced Pledges Scenario 2030 |
|---|---|---|---|
| **China** | 0.8% | 3.8% | 4.0% |
| **Europe** | 0.7% | 4.7% | 5.7% |
| **United States** | 0.4% | 5.4% | 6.3% |
| **Japan** | 0.1% | 1.7% | 2.2% |
| **India** | 0.1% | 1.7% | 2.5% |
| **Global** | 0.5% | 3.2% | 3.8% |

Note: Non-road electricity consumption from the World Energy Outlook 2022.

China remains the largest consumer of electricity for EVs in 2030, although its share of global EV electricity demand decreases significantly from about 55% in 2022 to less than 40% in the STEPS, and around 30% in the APS. This reflects wider adoption of electromobility across other countries in the period to 2030.

The size of the EV fleet becomes an important factor for power systems in both scenarios, with implications for peak power demand, transmission and distribution capacity. Careful planning of electricity infrastructure, peak load management, and smart charging will be critical. Reducing dependence on fast charging will allow for optimal planning and resiliency of power systems, mitigating peak power demand. More than 80% of the electricity demand for electric LDVs in 2030 in both scenarios is via slow chargers (private and public).

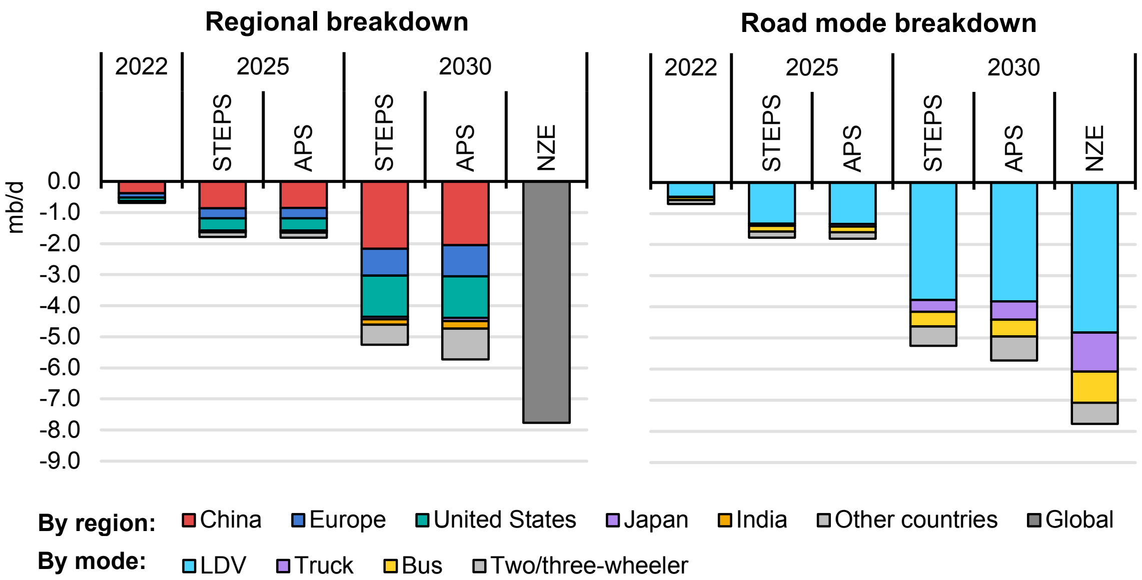
To help policy makers prioritise charging strategies according to the size of their EV fleet and their power system configuration, the IEA has developed a guiding framework and online tool for EV grid integration.

# Oil displacement

The growing EV stock will reduce oil use, which today accounts for over 90% of total final consumption in the transport sector. Globally, the projected EV fleet in 2030 displaces more than 5 million barrels per day (mb/d) of diesel and gasoline in the STEPS and almost 6 mb/d in the APS, up from about 0.7 mb/d in 2022. For reference, Australia consumed around 1 mb/d of oil products across all sectors in 2021.

However, recent price volatility for critical minerals that are important inputs to battery manufacturing, and market tension affecting supply chains, are a stark reminder that in the transition to electromobility, energy security considerations evolve and require regular reconsideration.

**Figure 3.13. Oil displacement by region and mode, 2022-2030**






Notes: STEPS = Stated Policies Scenario; APS = Announced Pledges Scenario; NZE = Net Zero Emissions by 2050 Scenario; LDV = light-duty vehicle. Oil displacement based on internal combustion engine (ICE) vehicle fuel consumption to cover the same mileage as the EV fleet.

**Oil displacement increases from 0.7 mb/d in 2022 to nearly 6 mb/d in 2030 if pledges supporting electromobility in road transport around the world are fulfilled.**

**Box 3.2 How much oil really gets displaced by electric vehicles?**

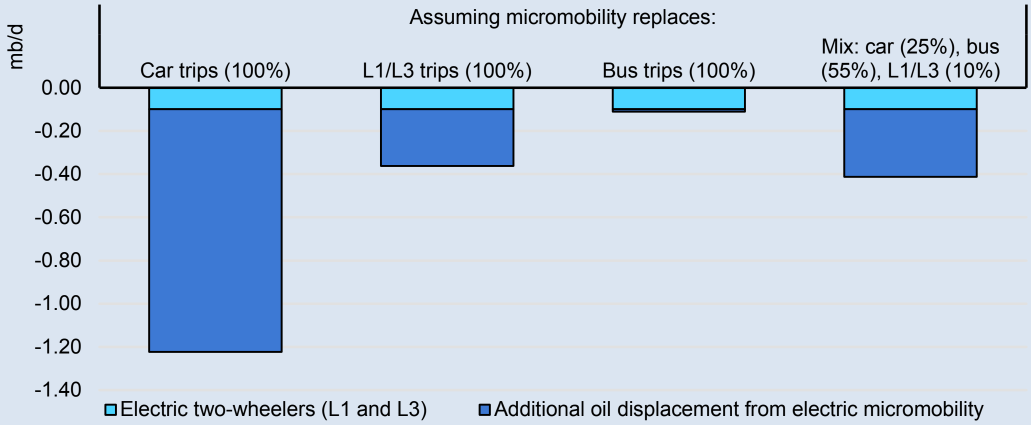
Oil displacement through the use of EVs can be estimated by assuming that the distance (total kilometres) travelled by EVs by segment each year would have otherwise been travelled by ICE vehicles or hybrid electric vehicles (HEVs) (based on the stock shares of each). In the case of PHEVs, only the distance covered by electricity gets included. The stock average fuel consumption of gasoline and diesel vehicles determines the total liquid fuel displacement, where the biofuel portion is taken out of the estimate based on regional blending rates. As a result, it can be estimated that in 2022, the stock of EVs displaced 700 000 barrels of oil per day.

This method of estimation assumes that EVs replace ICE or hybrid vehicles of the same segment, as opposed to some other means of transport, i.e. an electric car replaces an ICE car. The accuracy of this assumption is uncertain, in particular with respect to two-wheelers. In IEA analysis, only two-wheelers that fit the United Nations Economic Commission for Europe (UNECE) classification of L1 or L3 are considered. This definition excludes micromobility options such as electric-assisted bicycles and low-speed electric scooters, leading to a significantly lower stock (around 80% lower) than when including micromobility segments.

Whether or not electric micromobility avoids oil use is uncertain, as it might displace manual bicycles or walking rather than ICE two-wheelers. At the same time, there is evidence that in some cases micromobility displaces personal car or taxi trips. The estimate of the amount of oil use that is avoided by two-wheeled micromobility therefore strongly depends on the assumptions about the mode that is being displaced.

The case of China, which represents over 95% of the global stock of two-wheeled electric micromobility, is a good example. Assuming that all two-wheeled micromobility in China replaces conventional ICE two-wheelers would increase oil displacement by 260 kb/d (or 160%). If instead electric micromobility was assumed to replace only bus trips, then the total oil displacement from two-wheelers in China would increase by just 10 kb/d (10%). However, if it was assumed that they displaced car trips, then oil use avoided by two-wheelers in China would be more than 1 mb/d higher. Including oil displacement from the two-wheeled electric micromobility segment in China alone can therefore increase the estimated 2022 global oil displacement from all electric vehicles anywhere from 1% to 160%. But there is significant uncertainty as to whether any oil is displaced at all.

**Additional two-wheeler oil displacement in China when accounting for micromobility segments, 2022**






Notes: Electric L1 and L3 two-wheelers (based on UNECE classifications) are assumed to replace ICE two-wheelers. For this analysis, it is assumed micromobility two-wheelers travel on average 10 km/day. The mix shown is based on findings from an investigation of e-bike use in Kunming, China. The other 10% of the mix is assumed to replace active transport, and thus does not contribute to oil displacement.
Sources: IEA analysis based on BNEF and Cherry et al. (2016).

# Tax revenues

Taxes on petroleum-based road fuels can be a significant source of income for governments, [7] and are often used to support investments in transport infrastructure, such as roads and bridges. Given the levels of oil displacement discussed above, the transition to EVs will reduce these tax revenues. Additional tax revenue from electricity will not be sufficient to fully compensate for this reduction, both because taxes on electricity tend to be lower on an energy basis and because EVs are more efficient and thus use less energy than ICE vehicles.

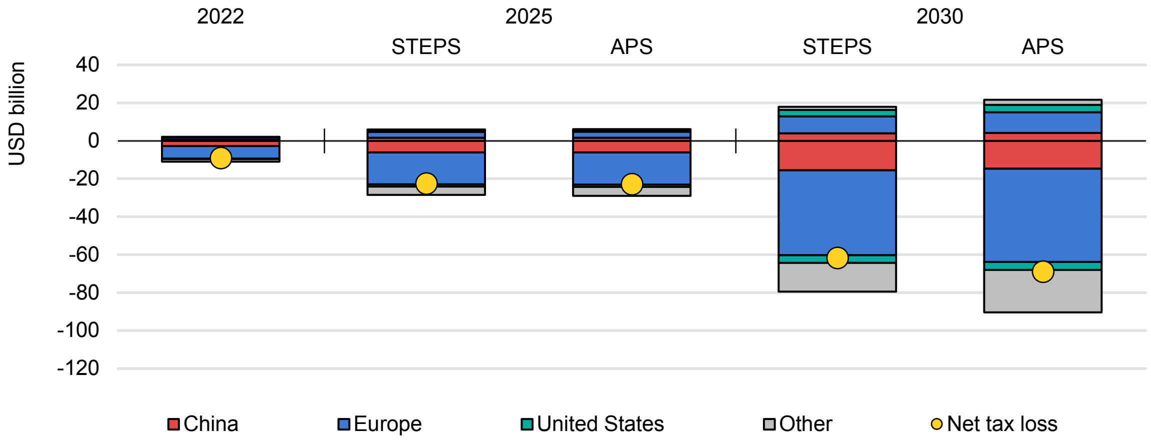
In 2022, the transition to electric vehicle stock displaced around USD 11 billion in gasoline and diesel tax revenues globally. At the same time, the use of EVs generated around USD 2 billion in electricity tax revenue, meaning there was a net loss of around USD 9 billion. Although China has the greatest stock of EVs, the greatest impact on tax revenues was seen in Europe, a trend which is expected to continue into the future. This is because Europe has some of the highest taxes on gasoline and diesel; for example, the gasoline tax rate in Germany is almost ten times the rate in China.

As the number of EVs increases globally, government fuel tax revenues are expected to decline, with global net tax losses increasing by around two-and-a-

[7] While the share of total government revenue from fuel taxes may be small, for example it has recently been less than 3% in the United Kingdom, in many cases it represents a large share of the budget allocations for transportation infrastructure.

half times by 2025 in both STEPS and APS. By 2030, this totals about USD 60 billion in 2030 in the STEPS, and about USD 70 billion in the APS. Europe is most affected, with fuel tax revenue to decline by around USD 50 billion in 2030 in the APS. Possible tax losses in countries outside of Europe, China and the United States increase to more than USD 20 billion, of which Korea represents about one-third. Impacts in the United States appear limited, with a total net loss of tax revenue of less than half a billion USD in 2030. However, this value is based on federal tax rates and thus does not represent the full impact at the state level. In 2022, the state tax rate on gasoline was on average around 70% higher than federal rate.

**Figure 3.14. Net tax implications of electric vehicle adoption by region, 2022-2030**






Notes: STEPS = Stated Policies Scenario; APS = Announced Pledges Scenario. Fuel tax rates are assumed to remain constant. Only federal tax rates are included.
Sources: Analysis based on tax rates from IEA Energy Prices.

**Additional tax revenue from electricity demand is not sufficient to balance the effects of displaced oil product consumption on fuel tax revenues.**

Governments need to anticipate a reduction in fuel tax revenues and develop new tax strategies to maintain revenue levels without discouraging the adoption of EVs. In the short-term, governments can increase tax rates to balance the decline in fossil fuel use, for example through a fuel tax escalator. However, this type of measure can be politically unpopular and create equity issues, especially in times of relatively high oil prices.

Longer-term measures to stabilise tax revenues that involve deeper reforms in tax schemes should be gradually phased in to allow for smooth adaptation to new vehicle technologies. For example, these reforms could include coupling higher taxes on carbon-intensive fuels with distance-based charges. While comprehensive tax reform can also address vehicle taxes (including vehicle weight-based taxes), an increase in taxes on EVs should only take place when the EV market is fairly mature, ideally when price parity has been reached.

Importantly, widespread EV adoption will reduce air pollution and GHG emissions, which should reduce health and environmental damage and their associated societal costs. In addition, distance-based charges, such as those that vary by time, place and vehicle type, could also reduce traffic congestion, noise and road infrastructure damage.

## Greenhouse gas emissions

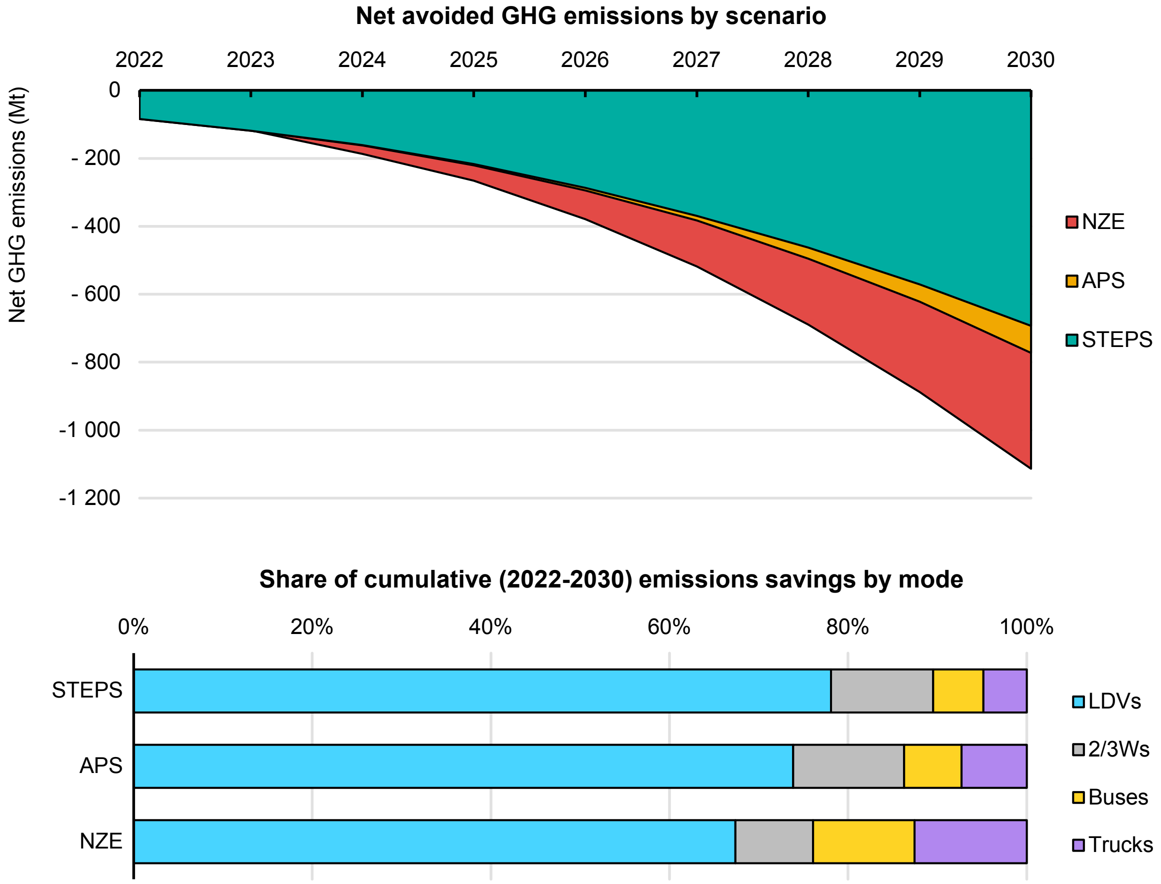
In 2022, EVs enabled a net reduction of about 80 Mt of GHG emissions, on a well-to-wheels basis. The biggest savings were achieved from EVs in China, where almost 30% of global emissions reductions come from the electrification of passenger cars in China. As the EV fleet continues to grow, it will contribute to further reducing GHG emissions on well-to-wheel basis through 2030. The net GHG benefit of EVs increases over time as the electricity sector is decarbonised. The global average GHG intensity of electricity generation and delivery falls from 2022 to 2030 by 28% in the STEPS, and by 37% in the APS.

In the STEPS, the net GHG emissions avoided through the use of EVs reaches nearly 700 Mt $CO_2$-equivalent in 2030. The production of electricity to fuel the EV fleet in 2030 in the STEPS results in 290 Mt $CO_2$-eq emissions, but this is more than offset by the avoidance of 980 Mt $CO_2$-eq that would have been emitted from an equivalent ICE vehicle fleet.

In the APS, the GHG emissions reduction benefit of EV adoption increases further, due to both a higher stock of EVs and a lower GHG intensity of electricity generation. The net GHG emissions avoided in 2030 are over 770 Mt $CO_2$-eq.

In the STEPS and the APS, electric LDVs as a segment contribute the majority of emissions avoided from 2022-2030, and the two/three-wheelers segment forms the next largest contributor. In the NZE Scenario, trucks play a key role in delivering the avoided emissions targets for achieving net zero goals.

### Figure 3.15. Net avoided greenhouse gas emissions from EV deployment and share of avoided emissions by mode, 2022-2030






Notes: GHG = greenhouse gas; STEPS = Stated Policies Scenario, APS = Announced Pledges Scenario; NZE = Net Zero Emissions by 2050 Scenario; LDVs = light-duty vehicles; 2/3Ws = two/three-wheelers. Net avoided GHG emissions are calculated as the total emissions from electricity generation, transmission and distribution and the negative emissions (i.e. avoided) that the equivalent ICE fleet would have emitted (both upstream and at the tailpipe) if running on fossil fuels. Projections include fuel economy improvements of ICE and electric vehicles as well as the growing share of renewable electricity generation, as described in the World Energy Outlook 2022.

**Nearly 25% of the avoided emissions from EVs in the Net Zero by 2050 Scenario can be attributed to the electrification of heavy-duty vehicles.**

# General annex

## Abbreviations and acronyms

| | |
|---|---|
| ACC | Advanced Chemistry Cell |
| ACC II | Advanced Clean Cars II |
| ACEA | European Automobile Manufacturers Association |
| AFC TCP | Advanced Fuel Cells Technology Collaboration Partnership |
| AFIR | Alternative Fuels Infrastructure Regulation |
| APS | Announced Pledges Scenario |
| AUD | Australian dollar |
| BaaS | battery-as-a-service |
| BEV | battery electric vehicle |
| BMW | Bavarian Motor Works |
| BNEF | Bloomberg New Energy Finance |
| BYD | Build Your Dreams |
| CAAM | China Association of Automobile Manufacturers |
| CAD | Canadian dollar |
| CATARC | China Automotive Technology and Research Center (CATARC) |
| CATL | Contemporary Amperex Technology Co. Limited |
| CAPEX | capital expenditure |
| CEF | Connecting Europe Facility |
| COP | Conference of the Parties |
| $CO_2$ | carbon dioxide |
| CPCA | China Passenger Car Association |
| CNY | Yuan renminbi |
| DC | direct current |
| EAFO | European Alternative Fuels Observatory |
| EFTA | European Free Trade Association |
| EMDE | emerging market and developing economy |
| EPA | Environmental Protection Agency |
| EU | European Union |
| EUR | Euro |
| EV | electric vehicle |
| EV100 | The Climate Group's EV100 Initiative |
| EVI | Electric Vehicle Initiative |
| EVSE | electric vehicle supply equipment |
| FAME II | Faster Adoption and Manufacturing of Electric Vehicles |
| FCEV | fuel cell electric vehicle |
| GBP | British pound sterling |
| GEC | IEA's Global Energy and Climate Model |
| GEF | Global Environment Facility |
| GHG | greenhouse gases |

| | |
|---|---|
| GM | General Motors |
| Gr | graphite |
| GM | General Motors |
| GVW | gross vehicle weight |
| HDV | heavy-duty vehicle |
| HEV | hybrid electric vehicle |
| HRS | hydrogen refuelling station |
| ICCT | International Council on Clean Transportation |
| ICE | internal combustion engine |
| IEA | International Energy Agency |
| IIJA | Infrastructure Investment and Jobs Act |
| iMHZEV | Incentives for Medium- Heavy-duty Zero-Emission Vehicles |
| INR | Indian rupee |
| IPO | Initial public offering |
| IRA | Inflation Reduction Act |
| ISO | International Organization for Standardization |
| JMC | Jiangling Motors Corporation Limited |
| JPY | Japanese yen |
| KRW | Korean won |
| LCA | lifecycle assessment |
| LCV | light commercial vehicle |
| LDV | light-duty vehicle |
| LEZ | Low-emission zone |
| LFP | lithium iron phosphate |
| Li | lithium |
| Li-ion | lithium-ion |
| MCS | Megawatt Charging System |
| MIIT | Ministry of Industry and Information Technology, China |
| MoU | memorandum of understanding |
| Na-ion | sodium-ion |
| Ni | nickel |
| NCA | lithium nickel cobalt aluminium oxide |
| NDC | Nationally Determined Contribution |
| NEV | new energy vehicle |
| NEVI | National Electric Vehicle Infrastructure Formula Program |
| NMC | nickel manganese cobalt oxide |
| NMCA | lithium nickel manganese cobalt aluminium oxide |
| NOK | Norwegian kroner |
| NOx | nitrogen oxide |
| NZE | Net Zero Emissions by 2050 Scenario |
| M/HDV | medium- and heavy-duty vehicle |
| OEM | original equipment manufacturer |
| PGE | Portland General Electric |
| PHEV | plug-in hybrid electric vehicle |
| PLDV | passenger light-duty vehicle |

| | |
|---|---|
| PLI | Production Linked Incentive |
| RoW | rest of world |
| SAIC | Shanghai Automotive Industry Corporation |
| Si-Gr | silicon-graphite |
| SEK | Swedish kronor |
| SME | small- and medium enterprise |
| STEPS | Stated Policies Scenario |
| SUV | sports utility vehicle |
| TCO | total cost of ownership |
| TEN-T | trans-European network-transport |
| TRL | Technology Readiness Level |
| UNECE | United Nations Economic Commission for Europe |
| USD | United States dollar |
| USGS | United States Geological Survey |
| VAT | value-added tax |
| VC | venture capital |
| VW | Volkswagen |
| WBCSD | World Business Council for Sustainable Development |
| WBMS | World Bureau of Metal Statistics |
| ZETI | Zero-Emission Technology Inventory |
| ZEV | zero-emission vehicle |
| 2/3W | two/three-wheeler |

# Units of measure

| | |
|---|---|
| °C | degree Celsius |
| $gCO_2$ | grammes of carbon dioxide |
| Gt $CO_2$ | gigatonnes of carbon dioxide |
| GW | gigawatt |
| GWh | gigawatt-hour |
| km | kilometre |
| kW | kilowatt |
| KWh | kilowatt-hours |
| kt | kilotonnes |
| mb/d | million barrels per day |
| Mt | million tonnes |
| Mt $CO_2$-eq | million tonnes of carbon-dioxide equivalent |
| MW | megawatt |
| t $CO_2$ | tonne of carbon dioxide |
| t $CO_2$-eq | tonne of carbon-dioxide equivalent |
| tkm | tonne-kilometre |
| TW | terawatt |
| TWh | terawatt-hour |
| Wh | watt-hour |
| Wh/kg | watt-hour per kilogramme |

# Currency conversions

| Exchange rates (2022) | 1 US dollar (USD) equals: |
|---|---|
| Australian Dollars | 1.44 |
| British Pounds | 0.81 |
| Canadian Dollars | 1.30 |
| Chinese Yuan Renminbi | 6.74 |
| Euros | 0.95 |
| Indian rupees | 80.40 |
| Japanese Yen | 131.50 |
| Korean Won | 1291.45 |
| Norwegian Kroner | 9.61 |
| Swedish Kronor | 10.11 |

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