Global EV Outlook 2025

Expanding sales in diverse markets

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Abstract

The Global EV Outlook is an annual publication that reports on recent developments in electric mobility around the world. It is developed with the support of members of the Electric Vehicles Initiative (EVI).

The report draws on the latest data to assess trends in electric vehicle deployment, demand for their batteries and charging infrastructure. It considers recent policy developments and industry strategies shaping the outlook for electric vehicles in different markets. This edition features analysis of electric vehicle affordability, manufacturing and trade of electric cars and their batteries, and the total cost of ownership of electric heavy-duty trucks across various markets, and makes projections to 2030**.**

The report is complemented by updated versions of two online tools: the Global EV Data Explorer and the Global EV Policy Explorer, which allow users to further explore EV statistics and projections, and policy measures worldwide.

Acknowledgements, contributors and credits

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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.

The International Energy Agency serves as the co-ordinator of the initiative. Governments that have been active in the EVI in the 2024-25 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.

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.

Executive summary

Electric car sales continue to break records globally, particularly in China and other emerging economies

Electric car sales exceeded 17 million globally in 2024, reaching a sales share of more than 20%. Just the additional 3.5 million electric cars sold in 2024 compared with the previous year is more than the total number of electric cars sold worldwide in 2020. China maintained its lead, with electric cars accounting for almost half of all car sales in 2024; the over 11 million electric cars sold in China last year were more than global sales just 2 years earlier. As a result of continued strong growth, 1 in 10 cars on Chinese roads is now electric. Europe saw sales stagnate in 2024 as subsidy schemes and other supportive policies waned, but the sales share of electric cars remained around 20% as stronger sales in some countries compensated for lower sales in others. In the United States, electric car sales grew by about 10% year-on-year, reaching more than 1 in 10 cars sold.

Emerging markets in Asia and Latin America are becoming new centres of growth, with electric car sales jumping by over 60% in 2024 to almost 600 000 – about the size of the European market 5 years earlier. In Southeast Asia, electric car sales grew by nearly 50% to represent 9% of all car sales in the region, with notably higher sales shares in Thailand and Viet Nam. In Brazil, the largest car market in Latin America, electric car sales more than doubled to 125 000 in 2024, reaching a sales share of over 6%. Sales in Africa also more than doubled, too, mostly thanks to growing sales in Egypt and Morocco, though electric cars still represent less than 1% of total car sales across the continent. Policy support and relatively affordable electric car imports from China played a central role in increasing sales in some emerging electric vehicle (EV) markets, accounting for 85% of electric car sales in both Brazil and Thailand, for example. Across all emerging economies outside of China, Chinese imports made up 75% of the increase in electric car sales in 2024.

Expected growth in electric car sales is led by China and Europe, alongside a surge in emerging economies

Electric car sales in 2025 are expected to exceed 20 million worldwide to represent more than one-quarter of cars sold worldwide. Sales were up 35% year-on-year in the first three months of 2025, with record first-quarter sales in all major markets. In China, the continuation of incentives for replacing older vehicles and falling electric car prices mean electric cars are projected to reach around

60% of total car sales in the country in 2025. Emissions standards in the European Union and the United Kingdom will require higher shares of zero-emission car sales in 2025. Building on more than 20% year-on-year sales growth observed in the first quarter, these policy pushes are expected to drive up electric car sales in Europe in 2025 to reach a sales share of 25%, despite flexibility given to automakers for meeting the 2025 EU emissions reduction target. While the 2025 outlook for electric car sales in the United States is uncertain based on today's policy direction, sales are currently expected to maintain the 10% growth observed in the first quarter; as consumers take advantage of existing tax credits in view of their potential repeal, electric car sales are projected to reach 11% of total car sales over the full year. In emerging economies other than China, sales are expected to continue growing strongly, increasing by 50% to reach 1 million in 2025.

Despite uncertainties in the outlook, the share of electric cars in overall car sales is set to exceed 40% in 2030 under today's policy settings. China is poised to continue leading in electric car sales to 2030, achieving a sales share of around 80% on the back of significant market momentum and competitively-priced EVs. In Europe, carbon dioxide (CO_2) targets support the achievement of a sales share of close to 60% by 2030, slightly below last year's projection. The sales share in the United States grows much more modestly than in our *Outlook* last year, reaching around 20% by 2030 based on today's policy direction – less than half the share projected for 2030 last year. In Southeast Asia, meanwhile, electric car sales are boosted by strong policy support and available domestic manufacturing capacity: by 2030, one in four cars sold in the region is poised to be electric. Two/three-wheelers – an important mode of road transport in the region – electrify faster: by 2030, almost 1 in 3 such vehicles sold are electric. Across all vehicle modes, the deployment of EVs replaces the use of more than 5 million barrels of oil per day globally in 2030, an important energy security consideration. Half of these savings are the result of EV adoption in China.

Uncertainty about the evolution of trade and industrial policy, downside risks to the economic outlook, and lower oil prices could affect EV uptake – but also car markets overall. Higher tariffs might increase the price of cars, including electric cars, and their components; lower GDP growth could dampen car sales; and lower oil prices affect the fuel cost savings from the use of electric cars. The way these factors will play out in practice is uncertain, but on aggregate they look to pose risks for overall car sales volumes more than for the share of EVs. In China, continued political support and competitive EV prices suggest that EV sales can withstand such headwinds. In Europe, where price differentials with conventional cars are larger, the combination of longer-term policy ambition and examples of policy responses from the pandemic suggest that sustaining EV sales is possible. Low oil prices can reduce fuel savings offered by battery electric cars, but even at global benchmark oil prices of USD 40 per barrel, there would be significant fuel cost savings in all major EV markets when charging at home. In China, public fast charging costs around twice as much as home charging, but it would still offer savings for EV owners compared with driving a conventional car.

Global trade of electric cars is growing as manufacturers eye new markets

China continues to be the world's EV manufacturing hub and is responsible for more than 70% of global production. Car manufacturers headquarted in China predominantly cater to the domestic market, accounting for around 80% of domestic sales in 2024 and almost all of the 25% growth in global EV production. In the European Union, production stalled at 2.4 million electric cars in 2024. North America saw contrasting trends: US production declined whereas Mexico's output doubled, supported by comparatively low manufacturing costs. Roughly 70% of Mexico's output was from US-headquartered manufacturers. Production also increased by 15% in Asia Pacific countries other than China, reaching about 1 million electric cars, mostly from incumbent carmakers from Japan and Korea.

Global trade of electric cars increased 20% in 2024; imports now represent almost one-fifth of global electric car sales. At 40% (nearly 1.25 million electric cars), China accounted for the largest share of global exports in 2024. The European Union also remained a net exporter of electric cars: exports reached over 800 000, mostly destined for other European countries (such as the United Kingdom) and North America. EU imports were below 700 000, of which 60% came from China. The United States remained a net importer of electric cars; imports increased by nearly 40% in 2024, while exports fell by nearly 15%.

Chinese EV export markets are diversifying as Chinese automakers make headway in Brazil, Mexico and Southeast Asia. Several potential markets for Chinese EV exports have recently adopted or are considering the use of tariffs. This has prompted Chinese manufacturers to either frontload their exports before such tariffs come into force (as in Brazil) or to seek new markets for their available output. Today, overseas manufacturing capacity from Chinese manufacturers supplies about 5% of electric car sales in emerging markets and is set to grow further.

Competition and declining battery prices are improving affordability, though progress is uneven

As a global average, the price of battery electric cars fell in 2024, but the purchase price gap with conventional cars persisted in many markets. The average battery electric car price in Germany, for example, remained 20% higher than that of its conventional counterpart. In the United States, battery electric cars remained 30% more expensive, dampening future sales growth expectations. In contrast, two-thirds of all electric cars sold in China in 2024 were priced lower than their conventional equivalents, without considering purchase incentives for EVs. This helped boost sales even as government incentives decreased.

Chinese electric car models are typically cheaper than the average EV in emerging markets, bolstering the competitive position of the Chinese industry. In Thailand, the average price of a battery electric car has now reached parity with an average conventional car, and the Chinese electric cars available are, on average, even cheaper. In Brazil, the price gap between battery electric cars and conventional cars shrank to 25% in 2024 from over 100% in 2023 as Chinese electric car imports grew to 85% of the country's EV sales. Similarly, the average price premium of battery electric cars in Mexico fell to 50% in 2024 from more than 100% in 2023 as Chinese imports reached two-thirds of sales.

Low critical mineral prices and increasing competition between battery manufacturers drove down battery pack prices in all markets in 2024, albeit with significant variations. In China, prices fell by about 30%, compared with 10-15% in Europe and the United States. The faster pace of cost reductions in China – enabled by strong competition, increasing manufacturing efficiency and supply chain integration, and access to a skilled workforce – is increasing the competitive advantage of Chinese battery manufacturers.

Improving charging coverage, capacity and integration is key to growing adoption of electric vehicles

Public charging stations have doubled in the past 2 years to keep up with growing EV sales. China and the European Union have maintained a steady pace of charger deployment compared with the number of EVs on the road. However, in both the United States and United Kingdom, which have higher rates of access to home chargers than China, public charger build-out has not kept pace with EV deployment, and the number of electric light-duty vehicles per public charging point increased in 2024.

Charging capacity is an important measure of the adequacy of public charging networks. The number of ultra-fast chargers, with power ratings of 150 kilowatts (kW) and above, grew by about 50% in 2024 and now account for nearly 10% of all public fast chargers. Public slow chargers in urban areas are a solution for EV owners without access to home charging, but fast chargers along highways help enable long-distance trips. In Europe, over three-quarters of all highways have a fast-charging station at least every 50 kilometres, compared with less than half of US highways. Globally, public charging capacity for light-duty EVs would need to grow by almost ninefold to 2030 to support EV sales implied by stated policies. Even so, EVs are set to account for only 2.5% of total global electricity demand in 2030.

Government efforts to promote interoperability, standardisation, smart charging and vehicle-to-grid integration can ease the transition to EVs for drivers and grid operators. Technologies such as smart chargers and vehicle-to-grid-capable EV models are becoming more available, but new market structures and legal frameworks will be needed for vehicles to maximise the potential benefits for the grid. China and the United Kingdom stand out for policy implementation and demonstration projects in this area. Battery technology innovations in recent years are also enabling safe high-power charging that could be as quick as refuelling a conventional car, but fully realising these advances hinges on deploying adequate infrastructure.

The value proposition for electric trucks is improving, even for long-haul operations

Electric truck sales grew by nearly 80% globally in 2024 to reach close to 2% of total truck sales. Spurred by a new scrappage scheme for conventional trucks, China's electric truck sales doubled to 75 000 vehicles, representing over 80% of global sales in 2024. In Europe and the United States, electric truck sales in 2024 remained similar to 2023 levels. The number of battery electric truck models available has grown from less than 70 in 2020 to more than 400, increasing the number of applications that can be met by electric trucks.

The total cost of ownership of a battery electric heavy-duty truck is already lower than for a diesel equivalent in China in certain cases. The purchase price of battery electric heavy-duty trucks remains two to three times higher than equivalent diesel trucks in major markets, which can discourage fleet operators, who often operate under tight margins. However, greater efficiency and lower energy costs – even including the cost of a high-power charger – make battery electric trucks more attractive the more they are used. By 2030, battery electric trucks in Europe and the United States are expected to reach parity on the total cost of ownership with diesel trucks for long-haul operations, as they already have in China, and are set to remain more cost-effective than hydrogen fuel cell trucks. However, the specific application and use profile of trucks are key factors for determining which powertrain technology is most suitable, meaning case-by-case analysis may be needed to evaluate the costs of various alternatives.

Mandated rest periods for truck drivers can play an important role in reducing the opportunity cost of charging en route. For long-haul trucking, the wait time for recharging an electric truck can pose difficulties for logistics operators. However, the 45-minute rest period mandated in the European Union can accommodate the addition of around 150 km of driving range for a heavy-duty truck using a 350 kW charger, and up to about 400 km if a megawatt charger is used. While the United States and China also have mandated rest periods, the design of the EU policy is currently most conducive to supporting EV adoption.

1. Trends in electric car markets

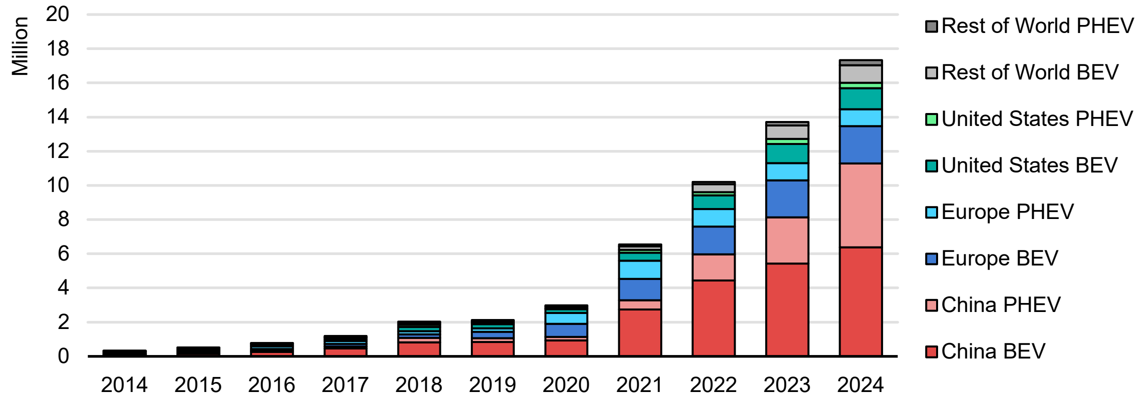
Electric car sales

Global electric car sales exceeded 17 million in 2024

More than 20% of new cars sold worldwide were electric

Electric car sales topped 17 million worldwide in 2024, rising by more than 25%.[1] Just the additional 3.5 million cars sold in 2024 compared to 2023 outnumber total electric car sales in the whole of 2020. China maintained its lead among major markets, with electric car sales exceeding 11 million – more than were sold worldwide just 2 years earlier. Global sales were slightly tempered by stagnating growth in Europe, as subsidies were phased out or reduced in several major markets, and as the EU CO_2 targets for cars remained the same between 2023 and 2024. Electric car sales continued to increase in the United States although growth was about one-quarter that of the previous year. Significantly, outside of these three major markets, there was a record increase in sales of nearly 40% to reach 1.3 million, closing in on the United States' sales of 1.6 million electric cars.

Global electric car sales, 2014-2024



Notes: BEV = battery electric vehicle; PHEV = plug-in hybrid vehicle. Includes new passenger cars only.
Sources: IEA analysis based on country submissions and data from the European Automobile Manufacturers Association (ACEA), European Alternative Fuels Observatory (EAFO), EV Volumes and Marklines.

[1] In this report "sales" represents an estimate of the number of new vehicles hitting the roads. Where possible, data on new vehicle registrations is used. In some cases, only data on retail sales (such as sales from a dealership) are available. New car sales or registrations exclude used cars. 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 the box at the end of Section 4.

The rapid growth in electric car sales over the past 5 years has had a significant impact on the global car fleet: At the end of 2024, the electric car fleet had reached almost 58 million, about 4% of the total passenger car fleet and more than triple the total electric car fleet in 2021. Notably, the global stock of electric cars displaced over 1 million barrels per day of oil consumption in 2024. Of course, the stock of electric cars is not spread evenly across the world – in China, for example, around one in ten cars on the road is now electric, whereas in Europe the ratio is closer to one in twenty.

Almost half of China's car sales were electric in 2024, representing almost two-thirds of electric cars sold globally

Electric car sales in China increased by almost 40% year-on-year in 2024, further driving up China's share of global electric car sales. In 2021, China accounted for half of global electric car sales; this share grew to almost two-thirds in 2024. On a monthly basis, sales of electric cars have overtaken conventional car sales in the country since July 2024, bringing the share of electric car sales close to 50% for the full year. In China, 2024 marks the fourth consecutive year in which the electric car sales share grew by approximately 10 percentage points year-on-year.

The growth in China reflects in no small part the growing price competitiveness of battery electric cars with conventional cars in the country. In addition, China's electric car market benefitted from the introduction of a trade-in scheme in April 2024. The scheme, which is part of a wider economic stimulus package, applies to the purchase of conventional and electric cars alike, but with different levels of financial support. It offers CNY 20 000 (Yuan renminbi) (USD 2 750) for consumers that replace an older vehicle (conventional or electric) with a new electric car, and CNY 15 000 (USD 2 050) for replacement with a new conventional vehicle. In 2024, about 6.6 million consumers applied for the incentive, 60% of whom bought an electric car. As such, more than one-third of the over 11 million new electric car sales in the country benefitted from this incentive.

In recent years, sales of plug-in hybrid electric cars have been growing faster than sales of battery electric cars in China. The share of plug-in hybrid electric vehicle (PHEV) sales, excluding extended-range EVs (EREVs)[2], in China's total electric car sales has risen from about 15% in 2020 to nearly 30% in 2024. Meanwhile, the share of EREVs has more than quadrupled since 2020, surpassing 10% in

[2] If not otherwise specified, PHEVs includes EREVs. Extended-range EVs are a subset of plug-in hybrid electric vehicles that have both an internal combustion engine (ICE) and a plug-in rechargeable battery. Throughout this report, EREVs refer to plug-in series hybrid powertrain configurations where the ICE only operates without direct mechanical connection to the wheels to recharge the battery through an electric generator. Other plug-in hybrid configurations (such as parallel and series-parallel configurations) fall under the "standard" PHEV category. EREVs generally feature larger battery and longer electric range than standard PHEVs.

2024. The acceleration of PHEV sales in China led the share of electric car sales that are battery electric to fall from 80% in 2020 to below 60% in 2024, though in absolute terms battery electric car sales increased sevenfold over the same period, demonstrating their continued appeal to new customers.

In Europe, electric car sales stagnated in 2024 as policy support waned in major car markets

About one in five new cars sold on the European market was electric in 2024, maintaining the sales share of the previous year. The electric sales share increased in 2024 in 14 out of 27 EU member states, while it either stalled or decreased in the rest, including in several larger markets, such as Germany and France, largely as a result of subsidies being phased out or reduced. In Germany, subsidies ceased at the end of 2023, while France has progressively reduced its subsidy over the years. At the start of 2024, France limited the amount of environmental bonus available to higher-income car buyers and reduced the number of vehicles eligible for the subsidy.

Besides subsidies, the policy design of the European Union CO_2 standards may also have held back further growth of the electric car market in 2024. As new targets come into effect every 5 years, car makers had no incentive to push sales of electric cars further in 2024 (in anticipation of strengthened targets in 2025). This is in contrast to markets such as the United Kingdom, where annually increasing targets move original equipment manufacturers (OEMs) towards electrification each year. In March 2025, the European Commission published its Industrial Action Plan for the European automotive sector, in which it proposed to amend the CO_2 emission performance standards for cars and vans, granting them additional flexibilities by averaging their performance over a 3-year period.

In the United Kingdom – the second-largest car market in Europe – electric car sales reached a share of nearly 30%, up from 24% in 2023. The year 2024 was the first under the Vehicle Emissions Trading Scheme, which required 22% of all new registrations to be BEV or fuel cell electric vehicle (FCEV). When accounting for the scheme's flexibilities, which allows OEMs to borrow credits from future years, they were able to comply with a battery electric car sales share of close to 20%. Norway reached near-total electrification of sales, with 88% of car sales being battery electric and just under 3% plug-in hybrid. As a result of the growing stock of electric cars, Norway's oil consumption for road in 2024 decreased by 12% compared to 2021. From April 2025, a tax increase on conventional internal combustion engine (ICE) cars and PHEVs is expected to further increase the battery electric share towards meeting the Norwegian government's 2025 goal of 100% zero-emissions car sales. In Denmark, the electric sales share increased by 10 percentage points to reach 56%, with nearly 100 000 electric cars sold.

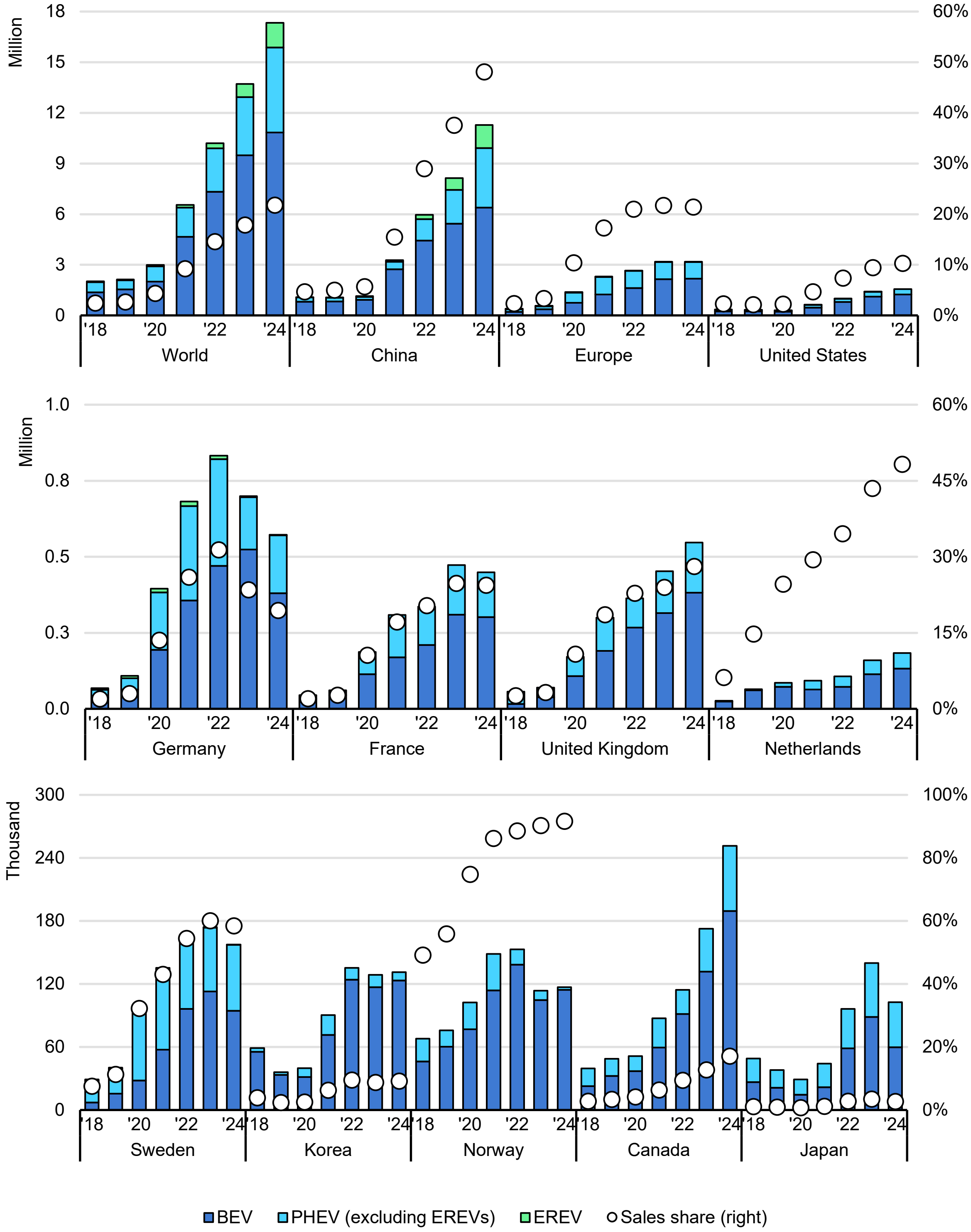
The market share of electric cars continued to expand in the United States

In the United States, electric car sales increased to 1.6 million in 2024, with the sales share growing to more than 10%. However, growth in electric car sales slowed down significantly in 2024, increasing by just 10% compared to 40% in 2023. In spite of this, electric car sales did boost the overall car market, as sales of conventional cars stagnated.

A total of 24 new electric car models were launched in 2024, increasing model availability by 15% compared to 2023, providing consumers with more choices and further increasing competition. While the Tesla Model Y and Model 3 have been the two best-selling models in the United States since 2020, the 110 new models that have entered the market since then have driven the market share of Tesla down from 60% in 2020 to 38% in 2024. Furthermore, 2024 was the first year in which Tesla saw a drop in sales in the United States, while other OEMs saw sales increase by 20% on aggregate.

A modification to the US Clean Vehicle Tax Credit at the start of 2024 enabled buyers to receive an instant discount (up to USD 7 500 for a new electric car and USD 4 000 for a used electric car) at the point of sale, which may have served to entice interested buyers. However, not all electric cars were eligible for the credit: in 2024 about 20 electric models (not accounting for different trim levels) out of a total 110 were eligible, which translated to over half of US electric car sales. The real share that benefitted from the tax credit may be even higher. In 2023, provisions were introduced on leased electric cars to reclassify them as commercial vehicles, thereby making them eligible for the tax credit without having to meet requirements on local manufacturing. As a result, by 2024, nearly half of all EVs sold were leased, more than double the share seen 3 years earlier. In addition to the federal tax credit, in 2024, 27 states offered additional incentives, rebates and exemptions promoting electric car adoption.

Electric car registrations and sales share in selected countries and regions, 2018-2024



Notes: BEV = battery electric vehicle; PHEV = plug-in hybrid vehicle, EREV = extended-range electric vehicle.
Sources: IEA analysis based on country submissions and data from ACEA, EAFO, EV Volumes and Marklines.

Emerging markets saw a strong uptick in electric car sales

Electric car sales shares doubled in a number of emerging markets

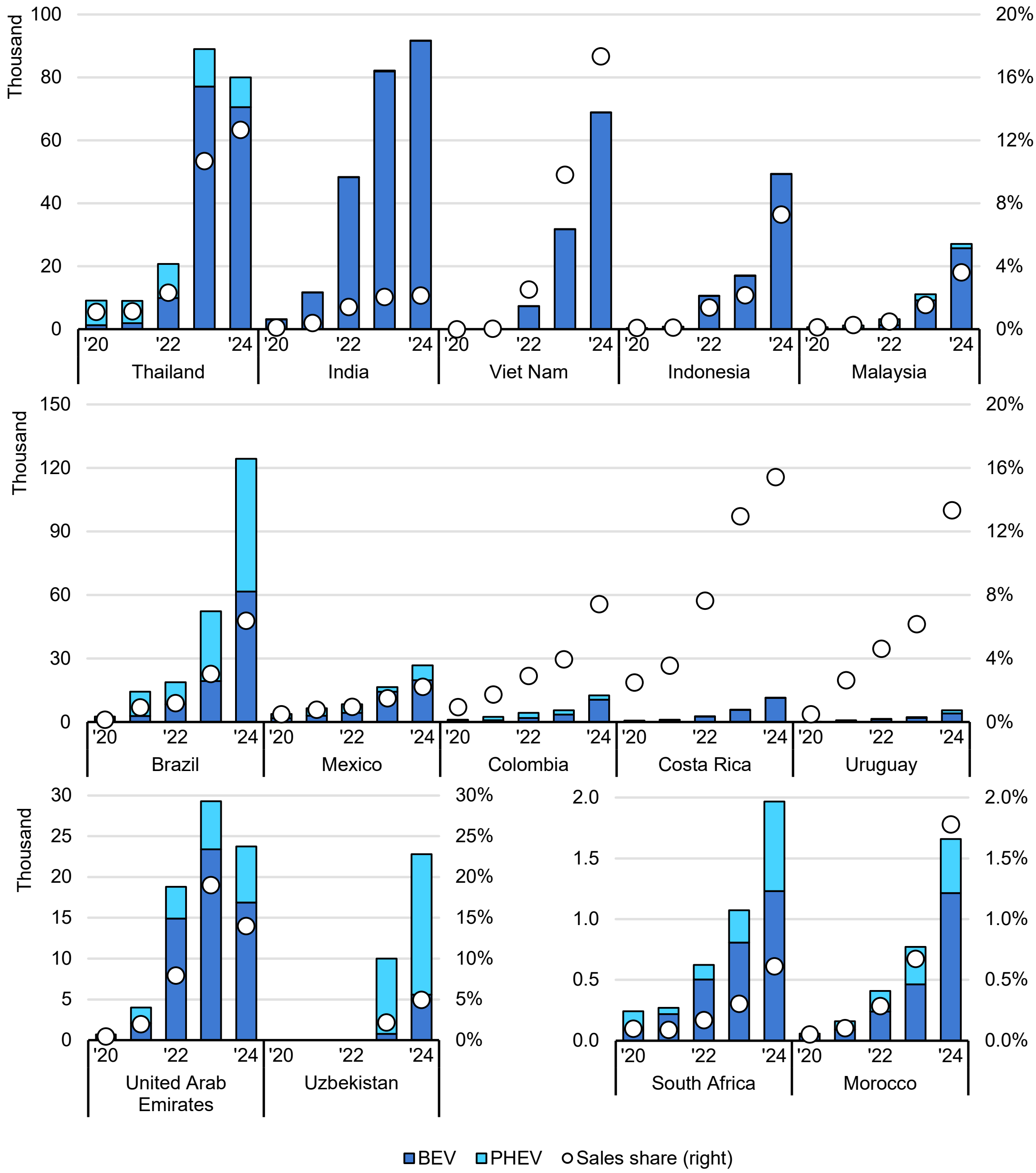
In emerging and developing economies in Asia, Latin America and Africa, electric car sales increased by over 60% year-on-year in 2024, and the sales share almost doubled from 2.5% to 4%. This rapid growth has been strengthened by policy incentives and the growing presence of relatively affordable electric cars from Chinese OEMs.

Emerging and developing economies in **Asia** (excluding China) saw a large increase in electric car sales, reaching almost 400 000 in 2024, up over 40% from 2023. However, in India, total electric car sales and their share of sales increased only slightly, approaching 100 000 (or 2%) in 2024. Thailand remained the largest EV market in Southeast Asia, despite a 10% drop in electric car sales. This decline was outweighed by an even steeper 26% drop in conventional car sales, largely due to stricter lending criteria, meaning the electric sales share rose to 13% in 2024, up from 11% the previous year. Within the region, Indonesia and Viet Nam also stood out, respectively tripling and nearly doubling their sales numbers and reaching sales shares comparable to countries such as Spain or Canada. In many Southeast Asian countries, BEVs are the most popular electric car type, with over 90% of all electric car sales being fully electric.

In **Latin America**, sales volumes and penetration rates doubled in many countries, with electric cars reaching a market share of 4% in 2024. Brazil towered over other countries in the region with nearly 125 000 electric car sales, more than twice the number of 2023 sales, and the electric sales share doubled to 6.5%. Costa Rica, Uruguay and Colombia also achieved impressive sales shares of around 15%, 13% and 7.5%, respectively. These increases are in large part the result of government incentives such as tax exemptions, reduced registration fees, a relaxation of traffic restrictions for EVs, and relatively high fossil fuel prices.

In **Africa**, electric car sales more than doubled to reach nearly 11 000 in 2024. Sales shares remained low, at under 1%, though there was growth in several countries, such as Morocco and Egypt, where new electric car sales increased to more than 2 000.

Electric car registrations and sales shares in selected countries, 2020-2024



Notes: BEV = battery electric vehicle; PHEV = plug-in hybrid electric vehicle.
Sources: IEA analysis based on country submissions and data from ACEA, EAFO, EV Volumes, Marklines, Asomove, AleTech, Andemos, OICA, AFMA, Gaikindo and AIVAM, sales of other macro regions can be found in the Global EV Data Explorer.

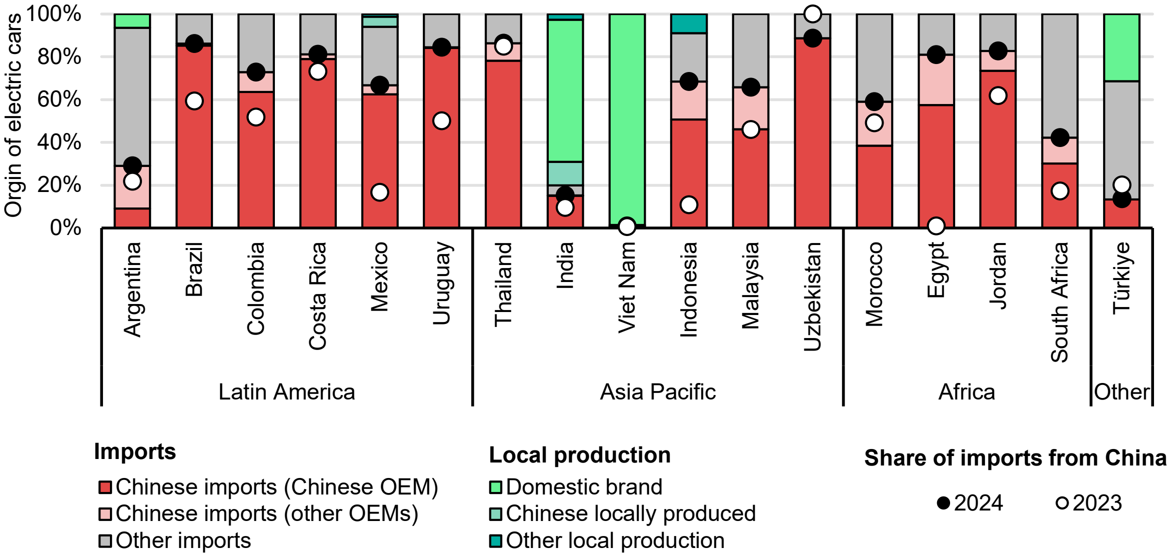
Emerging electric car brands are seeing local and even international success

Recent years have seen the birth of several new electric car brands in emerging markets, such as VinFast in Viet Nam, Togg in Türkiye, and Tito in Argentina, helping to drive up sales. In **Viet Nam,** local brands underpinned the near doubling of the electric sales share in 2024 to reach 17%. VinFast has also started to export to 11 different countries, with the largest share of exports going to Southeast Asian countries such as Indonesia (44%) and Malaysia (22%), but also to the United States (22%). The company has announced plans to double domestic production in Viet Nam, as well as expanding manufacturing into India and Indonesia.

Türkiye continues to deploy the domestically produced Togg electric cars, increasing its total production by 50% year-on-year. The increase in domestic production and in imports resulted in the country reaching an electric sales share of 10% in 2024. In July 2024, the Turkish government announced a USD 5 billion package to boost its annual production to 1 million electric cars per year.

India's electric car market is predominantly supplied by Indian OEM Tata. In addition, at the end of 2023, Indian steelmaker JSW signed a joint venture with SAIC Motor, a Chinese OEM, to work together on car production under the name MG Motor. In 2024, the joint venture produced about half of its electric cars sold in India domestically, while the other half were imported from China. At the end of 2024, JSW also announced the launch of its own EV brand, and is in talks with partners such as BYD and Geely regarding collaboration on technology transfer.

Origin of electric cars sold in selected markets, 2024, and share of total imports from China, 2023 and 2024



Notes: Chinese OEMs include BAIC, Geely-Volvo, GWM, GAC, BYD, Chery Automobile, JAC, Neta Auto, Seres Group, FAW, Changan, Dongfeng, Jiangling Motors, SAIC, Leap Motor, Xiaopeng, Aiways Automobile. The domestic brands are Tata Motors, Mahindra & Mahindra (India); Togg Inc. (Türkiye); VinFast (Viet Nam) and Tito (Argentina).
Sources: IEA analysis based on data from EV Volumes.

Overseas expansion plans of Chinese producers, prompted by changes to import tariffs, drove sales in emerging markets

Another notable trend from 2024 was the numerous manufacturing announcements from Chinese OEMs in countries such as Brazil, Thailand, Indonesia and Malaysia, where temporary exemptions from import tariffs for electric cars are coming to an end. In 2024, electric car sales in **Brazil** more than doubled, with over 85% of new electric cars coming from China. A key factor behind this impressive growth was electric cars being exempt from import duties of 35%, though this exemption started to be gradually removed in 2024 and is set to end by the middle of 2026. By then, automakers BYD and GWM will have begun producing models in Brazil, with a range tailored to the Brazilian market, such as BYD's Song Pro, which will be flex-fuel compatible.

In **Thailand**, Chinese imports play a key role in electrification, accounting for 85% of electric car sales. However, as in Brazil, this share is expected to decline due to changes introduced in the EV 3.5 program, under which import taxes on electric cars will be reintroduced at the end of 2025 and existing subsidies of up to THB 100 000 (Thai baht) (USD 2 800) per imported car will be gradually phased out. To continue to qualify for the exemption and subsidy, OEMs must commit to producing at least two battery electric vehicles (BEVs) domestically by the end of 2026 for every imported BEV sold in 2024 and 2025.

In **Indonesia**, electric car sales tripled in 2024 while the conventional market contracted by 20%, leading to an electric sales share of over 7%. The government has supported adoption by reducing the VAT rate on electric cars from 11% to 1% since 2023. However, what has potentially had an even greater impact on reducing the cost of electric cars for Indonesian buyers – and thus stimulating EV sales – has been the government waiving import taxes for EVs from car makers that invest in local electric car manufacturing from the start of 2024. Chinese car manufactures such as BYD and GAC Aion profited from this reduction, as did European OEM Stellantis. As a result, Chinese electric car imports increased 18-fold to 34 000 by the end of 2024.

In **Malaysia,** electric car sales more than doubled in 2024 and the sales share increased from less than 2% in 2023 to nearly 4% in 2024. Much of this success is due to imported electric cars being exempt from import taxes and excise duties until the end of 2025. Ahead of the tax exemption ending, Chinese car producer Geely, together with Proton (a Malaysian automotive company), will start domestically producing the e.MAS 7 by the end of 2025, backed by an investment from Geely. Malaysian OEM Perodua will also start producing its first electric car at the end of 2025, with a price of RM 80 000 (Malaysia ringgit) (USD 18 000).

More affordable electric cars and local policies have reshaped the EV landscape in more emerging markets

Policy measures such as tax incentives for electric cars contributed to the doubling of electric car sales seen in **Colombia** and **Costa Rica** in 2024. Colombia also proposed to increase import tariffs on all hybrid vehicles at the end of 2024, in a push to shift more sales towards BEVs. More than 70% of all electric cars sold in these two countries were imported from China, with Chinese imports to Colombia more than tripling in 2024, while imports from other countries grew by just 30%. In **Uzbekistan,** electric car sales shares doubled and the average price of an imported electric car fell almost threefold between 2023 and 2024.

In **Africa,** local policies and changing trade regimes are reshaping the electric car market. Developments such as the ban on imports of petrol and diesel cars introduced in **Ethiopia** at the start of 2024 have resulted in a reported deployment of 100 000 electric vehicles.[3] While model availability appears to be reasonable in the country, there are reports that garages struggle to source components for repairs, and that deployment of chargers outside of the capital has not kept pace with electric car sales. In **Morocco** and **Egypt,** efforts by car manufacturers to expand their production lines for batteries and/or electric cars in order to facilitate exports to the European Union have also pushed up domestic deployment, with the sales share reaching just under 2%. **Nigeria** is now looking into strengthening its EV manufacturing capacity with support from Morocco, and in 2024, signed the Zero Emission Vehicles Declaration to work towards all new sales of cars and vans being zero emission by 2040.

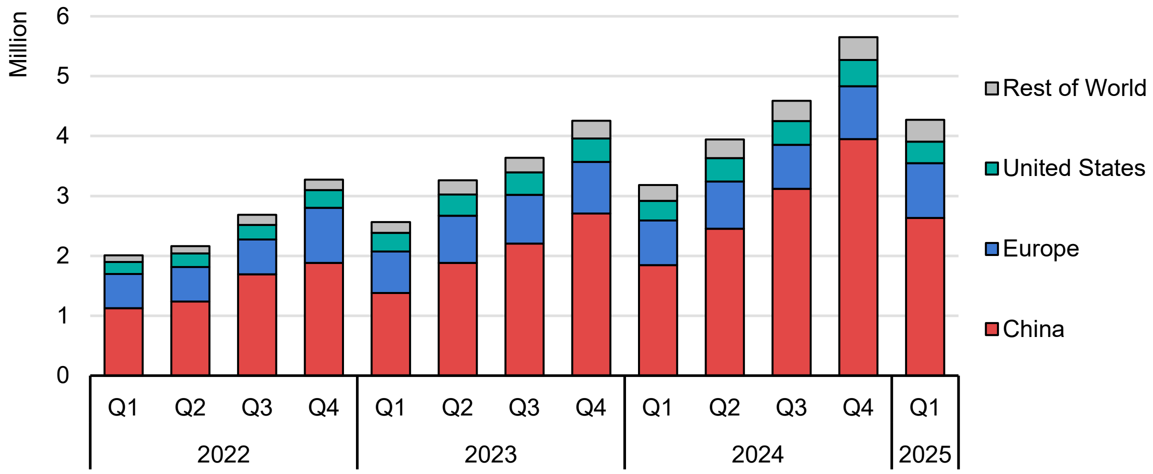
First quarter sales hint at strong sales for 2025, despite many uncertainties

Electric car sales increased 35% in the first quarter of 2025 compared to the same period in 2024

More than 4 million electric cars were sold in the first quarter of 2025 as sales grew by 35% compared to the first quarter of 2024, which was higher than the growth rate observed in the first quarters of the previous 2 years. Over 1 million more electric cars were sold in the first three months of 2025 compared to the same period in 2024 and about 60% of these were sold in China.

[3] Data on electric car deployment in Ethiopia is difficult to obtain, and sources are not well aligned. The Ministry of Transport of Ethiopia reports a stock of 100 000 electric vehicles but does not define how many of these are cars. In contrast, EV Volumes reports about 1 300 electric car sales in the past 5 years.

Quarterly electric car sales, 2022-Q1 2025



Sources: IEA analysis based on data from EV Volumes.

Between January and March 2025, China averaged monthly sales of around 875 000 electric cars, with total sales of more than 2.5 million. While the electric sales share was less than 45% in January, it reached more than 50% in both February and March. Across the full first quarter, the share of electric car sales was similar to that of 2024.

In Europe, electric car sales reached more than 900 000 in the first quarter of 2025, 625 000 of which were sold in the European Union. The electric sales share has also been increasing, averaging one in four cars sold in Europe in the first three months of 2025. In the United Kingdom, electric cars represented 30% of cars sold in the first quarter, while in the European Union the share was less than 25%.

More than 360 000 electric cars were sold in the United States in the first three months of 2025, around 10% more than during the same period the previous year. Total car sales grew at a similar rate, meaning the electric car sales share in the United States remained around 10%, the average across 2024.

In Canada, the federal government's iZEV incentive programme, which has supported electric car adoption with rebates of up to CAD 5 000 (Canadian dollars) (USD 3 500) since 2019, was paused in January 2025 as programme funds had been fully committed. Despite this, electric cars sales still grew by around 10% in the first quarter, in part because some province-level subsidies remain available.

Several emerging electric car markets continued to see strong growth in the first quarter of 2025. In Brazil, for example, electric car sales exceeded 30 000 across the first three months of 2025, 40% more than during the same period in 2024. Sales in India grew 45% year-on-year, nearing 35 000 electric car sales for the first quarter of 2025. Electric car sales in Viet Nam also approached 35 000 for the first quarter – nearly four times as many as were sold during the first quarter of 2024 – leading sales across Southeast Asia to double to over 100 000 between January and March 2025.

Electric car sales are expected to exceed 20 million in 2025, representing one-quarter of total car sales

For the full year 2025, electric car sales are expected to increase by 25% globally, which is similar to the growth rate from the 2024. As a result, electric car sales top 20 million worldwide. While sales volumes may be impacted by economic and policy uncertainties, more than one in four cars sold in 2025 is expected to be electric.

Building on strong sales in the first quarter of 2025, China is expected to sell over 14 million electric cars across the full year – more than were sold globally in 2023. Sales of both electric and conventional cars are supported by the extension of the trade-in scheme for older vehicles. The sales share of electric cars in China is expected to reach around 60% in 2025.

The European Commission announced in March 2025 that OEMs would be given flexibilities in meeting the 2025 CO_2 targets for cars and vans. On this basis, OEMs now only need to achieve the 15% emissions reduction target (compared to the 2021 baseline) on average over 2025-2027. This announcement was made in response to auto industry claims that the 2025 target would be unachievable, and would thus incur significant financial penalties that would damage the already struggling European auto industry. As yet, it is unclear how different OEMs will approach meeting the 3-year average target, in terms of the degree of under-performance that could be accepted in 2025 but would then need to be compensated for in the following 2 years.

The new phase of the CO_2 targets in the European Union is expected to drive up electric car sales, although the new flexibilities mean OEMs have less of an incentive to bring lower-priced electric cars to market this year. Given that a purchase premium for electric cars persists in Europe, the phase-out of EV purchase subsidies in some European countries could place downward pressure on sales, but there are signs to the contrary. At the end of 2024, the electric car purchase subsidy in the Netherlands came to an end, but electric car sales in the country in the first quarter of 2025 were about 10% higher than during the same period of 2024. In Italy, direct purchase subsidies for electric cars are no longer being renewed after 2024, though the government does aim to support the domestic production of EVs. In the first three months of 2025, electric car sales in Italy were up almost 50%.

Over the course of the year, electric car sales are expected to reach around 4 million across Europe. In line with this, the share of electric cars sales would increase several percentage points compared to 2024, to around 25%. The increase in electric car sales across Europe is boosted by the UK Vehicle Emissions Trading Scheme, which sets the target of 28% battery electric car sales in 2025.

In the United States, Executive Order 14154 directed the government to reconsider market interventions that favour EVs. Legislation has since been proposed that would end the Clean Vehicle Tax Credit for both cars and light commercial vehicles. In 2025, this proposal may result in consumers that have been considering buying an electric car rushing to do so before the tax credit is removed. A dampening effect on EV sales in the United States is expected only once the tax credit is repealed, and the timeline for that is uncertain. In addition, tariffs for conventional and electric cars have also been announced, which may result in lower car sales. For the full year, electric car sales in the United States are expected grow almost 10% in 2025, with a slight increase in the electric car sales share.

Across the rest of the world, electric car sales are expected to grow by over 30% to around 1.8 million. This would mean electric cars account for 6% of all car sales outside of the three major EV markets in 2025, up from 5% in 2024. The strong growth seen in Southeast Asia and Brazil is expected to continue, reaching sales of more than 0.5 million combined in 2025.

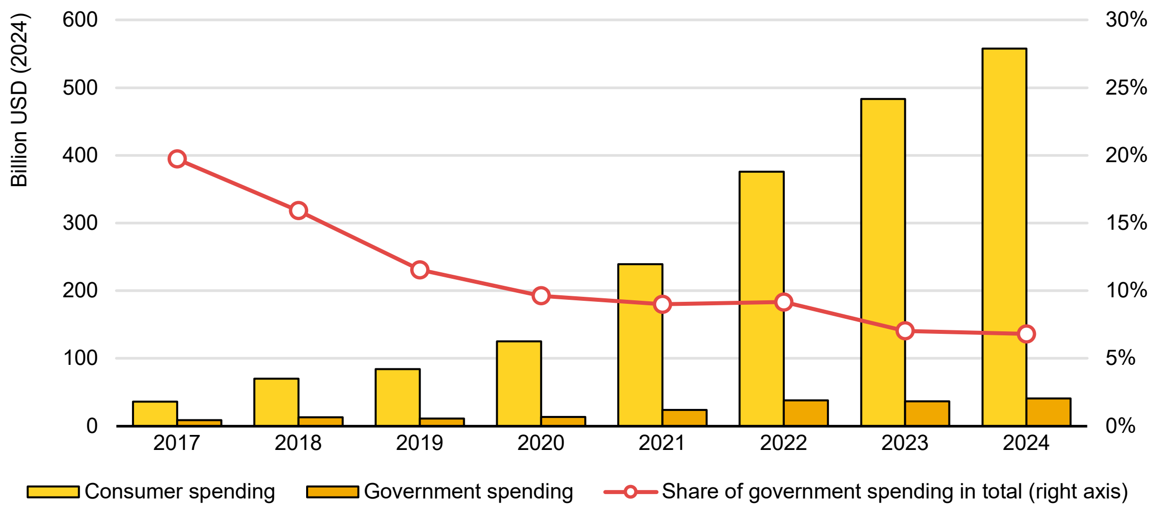
Government spending on electric cars

Subsidy phase-outs are leading to ever lower shares of government spending in the EV market

As electric car sales have grown over the past decade, government spending per vehicle, in the form of purchase subsidies and tax incentives, has steadily declined – a trend that accelerated in 2022 as subsidies were phased out.

In 2024, government spending accounted for less than 7% of total spending on electric cars globally, compared to 20% in 2017. In absolute terms, annual government spending on electric cars has hovered around the USD 38 billion mark since 2022. At the same time, total consumer spending on electric cars globally has grown continuously to reach USD 560 billion in 2024.

Global consumer and government spending on electric cars, 2017-2024



Notes: Government spending is the sum of direct central government spending through purchase incentives and foregone revenue due to purchase and registration 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. Values and trends may change slightly relative to previous publications following methodology improvements and better coverage of government support schemes.
Sources: IEA analysis based on EV Volumes and national policy documents.

China has had the largest absolute public spending since 2020, despite its subsidy scheme coming to an end in December 2022 after 12 years. Other incentives have remained in place – notably, electric cars being exempt from the 10% purchase tax that applies to other vehicles. In 2024, China introduced a trade-in subsidy with a higher premium for the purchase of EVs. The additional expenditure to support EV purchases is estimated to be around USD 2.7 billion for 2024.[4] Nevertheless, Chinese government expenditure per vehicle dropped 25% between 2022 and 2024. China has the highest share of subsidies going to PHEVs, at nearly 45%, as a result of the 10% purchase tax exemption being applied to PHEVs, which are on average more expensive than BEVs. In contrast, government incentives for PHEVs have almost disappeared from other key markets.

In Europe, subsidy schemes were significantly reshaped in 2023 and 2024. The most abrupt change was in Germany, where the EUR 4 500 per-vehicle subsidy was reduced to zero as of December 2023 – which was followed by a drop in EV market share of 4 percentage points in 2024. As a result, the German government

[4] The original funding allocation for the car trade-in subsidies in 2024 was close to CNY 11.2 billion (USD 1.5 billion), however, for the full year, 6.6 million cars were traded in. The additional expenditure for electric car purchases is estimated by applying the CNY 5 000 subsidy differential to the 60% of trade-ins that were for the purchase of an electric car.

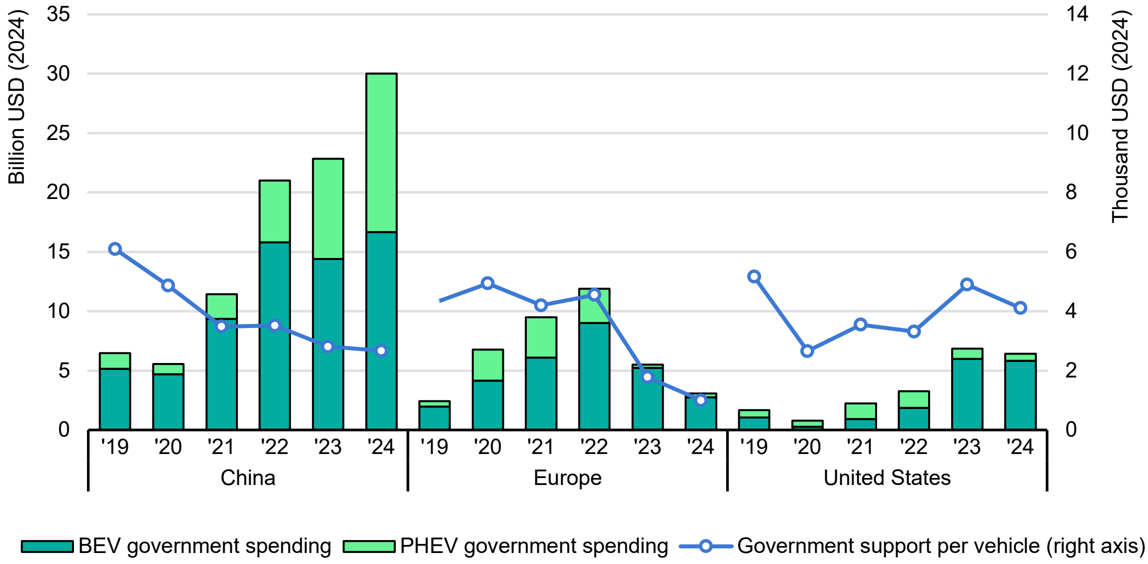
has introduced new tax benefits for companies buying EVs, effective from July 2024 through to 2028. Company cars account for about two-thirds of registrations in the country.

In the United Kingdom, all subsidies were removed at the end of 2022 but electric car sales have continued to increase, thanks in part to the Vehicle Emissions Trading Schemes, which set targets for zero-emission car sales starting from 2024. In addition, the growth in EV sales was underpinned by a set of tax rebates for company cars, which represented about 60% of total car registrations in 2024. When factoring in all government tax incentives, an ICE car would incur more than 10 times the company car tax of an equivalent BEV, compared to Germany where this ratio is around 4.

Similarly, Sweden ended its subsidy programme offering up to SEK 60 000 (Swedish kronor) (USD 5 800) per electric car in November 2022. Absolute volumes of electric car sales in the country decreased 10% in 2024, though the country's EV sales share fell only very slightly due to a drop in overall car sales. In several other European countries, subsidies were either reduced in absolute terms, or their conditions have become more stringent, with a faster roll-back of subsidies for PHEVs. As a result, the average subsidy per vehicle in Europe has fallen rapidly, from more than USD 4 500 per vehicle in 2022 to around USD 1 000 in 2024. The phase-down or interruption of subsidy schemes in Europe has had differing consequences on EV market shares at the national level, but the rapid decrease in subsidies has not been followed by an equivalent decrease in EV market share, providing an encouraging sign of market resilience.

In the United States, the introduction of the Inflation Reduction Act expanded the number of vehicles eligible for tax credits in 2023. However, the list of vehicles eligible for the USD 7 500 tax credit has since changed repeatedly as Internal Revenue Service guidelines have been implemented. The average tax credit in 2024 was approximately USD 4 000 per vehicle, since not all electric cars were eligible and some were eligible for only USD 3 750. In both 2023 and 2024, the United States had the highest per-vehicle subsidy of the three major EV markets.

Government spending on electric cars by region and powertrain, 2019-2024



Notes: BEV = battery electric vehicle; PHEV = plug-in hybrid electric vehicle. Government spending is the sum of direct central government spending through purchase incentives and foregone revenue due to purchase and registration 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.

Sources: IEA analysis based on EV Volumes and national policy documents.

2. Trends in the electric car industry

Manufacturing and trade

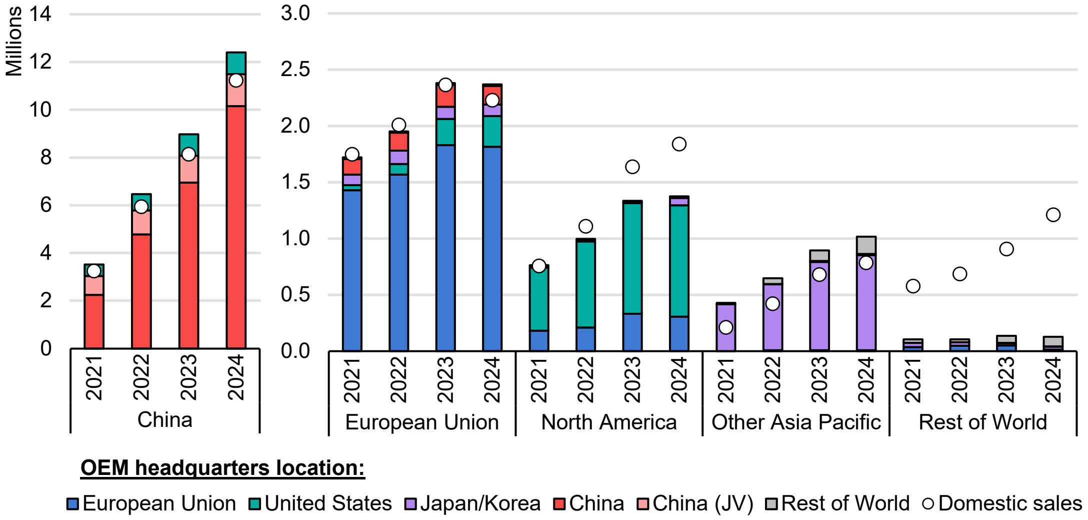
Steady growth in global electric car production masks differences at the regional level

A total 17.3 million electric cars were produced worldwide in 2024, about one-quarter more than in 2023, largely as a result of increased production in **China**, which reached 12.4 million electric cars. China remains the world's electric car manufacturing hub, accounting for more than 70% of global production in 2024. Production in China has been increasingly shaped by the expansion of domestic manufacturers. In 2024, Chinese OEMs accounted for more than 80% of domestic production, up from roughly two-thirds in 2021. Despite the numerous recently announced foreign direct investment plans from Chinese OEMs, their overseas production has yet to ramp up. Electric car production by Chinese OEMs operating outside China accounted for less than 2% of their global output in 2024.

In the world's second-largest electric car manufacturing region, the **European Union**, production stagnated at 2.4 million cars in 2024, but surpassed domestic sales by more than 5%. Domestic carmakers were behind nearly 80% of the region's total output, but there were contrasting trends among EU OEMs. While German OEMs marked a 5% year-on-year increase in their EU output, other EU OEMs (Stellantis and Renault) saw their regional production drop by over 15%, producing about 420 000 electric cars, or less than 20% of the region's output. Meanwhile, there was a sixfold increase in EU production by US OEMs between 2021 and 2024, predominantly led by Tesla and Ford. This contributed to the share of foreign OEMs in EU production reaching about 20% in 2024.

Elsewhere in Europe, the United Kingdom saw its electric car output drop 30% year-on-year in 2024 to around 80 000 electric cars, while Türkiye's production grew to 45 000, with two-thirds produced by domestic manufacturer Togg.

Production of electric cars by region and location of car manufacturer headquarters, 2021-2024



Notes: OEM = original equipment manufacturer; JV = joint venture. Other Asia Pacific includes Australia, New Zealand, Japan, Korea, India and Southeast Asia. North America includes Canada, the United States and Mexico. Tesla is the only foreign OEM producing electric cars in China that is not part of a joint venture with a Chinese OEM.
Sources: IEA analysis based on EV Volumes.

Manufacturing trends in **North America** showed notable contrasts. The gap between domestic production and sales in North America has increased steadily over the past 3 years. In 2024, despite electric car production falling 7% in the United States, overall output across the region remained unchanged year-on-year, as the decline in US output was offset by Mexico doubling its production to 220 000 electric cars. US-headquartered carmakers ramping up their manufacturing operations in Mexico were responsible for 70% of the country's total output, followed by Japanese and EU OEMs contributing equally to the remaining 30%. Meanwhile, Canada's output paled in comparison to its neighbours, remaining constant from 2023 at 25 000 vehicles.

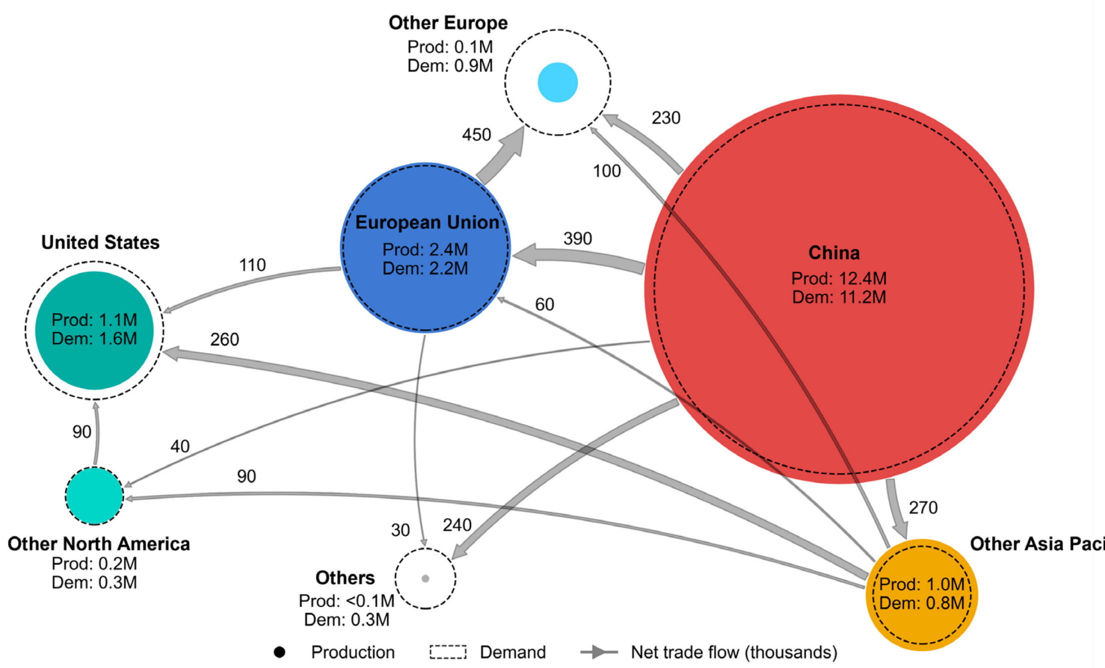
Electric car production also increased in **Asia Pacific** countries other than China to reach about 1 million. While incumbent carmakers such as Japan's Toyota and Korea's Hyundai were behind most of the region's output, emerging EV players like VinFast in Viet Nam or Tata in India were responsible for an increasing share of production, growing from 10% in 2023 to 15% in 2024. In India, in particular, domestic OEMs (Tata and Mahindra) accounted for more than 80% of the 75 000 electric cars produced domestically in 2024.

Global trade of electric cars grew nearly 20% in 2024

China and the European Union remained the world's largest EV exporters, while Mexico ramped up exports to the United States

Global electric car exports[1] surged by nearly 20% in 2024, reaching about 3.2 million electric cars and accounting for almost 20% of global sales, a share similar to that seen in 2023 and 2022. As with manufacturing, **China** accounted for the largest share, with 40% of global exports, or nearly 1.25 million electric cars.

Production, demand and net trade of electric cars in major global markets, 2024



Notes: Prod = production; Dem = demand; M = million cars. Net trade flows are in thousand vehicles and rounded to the nearest 10 000. Net trade flows under 20 000 vehicles are not shown. Stockpiling (the difference between exports and actual sales) of electric cars is not taken into account, and trade flows represent the number of electric cars manufactured in one country or region and sold in another region or country. "Other Asia Pacific" comprises Australia, New Zealand, Japan, Korea, India and Southeast Asia. "Other North America" includes Canada and Mexico. Other Europe includes Norway, Iceland, Israel, Switzerland, Türkiye, the United Kingdom and other European countries that are not EU member states.
Source: IEA analysis based on EV Volumes.

In 2024, the **European Union** saw its exports grow 9% year-on-year to nearly 830 000 electric cars. The key destination markets for EU-made electric cars remained unchanged, with other European countries accounting for almost 60%

[1] Unless specified otherwise, exports and imports of electric cars are calculated based on the sales of vehicles manufactured in a different location to the country in which they are sold. Global car exports and imports are assessed at the country level, except for the European Union, where internal trade between member states is excluded.

of exports (40% to the United Kingdom), followed by North America, accounting for about one-quarter of EU exports. The European Union remained a net exporter of electric cars in 2024, despite importing about 680 000 electric cars. While imports from China remained steady in 2024 at more than 400 000 electric cars (60% of EU imports), the share of Chinese OEMs in imports from China grew to two-thirds in 2024, up from 50% in the previous year. The Chinese OEM Geely accounted for almost 40% of these imports, mainly through its brand Volvo Cars, while Tesla's share decreased from 30% to 20% as more than half of its EU sales in 2024 were produced at its German assembly plant. **Other European countries** rely significantly on imports, primarily from the European Union. The majority of production elsewhere in Europe is based in the **United Kingdom** and **Türkiye**, but these countries were responsible for less than 15% of regional sales in 2024. China was the second-largest trade partner for electric cars, accounting for more than one-quarter of the 840 000 electric cars imported by non-EU European countries in 2024.

The **United States** remained a net importer of electric cars in 2024. Exports fell nearly 15% year-on-year to less than 200 000 electric cars, while imports grew 40% to 630 000. In 2024, **Mexico** became the United States' largest electric car trade partner, with net exports to the United States reaching 145 000 vehicles. Imports from Mexico grew threefold compared to 2023, representing more than two-thirds of Mexico's output. This surge was primarily driven by US OEMs (accounting for 70% of Mexico's exports to the United States) and Japanese OEMs (20%). Japan and Korea, previously the largest next exporters to the United States, each accounted for net exports of roughly 135 000 vehicles in 2024. Despite being the top source of imports in gross terms, the European Union ranked fourth in net electric car exports to the United States in 2024, totalling about 110 000 vehicles. Meanwhile, 40% of US-made electric car exports went to **Canada** in 2024, making it the largest US export market.

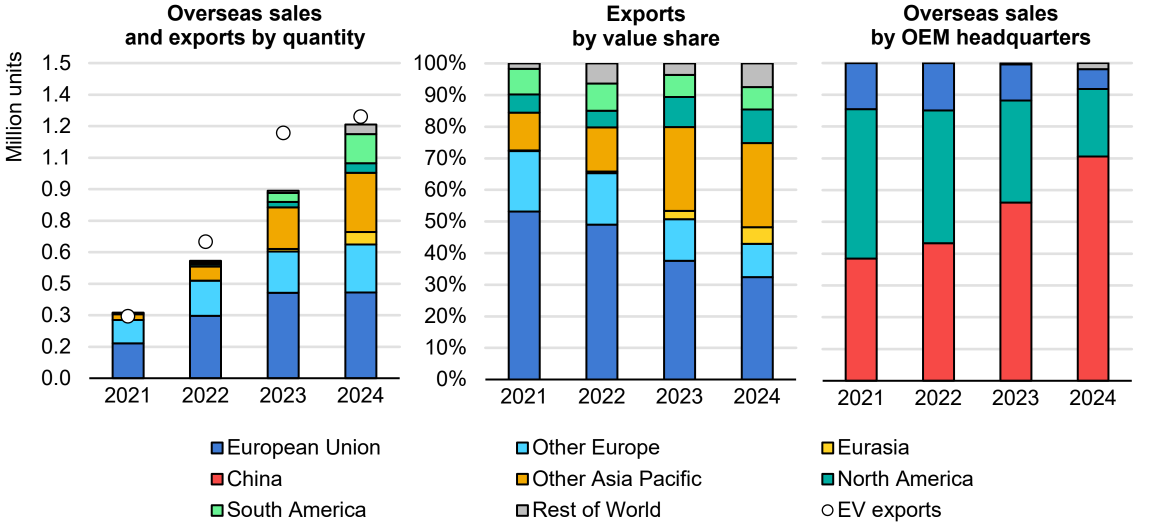
Japan and Korea accounted for the majority of the nearly 640 000 electric cars exported from the Asia Pacific region excluding China in 2024, primarily through their domestic manufacturers, with an increase of 15% from 2023. The United States was the main destination market for these exports, accounting for more than a quarter of the 1 million electric cars produced in the region. Europe followed, importing another quarter of the region's production.

Chinese exports are increasingly driven by domestic OEMs as their destinations diversify

While it remains the world's largest exporter of electric cars, China experienced a noticeable slowdown in export growth in 2024. According to the China Association of Automobile Manufacturers (CAAM), the country exported over 1.15 million electric cars in 2023, marking a staggering 80% growth from 2022. However, in 2024, annual export growth fell to just 7%, split unevenly across destination markets.

Several factors contributed to this slowdown. Firstly, the increase in trade restrictions resulting from tariff hikes in major export markets prompted Chinese OEMs to frontload their exports before such tariffs came into force. In Brazil for example, although Chinese imports saw strong year-on-year growth, with an increase of 120% in 2024, they dropped sharply by a factor of eight in the second half of the year following the reinstatement of tariffs. Europe remained the most important export market for Chinese-made electric cars, but weakening demand, reluctance of European consumers to buy Chinese EV brands and new countervailing duties in the European Union led the share of value attributed to Europe in total Chinese EV exports to fall from over 70% in 2021 to roughly 40% in 2024. As a result, Chinese exports increasingly shifted towards emerging markets such as Mexico (+370%), Southeast Asia (+10%), Russian Federation (hereafter: Russia) and countries in the Caspian Sea region.

Sales of Chinese-made electric cars outside China by region (left), export value shares per destination region (centre), and overseas sales by location of original equipment manufacturer headquarters (right), 2021-2024



Notes: EV = Electric Vehicles, which include electric cars only in this figure; OEM = original equipment manufacturer. Left and right figures use EV Volumes to represent the sales of Chinese-made electric cars in overseas markets by destination market and OEM headquarters location. Discrepancies with EV exports reported by China Association of Automobile Manufacturers (CAAM) (white dot) are explained by stockpiling of unsold Chinese electric cars in export markets. The exports by value in the central figure are taken from General Administration of Customs of the People's Republic of China (GACC) trade tables queried with HS codes 870360 and 870380, which also include low-speed EVs. Other Asia Pacific includes Australia, New Zealand, Japan, Korea, India and other Southeast Asian countries. Eurasia includes the Caspian regional grouping and Russia.

Sources: IEA analysis based on EV Volumes, CAAM and GACC.

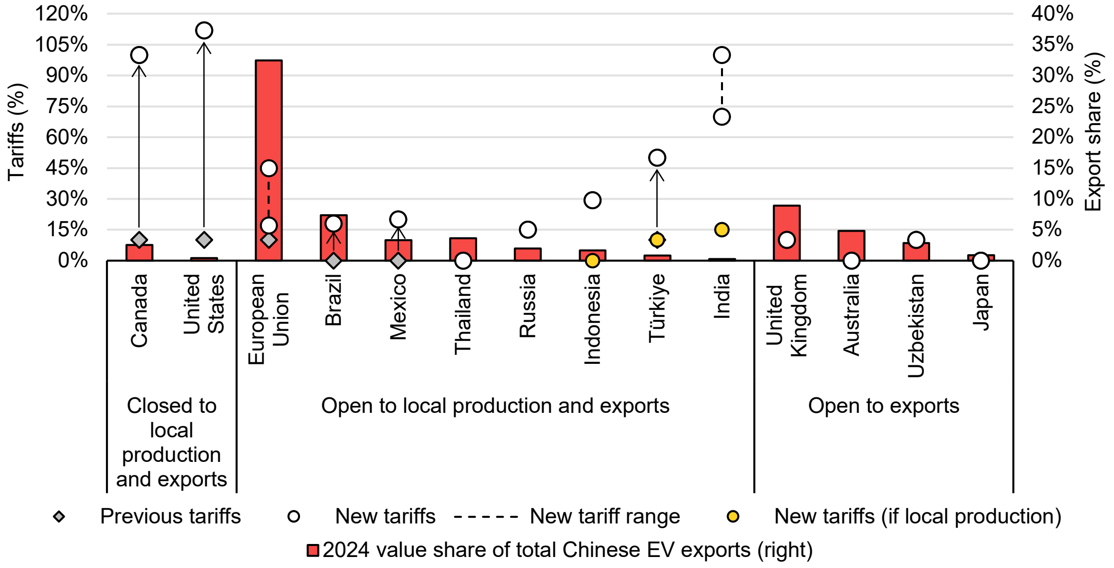
Inventory build-up by Chinese OEMs also contributed to the slowdown in Chinese export growth. In 2023, sales of Chinese-made electric cars outside China fell short by 275 000 cars compared to CAAM's reported exports. This led to clogged destination seaports, particularly in Europe and Brazil, and limited the capacity for additional imports in 2024 until excess inventory was cleared. However, this stockpile helped sustain overseas sales growth of 35% for Chinese-made electric cars in 2024, while exports grew only 7%.

Chinese OEMs accounted for 70% of 2024 total electric car exports from China, up from 55% in 2023. To sustain their export momentum, Chinese OEMs are investing in expanding shipping capacity through roll-on/roll-off (Ro-Ro) car carriers. In 2025, BYD commissioned the world's largest Ro-Ro vessel, bringing its total shipping capacity to more than 30 000 electric cars. Meanwhile, a leading Chinese car shipping company, COSCO Shipping Car Carriers, announced plans to expand its fleet to handle up to 700 000 cars annually. Despite the 2024 export slowdown, this surge in shipping capacity positions Chinese OEMs for renewed growth, playing a crucial role in facilitating exports from China and emerging manufacturing hubs like Southeast Asia.

Tightening trade restrictions are pushing Chinese OEMs to expand their overseas manufacturing footprint

As Chinese electric car production continues to outpace domestic demand, Chinese OEMs are increasingly looking abroad to capture a larger share of the global electric car market. However, tariff changes across several regions are making it more difficult for Chinese-made electric cars to remain competitive in key destination markets. In 2024, multiple regions introduced new tariffs on Chinese electric car imports. This included the European Union, which imposed OEM-specific countervailing duties on Chinese battery electric car imports, aimed at offsetting alleged manufacturing subsidies received by OEMs in China. Meanwhile, the United States and Canada implemented new tariffs exceeding 100% in 2024, with further increases to tariffs on Chinese imports announced in 2025 in the United States, effectively deterring future Chinese electric car imports. Mexico and Brazil, both of which have recently experienced a surge in Chinese EV imports, have also approved tariff hikes. In 2024, Mexico ended its 15-20% tariff exemption on EV imports from countries without a free trade agreement, including China. Brazil reinstated 10% import tariffs on electric cars in 2024, with plans to gradually raise them every 6 months to reach 35% by the middle of 2026.

Changes in tariffs on Chinese electric vehicle imports in selected regions, 1 January 2024-1 January 2025



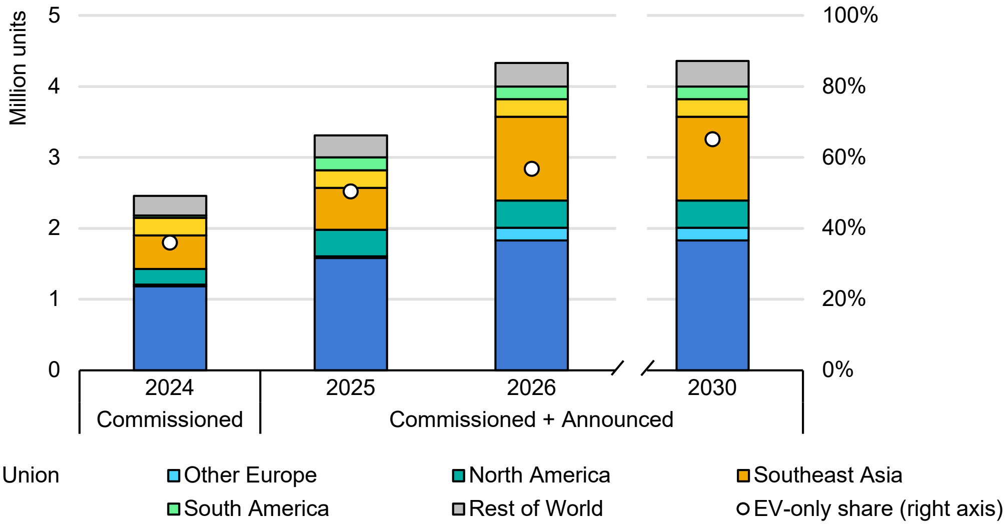
Notes: Previous tariffs refer to tariffs in place on 1 January 2024 while new tariffs refer to those in place on 1 January 2025. Indonesia has set a waiver on electric vehicle (EV) import duties for original equipment manufacturers (OEMs) committing to produce locally until 1 January 2026. The free trade agreement between Thailand and China reduces the usually applied tariff rate from 80% to 0%. In June 2024, Türkiye imposed a 40% additional tariff on China-made cars and, one month later, exempted vehicles imported under investment incentive certificates. Brazil's import duties on EVs are set to 18% (20% for plug-in hybrids) in the first half of 2025 and will gradually increase to 35% by 2026. The European Union's import duties apply only to battery electric cars and vary across OEMs. Russia's 15% tariff on EV imports does not include the recycling fee which amounts to USD 4 400 (RUB 360 000 Russian rubles) per imported EV. The Indian government announced a decrease in import duties to 15% for manufacturers committing to produce locally within 3 years with a minimum investment of about USD 500 million. 2024 value of Chinese EV exports is taken from General Administration of Customs of the People's Republic of China (GACC) interactive trade tables queried with HS codes 870360 and 870380.

Sources: IEA analysis based on ITC (Market Access Map), GACC.

These additional export costs are prompting Chinese OEMs to establish new overseas manufacturing capacities. The assembly plants being planned are intended to both directly supply local markets (like BYD's plant in Brazil) and produce EVs for exports, thereby limiting exposure to tariff hikes targeting imports from China (such as from BYD's plant in Türkiye for exports to the European Union).

Most of the overseas production capacity owned by Chinese OEMs today is in the European Union, primarily through Volvo Cars' assembly plants, which produced more than 160 000 electric cars last year. By 2026, when including both EV-only assembly plants and dual EV/ICE assembly plants, overseas manufacturing capacity belonging to Chinese OEMs is expected to almost double to reach over 4.3 million vehicles per year. Europe and Southeast Asia are likely to remain the primary locations of these new electric car assembly plants, with almost half of the total Chinese overseas manufacturing capacity being located in Europe by 2026.

Commissioned and committed announced overseas electric vehicle manufacturing capacity of Chinese original equipment manufacturers, 2024-2030



Notes: EV = electric vehicle. Manufacturing capacity refers to plants producing EVs, either exclusively or alongside internal combustion engine cars without specifying the EV share. The EV-only share is calculated as the share of EV-only commissioned and announced assembly plants in total manufacturing capacity shown. Volvo brand commitments to reach a 50% and 90% EV share in its 2025 and 2030 sales, respectively, are treated as EV-only manufacturing capacity and are therefore accounted for in the EV-only share. Both full-process manufacturing and knocked-down (in which pre-manufactured components are imported and assembled) types of assembly plants are considered. Announcements refer to committed investments only.

Sources: IEA analysis based on Marklines, Atlas EV Hub, OEM announcements.

Thanks to policies supporting EV manufacturing, access to raw materials, and a well-established automotive industry, Southeast Asia is poised to see the largest increase in Chinese OEMs' overseas manufacturing capacity. Countries including Indonesia, Malaysia, Thailand and Viet Nam have all put in place policies either favouring domestic manufacturing over imports, or providing exemptions from import and income taxes for OEMs committing to produce domestically. As a result, the combined EV-only and dual EV/ICE manufacturing capacity of Chinese OEMs in Southeast Asia is set to increase almost threefold by 2026 to reach 1.2 million vehicles (more than one-quarter of the total overseas manufacturing capacity of Chinese OEMs).

Model availability

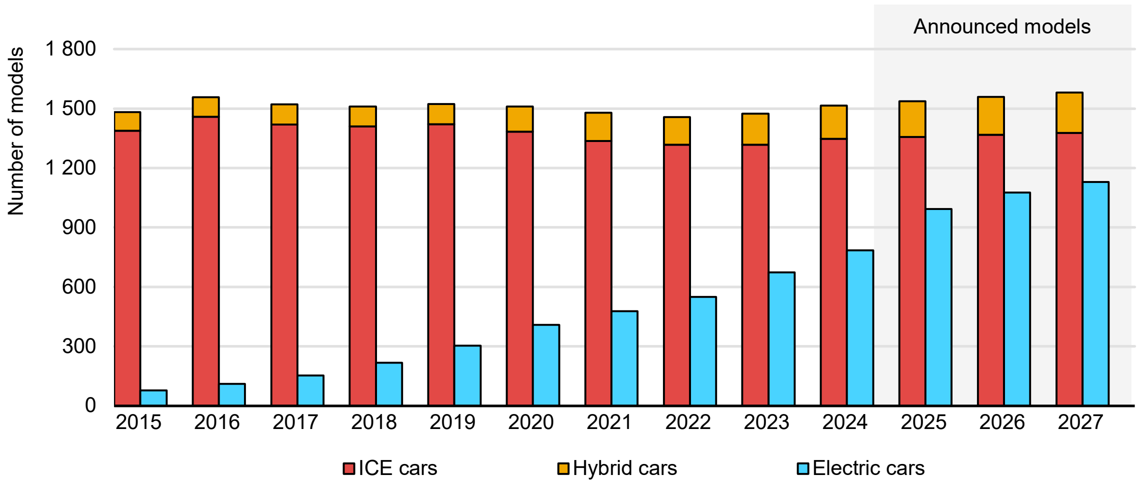
The number of electric car models keeps growing, especially for larger cars and SUVs

Available electric car models could number more than 1 000 by 2026

The number of available models for electric cars increased 15% year-on-year to reach nearly 785 in 2024. While today there are 50% fewer electric models than ICE and hybrid electric vehicle (HEV)[2] models, this gap is narrowing and is expected to shrink to around 30% by 2027 based on announcements by OEMs.

While its EV sales share remained largely unchanged, Europe saw the fastest increase in model availability over the past year, with a jump from 290 models to more than 360. The growth seen in 2024 is expected to almost double by 2026: As stricter emissions standards come into force in the European Union, more than 140 additional models are due to enter the market. For example, Volkswagen and Stellantis have announced plans to introduce about 35 new electric models between them by 2026.

Global availability of car models by powertrain, 2015-2027



Notes: ICE = internal combustion engine. Based on historic data and announced launches. Electric cars include battery electric vehicles (BEVs) and plug-in hybrid electric vehicles (PHEVs). Hybrid cars are full hybrid models, mild hybrids are included in ICE cars. 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. Models are counted by brand model and do not include different trims. The announced models from 2025 to 2027 are based on electric model announcements and the number of ICE and hybrid models based on the trend over 2022-2024.

Source: IEA analysis based on data from EV Volumes and Marklines.

[2] A hybrid electric vehicle (HEV), which is powered by an ICE in combination with one or more electric motors using energy from batteries, can be in either a mild configuration or a full configuration. Mild hybrids use a battery and electric motor to help power the vehicle but cannot power the vehicle using electricity alone. A full hybrid can power a vehicle using electricity over short distances and at low speeds, thanks to its more powerful electric motor and larger battery. HEV batteries are charged through regenerative braking and by the ICE; HEVs cannot be plugged in to charge the battery and are not considered under the definition of electric vehicle.

The share of larger cars and SUVs among EV models coming onto the market continues to expand. In 2024, 70% of available EV models were large (segments E to F) cars, SUVs or pick-ups, compared to 65% in 2023. Nevertheless, there are signs that this share is levelling out in some markets. In Europe, 23 additional small electric models (segments A and B) are expected to join the 33 small models currently on the market. The United States has the lowest number of small electric models available, and nearly 90% of models available today are large cars or SUVs.

China has the most EV models across all segments

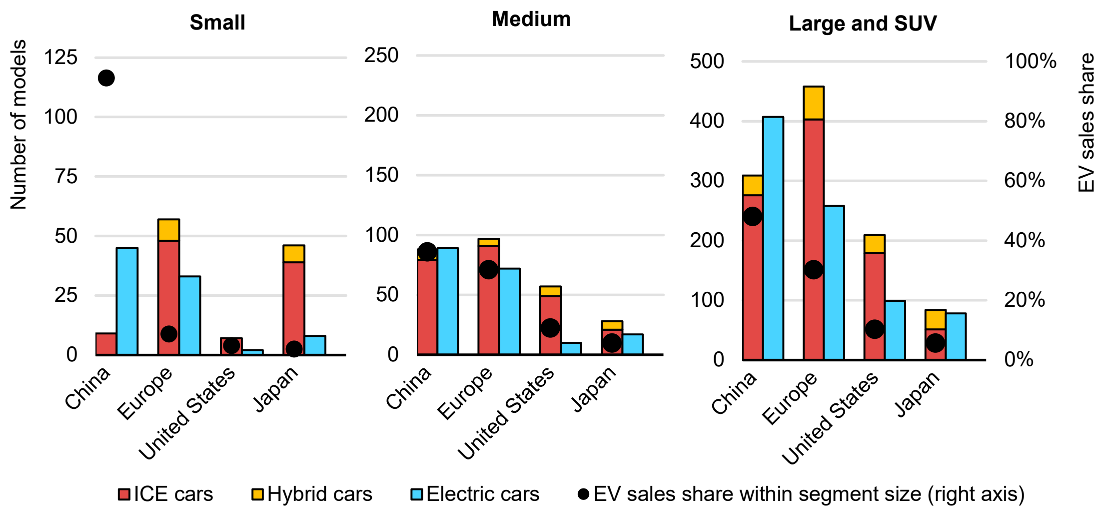
The highest model availability for electric cars can be found in China, where nearly 60% of all models on offer are electric – 5 times more than the number of electric models available in the United States. The large car and SUV segments are the most profitable for OEMs, and many have therefore developed these models as a preference. As a result, the number of small and medium models available in China is only one-third of the number of large or SUV models.

Yet despite model availability being more limited than for large cars, the small car segment is nearly fully electrified in China, with more than 90% of sales in the segment being electric. There were 45 small electric car models available in 2024, compared to fewer than 10 small conventional cars. The decline in number of conventional small models started in 2014 and by 2017 electric and conventional models were on par with around 30 models each. The small electric Seagull from BYD was one of the best-selling cars of 2024 across all segments and the best-selling small car, with about 440 000 sales. Sales came in just slightly behind the best-selling model overall, the Tesla Model Y (an SUV), which reached 485 000 sales. The fast pace of electrification of the small segment can be attributed to their affordability (see EV affordability in China), in combination with a push for local manufacturing and measures to improve air quality in China's provincial 'tier 3' cities.

In contrast, in Japan and Europe, the large car segment is the most electrified, and the small car segment the least. However, this does not necessarily reflect model availability: in Japan, the share of electric models on offer in the large car segment is about 50%, but only 6% of large car sales are electric. Similarly, in Europe, where more than 40% of all small and medium models available are electric, the electric sales share in these segments is just 20%. In the United States there are nearly 100 electric large or SUV models available, which is less than half of the number of ICE and HEV models available.

Growing model availability supports EV adoption, but price appears to be the key determinant of EV penetration within small and medium size segments. People purchasing small and medium cars are likely to be more price sensitive than buyers of larger models, making price parity particularly important for electrifying these segments. In Germany, less than 5% of small BEVs sold were cheaper than their ICE equivalent, as described in the section on EV affordability in Europe.

Number of available car models by powertrain and electric vehicle sales share per size segment for selected regions, 2024

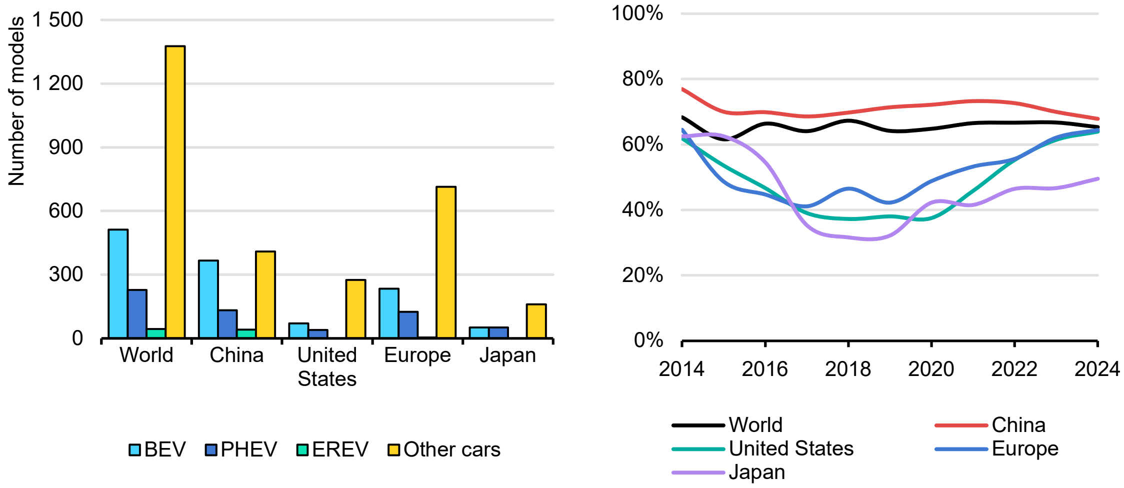


Notes: SUV = sports utility vehicle; ICE = internal combustion engine; EV = electric vehicle. Electric cars include battery electric and plug-hybrid vehicles; hybrid cars are full hybrid models; and mild hybrids are included in ICE cars. Analysis is based on models for which there was at least one new registration each year; a model on sale but never sold is not counted, and as such actual model availability may be underestimated. Models are counted by brand model and do not include different trims. Small cars include A and B segments; medium cars include C and D segments and A segments with SUV body type; large cars and SUVs include E and F segments, multi-purpose vehicles and C to B segments with SUV body type.
Source: IEA analysis based on data from EV Volumes and Marklines.

In major markets, battery electric models now represent around two-thirds of all electric car models

There are now more BEV models available than PHEV models. Over time, the share of BEV models among total electric car models in China, Europe and the United States has converged to reach a ratio of about two BEVs for every PHEV. While BEVs were the focus for OEMs in the early years (2014 and earlier), their share among electric car models then dropped in Europe, Japan and the United States, before beginning to increase again around 2020 in the United States and Europe. In Japan, the split remains at 50:50, while the average globally is more than three BEV models for every two PHEVs. Within the PHEV segment, the number of extended-range electric vehicle (EREV) models has grown in recent years, increasing by 40% from 31 models in 2023 to 43 models in 2024 (see Box below).

Number of models by powertrain in selected markets and globally, 2024 (left), and share of battery electric vehicle models in total number of electric car models (right), 2014-2024



Notes: BEV = battery electric vehicle; PHEV = plug-in hybrid electric vehicle not including EREVs; EREV = extended-range electric vehicle. Other cars include hybrids and internal combustion engine cars.
Source: IEA analysis based on data from EV Volumes and Marklines.

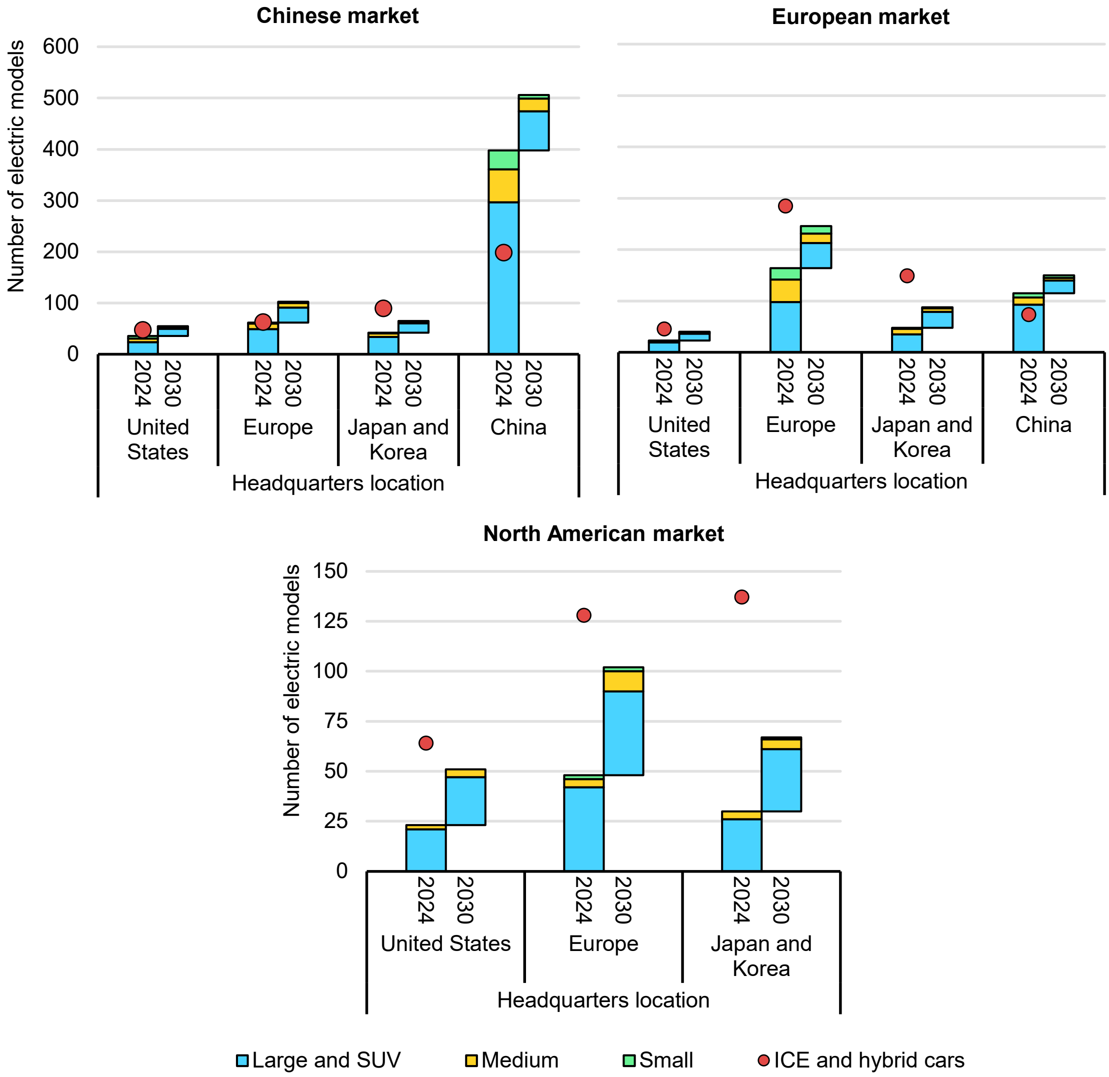
OEMs adopt different strategies for electric model announcements in different regions

The number of electric models on the **Chinese market** today is already greater than the number of ICE and hybrid models. Based on announcements, and assuming the level of ICE and hybrid models remains constant, by 2030 there will be two electric models available for every conventional car model. Domestic OEMs such as BYD and Geely already offer twice as many electric models than conventional models. This is in contrast to the offering from OEMs headquartered elsewhere in the world, which have slightly fewer electric than ICE models available in China. However, this balance is likely to shift in favour of electric by 2030, with around 80 additional electric models announced. OEMs headquartered in Europe (such as Volkswagen, BMW and Mercedes) offer the most electric models after Chinese OEMs.

Based on electric car model announcements, the gap between the number of conventional and electric models shrinks the most to 2030 in the **European market**. Chinese OEMs in this market already offer more electric models than conventional models, but European OEMs are now closing the gap by increasing their electric offerings by 50% by 2030, which is more than OEMs headquartered in other regions. About 40% of these new EV models are small or medium cars. Volkswagen and Stellantis, both of which have a greater focus on these vehicle segments than other European OEMs, are behind more than half of all announcements for small or medium models in the European market, as they are urged to release affordable models to meet their fleet-wide CO_2 target in the short term.

In the **North American market,** larger cars are the focus for many OEMs. Of the 110 electric car models available today, only 2 are small (the Mini Cooper BEV and Fiat 500 BEV), with sales totalling 3 000 in 2024 – less than 1% of all electric car sales. However, about 15% of the electric models due to enter the market in the next few years are medium sized, compared to 9% of available models today. Despite an increase of about 145 electric models by 2030, which will more than double the model availability for electric cars in the region, the number of conventional models will remain 70% higher.

Number of car models by location of manufacturer's headquarters and size segment, 2024, and announced models by 2030 for selected markets



Notes: SUV = sports utility vehicle; ICE = internal combustion engine. Small cars include A and B segments; medium cars include C and D segments and A segments with SUV body type; large and SUV cars include E and F segments, multi-purpose vehicles and C to B segments with SUV body type. The models from the Renault-Nissan Alliance have their headquarters assigned by brand. Brands with headquarters located in other regions such as India, Viet Nam and Chinese Taipei are not included and account for 8-12% of announcements, depending on the market. It is assumed that none of the current electric models will be phased out.

Source: IEA analysis based on data from EV Volumes.

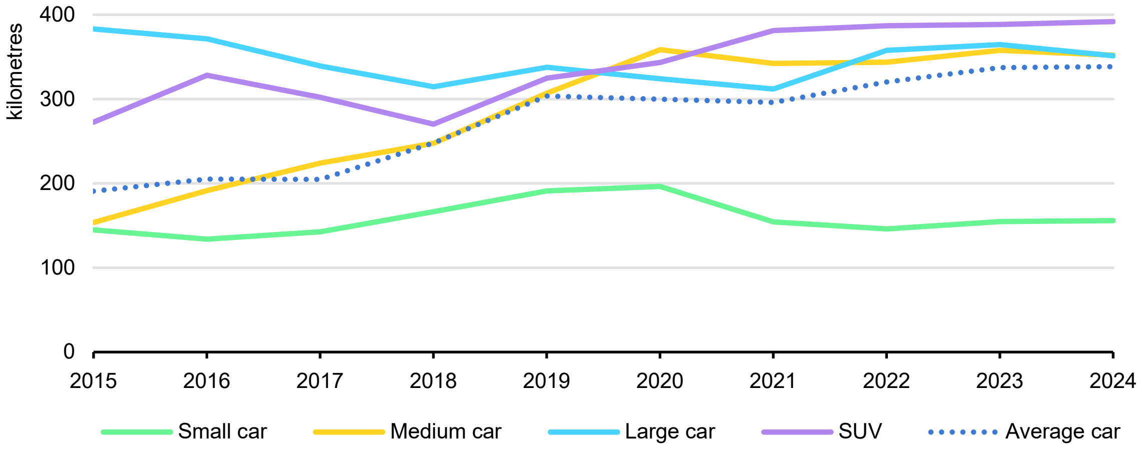
Electric vehicle range

No change to average range of battery electric cars in 2024

The sales-weighted average range (hereafter, "average range") of battery electric cars globally remained the same in 2024, at about 340 km under on-road conditions. The average range was significantly lower for small cars, at just above 150 km, while medium and large cars, as well as SUVs, all maintained ranges above 350 km. As market competition intensifies, the fact that average range has stabilised in the past year could indicate that carmakers have found an optimal balance between range performance and vehicle manufacturing costs. This levelling-off of driving range also offers energy and environmental benefits, as longer ranges also require larger batteries, which increase vehicle energy consumption and demand for critical minerals.

In the United States and Europe, the average electric range increased by less than 5%, primarily driven by the growing interest in electric SUVs, which continued to dominate the EV market – exceeding 75% of sales in the United States and reaching around 60% in Europe. Across Europe, the average range of a battery SUV car reached almost 400 km under on-road conditions. Nevertheless, this falls short of the 500 km that respondents to a recent survey stated as their range preference. Meanwhile, in China, the average range remained stable as EV producers prioritised cost-cutting in the face of strong domestic competition.

Sales-weighted average range of battery electric cars by segment, 2015-2024



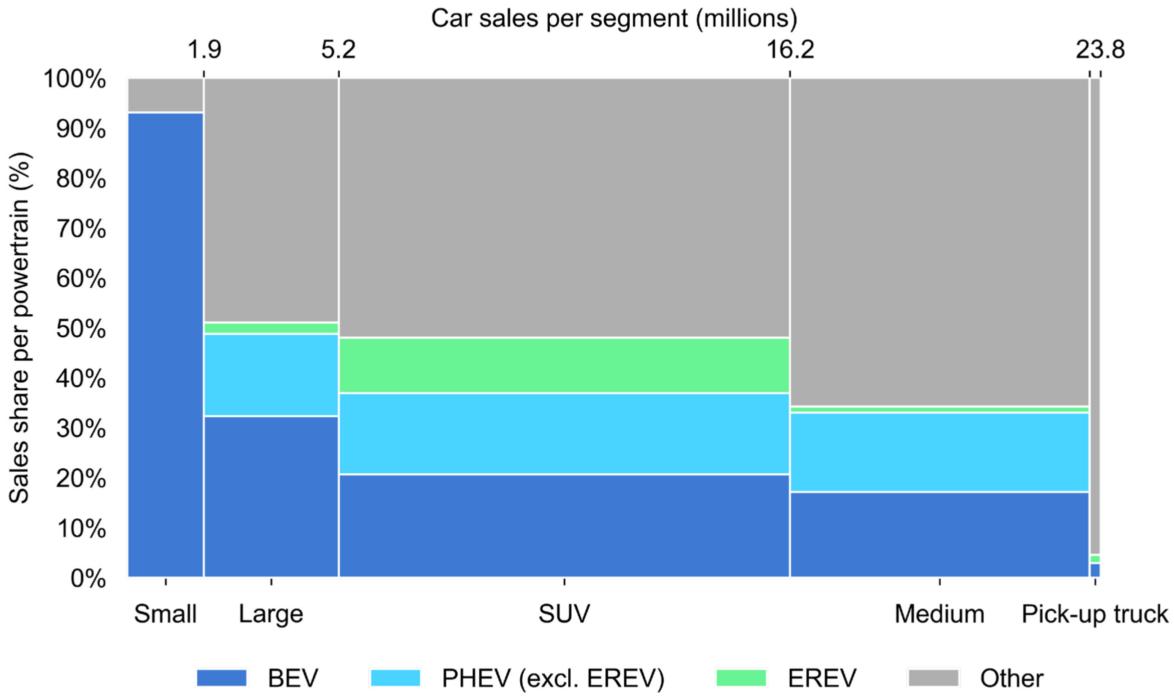
Notes: SUV = sports utility vehicle. Range is calculated using the global sales-weighted average vehicle efficiency of battery electric vehicles and their battery capacity by size segment. The vehicle efficiency considered in calculations reflects on-road driving conditions by applying a factor of 1.1 to the Worldwide Harmonised Light Vehicle Test Procedure (WLTP) vehicle efficiency (in [kWh/100 km]). The range considers full battery utilisation, from 100% to 0% state of charge. Small cars include A and B segments; medium cars include C and D segments, A segments with SUV body type and B segments with multi-purpose vehicle (MPV) body type; large cars include E and F segments, B segments with SUV body type and D segments with MPV body type; SUV includes segments C to F with SUV body type and remaining segments with MPV body type.

Source: IEA analysis based on data from EV Volumes.

Plug-in hybrid electric vehicles are growing in popularity in China

Consumers purchasing large cars and SUVs in China are increasingly opting to buy plug-in hybrid electric vehicles (PHEVs) as a more flexible option. The key appeal of PHEVs lies in their ability to handle long trips even when charging infrastructure is insufficient or congested. PHEV electric range in China grew by over 20% between 2020 and 2024, reaching almost 100 km. In contrast, electric ranges stalled in Europe and the United States at about 65 km. The environmental benefit of PHEVs largely depends on charging behaviour, which can lead to real-world tailpipe CO_2 emissions that are significantly higher than type-approval values.

Total car sales in China per segment and powertrain, 2024



Notes: BEV = battery electric vehicle; PHEV= plug-in hybrid vehicle; EREV = extended-range electric vehicle; SUV = sports utility vehicle. The width of each vehicle category in the horizontal axis is proportional to their Chinese market sales. Small cars include A and B segments; medium cars include C and D segments, A segments with SUV body type and B segments with multi-purpose vehicle (MPV) body type; large cars include E and F segments, B segments with SUV body type and D segments with MPV body type; SUV includes C to F segments with SUV body type.

Sources: IEA analysis based on EV Volumes and Marklines.

Extended-range electric vehicles (EREVs) have gained ground in recent years, almost entirely as a result of growing adoption in China. Uptake has been primarily in larger and heavier high-end vehicle segments. In 2024, EREV models accounted for nearly 25% of electric SUV sales in China, and they dominated the larger end of the electric SUV segment, making up 60% of large electric SUV sales (over 4.8 metres in length). More than 70% of the 40 EREV models available today belong to the SUV category (including multi-purpose vehicles and pick-up trucks), while the rest is mostly part of the large car segment category. In total, 14 additional EREV models are expected to be released by the end of 2025. Similarly, the four announced EREV models due for launch outside of China by 2026 (by Scout and RAM in the United States and Changan in Europe), in addition to the two already available today (Mazda and Leapmotor in Europe), are all positioned within the large pick-up truck and SUV segments.

Extended-range electric vehicles: advantages and limitations

In 2024, the average EREV in China had an electric range of about 120 km, compared to around 85 km for a standard PHEV. While the range of a standard PHEV has increased significantly in recent years, the longer electric range of EREVs could reduce charging frequency, increase the share of electric-only driving and lower reliance on liquid fuels.

As with standard PHEVs, the environmental benefits of EREVs are heavily influenced by charging behaviour and are generally overestimated in type-approval vehicle fuel economy ratings. In addition, when EREVs run on low battery, their fuel consumption compared to standard PHEVs varies depending on driving conditions. In some urban or low-power driving conditions, EREVs can be more fuel-efficient. However, in many other cases when the battery is low, the opposite is true: standard PHEVs tend to use less fuel because their engines can drive the wheels directly, unlike EREVs, which rely on a generator as an intermediate energy converter.

The components of EREVs also differ from those of standard PHEVs. EREVs require a generator, advanced power electronics and a larger battery, which can increase manufacturing costs, although the lack of traditional transmission and simpler engine design can reduce costs. Their competitiveness compared to standard PHEVs largely depends on optimising the size of the generator and battery, which are responsible for the majority of additional costs. Moreover, their chassis design, which is closer to that of a BEV than a standard PHEV, could accelerate technology transfer from rapidly evolving BEV battery pack and chassis technologies.

However, as battery electric cars continue to improve in range, charging speed and affordability, their simpler architecture and higher efficiency could outweigh the trend towards EREVs. Ultimately, wider adoption of EREVs will largely depend on the range and affordability of equivalent BEV models, as well as the availability of charging infrastructure.

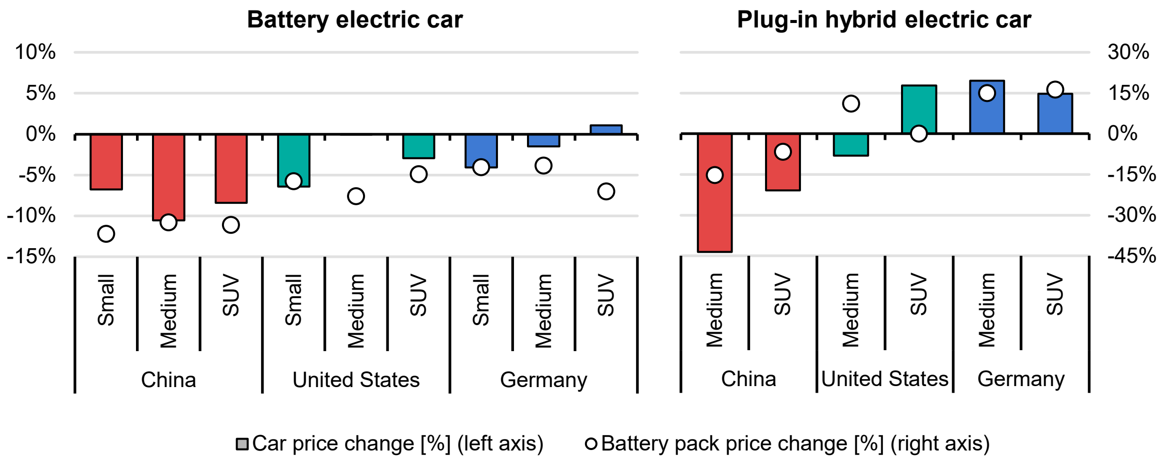
Electric car affordability

Falling battery pack prices and intensifying competition underpin progress in electric car affordability

Today, electric cars often have a lower total cost of ownership than ICE cars over the vehicle lifetime, due to reduced fuel and maintenance expenses. However, reducing the purchase price[3] gap will be key to broader uptake. In Europe, for example, respondents to a 2023 survey by the European Commission identified the price of battery electric cars as the main barrier to adoption. While battery electric car prices generally fell in 2024, the price gap with ICE cars remains in most regions.

Electric car affordability has made significant strides over the past decade, primarily driven by falling battery prices, intensifying market competition and carmakers reaching economies of scale. In 2024, despite the global average battery size growing slightly, the global average battery pack price fell more than 25% compared with 2023 levels. This resulted in a global drop in electric car manufacturing costs that was reflected in the price of electric cars.

Electric car price and battery system price changes in selected countries, 2023-2024

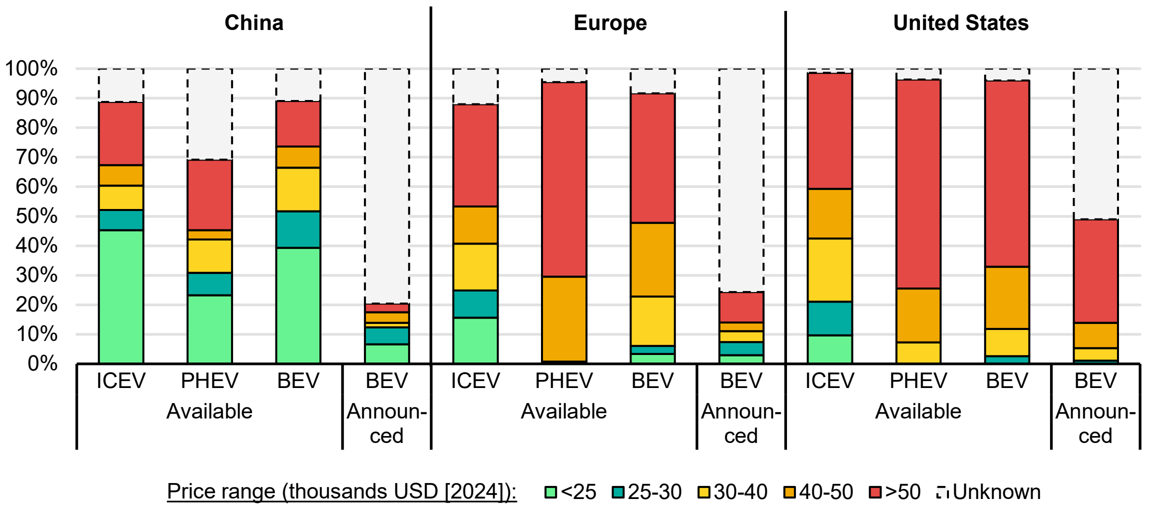


Notes: SUV = sports utility vehicle. Prices adjusted for inflation before indexing. Car price change values reflect the change in the sales-weighted average car retail price values over the 2023-2024 period. The battery pack price is calculated based on the average battery size in a given country, segment and year, multiplied by the corresponding regional pack price.
Source: IEA analysis based on data from S&P Global Mobility, BNEF and EV Volumes.

[3] By price we refer to the Manufacturer Suggested Retail Price (MSRP), also known as the sticker price, which includes value-added taxes, purchase taxes and dealer markups, but excludes purchase subsidies and registration taxes. It differs from the transaction price in that it does not account for any rebates and discounts applied at the dealership.

However, the trend towards falling prices has been uneven across markets, due to differences in carmakers' pricing strategies, and in market maturity and the level of competition. For example, in China, the sales-weighted average (hereafter, "average") price of a battery electric SUV fell almost 10% year-on-year in 2024, partly due to the 30% decline in the battery pack price. Similarly, in the United States, a 15% decline in battery prices contributed to a 3% drop in the average purchase price of electric SUVs in 2024. In contrast, in Germany, the price of electric SUVs slightly increased in 2024, despite their battery pack prices declining 20%. This suggests that the battery pack price is not the only factor influencing EV prices: other component manufacturing costs, trim levels and carmakers' pricing strategies also play a significant role.

Price range distribution of available and announced car models in selected markets, 2024-2026



Notes: ICEV = internal combustion engine vehicle; PHEV = plug-in hybrid electric vehicle; BEV = battery electric vehicle. "Available" includes models sold in 2024 in selected markets. Germany, the United Kingdom and Türkiye are used as proxy countries for available models in Europe. "Announced" only includes models with known release price and expected to be launched by the end of 2026.
Source: IEA analysis based on data from S&P Global Mobility, EV Volumes and OEM announcements.

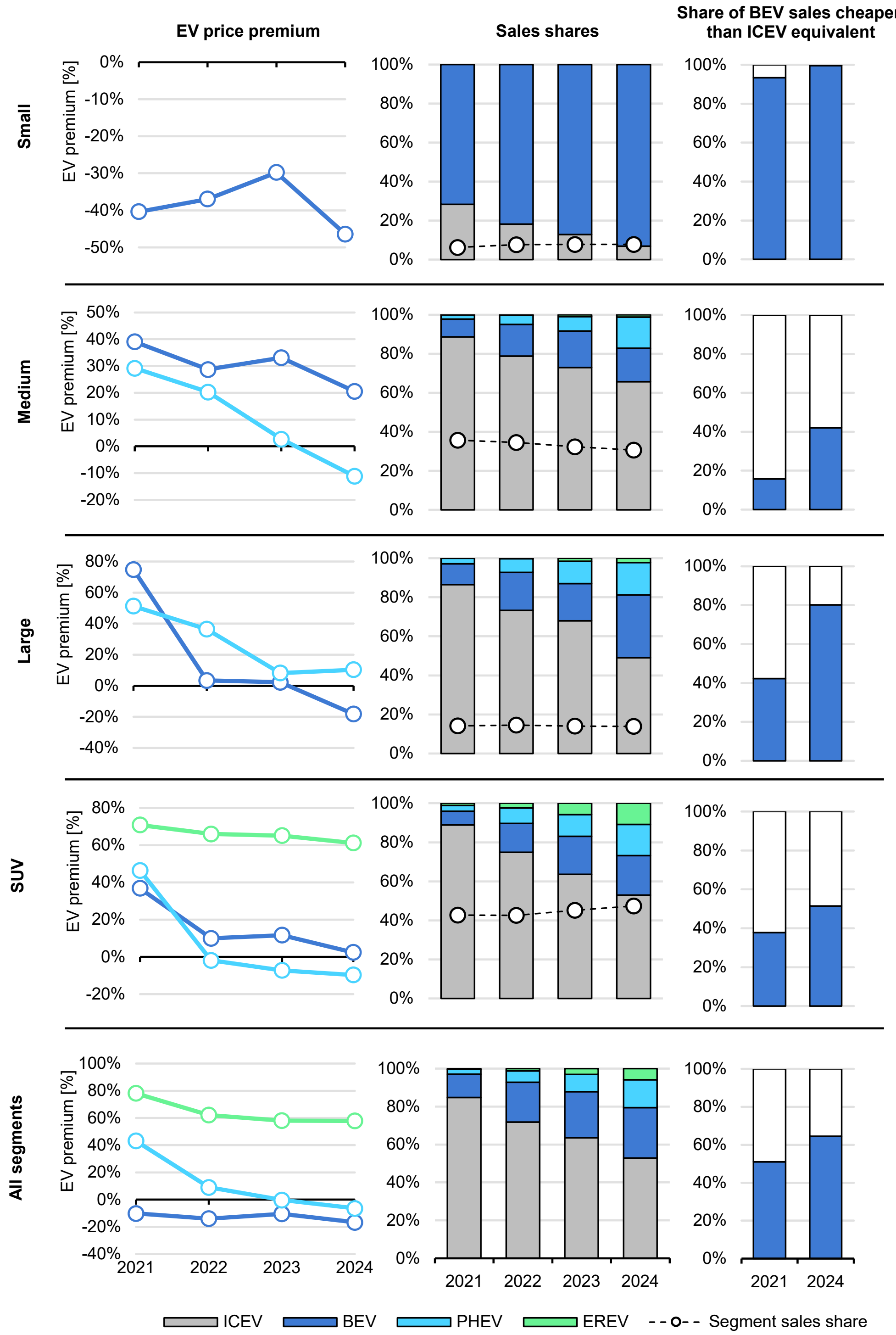
Availability of a wide range of affordable EV models will be key to unlocking mass-market adoption. In 2024, there were fewer BEV models available than ICEV models in the United States and Europe, and the range was skewed towards higher-end models with higher prices. Conversely, in China, the price distribution of available BEV models closely resembles that of ICEVs, with about 40% of available electric models priced below USD 25 000 (against 45% for ICEV models), and more than half below USD 30 000. In 2024, this price distribution was reflected in sales, with the median price paid for a battery electric car standing at around USD 24 000, about USD 700 less than for an ICE car. This trend towards a larger share of more affordable models is expected to continue in the short term, as 60% of announced models with a known price are expected to launch below the USD 30 000 mark.

Contrasting trends were also seen in the affordability of plug-in hybrids. In China, prices for medium PHEVs dropped 15% from 2023 to 2024, and SUV-type PHEV prices fell 7% over the same period. However, in Germany, the average purchase price of medium and SUV-type PHEVs grew more than 5% year-on-year. This was partly driven by their average battery size growing, causing their battery pack prices to increase by about 15%. In 2024, in Europe, only 1 of the around 130 PHEV models was priced under USD 40 000, compared with more than 40 BEV and 155 ICEV models marketed below this price tag. Similarly, in the United States, the 4 cheapest PHEV models available were priced between USD 30 000 and USD 40 000, while about 60 ICEV models were marketed below this price range. The US and German markets contrasted markedly with that of China, where nearly 40 PHEV models were available with a price tag below USD 25 000, competing with more than 250 ICEV and 140 BEV models within the same price range.

Price-competitive electric cars in China are driving rapid electrification across all segments

In China, the rapid electrification of small cars has been underpinned by their unrivalled affordability. In 2024, nearly all small battery electric car models in China were priced lower than the average small ICE car, and the average purchase price was about half that of the average small ICE car. This led to the almost complete electrification – nearly 95% – of small car sales in China in 2024, up from a share of 75% 3 years earlier. Nevertheless, the small car segment makes up only a small share of the Chinese car market, accounting for less than 10% of sales in 2024.

Electric car price premium compared to conventional models per segment (left), powertrain sales shares (centre) and sales share of battery electric vehicles cheaper than conventional equivalents (right) in China, 2021-2024



Notes: EV= electric vehicle; ICEV = internal combustion engine vehicle; BEV = battery electric vehicle; PHEV = plug-in hybrid electric vehicle; EREV = extended-range electric vehicle; SUV = sports utility vehicle. Price data is adjusted for inflation. Price of electric cars in data has been increased by 10% to adjust for the registration tax exemption in China. The share of battery electric cars cheaper than their conventional equivalent is calculated as the number of car sales priced lower than the sales-weighted average price of the ICE car in their segment category.

Source: IEA analysis based on data from S&P Global Mobility, EV Volumes and Marklines.

In 2024, BEVs also reached price parity with ICEVs in the SUV segment – the most popular car segment in China, accounting for half of all car sales. More than half of battery electric SUV sales were priced lower than an average ICE SUV. Plug-in hybrid SUVs were also sold at cheaper price levels than ICEV models for the third consecutive year, supporting their steady uptake in this vehicle segment. While progress on affordability has supported the growing sales shares of BEVs and PHEVs, adoption of EREVs seemed to be more a result of consumer preferences rather than purchase price competitiveness. In 2024, the average price premium of EREVs over ICEV models stood at 60%, marking slim progress from 70% three years ago. Despite their higher purchase price, the market share of EREVs within the SUV segment grew to reach 10% in 2024, suggesting that this hybrid powertrain technology is appealing to wealthier consumers who are less price sensitive and seek boosted range in high-end vehicle models.

In the medium car segment, which represents about one-third of total car sales in China, BEVs were 20% more expensive than conventional equivalents in 2024, down from 40% in 2021. PHEV prices also dropped. For the first time, the sales-weighted average price of medium PHEVs in 2024 was 10% lower than conventional models. As a result, PHEV sales in the segment more than doubled, and more than one-third of medium car sales in China in 2024 were electric.

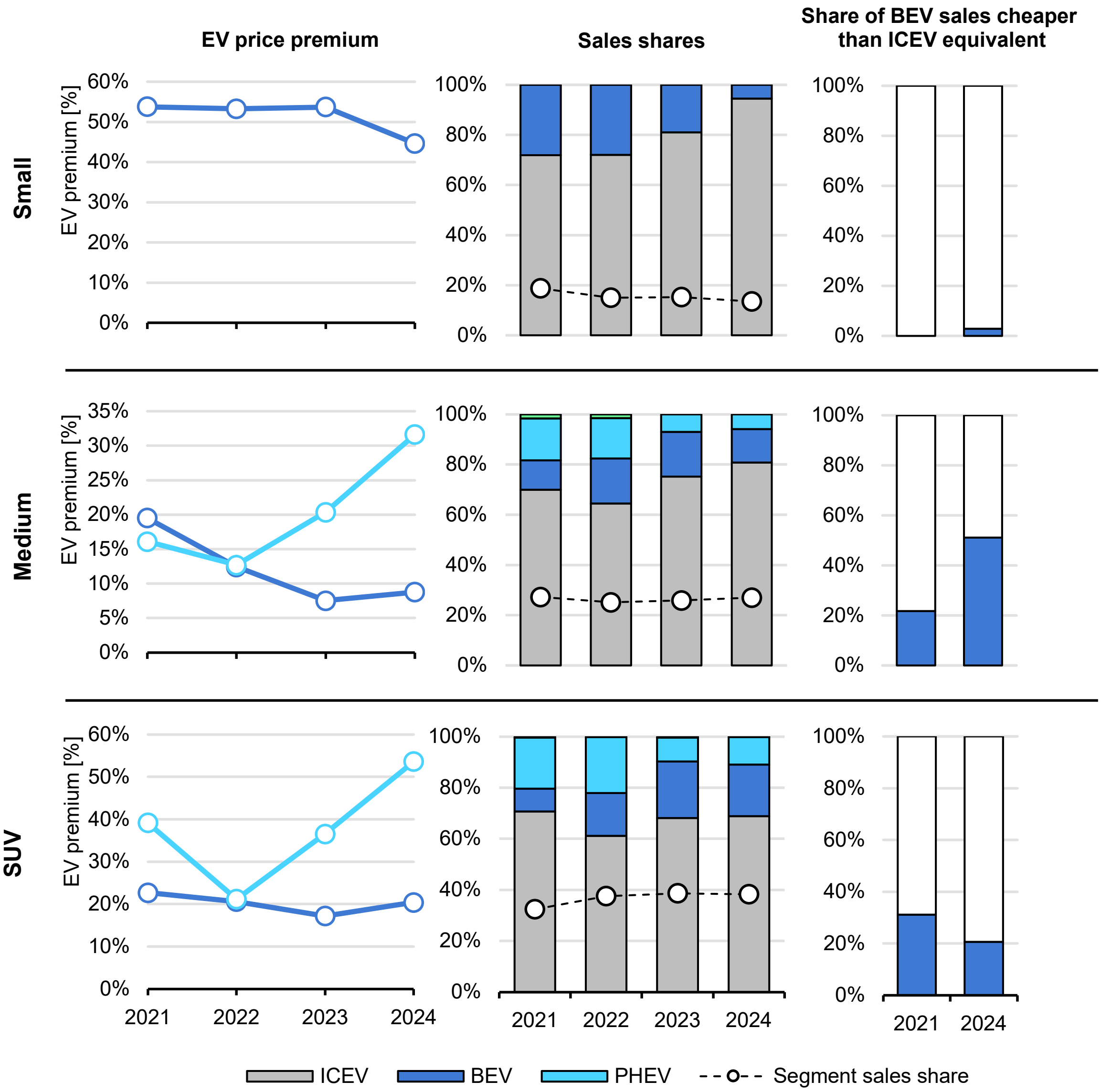
Electric car affordability improved in all car segments in China thanks to falling battery pack prices, a high level of supply chain vertical integration and fierce competition within the Chinese EV market. Overall, in 2024, close to two-thirds of the battery electric cars sold in China were cheaper than their ICE equivalents, up from half in 2021 and just 10% in 2018.

Affordability stagnates in Europe, but carmakers expand line-ups with low-cost EVs amid CO_2 standards shift

In Europe, carmakers' pricing strategies and focus on high-profit-margin premium models have led to stagnating battery electric car prices. In Germany, for example, the average price premium for small battery electric cars remained almost unchanged between 2021 and 2023, plateauing at over 50% more than equivalent small ICE models. The price premium for small battery electric cars fell slightly in 2024 to around 45%. In contrast, the price premium for battery electric SUVs increased to reach 20% in 2024, effectively reversing the small decrease seen over the 2021-2023 period. The price premium of PHEVs compared to conventional equivalents has grown consistently since 2022, reaching more than 30% for medium-size cars and 50% for SUV-type cars in 2024. This trend hindered electric car adoption in Germany in 2024, especially when combined with the phase-out of purchase subsidies in late 2023. In 2021, almost one-third of battery electric SUVs sold in the country were cheaper than their average ICE equivalent, but by 2024, this share had fallen to one-fifth.

In other European countries, the affordability of electric cars saw little change. In the United Kingdom, for instance, the average price premium of battery electric SUVs made only slim progress, dropping to 30% in 2024 from 40% in 2021. The pricing trend of plug-in hybrid SUVs was similar, with their price premium having been stuck at around 45% for the last 3 years.

Electric car price premium compared to conventional models per segment (left), powertrain sales shares (centre) and sales share of battery electric vehicles cheaper than conventional equivalents (right) in Germany, 2021-2024



Notes: EV = electric vehicle; BEV = battery electric vehicle; ICEV = internal combustion engine vehicle; PHEV = plug-in hybrid electric vehicle; SUV = sports utility vehicle. Price data is adjusted for inflation. The share of battery electric cars cheaper than their conventional equivalents is calculated as the number of car sales priced lower than the sales-weighted average price of the ICE car in their segment category.
Source: IEA analysis based on data from S&P Global Mobility, EV Volumes and Marklines.

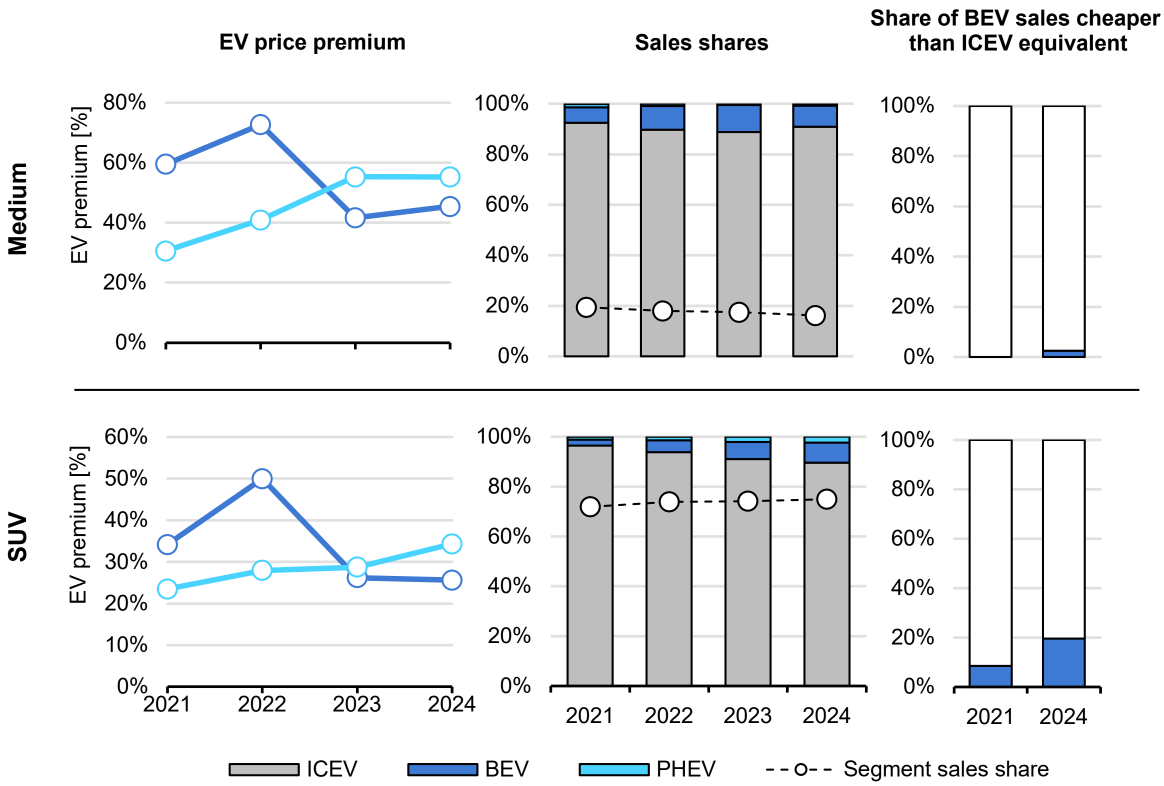
This lack of progress on affordability reflects the limited availability of cheap electric car models across Europe. In 2024, while nearly one-quarter of available ICE car models were priced below EUR 30 000, only around 5% of battery electric models were. Models priced below EUR 25 000 are expected to be key enablers of wider market adoption, but they accounted for only a slim share (3%) of available battery electric models in Europe last year. However, the new phase of the EU CO_2 standards entering into force in 2025 is expected to prompt carmakers to release more affordable electric models to boost their EV sales and comply with their respective fleet-wide CO_2 targets. So far, both European and foreign carmakers have announced launches of battery electric models for the European market priced at under EUR 25 000, including Renault, Volkswagen, Hyundai, and BYD. Overall, nearly ten battery electric models priced at under EUR 25 000 are expected to be released by the end of 2026.

Limited availability of affordable models hinders US electric car sales growth

In 2024 in the United States, about one in five electric SUVs (including pick-up trucks) was sold at a lower price than the average conventional SUV. This is particularly significant given that SUVs account for three-quarters of total car sales in the United States. Progress on battery electric car affordability has fluctuated in recent years. In 2023, the average purchase price premium of battery electric SUVs noticeably decreased to 25% from 50% in 2022, largely as a result of Tesla repeatedly slashing prices in an attempt to maintain its market lead in the United States. However, despite further price reductions to the Tesla Model Y SUV in 2024, Tesla's market share fell around 10% year-on-year. This decline outweighed the impact of the late price cuts, leaving the average price premium of battery electric SUVs in the United States unchanged from the previous year.

The contrast with conventional models is stark: in 2024, only 2 battery electric models (3% of battery electric car models) were priced below USD 30 000, compared to more than 50 ICE models (20% of available ICE models). In the short term, Honda, Fisker and Volkswagen have all recently announced they will launch "affordable" compact electric SUVs, bringing to market a handful of models under the USD 30 000 mark. However, most of the BEV model releases expected by 2026 that have been announced with launch prices are in the premium car category, with over 70% anticipated to have a purchase price of more than USD 50 000.

Electric car price premium compared to conventional models per segment (left), powertrain sales shares (centre) and sales share of battery electric medium cars and SUVs cheaper than conventional equivalents (right) in the United States, 2021-2024



Notes: EV = electric vehicle; BEV = battery electric vehicle; ICEV = internal combustion engine vehicle; PHEV = plug-in hybrid electric vehicle; SUV = sports utility vehicle. Price data is adjusted for inflation. The share of battery electric cars cheaper than their conventional equivalent is calculated as the number of car sales priced lower than the sales-weighted average price of the ICE car in their segment category.

Source: IEA analysis based on data from S&P Global Mobility, EV Volumes and Marklines.

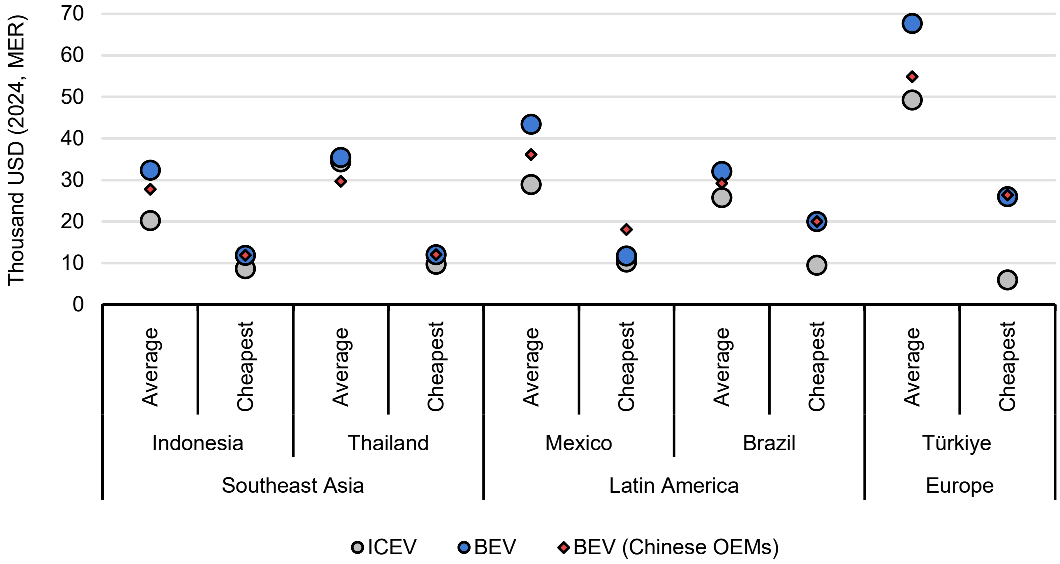
The average purchase price of plug-in hybrid SUVs has increased over the past 3 years. In 2024, the price was almost 10% higher than that of battery electric counterparts, and 35% higher than conventional SUV models. Fewer than 10% of the more than 50 available PHEV models were priced below USD 40 000 while 70% were above USD 50 000. This high price premium, combined with the limited availability of affordable models, remains a significant barrier to wider adoption. As a result, PHEV sales stood at 2% of total SUV sales in 2024, as in 2023.

In emerging markets, affordable Chinese models are driving EV adoption

In 2024, in most emerging EV markets, the price of the cheapest battery electric car was lower than the average price of an ICE car. In some markets – such as Indonesia, Thailand and Mexico – the cheapest battery electric car models even retailed at similar prices to the cheapest ICE models. Choosing an electric car in these markets could carry little to no price premium.

In all of the five emerging markets assessed – Brazil, India, Indonesia, Mexico and Thailand – electric models made by Chinese OEMs were, on average, cheaper than the average electric car, helping to drive uptake. The cheapest Chinese battery electric car was, in most cases, also the cheapest option on the market, so much that in **Thailand** in 2024, the average price of a Chinese EV was lower than the average price of a conventional car. In 2023 and 2024, more than four out of every five battery electric cars sold in Thailand were imported from China, bringing the average price of BEVs nearly in line with that of conventional cars. On average, medium and SUV model BEVs were more than 20% cheaper than their conventional equivalents, and the overall price premium of BEVs, across all car segments, stood below 5%.

Average and cheapest battery electric car price values by powertrain in selected emerging markets, 2024



Notes: ICEV = internal combustion engine vehicle; BEV = battery electric vehicle; OEM = original equipment manufacturer. Average price refers to the sales-weighted average price of cars per powertrain. The cheapest category shows the lowest price found in data.
Source: IEA analysis based on data from S&P Global Mobility.

In **Brazil**, where Chinese electric car imports increased to reach 85% of the country's EV sales in 2024, up from about 60% in 2023, the price gap between battery electric and ICE cars shrank from more than 100% to 25% over the same period. In 2024, not only was the cheapest battery electric car model produced in China by a Chinese OEM, but Chinese BEVs also retailed at less than half the price of those produced by non-Chinese OEMs on average (most of which belong to larger car segments). The average price of PHEVs also fell in 2024. In particular, plug-in hybrid SUVs – which accounted for nearly half of Brazil's electric car sales in 2024 – saw their price premium over ICE equivalents drop below 70%, compared to a premium of more than 80% for battery electric SUVs. This decreasing price gap boosted the adoption of PHEVs within the SUV segment, whereas BEVs gained more traction in the small and medium car segments, where their average price premium halved year-on-year to reach less than 40% in 2024.

In **Indonesia**, after import duties were waived under local investment requirements, Chinese EV imports surged to reach two-thirds of the country's EV sales in 2024, up from about 10% in 2023. Like in other emerging markets, Chinese battery electric car models became the most affordable options available, with an average price over 60% lower than BEVs from non-Chinese OEMs. As a result, the average price premium of BEVs dropped to around 50% in 2024, down from being, on average, twice as expensive as conventional cars in 2023.

In **Mexico**, the average price premium of BEVs fell to 50% in 2024 from more than 100% in 2023, as the share of Chinese imports in EV sales grew to nearly two-thirds. However, Chinese brands were not the only ones driving affordability. While the cheapest BEV model available (Renault's Kwid E-Tech Electric) was produced in China, it was sold under a European brand.

In **India**, high import duties on EVs and the availability of locally made, affordable electric models meant the share of Chinese imports in the country's EV sales remained below 15% in 2024. While the cheapest battery electric car model was produced locally by a Chinese OEM (SAIC's city car, the MG Comet EV, priced under USD 8 000), the average price of imported Chinese BEVs was twice that of those made by domestic manufacturers. In 2024, all BEV models manufactured by Indian carmakers started below USD 20 000, while none of the imported Chinese BEV models were priced under that threshold. Overall, the average price gap between battery electric and ICE cars fell below 15% for small cars and 25% for SUVs in 2024

3. Trends in other light-duty electric vehicles

Electric two- and three-wheelers

Contrasting regional trends mean global sales of electric two- and three-wheelers remain at around 15%

Two- and three-wheelers (2/3Ws)[1] remained the most electrified road transport segment in 2024, with more than 9% of the global fleet now electric. The global sales share of electric models remained at around 15% in 2024 with total electric model sales reaching 10 million. The electric sales share stalled in 2024, mostly due to the shrinking Chinese electric 2/3W market, although growth in other regions was steady. China, India and Southeast Asia remain the world's largest 2/3W markets, accounting for around 80% of 2024 global sales, with 2/3Ws serving as the primary mode of private passenger transport in India and Southeast Asia.

Electric 2/3Ws stand out as the most affordable and accessible entry point into electric mobility. Unlike cars, many models do not rely on extensive charging infrastructure, as removable batteries allow users to charge at home, and those with private parking or garages can easily charge their electric 2/3Ws using standard sockets. The removable batteries have also led to the growing emergence of battery swapping stations for 2/3Ws, which can be particularly useful for 2/3Ws that are used as taxis or for delivery services, where quick recharging is highly valued. This – combined with lower operating costs when compared to cars – means that electric 2/3Ws offer a promising solution for reducing urban emissions and improving air quality in emerging markets and developing economies, where 2/3Ws are widely used for daily transportation.

Another year of receding electric two-wheeler sales in China masks steady growth elsewhere in Asia

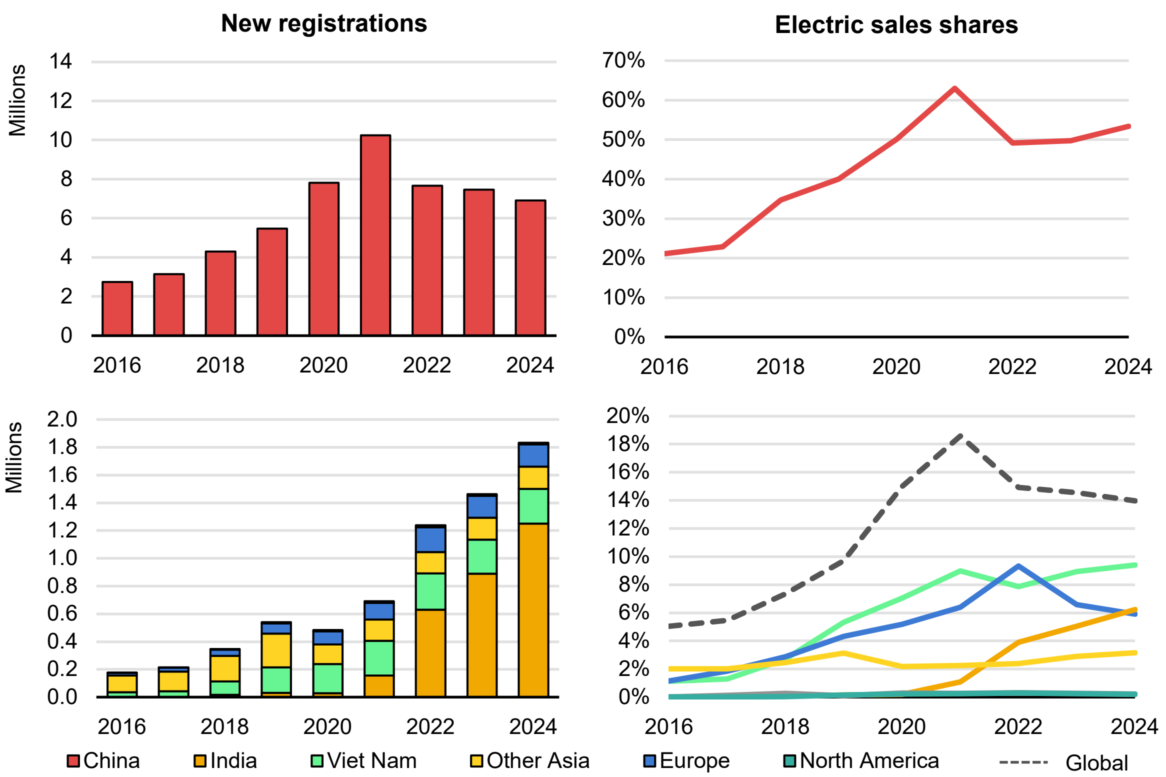
In **China,** falling sales of electric 2Ws in 2024 were the product of an overall decline in the 2W market, yet the country remains the world's largest market for electric 2Ws. Electric models have accounted for more than half of 2W sales since

[1] In this report, "two-wheelers" refers to vehicles with a top speed of at least 25 km/hr that fit the L1 and L3 classes defined by UNECE. This excludes micromobility options such as electric-assisted bicycles and low-speed electric scooters. The definition of a three-wheeler is aligned with UNECE L2, L4 or L5 classes.

2020, with sales totalling about 7 million in 2024. Sluggishness in China's 2W market reflects an increasing preference for cars for personal transport, and may also be a sign that consumers are responding to tighter restrictions on 2W use in major cities. The 2W market is shifting toward higher-value motorcycle models, likely indicating a change in consumer profile. At the same time, the Chinese government launched a trade-in programme for electric bicycles in 2024, boosting their sales. Urban commuters, in particular, may be attracted by e-bikes as a lower-cost alternative that enables access to bike lanes and areas where 2Ws are banned.

As the Chinese market for electric 2Ws continues to decline, the country's OEMs are looking abroad for growth opportunities. China's largest electric 2W manufacturer, Yadea, broke ground on a USD 150 million new assembly plant in Indonesia in 2024, which has a planned output of 3 million vehicles by 2028 (likely to also include e-bikes). In recent years, Chinese OEMs have also established manufacturing capacities in other large Southeast Asian electric 2W markets such as Viet Nam, the Philippines and Thailand, making their way into the top five electric 2W brands in each of these countries.

Electric two-wheeler sales and sales share by region, 2016-2024



IEA. CC BY 4.0.

Notes: "Other Asia" includes Afghanistan, Bangladesh, Brunei, Cambodia, Lao People's Democratic Republic, Myanmar, Mongolia, Nepal, Pakistan, Singapore, Sri Lanka and Chinese Taipei. "Two-wheeler" refers to vehicles with a top speed of at least 25 km/hr and which fit the L1 and L3 classes defined by UNECE.
Sources: IEA analysis based on country submissions and data from MotorcyclesData.com and AutocarPro.in.

India's increasingly dynamic electric 2W market hosted a total of 220 OEMs in 2024, up from 180 in 2023, although the 4 market leaders accounted for a combined 80% of the 1.3 million electric 2Ws sold in the country in 2024 (6% of the overall 2W market). While the upfront purchase price of electric 2Ws remains higher on average than that of conventional 2Ws, increasing competition is prompting OEMs to offer more affordable electric models. For example, the Indian market leader, Ola, released its S1X entry model, equipped with a 2 kWh battery and 6 kW peak power, with a sticker price of INR 70 000 (about USD 850) – lower than the average price of the five best-selling ICE 2W models. Policy support is also helping to bridge the affordability gap between electric and ICE 2W models, with the new PM Electric Drive Revolution in Innovative Vehicle Enhancement (PM E-DRIVE) policy continuing financial support formerly provided under both Faster Adoption and Manufacturing of Electric Vehicles (FAME)-II and Electric Mobility Promotion Scheme measures. This provides purchase incentives for electric 2Ws (offering purchase subsidies of up to INR 5 000/kWh for 2Ws fitted with lithium-ion batteries), as well as for 3Ws and other emerging EV categories (specifically excluding private cars), with a total budget of USD 1.3 billion. The scheme is planned to operate until March 2026 to support the roll-out of about 2.5 million electric 2Ws, up from 1 million targeted under the previous FAME-II policy. On the manufacturing side, the 80 largest electric 2W makers in India accounted for a combined production capacity of 10 million electric 2Ws in 2024, almost 8 times the domestic sales that year. Capacity is expected to increase to 17 million electric 2Ws in the near term, if all OEM announcements come to fruition.

Southeast Asia made notable progress on 2W electrification in 2024, particularly in Viet Nam, which recorded 250 000 sales (a sales share close to 10%); in Indonesia, where there were about 105 000 sales; and in the Philippines, with more than 25 000. **Indonesia** saw its electric 2W market almost double in size, but the share of electric sales remained below 2%. Nevertheless, the trend towards electrification in what is the world's third-largest 2W market is likely to continue given the strong policy support in place (in 2023, nearly USD 0.5 billion was allocated to support the deployment of 800 000 electric 2Ws over the following years), as well as the new manufacturing capacity being rolled out by established Chinese OEMs.

Viet Nam's 2W electrification success story has been underpinned by the continued roll-out of increasingly affordable electric 2W models manufactured by domestic champions like VinFast and Pega, and now also by Chinese OEMs. To date, several electric models are sold at under VND 20 million (Vietnamese dong) (USD 780) (such as VinFast's Evo200 and Yadea's Orla), making them price-competitive with conventional alternatives. These affordable purchase prices are partly a result of existing battery leasing options, which reduce the vehicle purchase price and can cost consumers as little as VND 350 000 (under USD 14) per month. They can also be easily integrated with battery swap programmes. The increasing affordability of electric models, ongoing development of charging infrastructure for models without removable batteries, and Viet Nam's ambition to fully electrify its road transport sector by 2050 is likely to drive further growth in electric 2W sales in the coming years.

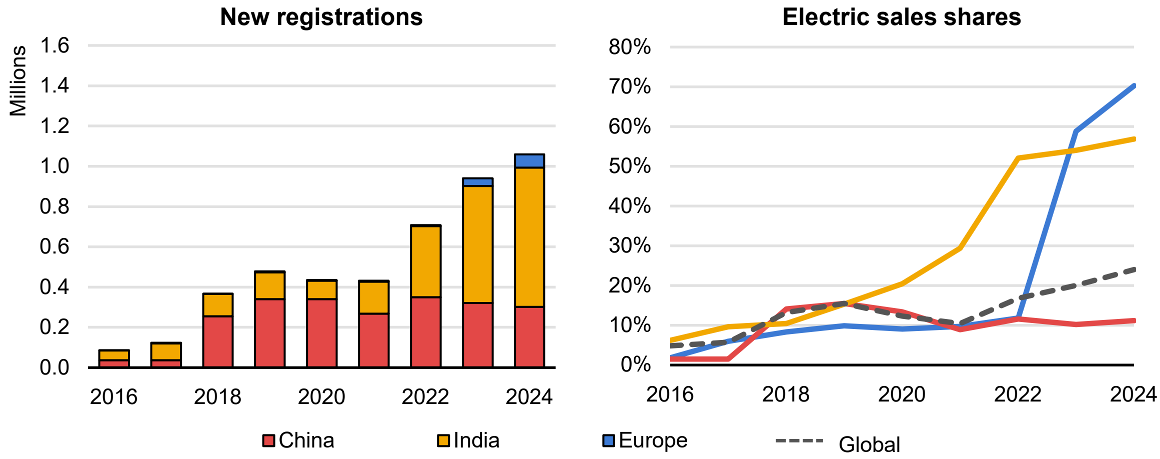
Sales of electric 2Ws in **Africa** grew nearly 40% year-on-year to reach 9 000 vehicles, marking a slim 0.5% sales share in the continent's total 2W sales. However, domestic OEMs have invested significantly in recent years to set up domestic manufacturing facilities. For example, Spiro is set to break ground on an assembly plant in Nigeria in 2025 with an expected annual output of 100 000 electric 2Ws, 100 times the capacity of its assembly plants in Togo and Benin. Other electric 2W manufacturers, such as Roam in Kenya and Ampersand in Rwanda, also recently announced investments to ramp up their capacity across African countries. Beyond increasing manufacturing investments, asset financiers like M-KOPA, Mogo, and Watu are helping consumers and small business owners access electric motorcycles through flexible payment plans and lease-to-own schemes.

Elsewhere, in **Europe,** the average electrification rate of 2W sales has decreased to about 6%, despite the 2W market growing overall. With year-on-year sales growing to more than 50 000 electric 2Ws, Türkiye has secured its position as the leading market outside of Asia, followed by France and the Netherlands, despite those markets stagnating in 2024.

India continues to drive most growth in the global electric three-wheeler market

Despite the global three-wheeler (3W) market shrinking 5% from the previous year, electric 3W sales grew more than 10% to surpass 1 million vehicles in 2024. Electric 3W sales represented almost one-quarter of all 3W sales, up from one-fifth in 2023. The market is highly concentrated, with China and India together accounting for more than 90% of both electric and conventional 3W sales.

Electric three-wheeler sales and sales share by region, 2016-2024



Note: The definition of a three-wheeler is aligned with : UNECE L2, L4 or L5 classes.
Sources: IEA analysis based on country submissions and data from MotorcyclesData.com and AutocarPro.in.

Electrification of 3Ws in **China** has stagnated at less than 15% over the past 3 years. In 2023, **India** overtook China to become the world's largest market for electric 3Ws, and it maintained this position in 2024, with sales growing close to 20% year-on-year to reach nearly 700 000 vehicles. This translated into a record 57% electric sales share in 2024, 3% up on the previous year. This growing trend looks set to continue thanks to policy support under the new PM E-DRIVE scheme, which allocated budget in 2024 to support the roll-out of more than 300 000 electric 3Ws for commercial use – for which the total fleet (electric and ICE) was estimated at more than 10 million vehicles in 2023.

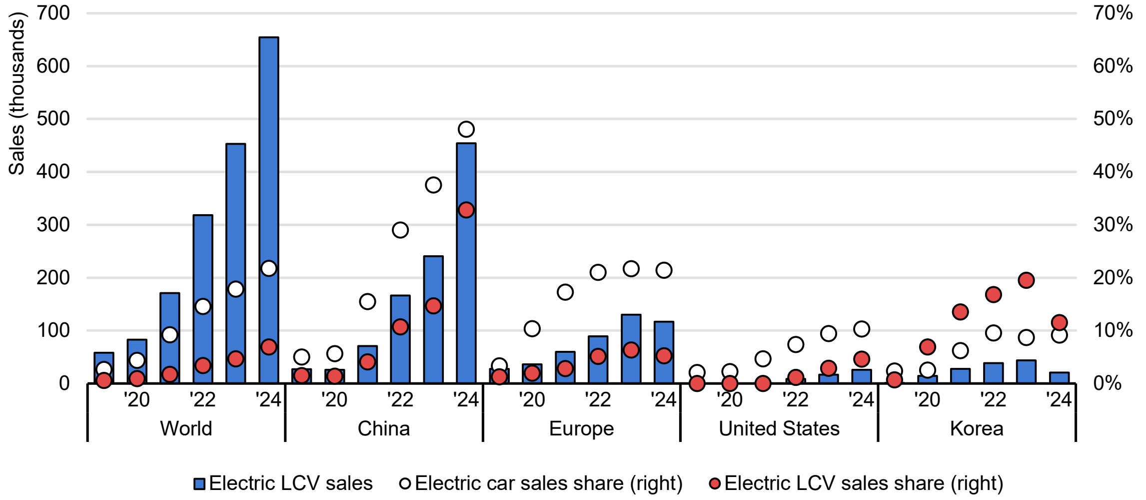
Elsewhere, in **Europe**, the electric 3W sales share has grown steeply in the past 2 years, pushed up by growth in the Turkish market. In 2024, Türkiye accounted for 60 000 electric 3Ws sold out of a total European 3W market of about 90 000.

Electric light commercial vehicles

China pushed up global electric light commercial vehicle sales in 2024, representing 70% of global sales

Sales of electric light commercial vehicles (LCVs) increased by more than 40% in 2024 to exceed 600 000, with a share of 7%, up from 5% in 2023. China and Europe remained the two largest markets for electric LCVs in 2024, but while China saw growth of almost 90%, with sales reaching roughly 450 000, sales in Europe declined by about 10% to less than 120 000. The United States emerged as the third-largest market, taking the spot from Korea, with sales of more than 25 000 and strong year-on-year growth of 55%.

Electric light commercial vehicle sales and sales shares, 2019-2024



Notes: LCV = light commercial vehicle, weighing less than 3.5 tonnes. In China, LCVs include small-sized buses, gasoline light-duty trucks and mini trucks. To better align with IEA classifications, diesel light-duty trucks are considered as medium-duty trucks (defined here as having a gross vehicle weight greater than 3.5 tonnes and less than 15 tonnes).

Sources: IEA analysis based on data from EV Volumes, China Commercial Vehicle Dealers Association, DaaS, ACEA, Marklines and Korean Automobile Manufacturer' Association.

The continued sales growth in China has been supported by LCVs being eligible for the vehicle purchase tax exemption for new energy vehicles that was put in place in 2014. The full tax exemption has been extended through 2025, and a 50% tax exemption will be available until the end of 2027. Preferential road rights policies, charging discounts and charging subsidies are further supporting EV adoption among commercial users.

In Europe, the electric sales shares declined in several important LCV markets, such as Germany, Norway and France, or stalled, as in the case of Sweden. However, in the United Kingdom – the largest market for electric LCVs in Europe – sales continued to grow, reaching nearly 7%. As with cars, 2024 was the first year of zero-emission van targets under the Vehicle Emissions Trading Scheme, which will progressively require higher sales shares of zero-emission LCVs over the coming decade.

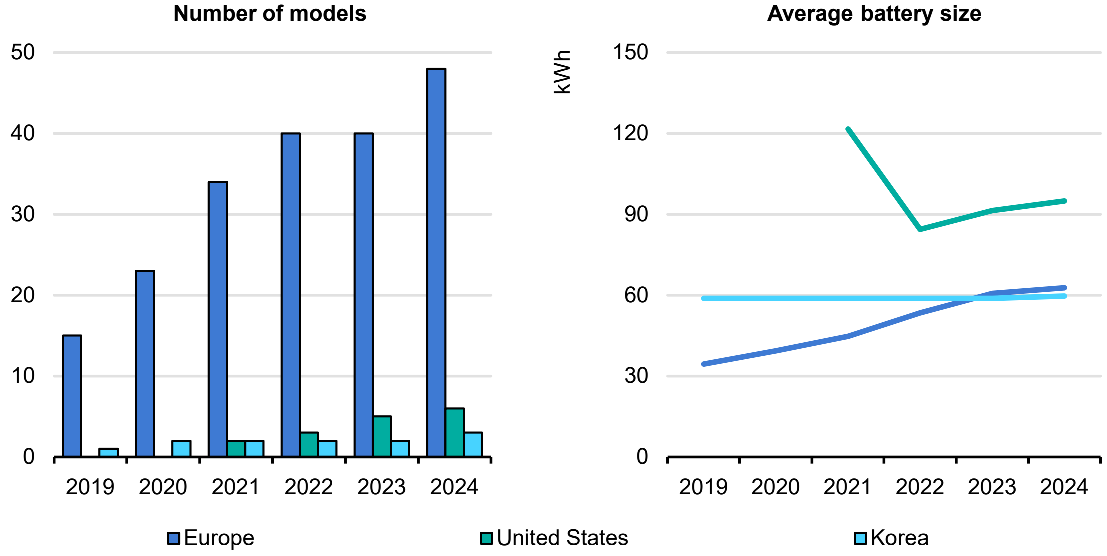
Some small markets such as Czechia, Greece, Hungary and especially Romania have seen notable increases, albeit starting from a very low base. Despite no new incentives being introduced between 2023 and 2024 in these markets, the growth suggests that there were some segments that could be easily electrified with existing technology. In fact, the total cost of ownership of electric LCVs is already equal to or below that of conventional alternatives for certain applications in Europe. Nevertheless, in Germany – a more developed market – the decline in sales may have been a result of the removal of incentives (which also affected LCV applications that are harder to electrify based on current pricing or model availability) and by the design of the EU CO_2 emission regulations for vans, which gave the automotive industry little incentive to accelerate sales in 2024 before the next phase taking effect in 2025.

Some European cities have promoted electric LCV adoption by establishing Low Emissions Zones (LEZs), though there is no uniform European regulation, with regulations being decided at the city level. London has the largest LEZ in the world, which has favoured uptake. As of the beginning of 2025, LEZs can also be found in Amsterdam and 14 other cities in the Netherlands, as well as in Brussels, Ghent, and Stockholm. In the case of the Netherlands, the introduction of LEZs from 2025, together with the exemption of vehicle tax for LCVs being removed for ICE LCVs, led the sales share of electric LCVs to leap to more than 90% in the first quarter of 2025, compared to less than 10% on average in 2024. The number of LEZs in Europe grew significantly from 228 in 2019 to 320 in 2022, with more expected to come online in 2025, further encouraging uptake of EVs and improving air quality, while also potentially reducing traffic congestion.

In 2023, the sales share of electric LCVs in Korea was double the level of electric passenger cars, continuing a trend that started in 2020. While the sales share of electric LCVs remained higher than cars in 2024, both the volume of sales and their sales share declined sharply. Despite strong initial adoption of electric LCVs in Korea, partially due to the availability of free commercial licence plates for electric models, drivers have since reported that real-world range and model availability is insufficient for many commercial applications, which may be influencing the slowdown. In 2023, the only electric LCVs on the market were the Kia Bongo and the Hyundai Porter, both 1-tonne trucks with a battery capacity of about 60 kWh. While these vehicles had initially been able to meet the needs of some portions of the market, boosting sales, reaching new market segments has proved difficult. In 2024, Hyundai launched the ST1 Cargo electric, which has a larger battery (76 kWh) and an advertised range of around 300 km, but also has a higher purchase price. In 2024, Korea introduced stricter performance requirements for their subsidy scheme, which effectively restricted subsidies for models with lithium iron phosphate (LFP) batteries, typically used in Chinese-manufactured models.

Across Europe, Korea and the United States, 2024 saw the introduction of around ten new electric LCV models, the majority of which were launched in European countries. Ford expanded its e-Transit line, which remains one of the world's best-sellers in the electric LCV category, offering a 30% increase in range and more possible applications, such as refrigerated delivery. BYD targeted the last-mile delivery market in Europe with the E-Vali, while Mercedes-Benz introduced the eSprinter in the United States.

Number of models of electric light commercial vehicles and sales-weighted average battery size in Europe, the United States and Korea, 2019-2024



Notes: EV = electric vehicle; LCV = light commercial vehicle, where weight is less than 3.5 tonnes. Average battery refers to sales-weighted average.
Sources: IEA analysis based on data from on EV Volumes.

Electric LCV fleets are becoming increasingly popular, particularly in the parcel delivery sector, as companies strive to reduce their environmental impact and operating costs. As part of its goal to reach 100 000 electric delivery vehicles by 2030, Amazon now has 20 000 vehicles through a 2019 agreement with Rivian, which has tailored a vehicle to Amazon's needs, with the first vehicles delivered in 2021. In 2024, Rivian represented 40% of the US electric LCV market and its sales are steadily growing.

Elsewhere, Ingka Group, the biggest IKEA franchisee, served 40% of home deliveries with zero-emission vehicles, advancing towards its goal of more than 90% by 2028. Shanghai was the first city to reach this goal, achieving 100% EV-based deliveries as early as 2019. In India, IKEA has partnered with EKA Mobility to supply last-mile delivery with electric vans, while in Korea, DHL has partnered with Kia to deploy the forthcoming Kia PV5 tailored to DHL needs from 2026.

4. Trends in heavy-duty electric vehicles

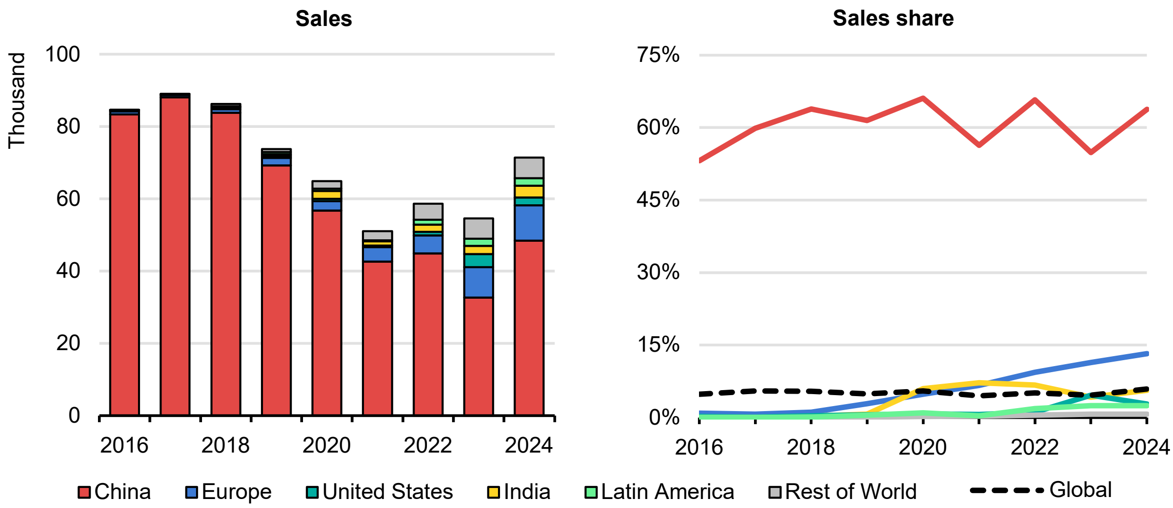
Electric bus and truck sales

The electric bus market continued to expand, backed by increasingly favourable economics

Electric bus sales grew by 30% in 2024

Global sales of electric buses reached more than 70 000 in 2024, driven by renewed growth in China. Sales outside of China increased by just 5% in 2024, although they have almost tripled compared to 2020. As electric bus sales have increased in a range of countries, China's share of global sales has fallen from around 99% in 2017 to less than 70% in 2024. Although electric bus sales in China generally declined from 2017 to 2023, the electric bus sales share has remained relatively stable, hovering around 60%.

Electric bus sales and sales shares by region, 2016-2024



Note: Only medium- and large-sized electric buses are included; minibuses and passenger vans are treated as light commercial vehicles.
Source: IEA analysis based on country submissions and data from EV Volumes, China Commercial Vehicle Dealers Association, and DaaS for sales data for China.

In **Europe**, the world's second-largest market for electric buses, sales increased by almost 15% in 2024, bringing the sales share to more than 13%. Several countries, including Denmark, Finland, the Netherlands and Norway, now have electric bus sales shares of more than 40%. The United Kingdom continues to have the largest number of sales in Europe, accounting for around 20% of the region's sales in 2024, with a year-on-year growth of over 40% and almost 2 000 electric buses sold in 2024. Italy follows, with almost 1 200 sales, and then Germany with almost 900. Sales were predominantly for city buses, for which ten European countries had battery electric sales shares above 80%, meaning almost half of all new city buses were battery electric in 2024, up from just over 35% in 2023.

Uptake of electric buses in the **United States** has not been linear. Despite averaging year-on-year growth of more than 70% between 2020 and 2024, electric bus sales declined in 2024 following a peak the previous year. Around 40% fewer electric buses were sold last year, in part due to supply chain issues. As a result, India and Korea overtook the United States to become the second- and third-largest national electric bus markets by sales volume in 2024, with more than 3 200 and 2 800 sales, respectively.

In **Latin America**, electric bus sales have risen from around 600 in 2020 to over 2 000 in 2024, which accounts for almost 40% of sales outside of China, Europe, and the countries mentioned above. City buses are driving the transition, like in Europe**.** In Mexico, close to 8% of all bus sales were electric in 2024, up from just above 1% in 2023. There has also been impressive growth in Colombia, Chile, Brazil, and other countries over the past few years.

Another notable trend is the decline in the share of PHEVs among electric buses. In China, the share of PHEVs in total electric bus sales peaked in 2014 at around 60%, but fell to less than 1% in 2017 and close to 0% in 2024. Similarly, in the rest of the world, there was a peak of around 60% of total electric bus sales in 2015, but this fell sharply to 5% in 2017, and around 1% of the share in 2024. Almost all electric bus sales are now battery electric, thanks in large part to declining battery prices, greater model availability and improved charging technology, all of which increase the share of use cases for which they are now practical.

Even as electric bus economics continue to improve, innovative financing and incentives help drive deployment

Innovative financing models, such as those available in the United Kingdom, Brazil (São Paulo), and Chile (Santiago), are also helping to drive up sales. In Santiago, for example, buses have been leased to the operator as opposed to traditional ownership, lowering the upfront cost, which can present a significant barrier to deployment. The scheme benefitted from investment by the International Finance

Corporation (IFC). A similar model is being explored for collaboration between the IFC and Transvolt in India to help deploy 8 000 battery electric buses.

Italy, which now has the highest number of electric bus sales in the European Union, more than doubled its stock from 2023 to 2024, with growth fuelled by incentives totalling EUR 50 million made available in July 2022. As in other countries, the majority of electric bus registrations are intended for urban use. In Milan, for example, the municipal public transport operator, ATM, has committed to having a 100% electric fleet by 2030.

In the **United States**, uptake has been greatest for school buses, which represented around half of the electric bus stock in 2024. As of mid-June, the Clean School Bus Program had funded approximately 8 100 electric school buses, using approximately USD 3 billion of the USD 5 billion allocated for fiscal years 2022-2026 under the Bipartisan Infrastructure Law. Oakland, California, became the first school district in the United States to have a fully electric fleet in 2024. This contrasts starkly with the experience of New York City, which has a legally binding target to fully electrify its fleet of 10 000 buses by 2035, yet has deployed under 50 to date, partly due to difficulties in negotiating affordable purchases.

India has seen rapid growth in electric bus deployment since 2020, with stock increasing from less than 3 000 to more than 11 500 at the end of 2024. A combination of increasingly favourable economics, available incentives and additional government support for charging infrastructure has enabled huge year-on-year growth. Demand has been boosted by schemes such as the National Electric Bus Programme, which targets deploying a further 40 000 electric buses by 2027, helping to generate large orderbooks and use aggregated procurement to drive down costs. This is further strengthened by new schemes such as PM E-DRIVE, which could support sales of a further 14 028 electric buses, with preference given to replacements of old public buses. The forthcoming Bharat Urban Megabus Mission aims to introduce 100 000 electric buses to cities with a population of over 1 million.

China's electric bus sales strengthen, but Chinese OEMs are also focusing on exports

China has the world's highest stock share of electric buses, at 30%, compared to 2% across Europe (the second-largest electric bus fleet), and this share has been steadily growing over the past decade. The country took an early lead in deploying electric buses, with almost 70% of the more than 680 000 electric buses in the country today having been deployed before 2020. The year 2024 saw an increase in electric bus sales following several years of decline, potentially reflecting the replacement of older electric buses in cities such as Shenzhen, which fully electrified their bus fleets years ago. The introduction of a national-level city bus scrappage scheme announced in January 2025 looks likely to further support the uptick in sales seen in 2024.

Chinese manufacturers have also been increasingly looking to exports to exploit their available manufacturing capacity. In 2024, more than 15 000 electric buses were exported from China, over 25% more than in 2023. BYD and Foton are some of China's leading manufacturers of electric buses, and together with other Chinese manufacturers supplied more than 80% of electric buses in Latin America's stock. In early 2025, the city of Tashkent, Uzbekistan, signed a purchase agreement for 2 000 BYD buses, 1 000 of which are set to be delivered by the end of the year. Chinese OEM Yutong has also seen success internationally, fulfilling orders in Greece, Italy and the United Kingdom, and solidifying their position as Europe's best-selling electric bus brand for the third year in a row. Yutong has already supplied fleets to places as diverse as Chile, Mexico, Norway and Uzbekistan since 2020. In Qatar, 70% of the public bus fleet was electrified between 2021 and 2023 through a partnership with Yutong, supporting the government's aim for all of its public transport buses to be electric by 2030. The Qatari government has also made plans for domestic production of electric buses in partnership with Yutong, with the aim of establishing a production hub for electric buses to serve international markets including Europe, the Middle East and North Africa, as well as meeting growing local demand.

Global electric truck sales grew by almost 80% in 2024

New incentives help China strengthen its lead as overall progress stalls in Europe and the United States

Sales of electric medium- and heavy-duty trucks grew for the third consecutive year in 2024 to exceed 90 000 worldwide. Year-on-year growth was almost 80%, a stark contrast to the decline in sales seen between 2018 and 2021. This spurt was largely a result of Chinese sales more than doubling between 2023 and 2024 – more than 80% of all electric trucks sold globally in 2024 were sold in China.

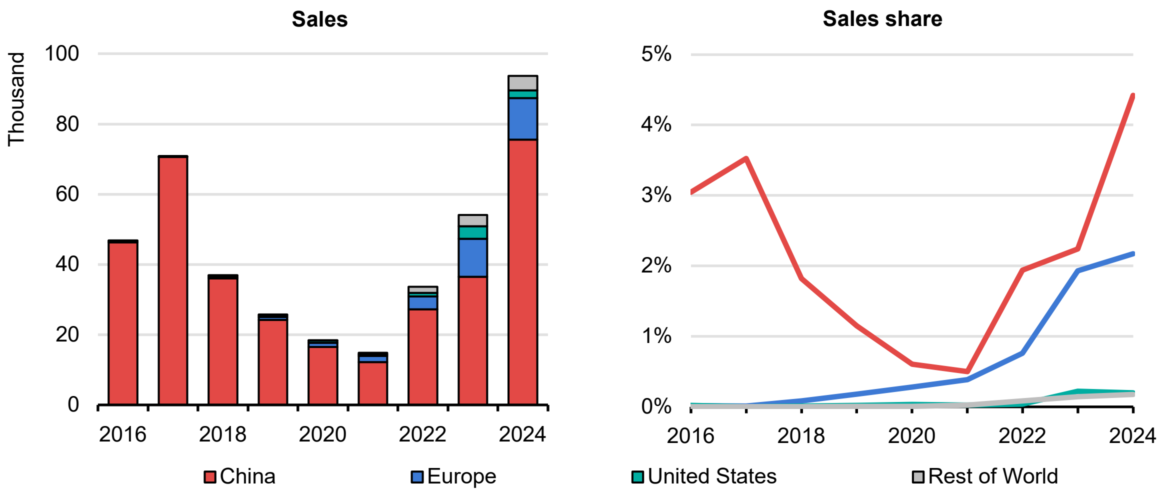
Strong growth in **China** was spurred in part by a vehicle scrappage scheme including purchase incentives, which is being renewed in 2025. Falling battery prices and the introduction of tighter emission standards for trucks issued in July 2023 further accelerated the shift. Pressure on heavy industries to reduce emissions is also translating into deployment of electric trucks, especially in heavily industrialised areas such as Hebei Province, where the fleet of electric trucks reached 30 000 vehicles.

In 2024, **Europe** saw more than 10 000 electric trucks sold for the second year in a row, despite a lack of substantial incentives. Denmark, Germany, Italy, the United Kingdom and others saw significant growth, though this was partially offset by drops in electric truck sales in key markets such as France and the Netherlands.

In the **United States**, electric truck sales in 2024 were similar to in 2023. Nevertheless, the number of electric trucks sold in 2024 – over 1 700 – was more than the cumulative number of electric trucks sold in the country between 2015 and 2022. Electric truck sales in the United States were supported by a tax credit of up to USD 40 000, as well as project grants for vehicle purchases, charging infrastructure and other expenses through the nearly USD 1 billion Clean Heavy-Duty Vehicles Grant Program.

There were positive developments elsewhere in the world, such as in Brazil, where almost 500 electric trucks were sold in 2024, and in Canada, with almost 2 000 sales for the second year in a row. In addition, Japan, South Africa and Thailand saw their collective sales jump from around 130 to almost 900 between 2023 and 2024. India saw a decline in electric truck sales in 2024, but in September the PM E-DRIVE scheme allocated a budget of USD 58 million for purchase incentives for electric trucks over the next 2 years.

Electric truck sales and sales shares by region, 2016-2024



Notes: Trucks refers to medium- and heavy-duty freight trucks. In China, gasoline light-duty trucks and mini trucks are categorised as LCVs, not trucks. Diesel light-duty trucks are classified as medium-duty trucks (defined here as having a gross vehicle weight greater than 3.5 tonnes and less than 15 tonnes).

Sources: IEA analysis based on country submissions and data from EV Volumes, China EV100, DaaS and China Commercial Vehicle Dealers Association for sales data for China.

Certain niches are quickly being electrified, including in the heavy freight segment

Deployment of electric trucks varies by application, as some duty cycles are more suited to electrification than others. Cycles with combinations of lower daily mileage, lower speeds, and predictable routes are typically easier to electrify, as seen at Manhattan Beer, which has begun to electrify its fleet. In California, drayage – the transport of shipping containers over a short distance to their final destination – has lent itself to the adoption of electric trucks. Across the United States, yard tractors have also proven to be an early adopter.

Similarly, in India, UltraTech Cement have ordered 100 electric trucks to decarbonise a 400 km route between two of their operations, and orders for 180 electric trucks from Billion E-Mobility (including 45 with a gross vehicle weight of 55 tonnes) have spurred Ashok Leyland to increase their production capacity. In China, successful battery swapping trials have supported an increase in electric trucks in the concrete industry.

Efforts to switch to electric trucks for delivery services are also spurring uptake and trials of new heavy truck models, where high mileages increase the potential cost benefits of electrification. In California, DHL recently tested the prototype of the Tesla Semi, which is expected to enter production in 2026, while in Germany, DHL deployed two Mercedes eActros 300s. Similarly, Amazon signed an order for more than 200 Mercedes eActros-600 electric trucks, which will be deployed in the United Kingdom and Germany with the goal of decarbonising high-mileage predictable routes, on which charging can be planned with a high degree of certainty. These trends indicate that certain niches will become cost-competitive in advance of the segment at large.

Electric heavy-duty models

The number of electric heavy-duty vehicle models reached almost 800 in 2024

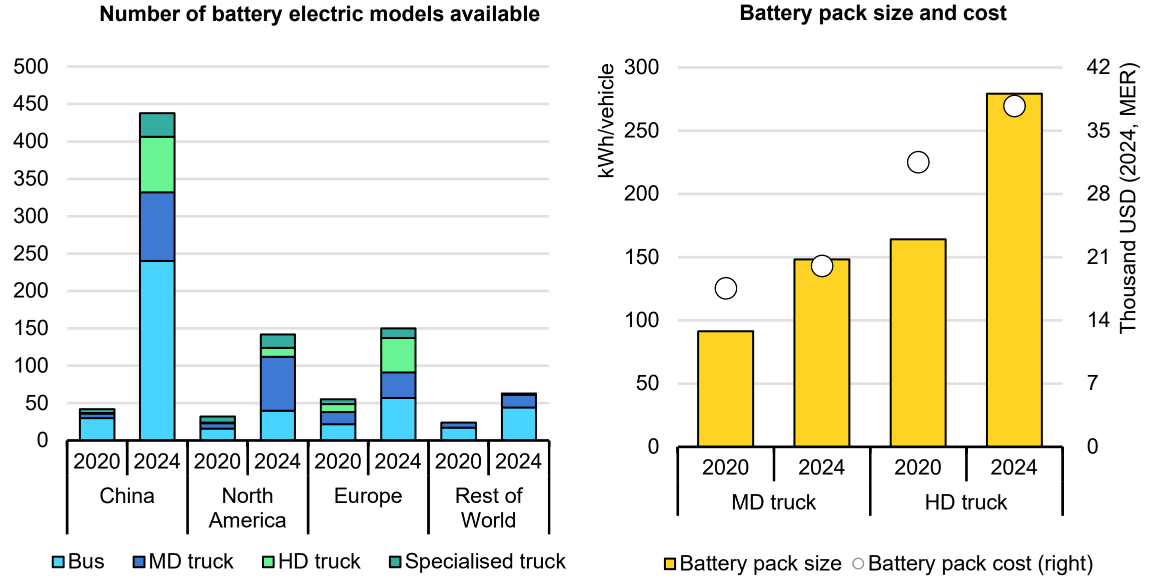
The number of electric heavy-duty models available worldwide has continued to grow steadily, driven by increasing demand as battery costs have declined. The market with the most models available remains China, with almost 450 – more than half of which are electric buses. In the United States, over 140 models are available, around half of which are medium-duty truck models, while buses represent less than 30%. The prevalence of medium-duty models in the US market could suggest that fleet operators are prioritising the electrification of lower-cost vehicles that cover shorter routes before transitioning to long-haul applications. In Europe, there are about 150 electric heavy-duty models available, with a more even distribution across buses, medium-, and heavy-duty trucks.

In Europe, truck OEMs are expanding their electric heavy-duty truck line-ups for regional-haul applications (<400 km), and improving performances for long-haul trucks amid increasing electric sales. In 2024, Volvo launched its latest electric truck, FH Electric, offering a range of 600 km, similar to the range offered by Scania’s latest electric truck model. On the other hand, OEMs such as Renault are targeting urban logistics.

Electric heavy-duty models are also becoming available in emerging markets. BAIC Foton has an electric truck on the market in Argentina, and German truck manufacturer TRATON has been producing their electric "e-Delivery" truck in Brazil since 2021 under the Volkswagen Caminhões e Ônibus brand. In 2024, BYD licensed Rêver to build electric buses and trucks based on BYD technologies in Thailand.

Falling battery prices have been a key driver of growth in electric trucks. Since 2020, battery prices[1] for commercial vehicles have dropped by 30%, enabling manufacturers to either extend vehicle range without increasing costs, or reduce costs to narrow the price gap between diesel and electric trucks. Between 2020 and 2024, the price of medium-duty electric truck battery packs increased only slightly, by almost 15%, despite battery size increasing by more than 60%. For heavy-duty trucks, battery pack size increased by around 70% between 2020 and 2024, but falling battery prices meant the rise in battery pack costs per vehicle was limited to less than 20% over the same period. Strategic partnerships between battery and commercial vehicle manufacturers, such as the agreement between CATL and FAW, seek to deliver even more affordable electric truck models through a more integrated supply chain.

Electric medium- and heavy-duty vehicle model availability by original equipment manufacturer headquarters, and battery size and cost, 2020-2024



Notes: MD = medium-duty; HD = heavy-duty. Buses do not include minibuses. Battery pack cost is calculated as the sales-weighted battery pack price per kWh for commercial vehicles multiplied by the sales-weighted battery pack size for the vehicle segment.

Sources: IEA analysis based on the Drive to Zero ZETI tool (left). IEA analysis based on data from Bloomberg New Energy Finance and EV Volumes (right).

[1] Battery price refers to the sales-weighted average battery pack price for commercial vehicles, including light-commercial and heavy-duty vehicles.

Truck total cost of ownership

For electric trucks to reach mass adoption, the total cost of owning an electric truck must be able to compete with the cost of owning a traditional diesel truck. Commercial vehicle owners and operators are typically more sensitive to the total cost of ownership (TCO) than personal car buyers, though higher upfront purchase costs can, of course, still present a hurdle.

The TCO of a vehicle depends on how the vehicle is used, and on the capital, energy and labour costs, all of which vary by region. Long-haul, heavy-duty trucks are often considered one of the hardest-to-electrify vehicle segments due to the need to balance battery size, range and payload constraints with charging requirements. In this section, we consider battery electric and fuel cell electric heavy-duty (HD) trucks, both of which have zero tailpipe emissions, and compare their TCO to diesel HD trucks in three major markets: China, the European Union and the United States.[2] A daily driving distance of 500 km is assumed.

The upfront cost of a battery electric truck was two to three times that of a diesel truck in 2024

While the TCO is important for overall business profitability, the upfront costs can be particularly important to small business that may have less access to financing. Small businesses make up the vast majority of hauliers in the United States (95%) and Europe (90%), and more than half in China (less than 70%),[3] where the haulage industry has been experiencing increasing consolidation.

Battery electric and fuel cell electric trucks are more expensive to purchase than conventional diesel trucks. This is mostly due to the batteries used in BEVs and the fuel cell stacks and hydrogen storage tanks in FCEVs being more expensive than equivalent diesel ICEV technologies. Today, for a truck with an 800 kWh battery (500 km range), the battery represents almost half of the upfront cost of a battery electric truck, and this is expected to fall to around 35% in 2030. For an FCEV, the battery, fuel cell system and hydrogen storage tank represent around half of the upfront cost today and this is not expected to change in 2030.

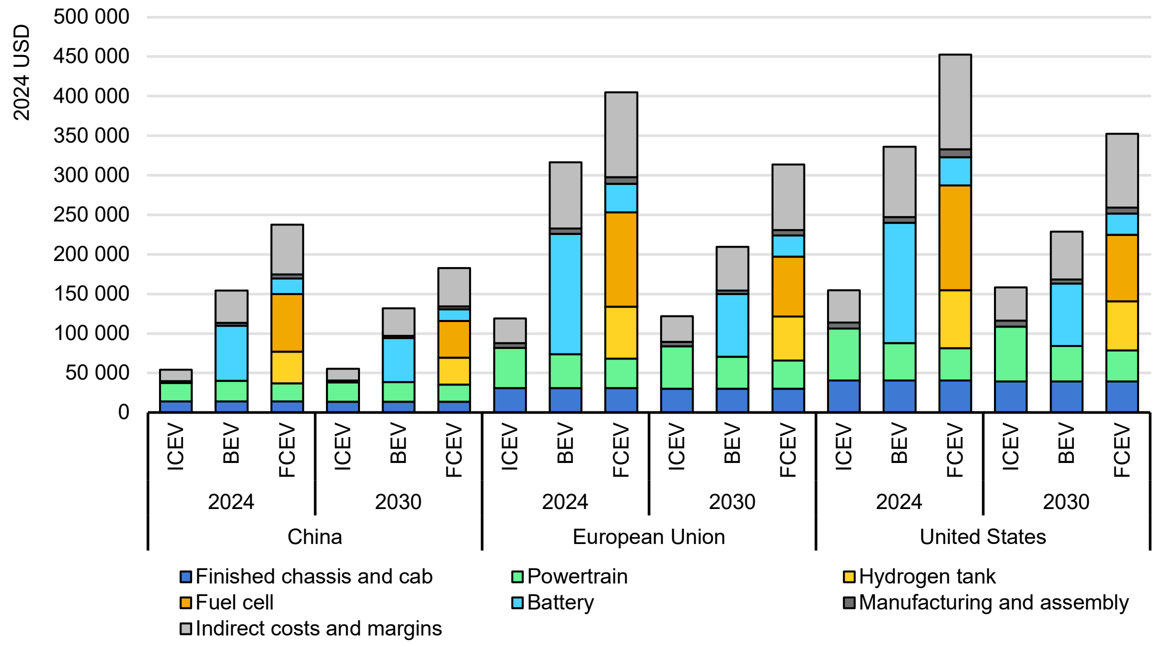
The costs of batteries, fuel cells, and hydrogen storage tanks are expected to fall thanks to greater economies of scale and manufacturing learnings, driving down the capital costs of both BEVs and FCEVs. In the next 5 years, the purchase price of a battery electric HD truck could fall by around 15-35%, depending on the

[2] Please see Annex A for full assumptions and costs used to calculate TCO in this section.
[3] Due to differences in reporting across the sources, in the case of the United States a small business is defined as having up to 10 trucks, in Europe up to 9, whereas in China the equivalent number is 20 or under.

region. That of a fuel cell HD truck could fall 20-25%. However, both are expected to remain more expensive than diesel ICE trucks at the point of purchase.

Purchase prices vary by region, and are lowest in China, primarily due to lower manufacturing and battery costs. Although the absolute price difference between battery electric and fuel cell electric trucks versus diesel equivalents is smallest in China, the low cost of diesel trucks means it has the largest relative price differences, at almost three (for battery electric) and four (for fuel cell electric) times the equivalent diesel price. The United States has the highest prices overall, while Europe enjoys both lower-cost diesel and zero-emissions trucks. Although not a like-for-like comparison, real-world price data shows that the premium for a zero-emissions truck was around USD 60 000 higher in the United States than in Europe in 2024, demonstrating the difficulties the United States is facing in achieving price competitiveness.

Estimated purchase price of hydrogen fuel cell, battery electric, and diesel heavy-duty trucks in 2024 and 2030



Notes: ICEV = internal combustion engine vehicle; BEV = battery electric vehicle; FCEV = fuel cell electric vehicle. The ICEV represents a diesel truck. The powertrain includes the engine for the diesel truck; the electric drive unit, electronics, DC/DC converters, on-board charger, thermal management, and other balance of plant components for both the battery electric truck and the fuel cell electric truck. Please see the Annex for a full list of sources, assumptions, and other inputs.

Increasing the utilisation of charging infrastructure can significantly reduce fuel costs for battery electric trucks

Fuel and infrastructure costs can make up a large share of the TCO for a heavy-duty truck. This is expected to remain the case into the future: over the next 5 years, vehicle efficiencies will likely improve by just 2-5%, meaning the levelised cost of fuel will remain a key component of TCO, especially for trucks with high daily driving distances. However, battery electric trucks are about 55% more energy-efficient than diesel heavy-duty trucks of the same size, while fuel cell electric trucks are about 30% more efficient. As such, based on 2024 fuel prices, the direct fuel costs associated with operating a battery electric heavy-duty truck are almost 70% lower than the diesel equivalent in China, and about one-third lower in the European Union and the United States.

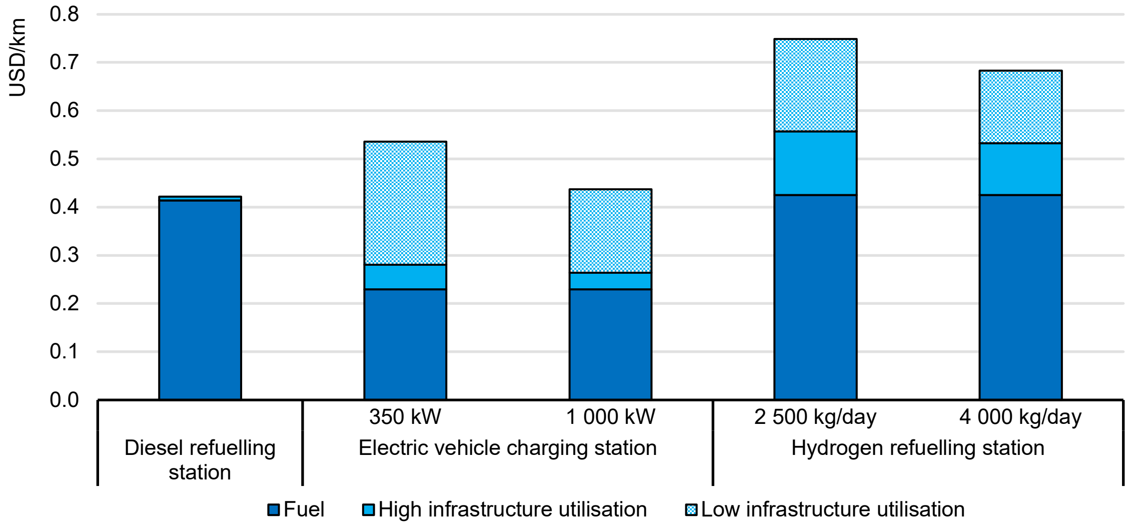
However, unlike diesel, both BEVs and FCEVs require the buildout of new, relatively expensive infrastructure, which adds to the fuel costs. Further, the levelised cost of both EV chargers and hydrogen refuelling stations (HRSs) is highly affected by utilisation rates. Overall, truck charging infrastructure could reach even higher levels of utilisation than LDV chargers, given that logistics operations are typically planned according to a predetermined schedule. Increasing the utilisation rate of an EV charger from 5% to 30% lowers the levelised infrastructure cost per kWh by about 80%, which would cut the overall fuel cost per kilometre by half based on 2024 prices. Increasing utilisation of en route chargers even further is possible, but may require solutions such as adaptive route planning.

While a single HRS is more costly to build than a charging point, it can serve a large number of trucks daily without the local grid impacts of high-powered chargers. As the utilisation rises from 30% to 80%, the hydrogen cost premium for infrastructure investment payment drops by nearly 60%, resulting in a 25% drop in overall fuel cost per kilometre. However, even at higher utilisation rates, such as for captive fleets (i.e. that are owned by the operators and return to depot) or on busy public routes, the energy plus infrastructure cost per kilometre remains about 5% higher than EV charging at low utilisation rates, and double the cost of EV charging at high utilisation rates.

For every USD 1 million spent on infrastructure, a highly utilised 350 kW charger covers more than twice as many vehicle kilometres as a highly utilised HRS. In addition, HRSs may present a greater barrier to entry, as they cannot be easily phased in gradually: an investment in HRSs must be accompanied by a large investment in FCEVs to avoid prohibitive per-vehicle fuel and infrastructure costs. On the other hand, chargers can be built modularly and more easily scaled as the fleet grows, beginning with depot charging, with en route high-powered charging following later to enable a greater share of journeys to be electrified.

Policies such as the EU Renewable Energy Directive, California's Low Carbon Fuel Standard, or China's multiple cross-cutting policies promote reductions in emissions associated with electricity and hydrogen production, but can also impact the future fuel costs. A smaller share of electrolysis projects reached final investment decision between October 2024 and October 2023 when compared to the previous 12 months, potentially constraining the supply of low-emissions hydrogen, which is more expensive than the fossil-fuel derived hydrogen predominantly used today. Meanwhile, low-cost solar and wind are driving down electricity grid emissions and can reduce electricity prices over time. However, further advances in electricity storage, smart charging and grid integration are needed to compensate for the intermittency of wind and solar and increase the benefits offered by electric trucks, requiring substantial investment.

World average levelised cost of diesel, electricity and hydrogen fuel for trucks, including infrastructure, 2024



Notes: "Fuel" represents the average price a truck operator pays, including taxes for each fuel. For hydrogen, the cost is the weighted levelised cost of production from all sources, meaning it is dominated by unabated steam methane reforming, plus the cost of distribution to the refuelling station. For electricity and hydrogen, "Infrastructure cost" is the annualised cost per unit of fuel/energy delivered, assuming a 10-year lifetime and 8% discount rate. For diesel, it is 2% of the fuel price. The "low infrastructure utilisation" factors are 5% for the 350 kW charger and 30% for the hydrogen refuelling station; the "high infrastructure utilisation" case assumes 30% utilisation of EV charger and 80% utilisation of the hydrogen refuelling station, which results in a reduced the cost per unit of energy delivered by serving a greater number of vehicles. Please see the Annex for a full list of sources, assumptions, and other inputs.
Sources: IEA analysis based on studies from the European Commission, the ICCT, and the US Department of Energy.

Battery electric trucks become competitive for long-haul applications this decade in China and Europe

For a diesel HD truck that travels an average 500 km per day, the truck capital cost represents only around 10% of the TCO across China, Europe and the United States. That means that outside of relatively fixed costs such as driver costs, insurance and maintenance, diesel fuel costs dominate the TCO. In comparison, for an 800 kWh battery electric truck, the cost of the truck represents about 20-25% of the TCO, demonstrating the potential trade-off between high upfront costs and lower running costs. For battery electric trucks, energy costs account for around 15-25% of the TCO, and for fuel cell trucks they account for 15-35%, across the three regions examined. For BEVs, more than 10% of the TCO can be attributed to charging infrastructure in Europe and the United States, while in China, this share is reduced to around 3%, thanks to lower industrial land costs as well as lower capital costs. The refuelling infrastructure for fuel cell trucks has higher costs, representing nearly 10% of the TCO in China and more than 15% in Europe and the United States.

In terms of operations, regulations on truck driver rest periods can play a role in determining the cost of the "dwell" time for recharging electric truck batteries. The time associated with charging is often considered to be a barrier to the adoption of battery electric trucks for long-haul applications as it can potentially disrupt operations, especially in very long-haul applications. This consideration is factored into the TCO calculation by adding the additional labour cost for the truck driver. In the European Union, drivers are required to take a 45-minute break every 4.5 hours. In the United States, a driver is not permitted to drive for more than 8 hours without a 30-minute break. In China, drivers are required to take a break every 4 hours, generally 20 minutes. As such, driving regulations can influence the TCO, and making use of rest periods for charging can make battery electric trucks more or less cost-competitive with diesel trucks. Based on a 500 km daily route and current regulations, an extra 15 (European Union), 30 (United States), and 40 minutes (China) would be needed in addition to the driver rest period in order to charge the battery electric HD truck sufficiently.[4] The net cost associated with dwell time represents a trade-off between the fuel and labour costs, and as such may make more economic sense in China, where diesel is more expensive than in other regions, and labour and electricity less expensive. In contrast, in the United States, lower costs for diesel and higher labour and electricity costs can make it more difficult to justify.

Charger power is also key in calculating this trade-off. A 350 kW charger, as used in the base case, can provide 200 km of range in around 1 hour, while a 1 MW charger could provide the same in about 20 minutes, potentially eliminating the dwell cost.[5] Destination charging, particularly where drivers must wait for loading and unloading, could also greatly reduce the dwell time.

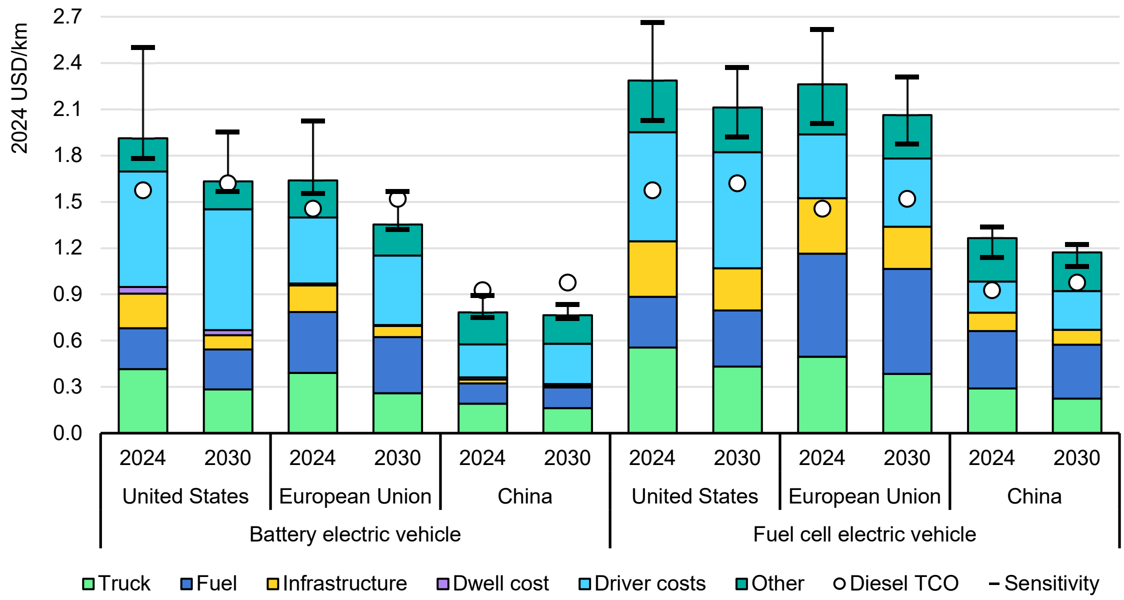
The impact on payload is another consideration for many hauliers. In the United States, 18% of trucks operate close to the general maximum gross vehicle weight, with a further 7% operating above the limit, meaning they could be impacted by the additional weight of either a fuel cell or battery electric truck compared to diesel. Derogations exist in the United States (907 kg) and the European Union (2 000 kg) to help offset the impact of the additional weight. A proposal from the European Commission to further increase this to 4 000 kg could eliminate the disadvantage relative to diesel trucks, but could also marginally

[4] 500 km daily distance is split evenly before and after the minimum rest periods of 20, 30, and 45 minutes in China, the United States, and the European Union, respectively, based on the driver's rest regulations for each country/region, after which drivers, if required, continue to use the 350 kW charger to provide sufficient range to perform the same daily mileage day after day, including for overnight depot charging, based on 2024 fuel economy values and minimum and maximum battery states of charge of 20% and 80%.

[5] Assuming 1.6 kWh/km fuel economy, and considering that this is below the length of the shortest minimum rest period.

increase road maintenance costs.[6] In China, industry stakeholders have also mooted increasing the weight limits as a means of making alternatively fuelled vehicles more competitive. These potential impacts are considered in the sensitivity case of the TCO.

Total cost of ownership for battery electric and hydrogen fuel cell heavy-duty trucks in 2024 and 2030



Notes: TCO = total cost of ownership. “Truck” refers to the cost of the truck including financing over 5 years at 5% interest and the residual value in year 5. “Infrastructure” is the levelised contribution to the cost of the EV charging or hydrogen refuelling station. “Driver costs” is the cost of employing a truck driver during normal working hours and does not include “dwell cost”, which is the additional cost incurred when a driver must continue charging beyond their rest period. “Other” costs include insurance and maintenance. Cost projections are based on the 2024 Global Energy and Climate Model Stated Policies Scenario, as published in the World Energy Outlook 2024 report. Please see the Annex for a full list of sources, assumptions, and other inputs.
Sources: IEA analysis based on a studies from Ricardo, US Department of Energy, ICCT, the European Commission.

In China, the TCO of battery electric HD trucks is already lower than that of diesel trucks in a number of applications. This reflects the lower cost of EV batteries in China, as well as the gap in fuel costs, as electricity already costs 65% less than diesel per kilometre. As such, energy costs for battery electric trucks are over 50% lower per kilometre compared to diesel trucks. Fuel cell trucks remained around 35% more expensive than diesel trucks in China in 2024, largely because of the higher infrastructure and fuel costs for hydrogen.

In the United States, higher electricity and infrastructure costs than Europe or China mean that the TCO of a diesel truck is almost 20% cheaper than that of a

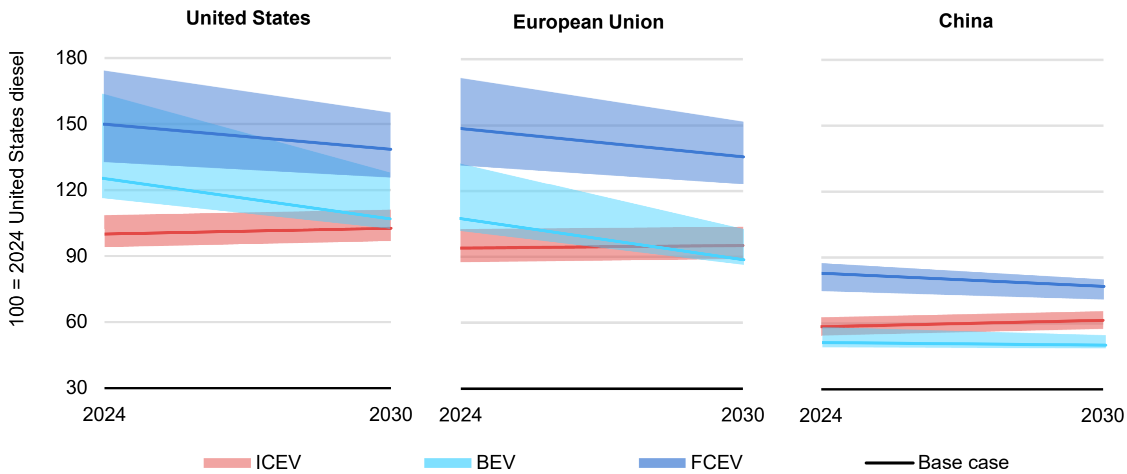
[6] A full table of maximum gross vehicle weights, estimated unladen vehicle weights, assumptions, and the resulting “payload penalties” is included in the Annex.

battery electric truck, though higher charger utilisation rates could reverse this by 2030. Compared to the European Union, US regulations on driver rest periods and maximum gross vehicle weight further hamper the uptake of zero-emissions trucks. However, in the coming years, the TCO of battery and fuel cell electric trucks is expected to fall due to improvements in infrastructure utilisation and costs, as well as further cost reductions for batteries and fuel cells. In contrast, diesel electric trucks are expected to become more expensive due to more stringent pollutant emissions regulation.

In all three markets, fuel cell trucks remain more expensive than battery electric trucks up to 2030, while continued development of high-powered charging – especially megawatt charging – reduces or eliminates the refuelling time advantage offered by FCEVs compared to BEVs. Increased utilisation of HRSs could result in further reductions to the TCO of fuel cell electric trucks, but battery electric trucks will remain cheaper to operate. For fuel cell electric trucks to become more competitive, substantial reductions in the capital costs of the truck and infrastructure, as well as lower fuel costs, will be necessary.

In 2030, the TCO of battery electric trucks is more competitive than diesel trucks in both China and the European Union. The gap also narrows substantially in the United States, achieving parity around 2030. Incentives such as grants towards the purchase of trucks, chargers, or HRSs, or differentiated taxes and charges could bring this date even closer, or indeed allow TCO parity to be achieved today in applications particularly suited to electrification.

Total cost of ownership for diesel, battery electric and fuel cell heavy-duty trucks, 2024-2030

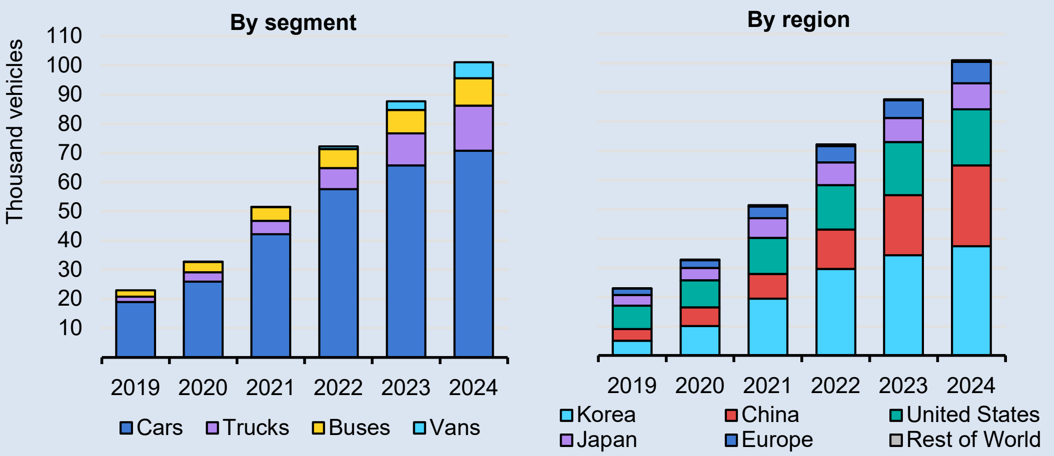


Notes: ICEV = internal combustion engine vehicle; BEV = battery electric vehicle; FCEV = fuel cell electric vehicle. The ICEV is a diesel truck. The total cost of ownership is indexed to the United States 2024 value of diesel heavy-duty trucks. Includes vehicle cost, labour, financing, fuel (including infrastructure costs), maintenance, insurance and residual value. Excludes taxes, charges not included in fuel costs, and any subsidies or incentives. Cost projections are based on the 2024 Global Energy and Climate Model Stated Policies Scenario, as published in the World Energy Outlook 2024 report. Please see the Annex for a full list of inputs and assumptions including the values that define the upper and lower ranges.

Sales of fuel cell trucks and buses outpaced sales of fuel cell cars in 2024

In 2024, the stock of fuel cell vehicles grew to over 100 000, 15% more than the year before. In comparison, the stock of EVs exceeded 60 million (excluding 2/3Ws) at the end of 2024, about 600 times the number of FCEVs. About 70% of the FCEVs on the road are cars, though this share has fallen since the end of 2023 (75%). Fuel cell trucks experienced higher growth in 2024 than fuel cell cars or buses, with the stock increasing by more than 40% compared to 2023.

Fuel cell electric vehicle stock by segment and region, 2019-2024



Sources: IEA analysis based on data from the Advanced Fuel Cells Technology Collaboration Programme, EV Volumes, Toyota, California Fuel Cell Partnership.

Growth in fuel cell car sales has slowed in recent years, with just 5 000 sold worldwide in 2024, compared to the peak of more than 16 000 in 2021. This slowdown is particularly acute in the United States and Korea – the two countries with the largest stocks of fuel cell cars. In California, where the majority of US fuel cell cars are sold, only around 600 new fuel cell cars were registered in 2024 – the lowest number since 2015. In Korea, almost 3 000 fuel cell cars were sold in 2024, about 35% less than in 2023 and 70% less than in 2022. Only a handful of OEMs produced fuel cell cars in 2024.

In contrast, the global stock of fuel cell buses grew by almost 20% in 2024. China continues to have the most fuel cell buses, accounting for three-quarters of the global stock. The number of fuel cell buses grew strongly in Korea in 2024 to reach a stock of 1 000, about 10% of the global total.

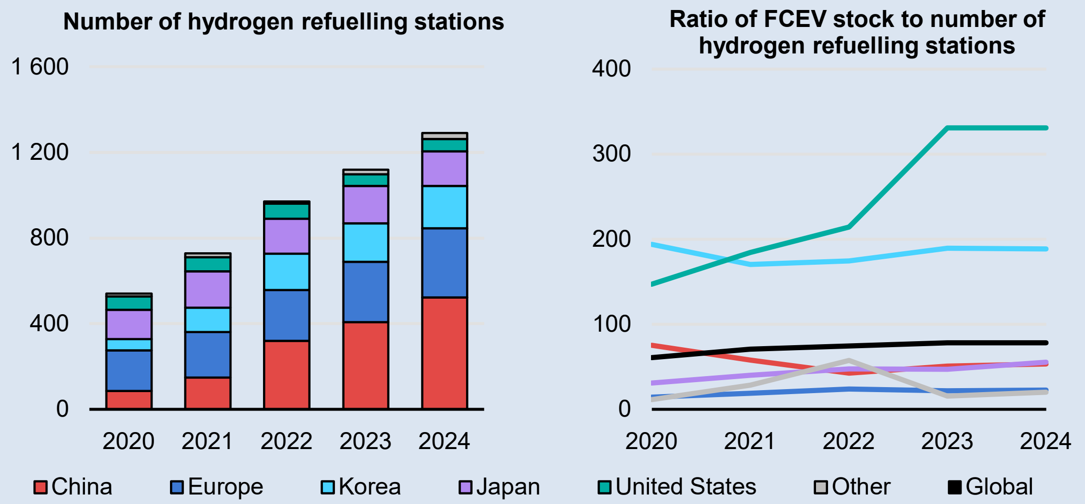
Unlike Korea, the United States and Japan – each of which has traditionally focused more on fuel cell car deployment than on any other segment – over 70% of the FCEV stock in China is commercial vehicles (including LCVs and heavy trucks). In China, cars make up only around 3% of the total fuel cell vehicle fleet, while in the

United States and Korea they account for up to 97%. In 2024, the stock of fuel cell trucks in China increased 40% compared to 2023, reaching almost 15 000 vehicles, about 5 times the amount at the end of 2020. In addition, the stock of fuel cell LCVs in China reached more than 5 000 by the end of 2024, nearly double that of the previous year. Almost 95% of the world's fuel cell commercial vehicles are in China.

Around 50 fuel cell commercial vehicle models were available worldwide in 2024. Over 60% of these were heavy-duty truck models, coming from 20 different manufacturers. However, Nikola, one of the pioneers of heavy-duty fuel cell trucks, filed for bankruptcy in February 2025, despite selling 200 vehicles in 2024 and securing orders for 100 more meant to be delivered in 2025.

To support the growing number of FCEVs, countries have supported the buildout of hydrogen refuelling stations (HRSs). The number of operational stations reached around 1 300 worldwide at the end of 2024, 15% more than at the end of 2023. The largest growth occurred in China, where the number of HRSs increased 30% in 2024 to reach more than 500. In Europe, the number of stations increased 15% to over 300 by the end of 2024, despite some closures in countries such as Denmark and the United Kingdom. The United States and Korea have also seen the number of available HRSs fluctuate over the past year or so, as hydrogen supply and station reliability issues have led to temporary and permanent closures. The number of operational HRSs in the United States increased in 2024, but remains below the number available between 2017 and 2022.

Number of hydrogen refuelling stations by region and ratio of fuel cell electric vehicle stock to number of stations, 2020-2024



Note: FCEV = fuel cell electric vehicle.

Sources: IEA analysis based on data from the Advanced Fuel Cells Technology Collaboration Programme, EAFO, US Alternative Fuels Data Center.

The number of FCEVs per HRS is significantly higher in the United States and Korea than in other regions. The global average number of FCEVs per HRS has remained at under 80 over the past 5 years, while in the United States this ratio exceeded 300 in 2023 and 2024 and has been close to 200 in Korea since 2020.

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

5. Outlook for electric mobility

Overview

In this part of the report, we focus on the outlook for electric mobility in road transport over the period to 2030. A scenario-based approach is used to explore the prospects for electric mobility, based on recent market trends, policy drivers and technology developments.

The purpose of scenario projections is to assess a plausible future for global electric vehicle (EV) markets and the potential implications. The scenario projections are not intended as predictions about the future. Rather, they aim to provide insights to inform decision-making by governments, companies and other stakeholders about the future of EVs.

In particular, the Stated Policies Scenario (STEPS) reflects the current policy landscape, taking into account existing policies and measures, as well as those that are under development. It includes current EV-related policies and announcements, 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.

The projections for EV markets in this year's Global EV Outlook (GEVO-25) are limited to 2030 in the STEPS. As the IEA highlighted in its 2024 edition of Energy Technology Perspectives, energy, industrial and trade policies are increasingly interwoven and there are challenges and trade-offs between these key areas of public policy. The way these interactions play out for electric mobility over the longer term will therefore be assessed holistically in the context of the scenarios of the entire global energy system that the IEA will develop later in the year using its Global Energy and Climate Model (GEC-M). Key uncertainties for EV markets for the medium-term – such as those related to the evolution of trade and industrial policy, downside risks to the economic outlook and the impact of different levels of oil prices – are, however, presented in this chapter of the report.

The projections in the STEPS in GEVO-2025 consider historical market data and stated policies up until the end of February 2025. These scenario projections incorporate GDP assumptions from the International Monetary Fund and population assumptions from the United Nations, as described in the 2024 GEC-M documentation.

EV deployment is projected by road transport mode and by region. For further details on EV projections and impacts, refer to the IEA's online Global EV Data Explorer, which is updated with each edition of the Global EV Outlook.

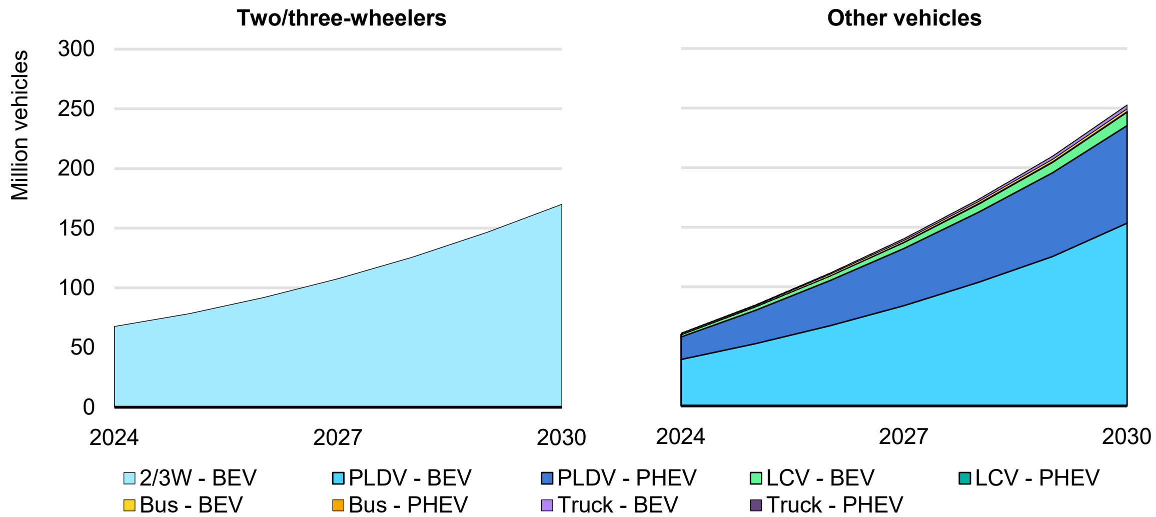
Vehicle outlook by mode

The global electric vehicle fleet grows fourfold to 2030 under stated policies

By 2030, the fleet of EVs across all modes except 2/3Ws reaches 250 million in the STEPS – four times as many EVs as there were at the end of 2024. More than 90% are electric cars, which is similar to the share in 2024. In this scenario, the stock of EVs (excluding 2/3Ws) increases at an average rate of about 25% per year, which is about half the annual growth observed from 2018-2024.

In 2024, the stock of electric 2/3Ws was higher than that of all other EVs combined. By 2030, however, the stock of electric cars overtakes that of electric 2/3Ws, despite the latter more than doubling to reach around 170 million in 2030 in the STEPS. As a result, EVs represent about 15% of all vehicles on the road (including 2/3Ws) in 2030 in this scenario. The share of global EV stock in China decreases from over 70% in 2024 to around 55% in 2030 in the STEPS as adoption in other markets grows.

Electric vehicle stock by mode in the Stated Policies Scenario, 2024-2030



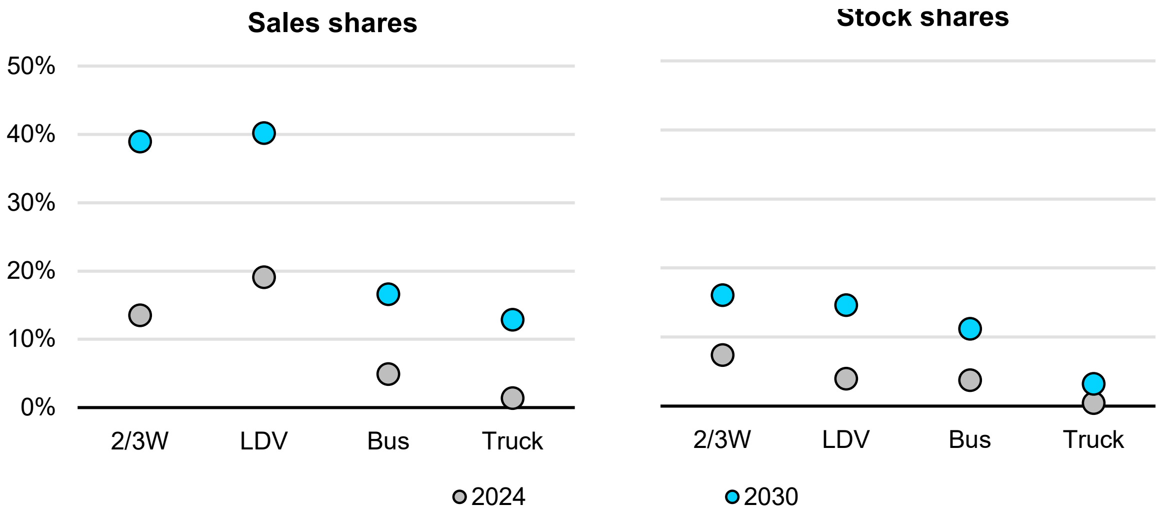
Notes: 2/3W = two/three-wheeler; PLDV = passenger light-duty vehicle; LCV = light commercial vehicle; BEV = battery electric vehicle; PHEV = plug-in hybrid electric vehicle. There are no plug-in hybrid electric two/three-wheelers.

In 2024, the EV sales share was higher for light-duty vehicles (cars and vans) than 2/3Ws, in a change to the trend prior to 2023. In 2030, the EV sales share for both light-duty vehicles (LDVs) and 2/3Ws reaches around 40% in the STEPS. In terms of stock shares, 2/3Ws remain the most electrified vehicle segment in 2030 in the STEPS, with around one in six 2/3Ws being electric compared to one in seven LDVs.

Despite electric buses and electric LDVs having about the same stock share in 2024, the sales share of electric buses grows more slowly, reaching less than 20% globally in 2030 in the STEPS. As a result, slightly more than 10% of the global bus stock is electric in 2030 in the STEPS.

Trucks remain the slowest mode to electrify but make some progress thanks to HDV emissions standards and improving economics. In 2030, electric truck sales reach around 13% globally in the STEPS, though only 3% of the truck stock is electric at that point.

Electric vehicle sales and stock share by mode in the Stated Policies Scenario, 2024 and 2030



Notes: 2/3W = two/three-wheeler; LDV = light-duty vehicle.

Economic and policy uncertainties could impact car markets and the global outlook for EVs

The recent surge in **trade policies and tariffs** may affect the price and resulting sales of EVs – especially electric cars – in several markets over the coming years. In particular, in March 2025 the United States announced an additional 25% tariff applicable to all automobiles, including electric cars, and to certain components. In 2024, 40% of electric cars sold in the United States (over 600 000) were imported, with over 10% of them coming from Europe and slightly less than 10% each coming from Mexico, Japan and Korea. Conventional car sales are more exposed, with over half of all conventional cars sold in the United States in 2024 having been imported. Conventional car imports generally come from the same countries as EVs, although there is a much higher reliance on Mexico and lower reliance on Europe. As a result, the impact of tariffs on the sales share of electric cars in the United States may be relatively small compared to the impact of potential changes in demand-side policies (such as fuel economy standards and tax incentives), some of which are already considered as part of the STEPS outlook.

The impact of tariffs might be more pronounced for EV batteries, their components and raw materials, all of which are highly traded across the world because supply is significantly more concentrated than demand. China produces the cheapest EV batteries, and was responsible for nearly 80% of global EV battery cell production in 2024. China's share of production was even higher for battery components, for which the country represented almost 85% of global cathode active material and over 90% of the anode active material production. A global shift towards higher tariffs could put upward pressure on battery prices, counteracting some of the significant battery price declines that have occurred since 2015. For example, a 25% tariff would override the 20% average battery price declines from the past year. However, countries across the world are simultaneously developing and improving the competitiveness of their local battery manufacturing industries, which is expected to contribute to narrowing regional cost gaps.

Emerging trade tensions also have implications for the **economic outlook**, which may create additional uncertainty for the EV outlook. In April 2025, the International Monetary Fund (IMF) released revised GDP projections, which show 2.8% growth globally in 2025 and 3% growth in 2026, as compared to 3.3% in both years in their January 2025 projections. The revisions to GDP growth were most pronounced in North America, with projected 2025 growth for the United States falling from 2.7% previously to 1.8% in the April 2025 update. The IMF now projects in its central scenario that in the United States and China, two of the largest EV markets in the world, GDP growth in 2025 will be one percentage point lower than in 2024. By 2027, the IMF expects global GDP growth to return back to levels previously projected, though for advanced economies as a whole, annual GDP growth projections remain lower through 2029 compared to the IMF's October 2024 publication.

Lower GDP growth could add pressure on already-strained government budgets, which, in turn, could lead to governments downscaling or terminating incentive schemes for EVs ahead of schedule. While direct subsidies are already quite small in most major markets, indirect subsidies, such as those related to company cars, could be affected. Similarly, budgets allocated to the deployment of charging infrastructure at different administrative levels (from national to local levels of government) could be reduced. While all these factors could slow down the uptake of EVs, policy responses can also be developed in a way that supports EV sales, as was done in European countries in the wake of the Covid-19 pandemic.

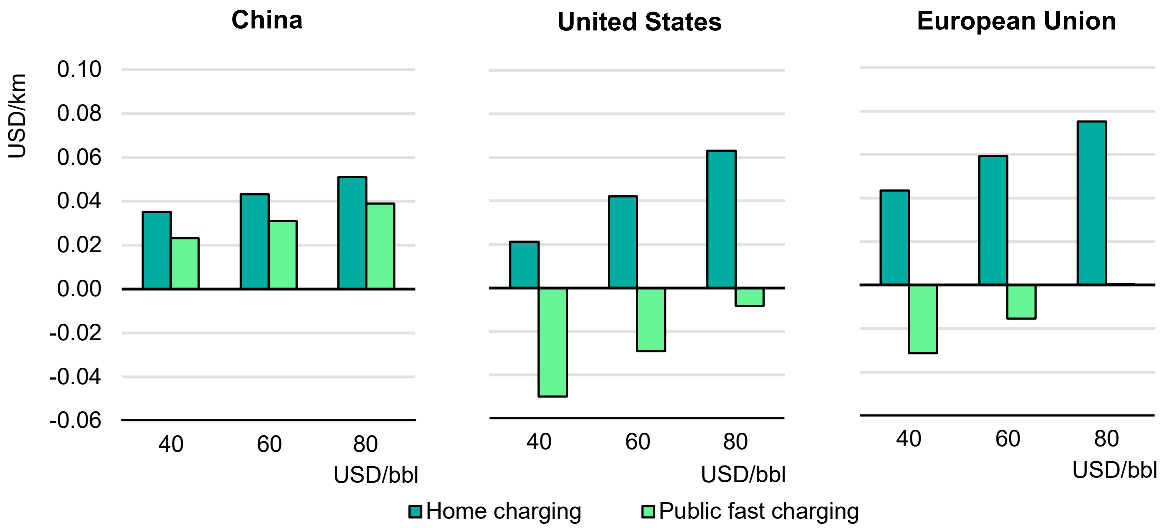
Lower economic growth and the corresponding effects on the purchasing power of consumers could slow down sales of new vehicles across all powertrain types, thereby potentially counterbalancing the impact on EV sales shares. Evidence shows that an economic slowdown can affect car sales. For example, pronounced and abrupt economic crises have led to double digit declines in car sales in the past, for example in the United States between 2007 and 2009 (GDP -2.5%, car sales -37%), and in Italy between 2011 and 2013 (GDP -5%, car sales -25%). More modest and gradual economic slowdowns can also have an effect, such as the slowdown in China between 2017 and 2019 (+6.2 % compared to a ten-year average of over +8%) that led to the first decline in car sales recorded in decades, of -12% over 2 years.

The extent to which car markets – and, as part of that, electric car sales – might be affected by a sluggish economic outlook is still uncertain. The Chinese market will be key to watch: it is the largest single car market in the world, and it drives the outlook for global electric car sales in the medium term, accounting for more than half of global electric car sales through 2030 in the STEPS. In China, electric cars are already price competitive with conventional cars and so there is little reason to believe that electric car sales would be more affected by an economic slowdown than conventional cars. Further, China's extension of its vehicle trade-in policy may also contribute to keeping overall car sales strong. Even if car sales volumes in China are lower than is projected in the STEPS, electric car sales shares are likely to remain relatively robust.

Finally, changes in **energy prices** can also affect the adoption of EVs. Weak demand prospects have led to a drop in global oil prices from an average of around USD 80 per barrel in 2024 to below USD 60 per barrel at one point in April 2025. Lower oil prices, if sustained, could translate into lower retail prices for gasoline and diesel, thus reducing the economic incentive to purchase EVs, all else being equal. The impact of such a drop is likely to vary across regions: it will be more moderate in regions with high fuel taxation (such as the European Union), and more pronounced in regions with lower fuel taxation, such as the United States and China. Nonetheless, oil prices would need to be extremely low to completely offset the savings offered by the lower running costs of EVs.

Taking oil prices around USD 40 per barrel as an illustrative example, there are significant savings to be made in all major markets from running a battery electric car if it is charged at home. In China, even at such a low oil price, battery electric cars remain cheaper to run when charged at public fast chargers due to a combination of low electricity prices and high charging infrastructure utilisation rates. In the United States, the vast majority of electric car owners have access to home charging, but public fast charging can be expensive compared to gasoline. In the European Union, most EV owners also have access to home chargers, though to a lesser extent. Low oil prices could therefore undermine the economic case for EVs for drivers without access to home charging depending on the speed and thus cost of public charging.

Electric car running cost savings compared to an internal combustion engine car for a range of illustrative oil prices, 2024

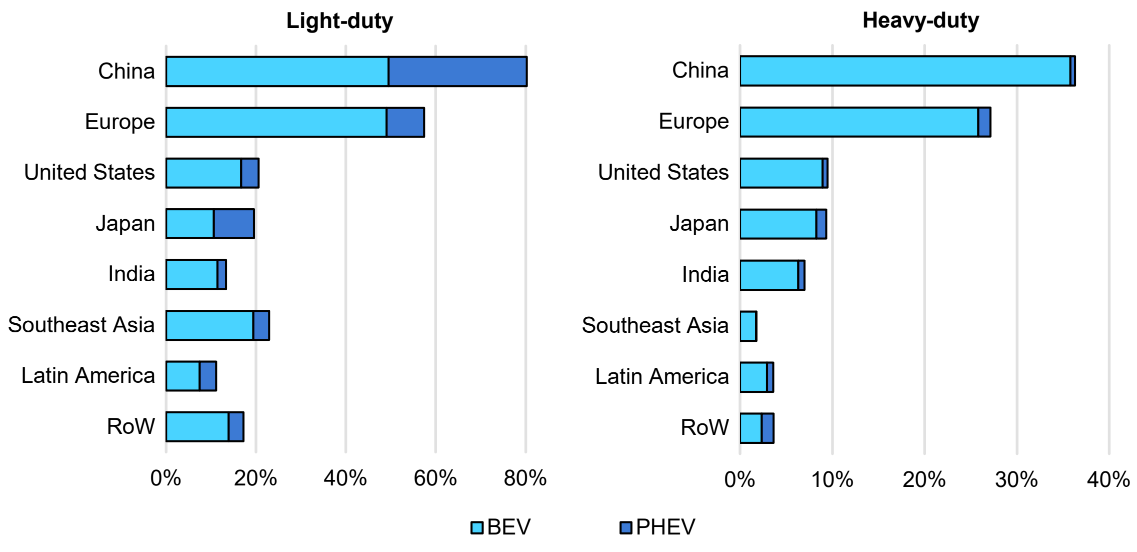


IEA. CC BY 4.0.

Notes: bbl = barrel. Negative savings indicate it costs more to run a battery electric car than an internal combustion engine car. Average on-road fuel consumption values in each region is assumed.

Vehicle outlook by region

Electric vehicle sales share by mode and region in the Stated Policies Scenario, 2030



IEA. CC BY 4.0.

Notes: BEV = battery electric vehicle; PHEV = plug-in hybrid electric vehicle; RoW = Rest of World. Light-duty refers to passenger light-duty vehicles and light commercial vehicles. Heavy-duty refers to buses, medium-duty and heavy-duty trucks. Regional projected EV sales and sales shares data can be explored in the interactive Global EV Data Explorer.

Market momentum in China sees electric cars reach a sales share of around 80% by the end of the decade

In the second half of 2024, China achieved the milestone of an electric car sales share of more than 50%, partly thanks to the cost competitiveness of EVs. For the past few years, over half of the electric cars sold in China have been cheaper than ICE cars of the same size, and as battery prices continue to fall, this trend is likely to continue.

Based on stated policies, the share of electric cars and vans in China is expected to reach around 80% of total sales in 2030, backed by continuing policy support and progress on affordability. China has already exceeded the official government target of reaching a sales share of 45% of new energy vehicles (NEV) among new cars by 2027, underscoring the strong market dynamics behind the shift to electromobility. Trade-in grants that were due to expire at the end of 2024 have been extended to 2025, and the NEV exemption from vehicle purchase tax has also been extended until the end of 2027, further supporting uptake of EVs in the short term. In addition, government plans to enhance charging infrastructure over the period to 2030 aim to keep pace with EV uptake by promoting the construction of charging stations in residential areas, as well as in parking spaces in enterprises, industrial parks and government buildings.

Policy action to restrict ICE 2/3Ws in several cities over the past decade has driven high adoption rates of electric 2/3Ws, with more than 30% of 2/3Ws now electric. In the STEPS, the share of electric 2/3Ws on the road reaches nearly 50% by 2030, driven by the continued momentum of electromobility in China and a further decline in battery costs.

This growing trend also extends to buses, especially in cities, where nearly all new buses are now electric. However, the electric market share of coaches for intercity transport was below 10% in 2024. By 2030 in the STEPS, the sales share of electric buses reaches almost 75% across all bus segments, up from less than two-thirds today.

China currently accounts for more than 80% of electric medium- and heavy-duty truck sales worldwide, and the sales share in the country increased to more than 4% in 2024, from 2% in 2023. In some months, the sales share of battery-electric heavy trucks reached a new high of almost 15%, as seen in late June. Truck manufacturers are making efforts to reduce costs, such as by adopting the less costly lithium iron phosphate (LFP) battery chemistry. In addition, policy support for HDV charging infrastructure and the increasing availability of battery-swap-capable vehicles could further accelerate electrification in this segment. Although the upfront cost is higher today compared to diesel powertrains, the annual savings from significantly lower fuel costs mean that electric medium- and heavy-freight trucks become a cost-competitive option in many applications in the short-term (see Truck total cost of ownership in Section 4). By 2030, the sales share of electric trucks exceeds 30% in the STEPS.

Given China's strong position in the shift towards electromobility, the sales share of EVs across all vehicle types (excluding 2/3Ws) reaches close to 80% by 2030 in the STEPS, well on track with what is needed for its target of reaching climate neutrality in 2060 and supporting efforts to reduce air pollution.

European policy environment continues to promote EVs while offering some flexibility in the short term

Electric car sales stagnated in Europe in 2024, due to a mix of factors including reduced availability of purchase subsidies and a lack of affordable mass-market EV models in OEMs line-ups, as well as sluggish car markets in general. Nonetheless, the policy environment in Europe is one of the strongest in terms of support for EVs, which could encourage strong growth in electric LDV sales over the remainder of this decade. OEMs are beginning to introduce more competitively priced models to comply with the new phase of EU CO_2 standards, which entered into force in 2025.

The 2025-2029 EU fleet-wide CO_2 targets that were originally proposed represent a 15% emissions reduction compared to a 2021 baseline. The stringency of the standard is further bolstered by two changes in the way CO_2 emissions are calculated starting from 2025. First, the utility factor (the share of distance driven in electric mode only) of new PHEV models, which is used to calculate their official CO_2 emission values, decreases, meaning PHEV sales are now less effective in helping OEMs reach target compliance. Second, the revised calculation of CO_2 emission targets will be more favourable to smaller, lighter OEM fleets, potentially increasing the challenge for manufacturers of heavier models.

As a response to concerns that compliance would be difficult for some European manufacturers, the European Commission recently published an Industrial Action Plan for the European automotive sector, which announced a proposal to offer flexibilities in meeting the 2025 CO_2 standards for cars and vans. This allows OEMs to reach target compliance by averaging their emissions over the period 2025-27, rather than needing to reach the target by the end of 2025. Despite giving more leeway to carmakers to fall in line with their CO_2 targets, the Action Plan has reaffirmed the overall impetus towards the 2030 and 2035 targets. It was also announced that the review of the 2035 targets would be sped up, with full technology neutrality as a core principle, though the outcome and thus impact on EV shares remains to be seen.

The European Union is also exploring measures to accelerate the adoption of zero-emission vehicles in corporate fleets, which currently account for around 60% of new car sales. Policies to support EV uptake in EU member states include national-level measures such as tax credits for EV company cars in countries including Belgium, or France's "social leasing" schemes for low-income households, which will be rerun in 2025. When considered alongside the zero emission vehicle mandate in the United Kingdom, stated policies drive the sales share of electric cars and vans in Europe to nearly 60% by 2030 in the STEPS, up from less than 20% today.

For buses and medium- and heavy-duty trucks, the EU HDV CO_2 standards serve as the key lever for further electrification. Policy momentum is particularly strong for electric buses in the European Union, and their share in total bus sales reaches around two-thirds by 2030 in the STEPS. For medium- and heavy-freight trucks, policies already in place towards meeting the EU CO_2 standards result in around one-third of new registrations in the European Union being electric by 2030 in the STEPS. The European Commission's proposal to exempt zero-emission trucks from road tolls could further support this trend. Toll charges for a long-haul diesel truck can amount to EUR 25 000 annually. Across Europe as a whole, the share of electric medium- and heavy-duty trucks in this scenario is around 25% in 2030, reflecting the varying levels of policy support across different countries.

In Europe, EV sales across all vehicle types (excluding 2/3Ws) are projected to exceed 55% by 2030 in the STEPS, with lighter vehicles such as passenger cars and light commercial vehicles making up the majority of sales.

Recent US policy directs the government to reduce support for EVs

On 20 January 2025, Executive Order 14154 declared that it was US policy to, among other things, eliminate subsidies and other policy measures influencing markets in favour of EVs. Following this, a bill was introduced to the US Senate that proposes to repeal the Clean Vehicle Tax Credit for both electric cars and commercial vehicles. In addition, the US Secretary of Transportation has directed the National Highway Traffic Safety Administration to review existing fuel economy standards for LDVs. The fuel economy standards that were finalised in 2024 require the fuel economy of passenger cars to improve around 2% per year for model years 2027-2031.

While emissions from vehicles are typically regulated at the federal level under the Clean Air Act, in December 2024, the US Environmental Protection Agency (EPA) granted California's request for a waiver from federal pre-emption (by which federal law supersedes conflicting state law) for their Advanced Clean Cars II

(ACC-II) regulation. The ACC-II regulation requires an increasing number of electric and fuel cell electric new car sales, from 35% in 2026 to 100% in 2035 and beyond. In 2024, California represented almost 30% of US electric car sales, but only around 10% of total US car sales. In addition to California, 11 other states and Washington DC have adopted the ACC-II regulation under Section 177 of the Clean Air Act. All together, the states that have adopted the ACC-II regulation represent about 30% of all US LDV sales. However, Executive Order 14154 also directed US policy to terminate, “where appropriate, state emissions waivers that function to limit sales of gasoline-powered automobiles.” Based on stated policy intentions, electric LDV sales in the United States increase from about 10% today to about 20% in 2030 in the STEPS. To put this in context, in the STEPS of GEVO-24, US electric car sales reached more than 50% in 2030, on the back of policies in support of EVs.

The availability and stringency of fuel economy and emissions standards also has significant implications for HDV electrification prospects in the United States. In April 2023, the US EPA granted a waiver of pre-emption for California’s Advanced Clean Trucks (ACT) Regulation, which requires that manufacturers produce and sell increasing quantities of medium- and heavy-duty near-zero and zero-emission vehicles. Ten states have since adopted the ACT regulation. On the other hand, California withdrew its request for a waiver of pre-emption for the Advanced Clean Fleets (ACF) Regulation, which would have required certain fleet owners to purchase increasing shares of near-zero and zero-emission trucks. Some elements of the ACF Regulation would not have been affected by the waiver and so state and local government fleets will still be required to comply with the regulation. At the federal level, in March 2024, the US EPA released final emissions standards for HDVs, which require CO_2 emissions reductions (per ton-mile) of about 25-60% for model year 2032 trucks compared to model year 2027, depending on truck type.

Given uncertainty in the longevity of the existing emissions standards and state waivers, the sales share of electric medium- and heavy-duty trucks in the United States reaches around 8% in 2030 in the STEPS, up from less than half a percent in 2024. This compares to 20% electric truck sales projected in 2030 in the STEPS of GEVO-24.

Electric bus deployment has historically been supported at the federal level through funding opportunities such as the Clean School Bus Program, but city and state policy also play a role in driving uptake, meaning that electric buses may be relatively insulated from changes to federal policies. For example, the Illinois State Legislature passed law that transit agencies in the state can purchase only zero-emission buses from 2026. The California state government also offers incentives for the purchase of buses and dedicated charging infrastructure, such as the

USD 500 million allocated to school buses during the 2023-2024 fiscal year. In the STEPS, EVs represent close to 15% of bus sales in 2030, up from about 3% in 2024.

Across all vehicle types, excluding 2/3Ws, EVs represent one in five vehicles sold in the United States in 2030 in the STEPS, meaning one in thirteen vehicles on the road in 2030 is electric. This is about half the sales share across the rest of the world, where around 40% of vehicle sales (excluding 2/3Ws) are electric in 2030 in the STEPS.

Strong domestic industry, fuel economy standards and targeted subsidies support EV growth in Japan

The policy framework in Japan has remained fairly stable over the past year. In 2019, the country published LDV fuel economy targets for 2030, aiming to achieve an improvement of 32% in fuel economy by 2030 compared to 2016. This 11-year lead time has given automakers time to incorporate the fuel economy standards in their company strategies, and the seven largest Japanese automakers now all have electrification targets in place.

In addition, purchase subsidies are available for electric and fuel cell cars to help achieve the country's net zero and Green Transformation target of 100% electrified (including fuel cell and hybrid) car sales by 2035. In the STEPS, Japan's electric LDV sales increase from 3% of total LDV sales in 2024 to 20% by 2030. This is in line with the low end of the range described in Japan's Next-Generation Vehicle Strategy, which aims for a 20-30% sales share of electric LDVs by 2030, with another 30-40% sales being hybrids, and 3% being fuel cell LDVs.

Fuel economy standards for HDVs, including buses and trucks, require a reduction in fuel consumption of more than 13% in 2025 compared to the 2015 baseline. Japan also has purchase subsidies in place for buses and trucks to support EV and FCEV uptake. Electric bus sales reach about 12% in 2030 in the STEPS, up from 2% in 2024. Electric medium and heavy freight truck sales are slow but rise from less than 0.5% today to around 10% by the end of the decade.

Japan is steadily moving towards the electrification of 2/3Ws, with electric 2/3Ws already accounting for 7% of sales in 2024. This is further supported by city-level policies, such as Tokyo's subsidies for eligible 2/3Ws, which have been introduced with the aim of all new sales being electric by 2035. The share of electric 2/3Ws continues to rise in the STEPS, reaching more than 45% by 2030.

Japan's EV sales share across all modes (excluding 2/3Ws) was at 3% in 2024 and increases to nearly 20% by 2030 in the STEPS, and just slightly over 20% when including 2/3Ws. As a result, about 1 in 20 vehicles in Japan is electric in 2030 based on stated policies.

Policy support in India focuses on the electrification of vehicles other than cars

Following years of support under the Faster Adoption and Manufacturing of Electric Vehicles (FAME) scheme, which was introduced in 2015, implementation of the new PM Electric Drive Revolution in Innovative Vehicle Enhancement (PM E-DRIVE) scheme began on 1 October 2024. The new scheme focuses on electric 2/3Ws, buses, trucks and charging infrastructure, while specifically excluding electric cars, and has a budget envelope of USD 1.3 billion to 31 March 2026.

The 2/3W segment is already the most electrified segment in India, with close to 10% of sales in 2024 being electric. This high electrification rate has been driven by the significant savings on total cost of ownership (TCO) offered by existing electric 2/3W models in India. As early as 2023, we estimated that, with subsidies in place, the TCO of an average electric 2W would be 40% less than its ICE equivalent after 5 years of ownership. The combination of policy support and advantageous economics mean that momentum in electric 2/3W sales is set to continue, and electric models are expected to account for more than one-third of 2/3W sales by 2030 in the STEPS.

Although there are no purchase subsidies for electric cars in India, other mechanisms may support adoption. These include the national vehicle scrapping policy (V-VMP), along with a number of federal and state-level policies, such as a reduction in the rate of the federal Good and Services Tax and in the Regional Transport Office state-level tax, as well as other registration and road tax waivers. In addition, the government's Production Linked Incentive scheme for Automobile and Auto Components and for manufacturing of Advanced Chemistry Cell Battery Storage aims to attract investments in domestic EV and battery manufacturing. In March 2024, the government approved the Scheme to Promote Manufacturing of Electric Passenger Cars in India to attract investment from global EV manufacturers. This allows EV manufacturers committing to invest in India to import electric cars with import duties reduced from 70% (or 100% if the purchase price exceeds USD 50 000) to 15%. These policies in support of domestic manufacturing are well-poised to help drive EV uptake.

The Indian Government is currently drafting new CO_2 emissions standards for cars, CAFE III (2027-2032) and CAFE IV (2033-2037), which have proposed WLTP CO_2 emission targets of 91.7 g CO_2/km and 70 g CO_2/km, respectively. This standard will be implemented with a super-credit mechanism, making it easier for OEMs to reach compliance through electric car sales rather than through sales of conventional cars and non-plug-in hybrids. Based on existing policy support (excluding the latest CAFE III and IV proposals which are still at the consultation stage), sales of electric cars increase from 2% in 2024 to almost 15% in 2030 in the STEPS.

In October 2024, the government of India also adopted the PM e-Bus Sewa-PSM Scheme to support the roll-out of 38 000 electric buses across the country, with a budget of INR 34.4 billion (USD 394 million). When considered alongside the support from the PM E-DRIVE scheme, electric bus sales reach 25% in 2030 in the STEPS, up from less than 6% in 2024. Electrification of other heavy vehicles, namely freight trucks, is expected to proceed less quickly, due to greater price barriers. Electric truck sales reach around 2% in 2030 in the STEPS, which is similar to India's 2024 EV sales share for cars.

Across all vehicle modes, excluding 2/3Ws, EVs represent 1 in 8 vehicles sold in India in 2030 in the STEPS, up from less than 1 in 50 in 2024. When 2/3Ws are included, stated policies imply that the electrification rate increases to one in three vehicles sold by 2030.

EV sales in Southeast Asia approach 30% of all vehicle sales in 2030 under today's policy settings

Indonesia, Southeast Asia's second-largest car market, has introduced a range of policies to meet its ambitious EV targets. One of the key incentives was the introduction in April 2023 of a VAT discount on EV sales, which is continuing in 2025. In addition, EV manufacturing and trade policies currently provide import duty exemptions for EVs made by manufacturers committing to establish domestic manufacturing facilities by 2026. Under stated policies, the electric car sales share reaches 25% by 2030, up from 9% in 2024. This translates into a stock of almost 1 million electric cars in 2030 in the STEPS, which is still less than half of the government's target of 2 million. The country has also set the target of 13 million electric motorcycles by 2030. Based on recent market trends, the EV share of 2/3W sales in Indonesia increases from less than 2% in 2024 to 30% in 2030. Despite this strong growth, the total stock of electric 2/3Ws is less than the government target for electric motorcycles.

Several other Southeast Asian countries have recently adopted manufacturing and trade policies to facilitate EV imports while also developing domestic EV manufacturing. In most of these countries, such policy developments are accompanied by measures to support EV uptake. In **Malaysia,** for example, the largest car market in the region in 2024, electric cars are exempt from import duties, registration and road taxes until the end of 2025, and until 2027 if locally built. **Thailand**, Southeast Asia's third-largest car market in 2024, implemented a set of measures called the EV 3.5 Policy to support the roll-out of electric passenger cars, pick-up trucks and motorcycles. This new scheme, adopted in

2024, is designed as the continuation of the previous EV 3.0 Policy, while at the same time giving BEV manufacturers more time to meet their production commitments under the 3.0 version to help avoid oversupply. The Thai government will establish new purchase subsidies and road tax exemptions until 2027 under the new framework, including some incentives also for hybrid vehicles, along with waivers on import duties for OEMs committing to produce EVs domestically. The **Philippines**, **Viet Nam** and **Singapore** have also adopted policies to reduce import duties, exempt EVs from excise taxes, or set up EV mandates to further support the adoption of EVs in the region.

The outlook for EV sales in Southeast Asia is bright, thanks to its emerging role as a manufacturing hub, and the existing set of manufacturing, trade and demand-side policies supporting the electrification of road transport. Under stated policies, electric car sales in Southeast Asia are likely to reach 25% of total car sales by 2030. Other vehicle modes are also expected to make significant strides in electrification, with electric 2/3Ws surpassing a 30% sales share and electric buses nearing 15%. Overall, across all vehicle segments, the EV sales share in Southeast Asia approaches 30% in 2030 in the STEPS.

Policy support in Latin America means electric bus sales could increase more than tenfold by 2030

Countries in Latin America have been increasing their policy support for EVs, especially since 2020. In particular, Brazil, Colombia and Chile stand out for passing legislation to promote EVs. This is important for the EV outlook in the region as together, these three countries represent almost half of Latin America's car and bus sales.

In 2024, **Brazil** approved the MOVER programme, which incentivises private sector investment in the R&D and manufacturing of sustainable vehicle technologies including EVs. **Colombia** also has relevant legislation, particularly to encourage the electrification of public buses, including a law that requires cities with mass transportation systems to ensure that electric or zero-emission vehicle sales increase from 10% in 2025 to 100% in 2035. In 2024, the government also created the Fund for the Promotion of Technological Advancement, which among other things will support electric LDV sales by covering the price differential with ICEVs. In 2024, new LDV fuel economy standards came into effect in **Chile**. These promote zero-emission vehicles by offering credit multipliers. Other countries in Latin America also offer policy support for EVs, mainly in the form of tax incentives.

Electric car sales in Latin America increased from 0.3% in 2020 to around 4% in 2024, and reach around 13% in 2030 in the STEPS. Latin America has also seen success in deploying electric buses, which is expected to continue: in 2030 in the STEPS, electric bus sales reach almost 14%, up from 2% in 2024.

Automakers' electrification announcements

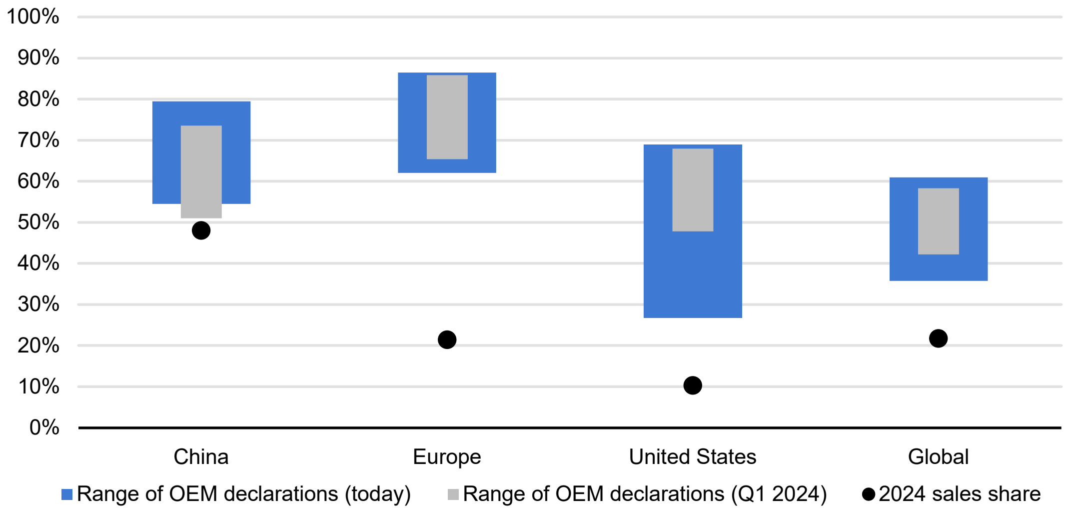
Near- and mid-term automaker electrification targets are increasingly uncertain

A number of automakers have scaled back their near-term targets for EVs over the past year, citing lower-than-expected consumer demand, and in the context of difficulties in achieving profitability with BEVs for many non-Chinese OEMs. Many, if not all, had previously set those targets with a degree of flexibility dependent on market conditions. The shifting policy landscape in some markets further increases uncertainty in automaker electrification targets out to 2030, though the outlook for electric car sales remains robust.

General Motors (GM) – the best-selling carmaker in the United States – missed its goal of producing and wholesaling 200 000 EVs in North America in 2024 by about 5%. The company expects to produce up to 300 000 EVs in 2025, and is no longer reiterating its previous target of reaching an annual production capacity of 1 million EVs by the end of 2025. Similarly, Tesla – the best-selling electric carmaker in the United States – dropped the goal of selling 20 million cars per year by 2030 from its 2023 annual impact report, despite this target having been included in consecutive previous reports. The uncertainty around whether Tesla will still aim to sell 20 million electric cars worldwide in 2030 has a significant impact on the range of OEM electrification targets in all of the major markets.

In 2021, Ford, GM and Stellantis released a joint statement announcing their aspiration to achieve sales of 40-50% electric or fuel cell electric cars in the United States by 2030, in line with the Biden administration's target. Given the change of administration in the United States, the future commitment to these targets is unclear. As such, the range of OEM declarations for electric car sales in the United States in 2030 now stretches from 70% electric car sales in 2030 to less than 30%; a year ago the lower end of the range of OEM declarations in the United States was around 50%. In spite of this, even if only the lower end of the OEM target range were to be achieved, the electric car sales share in the United States would almost triple by 2030.

Range of electric car sales shares based on automaker electrification targets, 2030



Notes: OEM = original equipment manufacturer. Q1 2024 OEM declarations reflect the interpretation of automaker targets as presented in the Global EV Outlook 2024. The range today reflects OEM announcements as of the end of Q1 2025. The relative market share of OEMs is held constant unless the OEM has EV volume targets rather than sales share targets.
Sources: IEA analysis based on company announcements and data from EV Volumes and Marklines.

With regards to the European market, Ford has abandoned its goal to shift entirely to electric sales in Europe by 2030, though in 2024 Ford was responsible for less than 5% of car sales in the region. Volvo Cars, also representing less than 5% of car sales in Europe, has also scaled down its 2030 all-electric target, allowing for up to 10% of its sales to be hybrids. Similarly, Renault had previously aimed for 100% of its car sales to be electric in Europe by 2030, but in 2024 its CEO announced that a two-pronged approach of selling both ICE and electric cars will continue for the next decade. Nevertheless, the range of OEM electrification targets for Europe remains the highest of the major EV markets, reaching from over 60% to around 85% of car sales in 2030.

In contrast, as Chinese EV sales remained strong over 2024, BYD surpassed its 2024 sales target, which had already been increased from 3.6 million new energy vehicles (i.e. EVs and FCEVs) to 4 million. In total, BYD represented about 15% of car sales in China; all-electric car brands (including Tesla, Li Auto, NIO and others) together represented one-quarter of car sales in China in 2024. As a result of the growing success of all-electric car brands, the EV sales shares in China in 2030 based on OEM targets has increased, despite there being no new targets for 2030. The range of OEM declarations for 2030 would imply a 55-80% electric car sales share.

While Honda has not scaled back its long-term zero-emission vehicle targets (100% of sales by 2040), it has announced the aim to double hybrid car sales by 2030. Indian OEM Tata has reduced its 2030 BEV sales target from 50% to 30%.

At the global level, the range of uncertainty in electric car sales in 2030 projected in automakers' declarations has grown over the past year, meaning that the increase in global sales as envisaged by their targets now ranges from 35-60%. However, achieving even the lower end of this range would mean that the number of electric car sales in 2030 would be approximately double that of 2024.

6. Electric vehicle charging

Charging electric light-duty vehicles

Public chargers have doubled since 2022 to reach more than 5 million

Access to public charging points is key to supporting mass adoption

Home charging remains the most popular way to charge for EV owners. However, more public chargers are needed to support mass adoption of EVs among segments of the population without access to home chargers.

In 2024, more than 1.3 million public charging points were added to the global stock, representing an increase of more than 30% compared to the previous year. Just the charging points added in 2024 were approximately equal to the total number of points available in 2020. About two-thirds of the growth in public chargers since 2020 has occurred in **China**, which now has about 65% of the charging and 60% of the electric light-duty vehicle stock globally.

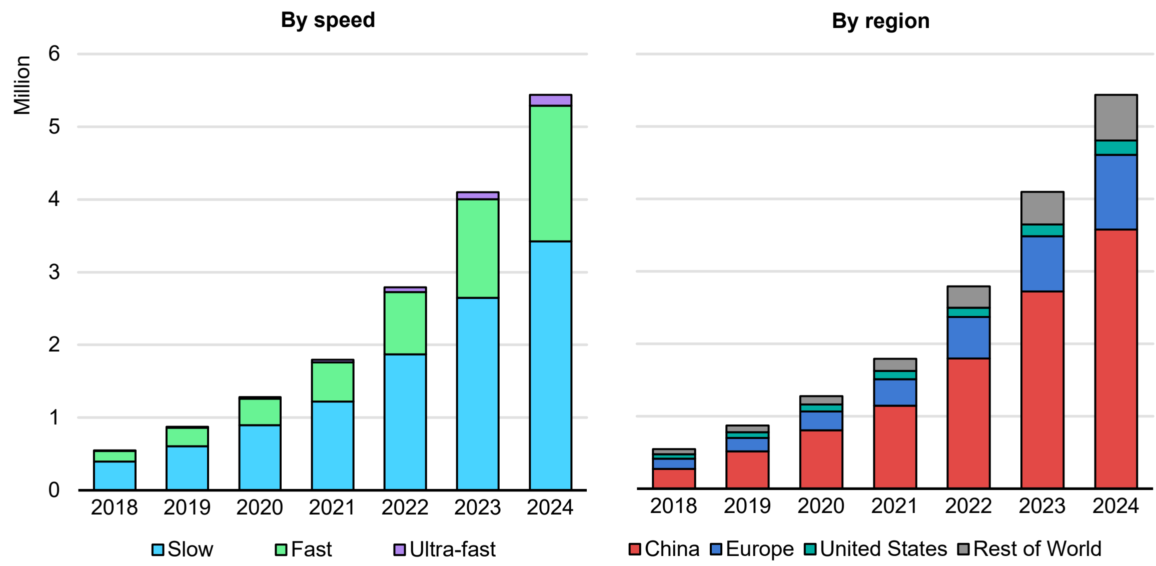
In **Europe**, the number of public charging points grew more than 35% in 2024 compared to 2023, to reach just over 1 million. However, there are significant variations across countries due to differing rates of EV adoption and charging infrastructure development. Within the **European Union**, 11 out of 27 countries saw their public stock of charging points increase by more than 50% in 2024 compared to the previous year. At the end of 2024, the **Netherlands** had the largest national charging network in Europe, with over 180 000 public charging points, followed by Germany (160 000) and France (155 000). In **Austria**, 8 000 public charging points were added in 2024, most of which were supported by a subsidy that ended at the beginning of 2025.

Installation of public charging points across the European Union is expected to increase as a result of the Alternative Fuels Infrastructure Regulation (AFIR), which mandates the installation of fast-charging stations for cars and vans of at least 150 kW every 60 km along the TEN-T core road network by 2025. Each station must offer a minimum total power output of 400 kW, increasing to 600 kW by the end of 2027. In addition, roll-out of private charging at residential and commercial buildings is covered under the revised EU Energy Performance in Buildings Directive, which establishes criteria for pre-cabling to prevent the future need to retrofit parking infrastructure, which can be costly.

The **United States** increased its charging stock by 20% in 2024 to just under 200 000 public charging points. The National EV Infrastructure Program, part of the Bipartisan Infrastructure Law that was passed in 2021, allocated USD 5 billion to fund fast chargers along corridors, although by the end of 2024 only around USD 30 million had been spent on charging points that are now in operation. In January 2025, Executive Order 14154 paused the disbursement of these funds for a review of the processes, policies and programmes associated with grant selections, making future disbursements of the remaining unspent funds uncertain.

Policy efforts in **India** continue to support charging accessibility, with about 40 000 new public chargers installed in 2024. In October 2024, INR 20 billion (USD 240 million) was allocated to charging infrastructure through the PM E-DRIVE scheme, with a focus on urban centres and heavily-used transport corridors. However, the Indian government has also introduced an EV policy that caps the investment in charging infrastructure eligible for tariff relief, potentially impacting automakers' plans to invest in EV charging networks.

Global stock of public charging points by speed and region, 2018-2024



Notes: Chargers less than or equal to 22 kW are classified as slow, chargers greater than 22 kW and up to 150 kW as fast, and 150 kW and above as ultra-fast.
Sources: IEA analysis based on country submissions and data from EV Volumes and EAFO.

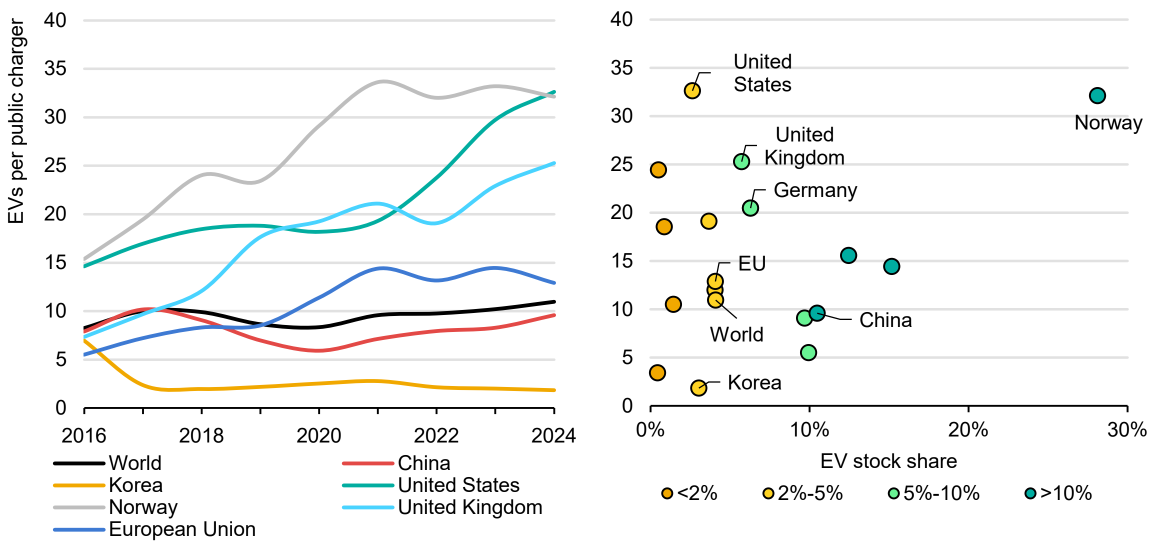
Brazil's charging infrastructure has expanded at speed. By early December 2024, there were over 12 000 public charging points across the country. Public charging networks have also experienced rapid expansion in other key emerging markets, reflecting strong policy support and investment in infrastructure. Public charging points have increased by 60% in **Colombia** and by 20% in **Mexico** since 2022.

Similarly, thanks to a mix of government initiatives and private sector collaboration, there are now over 24 000 chargers installed across **Indonesia**, **Thailand**, **Malaysia** and **Viet Nam**, 9 times more than in 2022.

Variation in ratio of EVs per public charger reflects differences in market maturity and population demographics

One way to think about public charging coverage is in terms of the number of public charging points compared to the stock of electric light-duty vehicles those points are meant to serve. **China** and the **European Union** have maintained a steady pace of charger deployment compared to the number of EVs on the road, though at different levels. There is now more than 1 public charger for every 10 electric cars in China. On average, the European Union has 1 charger for every 13 electric cars – a decrease of more than 10% compared to 2023.

Electric light-duty vehicles per public charging point in selected regions, 2016-2024 (left) and ratio compared to electric vehicle stock share in selected regions, 2024 (right)



Notes: EU = European Union; EV = electric vehicle. Historic trends in electric light-duty vehicle stock and public charging infrastructure by country can be interactively explored using the Global EV Data Explorer. The figure on the right-hand side shows selected regions as dots, with the over 10% group comprising China, Denmark, Norway and Sweden, the 5-10% group Belgium, Germany, the Netherlands, and the United Kingdom; the 2-5% group: European Union (average), France, Korea, the United States and the World average; and the group below 2%: India, Indonesia, Italy and Japan.
Sources: IEA analysis based on country submissions, EV Volumes, BNEF, EAFO, and US AFDC.

However, demand for public charging points also differs based on driver location and behaviour. In China's densely populated cities, many drivers rely on public charging points, whereas in Europe, access to home chargers is far higher. The combined stock of the top 15 cities by public charger stock in China covers more than 50% of the national stock, compared to a share of 25% in Europe. The types of housing typically available (apartment, terrace, detached, etc.) can also play an important role in shaping the need for public charging access. For example, Germany and the United Kingdom both have a similar electric car stock share, but the United Kingdom has 60% more electric cars per public charger. In Germany, more than 60% of people live in apartments or flats; whereas in England and Wales, fewer than 25% of people do, meaning it may be easier to install private charging.

In the early stages of electrification, greater availability of public EV charging points can encourage adoption. However, as EV adoption increases, and as charging speeds become faster and battery ranges improve, the number of charger points per vehicle can decrease as the system is optimised.

Fast charging continues to expand, with ultra-fast charging having more than doubled in Europe since 2022

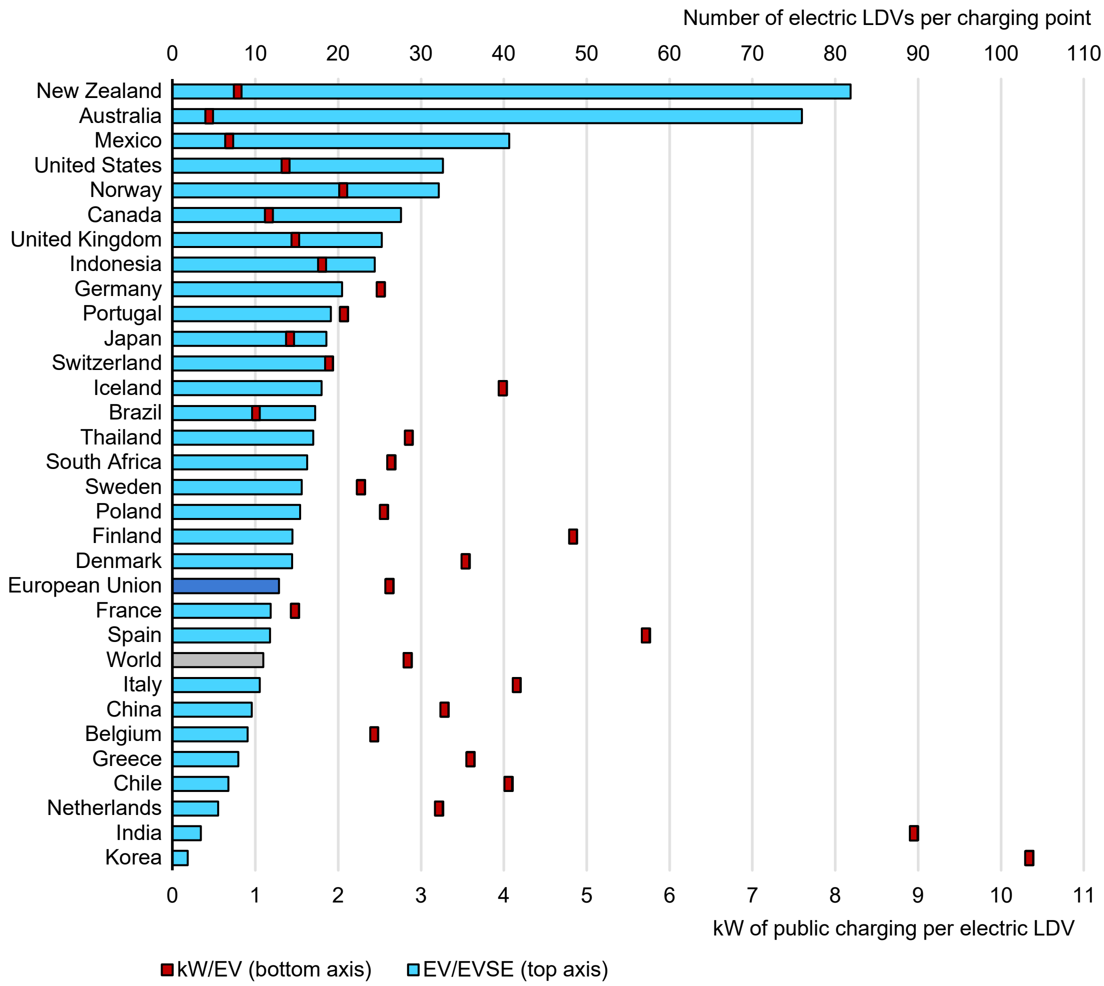
In addition to coverage, the capacity of public chargers can serve as an indication of sufficiency. Fast and ultra-fast public charging points can deliver more energy per day than slow chargers and thus serve a higher number of vehicles. In 2024, the global stock of fast chargers (with a power output higher than 22 kW and lower than 150 kW) reached 2 million, and ultra-fast chargers – capable of delivering 150 kW or above – growing by over 50% in 2024 and now accounting for nearly 10% of all fast chargers. Falling costs have played a role in this shift, with the price of ultra-fast chargers falling by 20% between 2022 and 2024.

China remained the largest player in fast charging deployment last year, responsible for 80% of the global growth, with the number of fast chargers surging from 1.2 million in 2023 to 1.6 million in 2024. Today, the estimated public charging capacity per electric LDV in China is over 3 kW. In comparison, the **United States** expanded its total fast charger stock (including ultra-fast) from 40 000 in 2023 to over 50 000 in 2024, growing at a similar rate to in China. At the end of 2024, there was less than 1.5 kW of public charging capacity available in the United States per electric LDV.

Meanwhile, the **European Union** expanded its network of fast chargers (excluding ultra-fast) nearly 50% from 2023 to reach 71 000 in 2024, and has an average public charging capacity of 2.6 kW per electric LDV. It also saw strong deployment of ultra-fast charging points in 2024, increasing by 60% compared to 2023 to reach over 77 000 chargers. Denmark saw its stock of ultra-fast chargers more than double in 2024, and in France, Finland and Germany the stock increased by between 70-95%. Further expansions are also being planned, for example in France, where "Charge France", a charge point operator association established in 2025, committed to investing EUR 4 billion to expand the national stock of ultra-fast charging points from over 17 000 today to 40 000 by 2028.

Of the ultra-fast chargers in the European Union, about 20% deliver a power of 350 kW and above. Today, only a few high-end electric cars are capable of charging at this speed, but charging point operators such as FastNed and Iberdrola and BP Pulse are deploying these stations in anticipation of future demand. In 2024 this higher segment of ultra-fast chargers almost doubled compared to 2023.

Number of electric light-duty vehicles per public charging point and kilowatt per electric light-duty vehicle, 2024



Notes: EV = electric vehicle; EVSE = electric vehicle supply equipment; LDV = light-duty vehicle. Kilowatts per EV are estimated assuming 15 kW for slow and 50 kW for fast chargers and 150 kW for ultra-fast chargers. For countries in Europe, average power per EVSE was used per power group: slow (lower than 22 kW), fast (between 22 kW and 150 kW) and ultra-fast (higher than 150 kW) and multiplied with reported stock of chargers. Official national statistics, which rely on more granular data, might differ from these values.

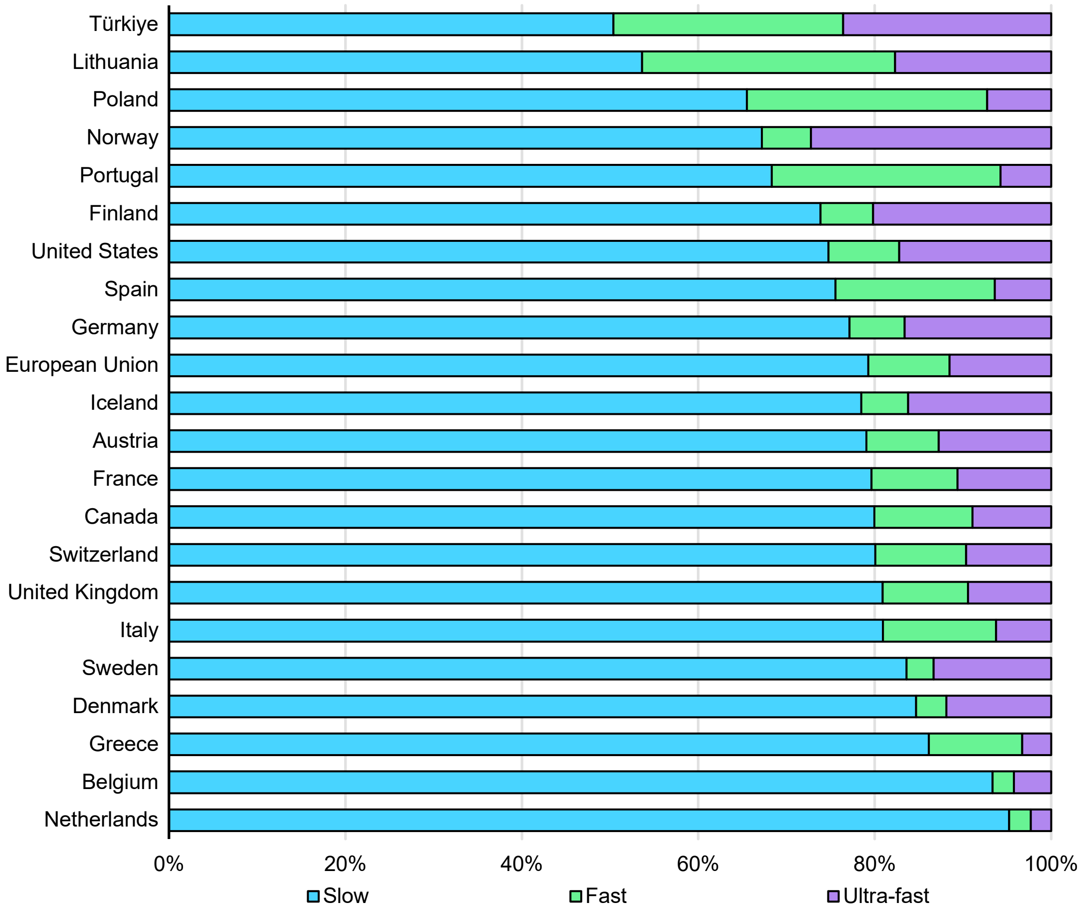
Sources: IEA analysis based on BNEF, EV Volumes, EAFO and Eco-Movement, US AFDC.

Ultra-fast charging infrastructure projects are also underway in **Chinese** cities. Beijing aims to build 1 000 ultra-fast charging stations by the end of 2025, and Chongqing to deploy 4 000 additional ultra-fast chargers by the end of 2025.

These regional plans also align with XPeng and Volkswagen's plans to roll out 20 000 ultra-fast chargers across more than 400 Chinese cities.

Elsewhere, **Korea** has seen rapid growth in its fast charger stock (including ultra-fast), rising from 34 000 in 2023 to 47 000 in 2024. In 2025, authorities plan to deploy 4 400 new fast chargers in high demand areas. Korea's total budget for enhancing charging infrastructure was raised by 40% compared to 2024 to KRW 620 billion (Korean won) (USD 425 million), with 60% of the assigned budget targeting fast chargers, and the remainder dedicated to slow smart-charging installations. In **India**, three major government-owned oil marketing companies built nearly 8 000 fast-charging points over the course of 2023 and 2024, funded by the FAME Phase II scheme.

Proportion of slow, fast and ultra-fast public chargers in selected countries, 2024



Notes: Chargers less than or equal to 22 kW are defined as slow, chargers between 22 kW and 150 kW are fast, and ultra-fast chargers are those of 150 kW or more.
Sources: IEA analysis based on EAFO and US AFDC.

Advances in battery technology for electric cars can make charging competitive with refuelling time, if charging infrastructure can keep up

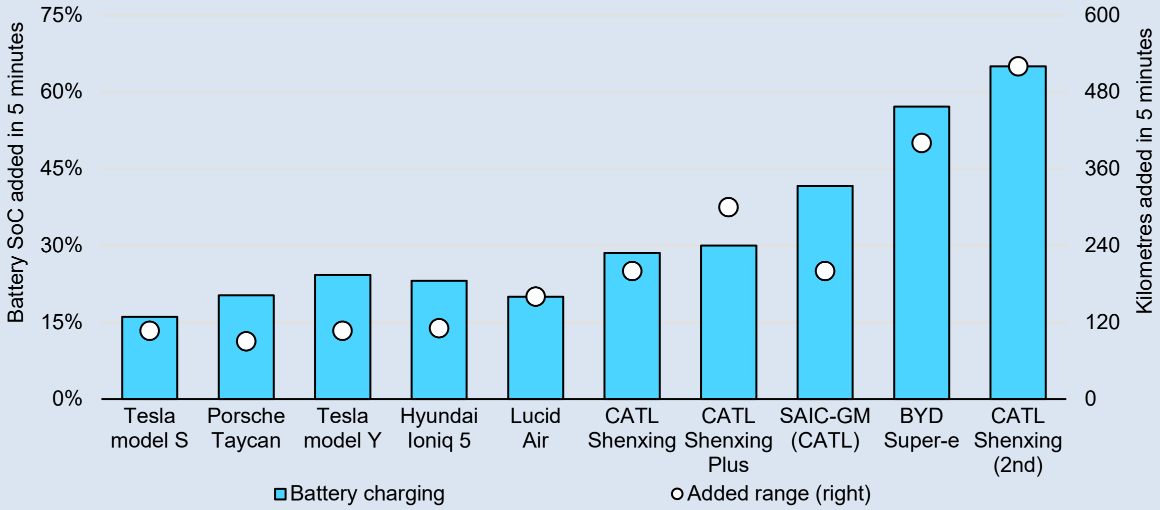
EV owners report that charging speed is their most important consideration when using public chargers. Safety concerns relating to EV battery technology have long been a limiting factor in reaching faster charging, but recent innovations are now reshaping the fast-charging landscape.

During charging, lithium ions are released from the cathode to the anode. If the process is too slow compared to the desired charging speed, lithium can accumulate on the anode surface, forming dendrites – needle-like structures that can pierce the battery, potentially causing short circuits and uncontrolled fires. Recently, however, some battery manufacturers have largely succeeded in addressing this through advanced anode designs, such as multi-gradient layered structures, which accelerate lithium uptake.

In 2023, CATL launched the Shenxing battery, which is able to charge about 30% of the battery in just 5 minutes, providing 200 km of additional range. This was further improved in 2024, when they released a battery offering similar energy density but faster charging speeds in collaboration with SAIC-GM – allowing to recharge over 40% of the battery capacity in 5 minutes – as well as a battery with the same charging speed (30% in 5 minutes) but increased energy density, providing 300 km of additional range in 5 minutes. For comparison, a typical Tesla supercharger can offer about 100 km of additional range during the same time.

In March 2025, BYD set a new benchmark with its Super-e platform, which is claimed to deliver around 400 km of range in 5 minutes. This leap was made possible by next-generation silicon carbide power chips, all-liquid-cooling, and a 1 000 V architecture, which allows for coupling with 1 MW charging. Just one month later, CATL announced the second generation of its Shenxing battery, offering even higher charging speeds. Megawatt charging was previously limited to heavy-duty vehicles, where the energy was distributed across battery packs roughly ten times larger than those in passenger cars. Now, advances in battery technology and charging platforms are bringing this capability to the passenger car market, with the first models already on sale in China.

Maximum share of battery capacity charged and electric range added in 5 minutes by electric car model or battery technology



Notes: SoC = state of charge. Battery SoC added indicates how much the battery is recharged starting from a low SoC (20%). For example, adding 30% SoC means charging the battery from 20% to 50%. The additional range is calculated by multiplying the manufacturer's stated electric range by the proportion of the battery that can be recharged in 5 minutes under optimal conditions. Tesla model Y and S are assumed to be charged through a third generation supercharger.

Sources: IEA analysis based on data from EV Volumes, Tesla, Porsche, Hyundai, Lucid, CATL, GM authority, and BYD.

The full realisation of these advantages, however, hinges on deploying ultra-high-power charging infrastructure. Megawatt chargers impose significant loads on grids, often requiring upgrades that could significantly slow down or limit deployment, and are more expensive than fast chargers, which could result in higher charging prices for consumers. Pairing these chargers with battery storage to alleviate peak demand and optimise grid usage might offer a pathway to accelerate their roll-out. In recognition of the infrastructural challenge, BYD – together with its Super-e platform – has announced plans to deploy 4 000 megawatt chargers supported by battery storage in China. This evolution would also strengthen the interdependencies between the two biggest battery markets – EV batteries and battery storage – potentially increasing the competitive advantage of producers manufacturing both, such as BYD and CATL.

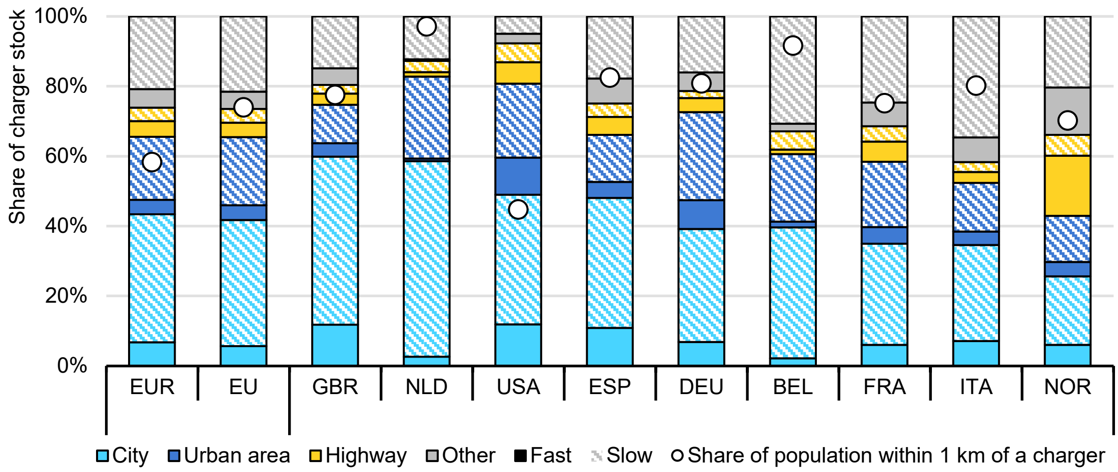
For most consumers, reliable fast charger networks capable of recharging a vehicle in 15-20 minutes may be sufficient for long-distance travel. However, the ability to charge EVs in a timeframe comparable to refuelling conventional cars could further accelerate consumer adoption.

The location and speed of public charging stations reflect typical usage

Most public chargers are slow chargers in urban areas but highway chargers account for a larger share of capacity

Individual countries and cities have taken different approaches to public charging station deployment, based on the distribution of population, availability of home charging, and road networks, although there are some commonalities. Currently, in Europe and the United States, more than two-thirds of chargers are located in urban areas. In the European Union, deployment has broadly followed housing patterns, and over 70% of the population now lives within 1 kilometre of a charging point. In the United States, which has a lower population density, less than half of the population lives within 1 kilometre of a charger.

Type and location of public charging in selected regions and countries and the share of population living within 1 kilometre of a charger, 2024



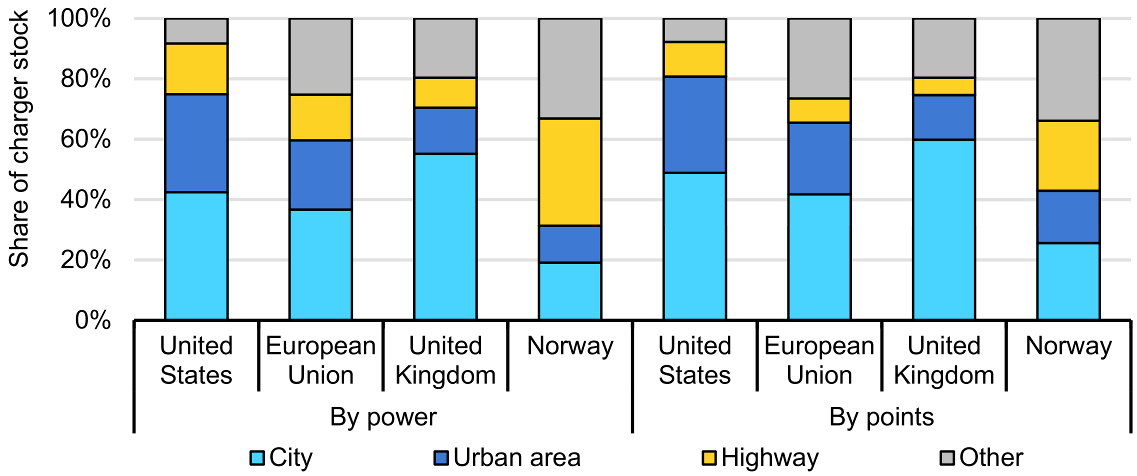
Notes: EUR = Europe; EU = European Union; GBR = United Kingdom; NLD = Netherlands; USA = United States; ESP = Spain, DEU = Germany; BEL = Belgium; FRA = France; ITA = Italy; NOR: Norway. Solid colours represent fast chargers and hatched colours slow chargers. Chargers less than or equal to 22 kW are defined as slow; fast chargers are over 22 kW.

Sources: IEA analysis based on US AFDC, EAFO, Eco-Movement. Urban areas for Europe are taken from the Functional Urban Areas of 2020 and consists of the city and the commuting zone, urban areas for the United States are the Census Populated Place Areas from the US Energy Atlas.

The public charging infrastructure in cities and urban areas consists mainly of slow chargers (less than or equal to 22 kW), which was the most widely adopted technology until relatively recently. Only 15% of the urban public chargers in Europe are rated over 22 kW. This share is slightly higher in the United States, where nearly 30% of urban public chargers are fast. While deploying fast chargers can help to serve more EVs per charging point each day, limited available network capacity in city centres or urban areas can present a hurdle.

On average, in the United States and Europe, between 4% and 6% of public charging points are positioned along highways and have at least 22 kW rate power. Norway is an exception, with nearly 20% of its charger stock being fast chargers positioned next to highways, as a result of a 2016 target to install fast-charging stations at least every 50 km on major roads to support long-distance trips. When considering charging power rather than points, the share becomes even larger, with 35% of public charging capacity being located along the highway in Norway. Across all countries considered, the share of highway chargers in terms of total power is higher than by charging point stock, as highway chargers tend to be the fastest.

Location of public charging stock by capacity and number of charging points in selected regions and countries, 2024



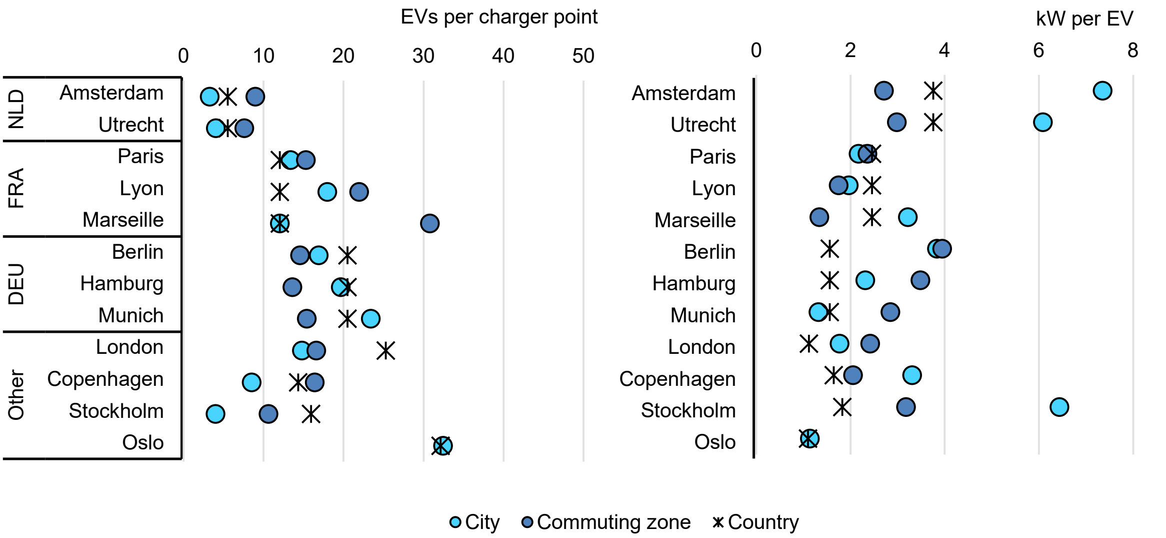
Sources: IEA analysis based on US AFDC, EAFO and Eco-Movement. Urban areas for Europe are taken from the Functional Urban Areas of 2020 and consists of the city and the commuting zone, Urban areas for the United States are the Census Populated Place Areas from the US Energy Atlas.

Major European cities typically have more chargers per EV than surrounding areas

The different characteristics of roads, buildings and parking spaces in different cities can affect the strategy for deploying public chargers. In cities such as Amsterdam, where residential and office buildings often have less private parking, more public chargers need to be available. Public chargers in cities must also serve taxis and delivery vehicles, for which overnight charging is not sufficient, as well as other visitors to the city that may need to charge during the day. The split between overnight charging by residents and opportunity charging for other vehicles will affect the speed and distribution of public charges, as reflected by the charging capacity per EV in the stock.

European cities have different levels of electric car adoption. Scandinavian cities such as Oslo, Stockholm and Copenhagen have the highest share of electric cars in their fleet, with 55%, 35% and 20% of the cars being electric. As the most mature market, Oslo also has one of the highest ratios of EVs per charger (over 30) and the lowest capacity available per EV (around 1 kW). Both Copenhagen and Stockholm have less than 10 EVs per public charging point in the city – lower than their national average, which indicates that expanding coverage in cities has been prioritised ahead of rural areas around highways.

Charger to electric vehicle ratio and kW per electric vehicle for selected cities and their commuting zones, and country averages, 2024



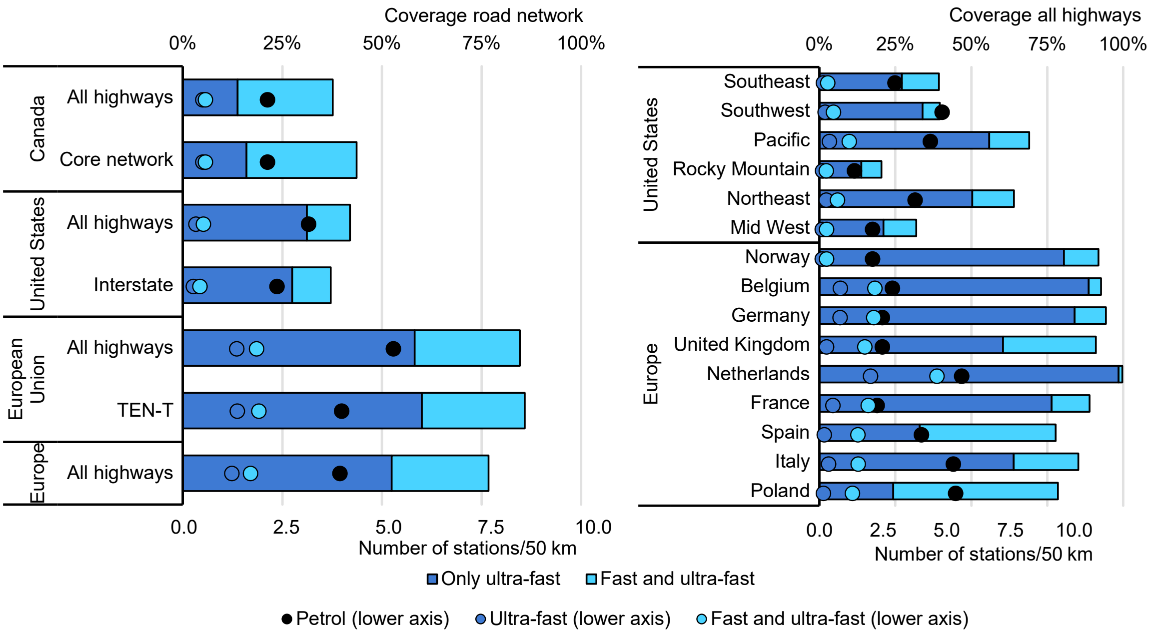
Notes: NLD: Netherlands; DEU: Germany; FRA: France. Data on chargers in Oslo's commuting zone are not available.
Sources: IEA analysis based on national statistics, EAFO and Eco-Movement. City EV stock: NLD: Atlas van de auto; FRA: AAA Data; DEU: KBA; London: Department for Transport and Driver and Vehicle Licensing Agency; Stockholm: TRAFA; Oslo: SSB; Copenhagen: SDG Statistikbank; number and capacity per city and commuting zone was determined using point location of charger database of Eco-Movement, consulted February 2025.

Cities in the Netherlands, Germany and France have a lower share of electric cars in the fleet; across Amsterdam, Utrecht, Paris, Berlin and Munich, between 6% and 13% of cars are electric. In terms of both coverage and capacity, the Dutch cities perform better compared to the national and urban averages. In particular, the gap between the city capacity per EV and the national average indicate that these cities have placed greater emphasis on faster chargers and installing them in a higher density compared to other areas outside the city.

European highways have more charger coverage than highways in the United States

At the end of 2024, over 75% of the European highway network had chargers at most 50 km apart, whereas only 35% of the US interstate highway system had the same level of coverage. Within Europe, coverage is varied: For example, in the Netherlands, Belgium, Norway, Germany and France, over 90% of the highway network has a charging point every 50 km, while in Spain and Poland the share is below 80%. Similarly, deployment in the United States varies across regions. In the Pacific region (e.g. California, Oregon and Washington), which has the largest share of EV stock, 70% of the highways have charging infrastructure every 50 km, but in the centre of the country that share is between 20% and 30%.

Percentage of highways that are covered by a fast or ultra-fast charger in selected markets and road networks and number of chargers and petrol stations per 50 km of highway, 2024



Notes: TEN-T = Trans-European Transport Network. Chargers between 22 kW and 150 kW are classified as fast, and ultra-fast chargers are those of 150 kW or more. For regional groupings for the United States see Annex B. Only chargers within a radius of 150 metres of the highway are included; stations with less than 4 charging points are excluded. Coverage is calculated by setting a radius of 25 km around each charging point, so actual driving distance between two charging points likely exceeds 50 km based on the curvature of the road and the routing. To determine the number of stations on the bottom axis all charging points within 500 metres of each other are considered as one station.

Sources: IEA analysis based on US AFDC, EAFO and Eco-Movement. Existing and planned TEN-T highways roads were taken as depicted in TENtec viewer, other highways for Europe are taken from Esri filtered on attribute "Highway". The Interstate highway network can be found on the National Highway System Map provided by the Federal Highway Administration. North American highways other than the interstate network are taken from the National Transportation Atlas Databases for the United States, whereas the highway system of Canada is taken from Transport Canada. Location of petrol stations was taken from Open Street Maps using amenity "fuel"; points within 150 metres of each other were considered as one petrol station.

Ultra-fast charging (150 kW and above) allows the most direct comparison with a conventional highway pit stop, where charging times of 15 minutes can provide an additional 150 km of driving range.[1] For long trips on interstate or international corridors, EV drivers may prefer a longer break, meaning fast charging at rates between 22 kW and 150 kW may also be an attractive option. If fast chargers are also taken into account, the charging coverage in the European Union increases, with an additional 25% of the roads having a fast charger at least every 50 km. In the United States, the share of the interstate road network covered by a charging station also increases from nearly 30%, when considering ultra-fast charging exclusively, to nearly 40% when also including fast charging.

Despite the high charging infrastructure coverage along European roads, the number of fast-charging stations along highways remains significantly lower than that of petrol stations. Ensuring a denser charging network would help to address range anxiety and help instil confidence in EV adoption by making charging as convenient and reassuring as conventional refuelling. This would allow for more flexibility in planning routes around charging stops and help address worst-case scenarios, such as unexpected detours, traffic delays, or extreme weather conditions.

Public charging does not always equal accessible charging

About 20% of public chargers in Europe are in fact “semi-public”, meaning that access is limited to part of the population, such as chargers provided by hotels or supermarkets that are only accessible to customers. Such chargers may also have physical barriers and more limited hours, which degrades charging access and experience.

Technical barriers can also hinder ease of use, even for fully public charging stations, as can occur with incompatible plug types (e.g. Type 2, Combined Charging System, CHAdeMO). Other factors, such as the payment system or (in the case of Tesla chargers), the brand of the vehicle, can also limit the usability of charging infrastructure, reducing overall accessibility. Standardisation, in combination with access to reliable data on the availability and pricing of charging stations, will therefore be important for making public charging infrastructure more accessible.

[1] This estimate assumes a fuel economy of 20 kWh/100 km and a minimum charging level of 20%. For reference, the fuel economy of the Tesla Model X is rated at 22.5 kWh/100 km

Light-duty vehicle charging outlook

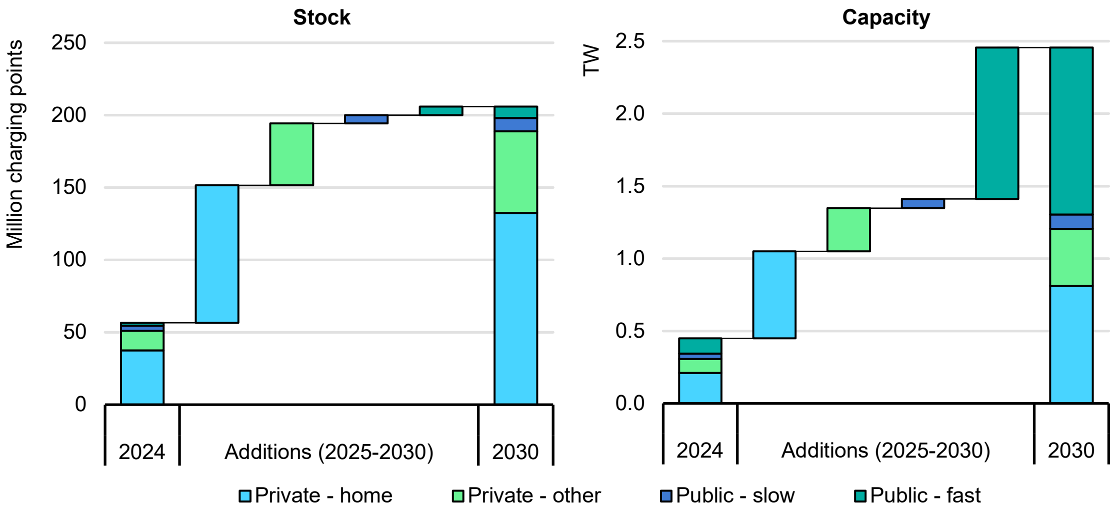
Public charging capacity for light-duty EVs grows almost ninefold to 2030

In general, early adopters of electric cars have tended to have higher rates of access to home charging than the broader population. Even though electric LDVs represent 15% of the global stock in 2030 in the STEPS – which could be considered as moving past the early-adopter phase – home charging is expected to remain the preferred way to charge an EV when available, given the affordability and convenience. Charging availability at other private locations, such as at workplaces, and public charging, will also support more widespread adoption of EVs, especially among populations without access to home charging, or for travelling long distances. In the STEPS, around 150 million charging points are added from 2025 to the end of 2030, with almost two-thirds of those being home chargers, 30% other private chargers, and the remaining 8% public charging points.

The build-out of public charging points in the STEPS is intended to reflect the number required to serve the stock of electric LDVs projected in the scenario. As such, the charging projections are based on the policies and market trends driving the vehicle projections as opposed to simply matching charging-related policies and regulations. The charging point projections do, however, account for regional trends, such as the historical evolution of the number of charging points per EV, the share and capacity of public fast chargers, and access to home and other private charging. Generally, as EV markets mature, optimisation of the public charging network is expected to improve, meaning that utilisation can increase with no negative effect on user experience. In line with this, in the STEPS, the number of electric LDVs per public charging point worldwide increases from about 11 in 2024 to around 14 in 2030.

The number of charging points available constitutes just one metric of coverage; the installed charging capacity is also important. Public fast chargers, with their higher charging capacity, are able to provide more energy and thus serve more EVs per day than slow chargers. Over half of the charging capacity installed to serve electric LDVs between 2025 and the end of 2030 in the STEPS takes the form of fast public chargers. That means that the public fast charging capacity increases more than tenfold by 2030, while private charging capacity increases less than fourfold.

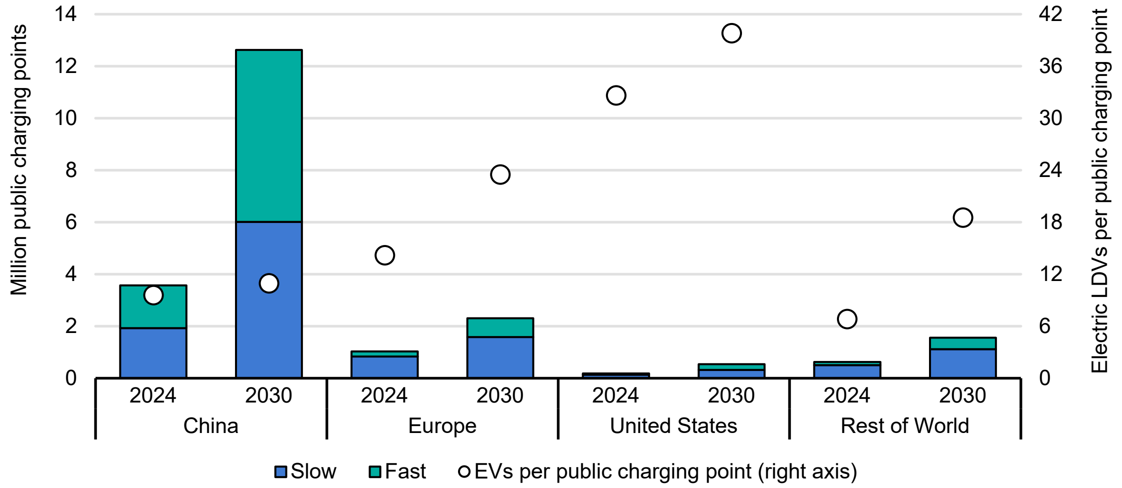
Global light-duty vehicle charger stock and capacity in the Stated Policies Scenario, 2024-2030



Notes: "Private – other" refers to charging points that are neither publicly accessible nor at private residences. Home charging stock in 2024 is estimated based on electric light-duty vehicle stock and regional assumptions regarding the ratio of home chargers to vehicles. Regional projected electric vehicle supply equipment (EVSE) stock data can be explored via the interactive Global EV Data Explorer.

In **China**, the relatively low ratio of electric LDVs to public charging points that has been maintained over the past decade is partly because Chinese EV owners have tended to be concentrated in dense cities with limited access to home charging. In the STEPS, the ratio of electric LDVs per public charging point remains relatively low but still grows to around 11. The stock of public charging points in China grows more than threefold by 2030 in the STEPS, reaching over 12 million charging points. The share of public fast chargers continues to grow, as it has during the first half of this decade, increasing from around 45% in 2024 to over 50% in 2030. In 2024, China added about 850 000 public charging points. The average annual additions needed to reach the public charging stock projected in the STEPS in 2030 are about 75% higher than was observed in 2024, and 60% higher than the additions in 2023. For China to reach an electric LDV stock of around 140 million in 2030, as in the STEPS, maintaining a ratio of 11 EVs per public charging point would require, on average, net additions of 1.5 million charging points each year. The public charging capacity in China increases by about 900 GW to 2030 in the STEPS. To limit the stress that EV charging puts on the grid, the Chinese government has published a policy for standardising vehicle-to-grid technologies, through which EVs are expected to provide 10 GW of flexible capacity by 2030 (see Smart charging and vehicle-grid integration below).

Number of public light-duty vehicle charging points by region in the Stated Policies Scenario, 2024-2030

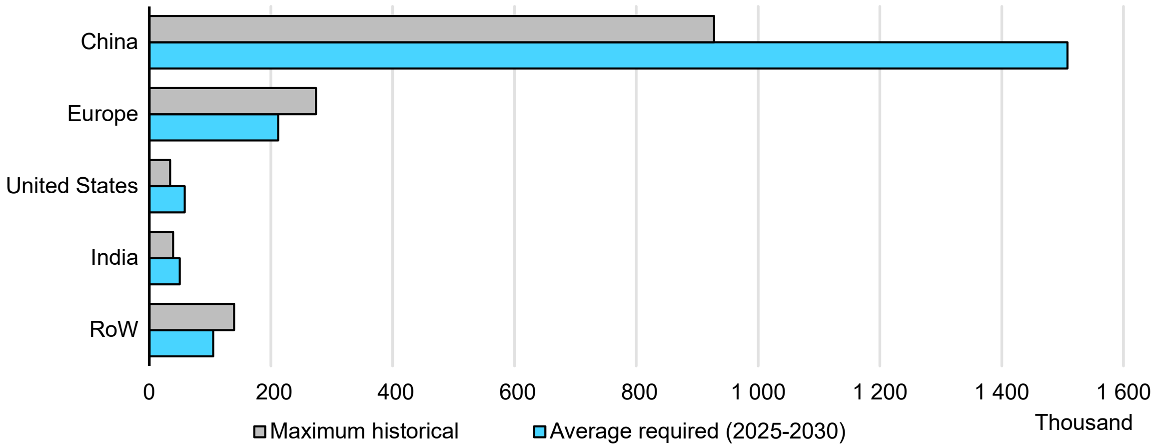


Notes: EV = electric vehicle; LDV = light-duty vehicle. Slow refers to charging points with a power rating of 22 kW and under, while fast refers to higher power ratings. Regional charging point projections can be explored via the interactive Global EV Data Explorer.

In **Europe**, the stock of public charging points doubles by 2030 in the STEPS to reach more than 2 million. The share of fast chargers continues to increase and reaches 30% in 2030 in the STEPS, up from less than 20% in 2024. As such, public charging capacity across Europe reaches 115 GW in 2030, including slow and fast chargers. The increase in the share of fast chargers, as well as the growth in their average power rating, means that while the ratio of electric LDVs per charging point increases from less than 15 in 2024 to close to 25 in 2030, the public charging capacity per vehicle increases to over 2 kW per electric LDV. This level of public charging capacity exceeds the power output targets laid out in the EU AFIR (1.3 kW per battery electric LDV and 0.8 kW per plug-in hybrid). To reach the level of public charging projected in the STEPS in 2030, Europe must add 210 000 public charging points per year on average through 2030, which is less than the 275 000 public charging points added across Europe in 2024.

Beyond EU regulation, there are national targets for public charging infrastructure in Europe. For example, the French government aims to have 400 000 publicly accessible charging stations by 2030, about two-and-a-half times the number available at the end of 2024. The UK government has stated an aim for at least 300 000 public charging stations in 2030, about three-and-a-half times the stock in 2024. The German government has also previously set a target of 1 million public charging points by 2030, though energy industry groups have criticised this target for being more than will be needed.

Annual public charging point additions by region needed to reach the stock in the Stated Policies Scenario, 2030



Notes: RoW = Rest of World. In all regions shown, except China, the maximum historical public EV charging point additions were observed in 2024; in China the most additions took place in 2023.

In the **United States**, the stock of public LDV charging points grows from almost 200 000 at the end of 2024 to over 500 000 at the end of 2030 in the STEPS. This assumes the historic trend in the increasing ratio of electric LDV stock per public charging point continues, and that in 2030 there are almost 40 electric LDVs per public charging point, up from around 32 in 2024. Although this ratio is significantly higher than the global average, recent survey findings suggest that over 85% of US EV owners have access to home charging. However, with rising EV sales, this share is expected to decrease. In addition, the majority of EV owners with home chargers still use public chargers weekly.

The share of fast chargers in the United States grows from less than 30% in 2024 to 40% in 2030 in the STEPS, meaning that the available public charging capacity per electric LDV grows to over 1.5 kW per EV. In 2024, the United States added about 35 000 public charging points across the country. To reach the more than 0.5 million projected in the STEPS in 2030, the United States would need to build out an average of 58 000 public charging points per year. At the end of 2024, fewer than 200 stations funded through the NEVI programme were in operation (representing less than 1% of the 2024 public charging additions), but over 3 500 had conditional awards or agreements in place. However, as the policies underlying the implementation of the NEVI Formula Program are now under review, the future of federal funding for EV charging infrastructure is uncertain. Nevertheless, NEVI and other federally funded charging points have previously been estimated to represent less than 15% of announced non-home charging deployments.

In **India**, the number of public charging points increases from 75 000 at the end of 2024 to around 375 000 by the end of 2030 in the STEPS to support a stock of less than 3 million electric LDVs. As a result, in 2030 in the STEPS there are around 7 electric LDVs per public charging point, up from fewer than 4 in 2024. To reach this projected stock of public charging points, around 50 000 charging points would need to be added on average each year through 2030, about 30% more than the number of additions observed in 2024. India's PM E-DRIVE Scheme includes INR 20 billion (Indian rupees) (USD 240 million) for public EV charging stations, with plans to support a targeted 22 100 EV chargers for electric four-wheeled vehicles through March 2026.

Across other countries, about 630 000 public charging points are added between the end of 2024 and 2030 in the STEPS, or an average of 105 000 new public charging points per year. Governments around the world have set targets for public charging points to support expansion to 2030 and beyond. Japan targets a stock of 300 000 public charging points by 2030, about 9 times the stock at the end of 2024. The government of New Zealand aims to have 10 000 charge points by 2030, a seven-fold increase from the end of 2024. Across Southeast Asia, Indonesia aims to reach 30 000 charging stations by 2030 and Thailand 12 000.

Charging electric heavy-duty vehicles

Megawatt-scale chargers are now being deployed

In general, electric heavy-duty vehicles (HDVs) can use the same charging equipment as LDVs, although different charging station configurations may be needed to accommodate the HDVs, given their larger size. In addition, as the batteries of HDVs are larger and therefore take longer to replenish, higher-powered chargers are needed to minimise disruptions to regular operations. The effective deployment of electric HDVs is therefore likely to require the buildout of devoted charging equipment to ensure charging times compatible with the operational efficiency of commercial fleets. Most electric HDV operators today rely on depot charging when the vehicles are not in use, typically overnight, but en route or opportunity chargers are generally also needed to enable longer-range applications.

The growth in deployment of electric buses has been enabled by the buildout of charging depots by national and local governments as well as by transit agencies. For example, in the United Kingdom, the government's Zero Emission Bus Regional Areas scheme supported the establishment of an electric bus charging hub to power South Yorkshire's first electric buses. Germany's Deutsche Bahn and various partners have supported charging infrastructure for electric buses that charge exclusively at the depot overnight. In China, policy support for bus charging infrastructure has helped to enable huge growth in the electric bus stock, with megawatt-scale charging being demonstrated for buses in Sichuan at the end of 2024.

As with buses, the roll-out of depot chargers is expected to lead the first phase of electric truck charging deployment, as fleet operators have the greatest control over private charging infrastructure. However, scaling up public chargers of 350 kW or more will be critical to support wider adoption. The EU Alternative Fuels Infrastructure Regulation sets specific targets for HDV charging, including charging points with an individual power output of at least 350 kW every 60 km along primary roads and every 100 km along secondary roads. Megawatt chargers are also expected to play a role in HDV charging, given that reducing charging time is highly valued in the sector. An HDV with a battery pack of 300 kWh (similar to the global sales-weighted average in 2024) would require about 30 minutes to recharge[2] using a 350 kW charger, but only about 15 minutes using a megawatt charger.

In 2024, the world's first megawatt chargers for trucks were deployed in the United States and Europe, marking a key technological milestone. Enabling such higher-powered charging requires timely planning, permitting and investment to upgrade power grids. Both depot and public charging frequently require grid reinforcements to enable ultra-fast charging, sometimes in remote locations. Even if overnight charging in depots or service stations is relatively slow, the grid connection must be able to handle the parallel charging of multiple vehicles. Coupling megawatt chargers with battery storage can alleviate grid stress, reducing the need for power grid upgrades and accelerating megawatt charger deployments. This approach could be important for speeding up the roll-out of electric trucks, and has also been announced for ultra-fast charging of cars (see the Box above).

National statistics on HDV-specific chargers are not readily available for most countries. However, there is evidence that in China, one company alone had built about 1 350 charging stations with over 5 500 charging points for electric trucks by the end of October 2024, each with a charging capacity of more than 320 kW. Based on data compiled by Atlas EV Hub, the United States reported around 500 operational HDV charging points in October 2024 – about double the number at the beginning of 2024 – and over 1 000 more are planned. Less than one-third of the existing chargers are accessible to the public, but around 85% of all planned chargers, including at high-power charging stations, are expected to be publicly accessible.

[2] Between 20% and 80% of the battery state of charge.

The expansion of HDV charging infrastructure extends beyond these major EV markets. In India, the PM E-DRIVE scheme proposes installing 1 800 fast chargers for e-buses in larger cities and on selected highways. Elsewhere, Qatar's Public Bus Infrastructure Program has built over 650 charging points for electric buses to support the country's goal of reaching 100% public bus electrification by 2030. In Latin America, countries are collaborating to build EV recharging corridors, including for buses and trucks, and the first truck charging station in Peru was opened at the Port of Callao in 2024. In Singapore, Volt has been awarded a contract to develop and operate an 80-point direct-current charging hub for electric taxis, buses and other EVs. Meanwhile, Malaysian government-owned Prasarana has issued tenders for electric bus procurement and charging infrastructure deployment.

Industry players are teaming up to deploy charging for heavy trucks

HDV charging infrastructure is still in its early stages and requires significant investments, but it is gaining momentum. Private companies are joining forces to expand charging networks. In the United States, Greenlane – a joint venture between Daimler Truck North America, NextEra Energy and BlackRock – announced plans for a commercial EV charging corridor from Los Angeles to Las Vegas, with over 100 chargers. Meanwhile, DTNA, Navistar and Volvo teamed up to establish the Powering America's Commercial Transportation coalition to accelerate deployment of chargers for medium- and heavy-duty trucks.

In Europe in 2024, Milence, a joint venture between Daimler Truck, TRATON and Volvo, presented its plans to establish a European charging network of 70 hubs, accounting for more than 570 high-power (some > 1 MW) charging points by the end of 2025. The company has previously announced the goal to reach 1 700 charging points across Europe by 2027. In addition, E.ON and MAN Truck & Bus are collaborating to set up around 400 electric truck charging stations in 170 different locations in Europe, as part of a project that has received EUR 45 million in EU funding. The BP subsidiary Pulse, which today owns the majority of truck charging stations in Germany, also announced its co-operation with the Polish charging infrastructure manufacturer Ekoenergetyka, although the terms of the collaboration have not yet been disclosed. Various project partners are collaborating under the CLOSER platform to support electrified logistics, including to develop a Scandinavian charging network for electric trucks.

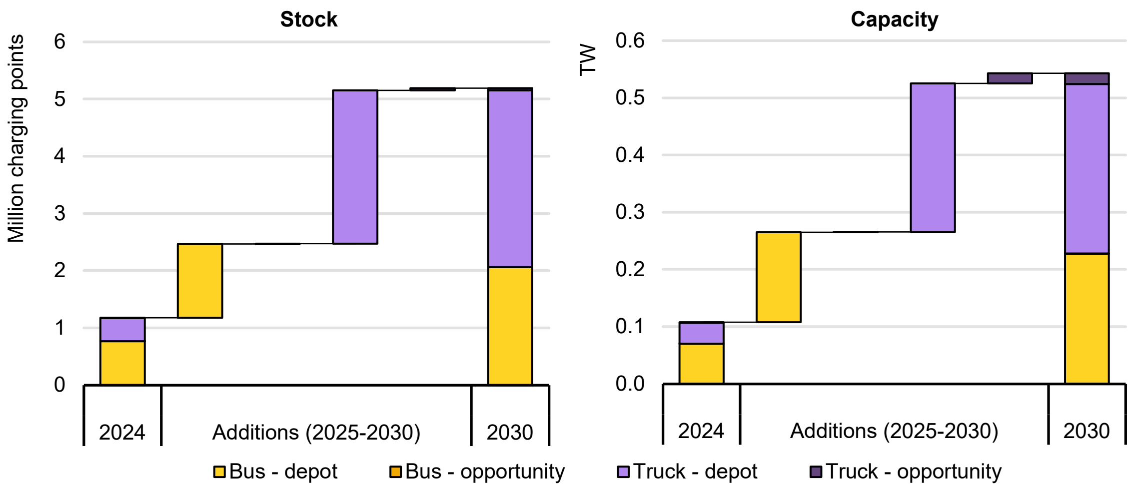
International programmes and initiatives can also support the advancement of HDV charging. Zero-Emission Vehicle Infrastructure Support and Expansion (ZEVWISE) leads the Global Green Road Corridors Initiative, aiming to develop at least ten green road corridors worldwide by 2026, with the latest two new corridors announced at COP29. These corridors aim to deploy sufficient charging infrastructures along key routes connecting industrial hubs, ports and cities, and focus on creating replicable models for infrastructure deployment and financing, aiming to accelerate global deployment. The Kuehne Climate Center and Smart Freight Centre have also initiated the Green Freight Support Program in Eastern Africa.

Heavy-duty vehicle charging outlook

Charging capacity for trucks and buses increases more than fivefold by 2030

Just as for charging LDVs, overnight charging tends to be the most attractive option for buses and trucks, as it requires lower power and is typically cheaper. This is especially the case among early adopters. While public or opportunity charging infrastructure for electric HDVs is limited, electric fleet owners and/or operators typically choose to install depot chargers at close to a one-to-one ratio to allow the fleet to charge concurrently during the night. Of course, to enable longer daily driving ranges, en route or other opportunity chargers (such as at terminal bus stops or highway service stations) are needed to expand the applications that can be met by electric HDVs.

Heavy-duty vehicle charger stock and capacity in the Stated Policies Scenario, 2024-2030



Note: Charger stock in 2024 is estimated based on the number of electric buses and trucks.

In the STEPS, the stock of charging points for electric HDVs increases from around 1 million in 2024 to over 5 million in 2030. The vast majority of charging points remain located at depots through this decade in this scenario. The stock of chargers for trucks grows more quickly than for buses, increasing from a third of all HDV chargers to almost 60% in 2030 in the STEPS.

The charging capacity for electric HDVs grows similarly to the stock – increasing about five times to 2030 in the STEPS to reach more than 500 GW. Given that the role for higher-power opportunity chargers is expected to remain limited this decade, the overall charging capacity for HDVs remains around 100 kW per electric HDV.

Despite the relatively low power rating for depot chargers – typically 50-150 kW compared to 350 kW to 1 MW+ for some opportunity charging – grid upgrades at depots may be needed, especially for larger fleets. Grid upgrades can take from one to several years, depending (in particular) on the voltage. Anticipatory planning is needed to ensure adequate availability of HDV chargers in the medium- to long-term.

Daytime charging of HDVs may also be suited to renewables, such as solar PV, which would support integration and ease grid demand. Co-locating HDV charging stations with battery storage can also be a way to ease grid infrastructure requirements and accelerate the deployment of HDV charging, especially in the context of record-low battery prices. Battery-swapping and electric road systems are other options being explored that could reduce impacts on the grid.

Government policies and support will be needed to ensure a smooth roll-out of charging for HDVs. The EU AFIR includes increasing coverage requirements for HDV charging points with a power output of at least 350 kW along the TEN-T Network starting in 2025. According to the Action Plan for the EU automotive sector, the European Commission will make another EUR 570 million available under the Alternative Fuels Infrastructure Facility towards the roll-out of alternative fuels infrastructure in 2025 and 2026, with a particular focus on HDVs.

Smart charging and vehicle-grid integration

Smart charging gains popularity, bolstered by smart charging roll-out mandates

Electric vehicles represent less than 1% of global electricity demand today, but their contribution to power demand is affected by charging behaviour. Depending on local grid conditions, EV charging can put stress on electricity grids. Extra demand from unmanaged EV charging during peak times can mean grids need to enlist more carbon-intensive power plants and may increase electricity prices for households using electricity at these times. As a result, governments, utilities and private companies have started to develop and deploy technologies to enable smart charging. Smart chargers can be connected to the internet and accessed remotely, allowing for controlled scheduling. When used in conjunction with differentiated tariffs, smart chargers enable EV owners to charge flexibly and take advantage of the cheapest tariffs under different pricing regimes (e.g. time-of-use, dynamic real-time, critical peak pricing, etc.), while providing demand-side flexibility for grid operators. Smart charging can also support EV battery health, such as by adjusting the maximum charging rate to avoid overcharging and excessive heat, which can degrade batteries over time.

Smart charging is advancing towards wider commercial deployment. The United Kingdom was among the first countries to mandate that all new home charge points for EVs must have smart functionality from 2022. Prior to this, only 52% of UK EV owners with home charging capabilities had a smart charger. The EU AFIR specifies that all chargers that are installed or renovated from April 2024 must support smart charging. China has longstanding policies on smart charging roll-out from previous Five-Year Plans on Electric Vehicle Deployment, with newer chargers now having smart charging capabilities. Elsewhere, Brazil is taking strides in expanding EV infrastructure through its "electrocenters" – charging hubs designed to optimise power distribution to ensure grid resilience while accommodating multiple vehicles simultaneously, launched in March 2024.

Multiple actors are involved in efforts to implement vehicle-to-grid solutions

While smart charging enables EV owners to choose when to charge their EVs, bi-directional charging provides them with the opportunity to discharge power from their EVs to their homes (vehicle-to-home, or V2H), buildings (V2B), or other appliance loads (V2L) and the grid (V2G). Bi-directional charging can be used to recharge car batteries when electricity is cheapest, and then sell electricity back to the grid (V2G) when prices are higher. It can also be used to discharge car batteries to provide emergency or off-grid power supply to buildings or loads (V2B, V2H, V2L).

For widespread application of V2G, multiple legal and technological hurdles need to be overcome so that demand-side flexibility from EVs can work effectively for the maximum benefit of EV owners and grid operators. Progress across markets is currently mixed due to the complexity of the requirements needed along the V2G pipeline.

As a first step, smart chargers that can schedule charging and discharging from the grid must be deployed across the EV charging network. Secondly, EVs must be capable of bi-directional charging. Today there are over 30 bi-directional-capable models available, an increase of nearly 20% from 2023. Bi-directional models now make up more than one in eight new electric cars sold, with models such as the Hyundai Ioniq 5 and 6; BYD Dolphin and Yuan Plus; MG 4/Mulan and Kia EV6 among the most popular. In addition, OEMs have begun to work together to address common challenges associated with V2G integration, such as through ChargeScape, which brings together Nissan, BMW, Ford and Honda.

Different market structures will also be needed to support the application of V2G technologies. For example, differentiated tariffs provide financial incentives for EV owners to optimise their charging. Aggregators and ancillary service markets act as middle management between grid distribution operators, to provide bids and pool flexible EVs and other storage devices so that grid operators can then purchase this flexibility. To facilitate the transmission of electricity between these market aggregators, sufficient management of EV batteries connecting to the grid must also be supported by adequate grid infrastructure so as to avoid grid congestion and enable bi-directional charging.

Demonstration trials of V2G projects are currently underway in markets including Australia, China, Germany, Korea and the United Kingdom, where the government is funding 20 V2G projects involving around 600 cars. A demonstration project launched in November 2024 in the Netherlands represents one of the largest V2G car-sharing services in Europe to date, using 500 Renault 5 E-Tech BEVs. In 2023, the Korea Electric Power Corporation was involved in a 100-vehicle V2G pilot programme. It found that EVs effectively contributed to peak shaving, and that battery degradation was minimal, but further refinement of financial incentives would be needed to make the V2G system financially attractive to a wide consumer base. In August 2024, China's National Development and Reform Commission issued a notice promoting the piloting of large-scale applications of V2G interactions, and selected 5 cities to kick off at least 50 V2G pilot projects. The notice also established grid communication standards for EV charging equipment that enables V2G bi-directional charging. A national road map for bi-directional charging has been developed by Australia, which suggests that adopting V2G in just 10% of Australia's projected EVs could help meet more than one-third of the national electricity market's storage needs in 2030. As of February 2025, a small number of Australian households have adopted V2G technology and are selling power back to the grid. In the United States, in March 2025, ComEd, an energy provider in northern Illinois, partnered with Nuvve to launch a V2G pilot programme focusing on electric school buses.

Policy measures targeting bi-directional charging are increasingly being introduced in different markets worldwide. In the European Union, updated AFIR requirements will include standards that enable bi-directional charging, starting in 2027. In the United States, the Federal Highway Administration previously mandated via the Infrastructure Investment and Jobs Act (2021) that chargers must conform to and possess hardware capable of implementing both smart charging and bi-directional charging for compatible vehicles (ISO 15118-20). At the state level, California enacted legislation to promote V2G adoption in September 2024.

Ensuring compatibility and interoperability of the chargers and EVs involved are the final challenges. The CHAdeMO EV charging system first introduced V2G communication in 2010 and has been the first mover in this domain. Since then, the charging protocols adopted by the CHAdeMo Association have continued to evolve as technology has developed. Several organisations have also been working to define appropriate standards and use cases. Efforts to standardise protocols and grid codes are ongoing through the Electric Vehicle Technology Collaboration Programme Task 53: Interoperability of Bidirectional Charging. In addition, the International Electrotechnical Commission has published use cases on how EVs might provide distributed energy resource functionality.

Progress in power system measures to enable smart charging and vehicle-to-grid capabilities, 2025

Country	Market access and legal frameworks					Technology availability	
	Differentiated tariffs (e.g. time-of-use, dynamic real-time, critical peak pricing)	**Aggregators** (grouping multiple users that combine loads or generation)	**Ancillary services** (electricity market services related to frequency control, voltage control, and emergency and restoration plans)	**Local flexibility** (DSOs procure local flexibility to reduce congestion, minimise outages and allow for deferral of grid expansion investments)	**Standards and legal definitions**	**Smart charging deployment**	**V2G model availability**
Brazil	Green	Red	Green	Red	Orange	Green	Green
Chile	Orange	Orange	Red	Red	Orange	Orange	Green
China	Green	Orange	Green	Orange	Orange	Orange	Green
Denmark	Green	Orange	Orange	Red	Orange	Green	Green
Finland	Green	Orange	Green	Green	Orange	Green	Green
France	Green	Orange	Red	Green	Green	Green	Green
Indonesia	Green	Red	Red	Red	Orange	Orange	Green
Italy	Green	Green	Red	Red	Green	Orange	Green
Japan	Green	Green	Orange	Red	Green	Orange	Green
Korea	Green	Orange	Red	Green	Orange	Orange	Green
Netherlands	Green	Green	Green	Green	Green	Green	Green
South Africa	Green	Green	Green	Red	Orange	Green	Green
United Kingdom	Green	Green	Green	Green	Green	Green	Green
United States	Green	Orange	Orange	Orange	Orange	Orange	Green
Thailand	Green	Red	Red	Red	Orange	Orange	Green

Notes: DSO = distribution system operator. Evaluation overview: green = measures in place; orange = field test/pilot phase, or measures announced; red = no framework. United States assessment is based on an aggregate of state rules and aggregators in the country (New York Independent System Operator, Massachusetts, Maryland)

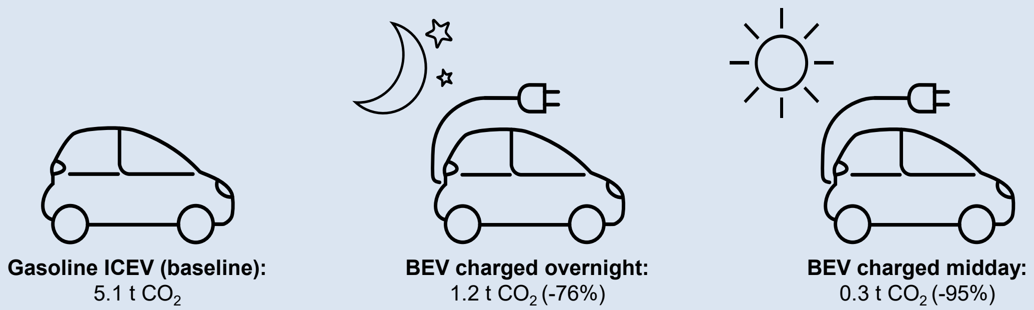
Sources: IEA (2023), Facilitating Decarbonisation in Emerging Economies through Smart Charging; IEA (2024), Enhancing Indonesia's Power System; IEA (2024), Meeting Power System Flexibility Needs in China by 2030; Mobility House (2023), The V2G status quo - how much progress has been made in which country?; United Kingdom, Department for Transport (2018), Government funded electric car charge points to be smart by July 2019; Yeboah, D. et.al. (2023), Tariff Development for Smart EV Charging for Households; Korea, Ministry of Trade, Industry and Energy (2023), Act No.19437; IRENA (2019), Innovation outlook: Smart charging for electric vehicles; Chile, Ministry of Energy (2022) Approval of regulation on establishing interoperability of EV charging systems; Wood Mackenzie (2024) Ancillary services in Asia-Pacific; Otsuki, T. & Ogura, T. (2019), EV Charging Standards and V2X.

Shaping human behaviour around charging will be key to unlocking the full benefits of electric vehicles

Patterns of human behaviour will have a big impact on how EVs affect the grid. Different charging habits will affect the costs of charging, grid congestion and reliability, but with the right incentives to align charging behaviour with the needs of the grid, EVs could become a major source of flexibility and demand response.

Charging behaviour also affects emissions. Many electric grids – such as those in California, Germany, and Spain – have deployed large amounts of solar power, which peaks around midday. If EV charging uses this solar power, while avoiding peak load periods such as early evening when people return home after work, EVs could help stabilise the grid while also maximising emissions reductions. In California, electric cars charged overnight emit 76% less CO_2 than conventional ICE vehicles – but EVs charged around midday go much further, slashing emissions 95% relative to ICEs.

Annual well-to-wheel emissions from gasoline and electric cars in California, 2024



Source: Emissions estimated by UC San Diego based on data from the California Air Resources Board.

Social science research is now looking at how to influence behaviour in ways that help EVs become a reliable resource for the grid and cut emissions. Researchers from the University of California San Diego (UC San Diego), working with the Electric Power Research Institute and others, are using randomised controlled trials at UC San Diego's network of over 500 charging points. Experiments that derived from 1 200 drivers are assessing whether interventions change habits in the real world.

In one study, they told drivers how midday charging reduces emissions and found that drivers responded by reducing their campus charging at times other than midday by 5%. While modest, this effect is similar in scale to other kinds of informational "nudges" studied with other behaviours that affect the grid, such as household energy choices. A key issue the research team explored is that many EV drivers have little prior knowledge about charging costs and emissions impacts. Information helps fill that void.

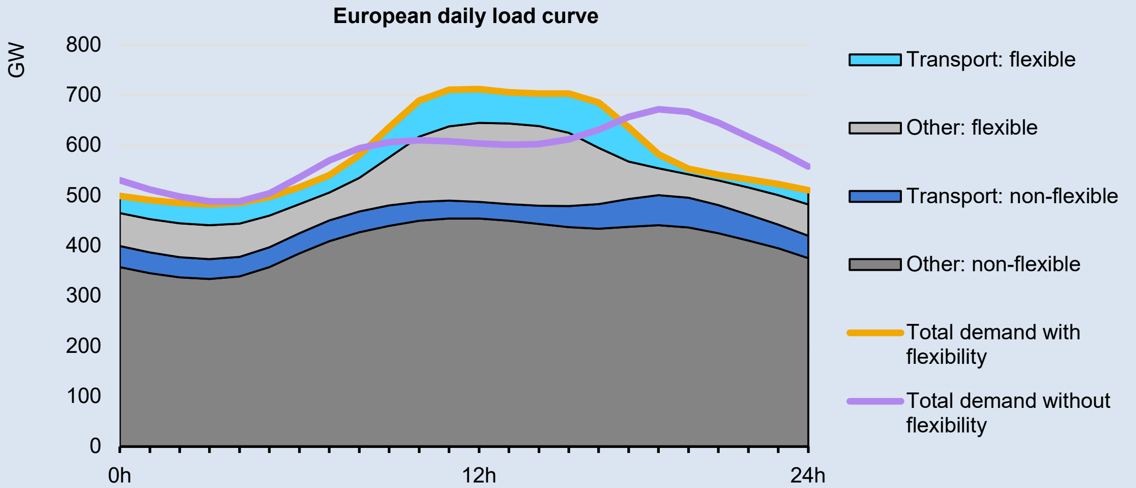
A second project offered discounts for campus charging to test drivers' willingness to relocate their charging. In a twist, incentives to charge on campus actually led drivers to charge more (7%) in the early morning and overnight, rather than during the midday solar peak. The findings suggest that scarcity of chargers was the reason for this unexpected behaviour – drivers expected that the discounts would increase competition for scarce chargers and tended to hoard access as a result.

Some recent preliminary findings suggest that network quality also affects charging behaviour. When drivers have poor charging experiences, they are reluctant to return. This points to the increasing need to focus on the quality of charging networks, not just the quantity of charge points. Some policy makers have begun this shift, such as in Germany.

As the number of EVs on the road increases, choices about charging will have bigger impacts on the grid. That raises the stakes for learning how to get people to charge in more optimal ways, which will often mean at offices and other locations away from home at differing times of the day. Using real-world charging data to test business models will be vital for sustainably building the networks to support such charging.

Transport flexibility through methods such as smart and managed charging has relevance around the world. For example, in a case where EVs represent 80% of the vehicle stock in Europe, and over 40% of final energy demand is met by electricity, around a quarter of this electricity demand has some flexibility potential. Over a third of this flexibility potential comes from EVs, where optimised smart charging and changes in charging behaviour can shift peak demand away from the congestion and higher emissions that occur during evening hours to the middle of the day when the availability of renewables, especially solar, to supply the grid would be higher than the electricity demand without the additional charging load.

Potential for transport demand response flexibility across Europe based on an 80% electric vehicle stock share.



Notes: In this example, over 40% of total final energy demand in Europe is electrified.

Source: Adapted from the World Energy Outlook 2024.

Innovative charging solutions

While cabled charging is expected to remain the predominant technology for charging EVs into the foreseeable future, alternative solutions are also making headway. Battery swapping systems, for example, have been around in some form for over a century, though use has been somewhat limited, but deployment is now rapidly growing in certain regions and segments. Battery swapping is proving especially successful in commercial applications such as delivery or ride-hailing services, where downtime for charging can be costly.

Battery swapping can offer benefits by reducing the upfront cost of EVs; improving battery longevity, especially with professional handling of swaps; alleviating stress on power grids; and facilitating reuse and recycling efforts when batteries remain under the ownership of the swap company. However, these systems may increase overall demand for batteries and would benefit from design standardisation that could be difficult to achieve at large scales in some markets. Standardising batteries could also inhibit innovation, such as the development of cell-to-chassis architectures that can improve EV efficiency by reducing the weight of battery systems. The benefits of standardisation for battery swapping must be weighed against the risk of constraining market competition and innovation.

Dynamic charging – which takes place while vehicles are moving – is also being explored. This can be accomplished through conductive charging, such as using overhead catenary lines, which are already commonly used to power transport systems like trams and light rail systems, or through inductive, wireless charging, which is at an earlier stage of development and deployment. Both systems can be deployed at strategic locations for stationary charging, such as at bus stops or logistics centres where vehicles already spend time idle.

These systems and other innovations, such as solar-coupled charging systems, can play a role in making charging more convenient and/or a source of flexible demand for renewables, as well as reducing charging-related stress on grids.

Battery swapping for 2/3Ws is increasingly popular in emerging markets

Battery swapping systems for 2/3Ws offer a number of benefits, including improving affordability, which can be particularly helpful for consumers in developing economies, where upfront costs can be a barrier. The “battery-as-a-service” subscription model can lower the upfront investment required for an electric 2W, as the battery typically accounts for around 40% of the total price. In terms of operational costs, for the amount of range provided, battery-swap-enabled 2/3Ws are around 20-50% cheaper than petrol 2/3Ws, and the economic case improves as daily driving distance increases. Battery swapping can also offer time savings. While at least 20 minutes (and typically several hours) is required for recharging an electric 2W, battery swapping can be performed in just 2-5 minutes – approximately the same amount of time needed to refuel a gasoline motorcycle. It can eliminate the need for home charging, making electric 2/3Ws more accessible to drivers with limited electricity access. In addition, in countries with underdeveloped power grids, the more centralised load/demand management offered by some battery swap stations can be beneficial.

Thailand, for example, is targeting 1 450 battery swapping stations by 2030. In Indonesia, the start-up SWAP Energi currently operates around 1 500 electric 2W battery swap stations in the country. The Indonesian government has set the target of about 67 000 battery swap stations, for either motorcycles or cars, by 2030.

Battery swapping has also taken off in India in the past 5 years, thanks to technological improvements for batteries and falling costs coinciding with a rise in gasoline prices. Electric 2/3Ws – sold without the battery – have now become accessible even to low-income buyers. Battery Smart is India's largest battery swap operator for 2/3Ws and reached 1 000 stations in April 2024. Indian company Sun Mobility is also growing fast, with more than 630 swapping stations in 19 Indian cities. There are also plans to deploy 10 000 Piaggio electric 3Ws with swappable batteries in the country, alongside 300 new swapping stations.

In Chinese Taipei, the market for electric 2/3Ws has grown significantly due to strong demand and government support, accompanied by an innovative, widespread battery swapping mechanism that has become a global leader. Domestic battery swapping pioneer Gogoro now has around 13 000 battery swap stations worldwide, each roughly the size of 2 vending machines and able to hold around 30 scooter batteries. In the city of Taipei, there are now more Gogoro battery swapping stations for 2Ws than gas stations. A total 2 500 Gogoro stations use artificial intelligence (AI) and can act as a virtual power plant – drawing power from the grid when usage is low, and returning it when usage is high, and even supplying back-up power in emergencies. After the country was hit by an earthquake in April 2024, battery swap stations made 6 MW of power available, enough to power thousands of homes. However, Gogoro has struggled to find a sustainable business model and benefits from government purchase subsidies.

In Africa, Spiro, an electric motorbike manufacturer and battery swapping provider, has put over 22 000 e-bikes on the road across a number of different countries. Kenyan company Arc Ride runs a battery-as-a-service model for 2W battery swapping, with over 140 stations, mostly around Nairobi. Kenya is also a target for Rwandan Ampersand's expansion plans, and Roam is setting up solar-powered fast battery charging and swapping for electric motor cycles in the country.

Battery swapping systems for 2/3Ws are still in their infancy in Europe, a far smaller market for 2/3Ws, although the supermarket chain Kaufland is operating swapping stations for batteries for small electric cars or electric 2Ws in Romania in co-operation with the e-Mobility Rentals start-up. Honda is also launching battery swap stations in Sweden for their electric scooters.

Greater standardisation and interoperability would be needed to fully reap the benefits of battery swapping and reduce the need for costly charging infrastructure. This would also enable the aggregation of demand for electric 2/3W batteries and help to guide industry development. In 2022, various Japanese OEMs established a new company, Gachaco, to offer a battery sharing and swapping services for standardised, exchangeable 2W batteries. More recently, in 2024, Thailand launched the Thailand Standard Swappable Battery Consortium for Small e-Mobility to work towards elevating the national standard to the level of international standards.

Battery swapping for cars is growing in China and entering new markets

Chinese EV manufacturer NIO built its first battery swap station for electric cars in 2018 and has remained the market leader ever since. By the end of 2024, NIO had built over 3 000 battery swap stations in China and 50 in Europe. In just 2 years, the company more than doubled its battery swap stations in China. In an effort to co-ordinate battery standards and battery swapping technologies, and maximise the utilisation of NIO's network, the company has agreements with Geely Group, JAC Group and Chery Automobile, which together represented 15% of electric car sales in China in 2024.

Battery maker CATL introduced its battery swap solution, EVOGO, in 2022. The company has since announced the ambition to reach 3 000 stations by 2027, and eventually 10 000 stations. In 2024, CATL and ride-hailing company DiDi formed a joint venture to build out battery swap stations and swappable vehicles, and at the end of the year, CATL launched a Battery Swap Ecosystem with nearly 100 partners to move towards the standardisation of EV battery swapping. The programme also aims to build 30 000 battery swap stations that will also work as battery-to-grid energy storage facilities.

In 2024, Ample announced it was partnering with ENEOS to bring battery swap stations to Kyoto, in a first for Japan. Ample is also partnering with Stellantis, beginning with a programme to provide battery swap stations in Madrid for Fiat 500e cars in the Free2Move car-sharing service.

For trucks, battery swapping can offer savings in terms of reducing charging time

As of June 2023, there were around 400 battery swap stations for trucks in China. While battery swapping for heavy-duty trucks is still at an early stage of deployment, it has the potential to support faster uptake of electric trucks by extending battery lifespan and reducing the wait time for charging, thus enhancing efficiency for commercial operations. For example, even electric truck batteries large enough to enable daily mileage suitable for long-distance transportation can be exchanged in around 10 minutes – almost as fast as refuelling a diesel truck. Battery swapping for trucks can offer greater benefit in terms of preserving battery health compared to other EV segments; the constant use and long distances travelled by trucks result in increased battery degradation, which is compounded by reliance on fast-charging solutions that further accelerate degradation.

Battery swapping is particularly well-suited to fleets of identical trucks with heavy operational demands, operating on well-defined routes. These fleets could justify the significant investment required in automated swapping facilities and additional batteries. As such, battery swapping has been deployed for trucks used in short-haul applications at ports, mining sites, urban and even regional logistics, particularly in China where sales of swap-capable electric trucks reached almost 30 000 last year. Elsewhere, Rio Tinto announced in 2024 they would trial eight electric dump trucks with battery swap technology for their mining operations in Mongolia. In Japan, field tests using courier services also began in 2024 for a Mitsubishi Fuso and Ample truck battery swap demonstration.

Technological advances have enhanced the safety, reliability and convenience of battery swapping systems for trucks in recent years. Intelligent systems can now automatically assess battery status and perform the swapping service. In China, new policies were announced in 2024, enacting safety standards for swap-capable HDVs and establishing technical specification systems. However, in other parts of the world, the required level of standardisation may make it difficult for battery swapping to compete with conventional plug-in charging, especially for certain heavy-duty truck segments.

In Europe, the region's first fully automated heavy-duty electric truck battery swapping station opened in Germany in 2023. Swappable batteries are also being used as hybrid solutions for trucks, for example in German company Trailer Dynamics' electric trailer with a swappable battery. Similarly, in the United States, Revoy has launched a battery swapping solution that can integrate with semi-trucks, offering up to 235 miles of range, which can essentially turn a diesel truck into a hybrid vehicle, or serve as a range extender for an electric truck. While battery swapping demonstrations and technology developments are ongoing, outside of China, manufacturers have been reluctant to separate battery ownership from vehicles, which would disrupt traditional revenue streams, and to standardise, which has been crucial to China's success.

Electric road systems are being tested across major EV markets

Electric road systems (ERS) enable vehicles to receive electricity while moving using one of three main technologies: conductive overhead (catenary) lines, conductive contact rails beneath the vehicles, and inductive wireless systems embedded in the road. Conductive contact rails and inductive systems can charge both light and heavy vehicles, while overhead lines are used for heavy vehicles. In all cases, vehicles must be equipped with appropriate pantographs or receivers.

ERS allow for smaller batteries and could therefore be a cost-effective solution for electrifying the road sector, especially for heavy-duty trucks that follow well-defined routes, while ERS-enabled smaller batteries can increase a commercial vehicle's payload and profitability. Research has highlighted the benefits of wireless charging of buses to resolve space constraints at depots and to enable en route charging that can make battery electric buses more comparable to gasoline fuelled buses in terms of operations. Similar benefits exist for catenary charging solutions strategically located at bus stops. However, ERS infrastructure is expensive to install – depending on the type of system, the cost per kilometre could range from EUR 1.5 million for overhead catenary to over EUR 3 million for inductive charging.

Test projects for electric road technology are ongoing worldwide, exploring both inductive and conductive methods. Sweden has been a global pioneer, while projects are also being undertaken in the United States, China and Japan. The United States primarily focuses on inductive technology, while Germany and France, historically focused on conductive technology, are now also testing inductive systems. Some of the earliest test projects in Europe, particularly in Sweden, have now been retired.

Selected operational and planned electric road system projects

Location	Description
Datong, China	Trial of pantograph system with trucks launched in 2023 as part of Shanxi project. Project developed by CRRC Datong (part of China National Railway Locomotive & Rolling Stock Industry Corporation) and research partners.
Xinjiang province, China	Plans to electrify more than 1 800 km of highway launched in mid-2023.
Jilin province, China	120 m long high-power dynamic wireless charging road system unveiled at FAW Sci-Tech innovation base in Changchun in 2023.
Chamonix Mont Blanc Valley, France	eRoad Mont Blanc is a 1 km conductive contact rails-based project launched in 2023. It uses Alstom's ground-level power supply system and is funded by the French Government and European Union. Works on the 420 m demonstrator carriageway completed in December 2024; System and vehicle validation checks to be undertaken in 2025.
Greater Paris, France	A 2 km section of the A10 motorway has been equipped with Elonroad's conductive rail charging system, in partnership with VINCI Autoroutes. Testing expected to begin in 2025.
Schleswig-Holstein, Germany	A 5 km e-Highway field trial using catenary lines launched in 2019 has enabled pantograph-equipped trucks to cover more than 55 000 km.
Hessen, Germany	17 km overhead catenary system, installed by Siemens, in operation since May 2019, with 11 trucks in operation (one BEV).
Baden-Württemberg, Germany	3.4 km-long eWayBW overhead catenary system, supplied by Siemens, in operation since 2021 with five trucks in regular operation.
Bayern, Germany	Planned electrified road system.
Rhein-Main/Rhein-Neckar, Germany	Lkw-Innovationscluster planned electrified road system.
Cologne, Germany	100-m E-Charge inductive charging track installed by ElectReon undergoing testing.
Balingen, Germany	ELINA project by ElectReon with 1 km of induction charging to power an electric bus announced in 2022.
Karlsruhe, Germany	100-m ElectReon induction charging system to power an electric public bus in the Port of Karlsruhe.
Bavaria, Germany	Planned 1km ERS announced in 2022 as part of E|MPOWER pilot project.
Brescia, Italy	Arena del Futuro test project uses 1km of induction charging.
Kashiwa, Japan	Tests began in October 2023 on a system using embedded wire coils for inductive power transfer at traffic lights.
Trondheim, Norway	Induction charging installed by ElectReon to power an electric bus, with funding from the Norwegian government.
United States	In late 2023, the country's first wireless charging road system entered operation. Technology developer ElectReon is now partnering with parcel delivery service UPS and electric truck manufacturer Xos to test both stationary and dynamic wireless charging technologies for commercial vehicles.
Indiana, United States	Construction of a test bed for wireless charging began in April 2024, with plans to electrify a section of an Indiana interstate in the next 4-5 years.

Sources: IEA analysis and the International Council on Clean Transportation (2024) Market Spotlight.

Wide application of ERS faces many hurdles – besides the large investments required for infrastructure development, vehicles must be adapted to the specific charging technology. Governance can also be difficult, as ERS requires a market design appropriate for both the transport and energy market, which have distinct regulatory regimes. The costs of ERS must also be evaluated in the context of alternative charging systems: A 2024 report commissioned by the Swedish government (which had previously announced ambitions to build 3 000 km of electric roads by 2035) recommended against further expansion of ERS in Sweden, in part as the development of batteries for EVs has progressed rapidly. Plans to build the world's first permanent electrified road, which would have connected Stockholm, Gothenburg and Malmo, were paused in 2023.

7. Electric vehicle batteries

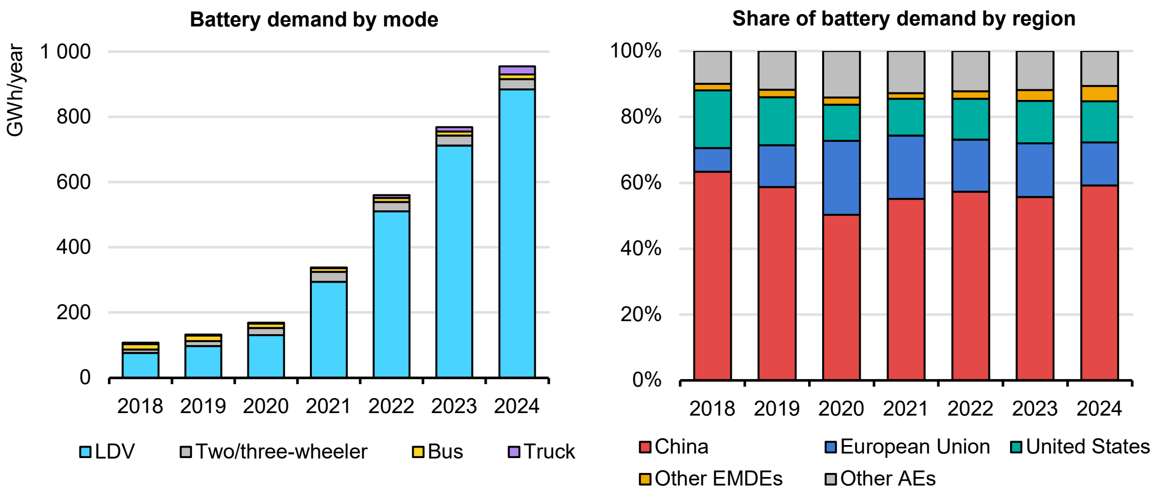
Trends in battery demand

Global battery demand for the energy sector hit the 1 TWh milestone in 2024

Electric cars remain the main driver of battery demand, but demand for trucks nearly doubled

Battery demand in the energy sector, for both EV batteries and storage applications, reached the historical milestone of 1 TWh in 2024. Demand for one average week alone in 2024 exceeded the total demand for an entire year just a decade earlier. Demand was largely driven by growth in EV sales, as demand for EV batteries grew to over 950 GWh – 25% more than in 2023. Electric cars remain the principal factor behind EV battery demand, accounting for over 85%. Compared to 2023, the sector whose demand grew the most was electric trucks, growing over 75% in 2024 to reach nearly 3% of global EV battery demand. Electric truck battery demand was driven by growth in China, but demand also ramped up in Europe (about 25%), which accounted for about 10% of the global total.

Electric vehicle battery demand by mode and region, 2018-2024

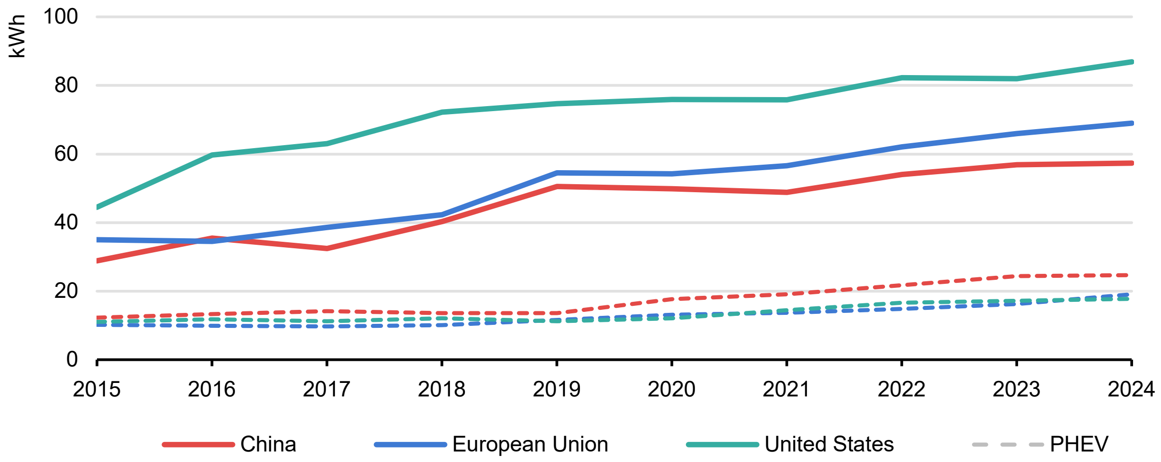


Notes: LDV = light-duty vehicle, including cars and vans; EMDEs = Emerging markets and developing economies; AEs = Advanced economies. Battery demand is defined here as the volume-weighted average battery size multiplied by vehicle sales by mode and region. It reflects the batteries installed in vehicles sold in each region, and not the battery demand for vehicles manufactured in each region. Electric vehicle and battery stockpiling are excluded from the analysis.

Source: IEA analysis based on EV Volumes.

In 2024, EV battery demand grew by over 30% in China, and by 20% in the United States, in stark contrast with the European Union, where demand stalled. Battery demand in the United States nearly matched that of the European Union in 2024, in part as a result of its approximately 25% larger battery size per EV. Emerging markets and developing economies other than China continued to represent only a small share of global battery demand, reaching nearly 5% in 2024. Nevertheless, their share has doubled since 2022, underpinned by sustained growth in Southeast Asia, India and Brazil.

Average electric car battery pack size by region and powertrain, 2015-2024



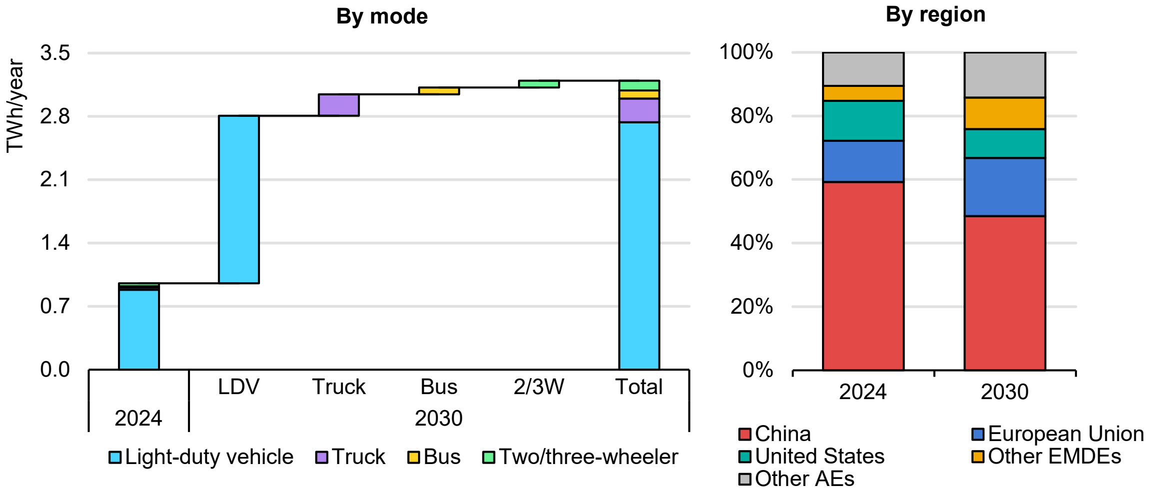
Notes: PHEV = plug-in hybrid electric vehicle. Solid lines represent the sales-weighted average battery pack size for battery electric cars, while dashed lines indicate the same for plug-in hybrid electric cars.
Source: IEA analysis based on EV Volumes.

Outlook for battery demand

Electric vehicle battery demand jumps more than threefold by 2030

EV battery demand continues to grow, and is expected to reach more than 3 TWh in 2030 in the STEPS, up from about 1 TWh in 2024. While electric cars will remain the primary driver of battery demand, other modes are set to gain market share. Notably, the contribution of electric trucks to EV battery demand triples by 2030 to reach more than 8%, up from nearly 3% in 2024.

Battery demand for electric vehicles by mode and region in the Stated Policies Scenario, 2024-2030



Notes: LDV = light-duty vehicle, including cars and vans; 2/3W = two/three-wheeler; EMDEs = emerging markets and developing economies; AEs = advanced economies. Battery demand is defined here as the volume-weighted average battery size multiplied by vehicle sales by mode and region. It reflects the batteries installed in vehicles sold in each region, and not the battery demand for vehicles manufactured in each region. Electric vehicle and battery stockpiling are excluded from the analysis.

Battery demand is also set to become more geographically diverse. In the STEPS, emerging markets and developing economies other than China are expected to double their share of EV battery demand, from nearly 5% in 2024 to 10% in 2030. The share of global demand in the European Union and other advanced economies, such as the United Kingdom, Canada, Japan and Korea, is also projected to grow, while the share of the United States is projected to decline from about 13% in 2024 to less than 10% by 2030. Meanwhile, China's share of global battery demand declines from 60% in 2024 to just under 50% by 2030, although it remains by far the single largest source of demand.

Battery industry trends

Chinese manufacturers are increasing their competitive advantage

Low critical mineral prices and intense competition drove down battery prices in 2024, but China's price advantage is widening

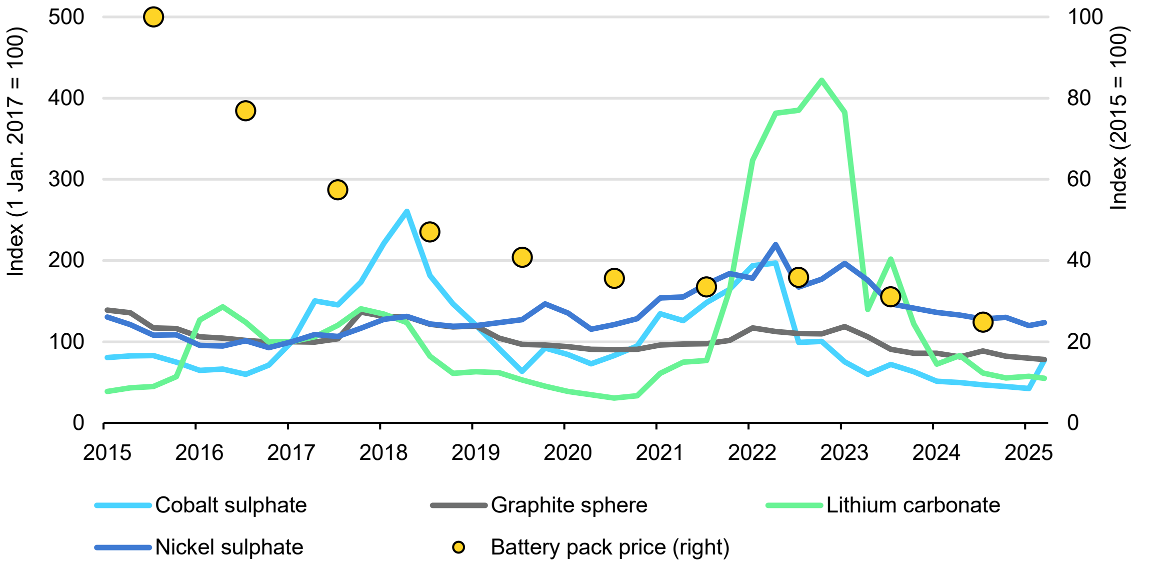
Prices for lithium-ion battery packs fell 20% in 2024 – the largest drop since 2017 – as a result of low critical mineral prices and battery margins being squeezed through competition, predominantly in China. Lithium prices, in particular, dropped nearly 20% in 2024, reaching similar prices to those at the end of 2015, despite lithium demand in 2024 being about six times bigger than in 2015.

Low critical mineral prices are primarily driven by supply surplus, which is making it difficult for some mining companies to compete, thus increasing the level of supply chain concentration among established players. This surplus is expected to persist over the next few years, but low prices could discourage future investments and might cause supply shortages for lithium and nickel by 2030. In addition, the high geographical and ownership concentration of their supply chains may cause market distortions, increasing market risk.

An undersupply of lithium would push up prices, to the benefit of the mining sector but to the detriment of battery and EV makers, as well as final consumers. The recycling sector, which could help curb cost increases, would also benefit from higher mineral prices. However, due to feedstock limitations, it will take about a decade before recycling has a significant impact on reducing primary mineral demand (see the Box on battery recycling below).

Technology innovation, particularly related to sodium-ion batteries or direct lithium extraction, could be instrumental in reducing the risk of lithium undersupply and its potential impact, and avoiding price spikes similar to those seen in 2022. Additionally, vertical integration through upstream investments can help battery suppliers to lower production costs while safeguarding against the risk of volatile critical mineral prices.

Price of selected battery metals (left) and lithium-ion battery packs (right), 2015-2025



Notes: "Battery pack price" refers to the volume-weighted average pack price of lithium-ion batteries across the electric vehicles and battery storage sectors. 2025 refers to data up to the end of March 2025.

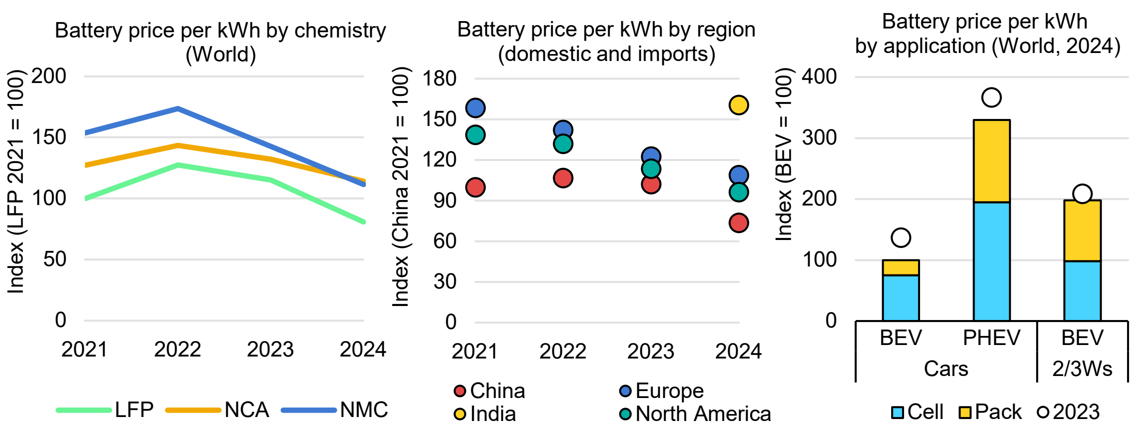
Sources: IEA analysis based on data from Bloomberg and Bloomberg New Energy Finance Lithium-Ion Price Survey (2024).

Battery pack prices fell in all markets, but the extent of the drop varied significantly, with the fastest declines seen in China, where prices fell nearly 30% in 2024, compared to 10-15% in Europe and the United States. This widened the gap between battery prices in China and the rest of the world, increasing the competitive advantage of Chinese EV and battery producers. The faster pace of battery cost reduction and innovation in China has been enabled by fierce competition that has driven down profit margins for most producers (though not all), at the same time as driving up manufacturing efficiency and yields, as well as access to a large skilled workforce, and battery supply chain integration.

Battery chemistry also plays an important role, with lithium iron phosphate (LFP) batteries – the main battery chemistry used in China – being almost 30% cheaper per kilowatt-hour (kWh) than lithium nickel cobalt manganese oxide (NMC) batteries, which remain the most widely used batteries in the United States and Europe. NMC batteries still provide an energy density advantage, though the gap has narrowed in recent years. The energy density of LFP battery packs is about one-fifth lower by mass (Wh/kg) and about one-third lower by volume (Wh/L) than that of NMC packs. This is, however, partially offset by LFP's ability to reach 100% state of charge when required without significant degradation, whereas NMC batteries are typically limited to 80% to preserve long-term performance.

The higher energy density of NMC batteries remains an advantage for applications requiring longer ranges or operation in cold climates, where LFP technology is typically less effective. However, LFP batteries have now reached a performance level sufficient for most EV applications, making their lower cost a key advantage for automakers aiming to mass markets.

Average battery pack price per watt-hour index by selected battery chemistry, region and mode, 2021-2024



Notes: LFP = lithium iron phosphate; NCA = lithium nickel cobalt aluminium oxide; NMC = lithium nickel manganese cobalt oxide; BEV = battery electric vehicles; PHEV = plug-in hybrid electric vehicle; 2/3Ws = two- and three-wheelers. Battery price refers to price per kWh for battery packs. Battery prices by region refer to the average battery price in a given region, including locally produced batteries and imports across EVs and battery storage applications. Data for India is not available between 2021 and 2023. Battery price by application refers to an average-sized vehicle.

Source: IEA analysis based on data from Bloomberg New Energy Finance.

The battery price per kWh is also heavily dependent on the targeted application, with BEVs enabling the lowest costs. In 2024, battery pack prices per kWh for plug-in hybrid electric cars were more than three times those for battery electric cars, because of their smaller size and greater power requirements. In 2024, the average price of a 20 kWh PHEV battery pack – roughly the global sales-weighted average for standard plug-in hybrids – was about the same as a 65 kWh BEV battery pack, the global sales-weighted average for battery electric cars.

Pack components such as the battery management system are common to BEV and PHEV battery packs, but given that PHEV packs are smaller, the price of such components is spread across fewer battery cells, increasing the price per kWh. PHEV battery packs may also require more complex designs to accommodate the internal combustion engine, which increases their production cost. Additionally, because of the smaller pack size, each battery cell in the PHEV pack has higher power requirements to guarantee minimum acceleration standards while driving in full electric mode. This demands different battery designs, such as thinner electrodes, to improve battery power at the expense of its energy density,[1] further increasing the cost per kWh compared to BEVs. Smaller battery sizes also increase prices per kWh for 2/3W batteries.

Battery specifics, however, only determine prices for high volume. For instance, in China, electric truck battery prices per kWh are slightly lower than for battery electric cars, thanks to their larger size and therefore the reduced contribution of the battery pack cost. Electric truck markets in other countries are far less mature, and their battery price per kWh remains significantly higher – in 2024, prices were more than double those in China.

Lithium iron phosphate batteries continue to gain market share, and with them so do Chinese manufacturers

In 2024, LFP batteries made up nearly half of the global EV battery market, underpinning the efforts of manufacturers to lower EV prices and production costs in order to maintain or gain market share in an increasingly competitive market. China leads on the uptake of LFP batteries, which met nearly three-quarters of its domestic battery demand in 2024, and their share shows no sign of slowing down, reaching 80% of batteries sold in November and December 2024.

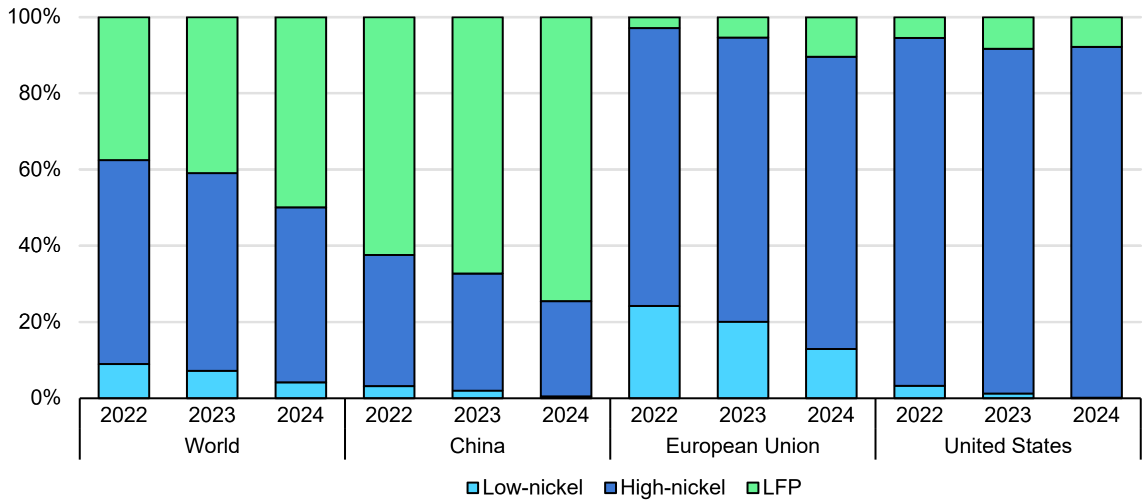
In the United States, the share of LFP batteries used in EVs slightly contracted in 2024, remaining below 10%, which may be a result of tariffs on Chinese batteries. In contrast, in the European Union, LFP battery adoption grew by about 90% for

[1] "Energy density" is used here as a general term referring to the amount of energy stored per unit of mass or volume. It can be divided into two specific metrics: specific energy (Wh/kg) and energy density (Wh/L). Specific energy influences the additional weight the battery adds to the vehicle, thereby affecting its efficiency. Energy density determines the amount of energy that can be stored in a battery pack of a given size, typically defined by the vehicle's chassis dimensions and shape.

the second consecutive year to reach more than 10% of the EU EV market. Notably, nearly all the LFP batteries for electric cars sold in Europe or the United States were produced in China, which today has a de facto monopoly on this type of battery. Market penetration of LFP batteries is moving even faster in other markets. In Southeast Asia, Brazil and India, the share of electric car batteries using LFP reached more than 50% in 2024. In Southeast Asia and Brazil, LFP uptake is led by imports from China, mostly by BYD, whereas in India it is driven by cars produced domestically, led by Tata Motors.

In the United States, the vast majority (three-quarters) of EVs equipped with LFP batteries are produced domestically, whereas in the European Union nearly two-thirds are imported from China. In both regions, LFP batteries are primarily sourced from China, with Tesla playing a central role – accounting for 85% of LFP battery-powered EVs produced in the United States and almost half of those sold in the European Union. Of Tesla's LFP EVs sold in the European Union, over half are produced in Germany, with the remainder imported from China.

Share of electric vehicle battery sales by chemistry and region, 2022-2024



Notes: LFP = lithium iron phosphate. Low-nickel includes lithium nickel manganese cobalt oxide (NMC) 333, NMC442, and NMC532. High-nickel includes NMC622, NMC721, NMC811, lithium nickel cobalt aluminium oxide (NCA), and lithium nickel manganese cobalt aluminium oxide (NMCA). LFP also includes lithium iron manganese phosphate (LFMP). Battery chemistry sales share is based on the battery capacity of EVs registered in the different regions. This calculation assumes that 95% of electric trucks, buses and light commercial vehicles sold in China use LFP, and that 70% of electric trucks and electric buses sold outside of China use high-nickel chemistries. Two/three-wheelers are excluded from the analysis. Battery sales reflect the batteries installed in vehicles sold in each region, and not the battery demand for vehicles manufactured in each region. Electric vehicle and battery stockpiling are excluded from the analysis.
Sources: IEA analysis based on data from EV Volumes and China Automotive Battery Industry Innovation Alliance.

European OEMs are looking increasingly favourably on LFP batteries as a way of reducing production costs and are therefore interested in securing more supplies. Initiatives such as the recently announced joint venture between Stellantis and CATL for an LFP battery manufacturing plant of up to 50 GWh in Spain could therefore help the European automotive industry to reduce costs and increase its competitiveness in the coming years. However, investments in LFP battery manufacturing in Europe might suffer as a result of the recent proposition from the Chinese government to limit exports of key battery technologies, including LFP cathode production and lithium processing. Overall, renewed interest in the LFP chemistry exacerbates the difficulties facing the European battery industry, which has historically focused on NMC batteries.

The year 2024 was a challenging one for the European battery industry, with both small and large producers suffering for different reasons. New players such as Northvolt, which filed for bankruptcy in the United States and Sweden, faced serious difficulties in scaling up production, leading to insufficient manufacturing yield and high production costs. The case of Northvolt was further aggravated by limited experience, ambitious expansion plans, and excessively widened scope, leading to insufficient focus on scaling up high-quality battery cell production. Falling battery prices worldwide also weighed heavily on small producers, which have fewer resources and insufficient production volumes to withstand lower profit margins, and are now turning to a more cautious growth path.

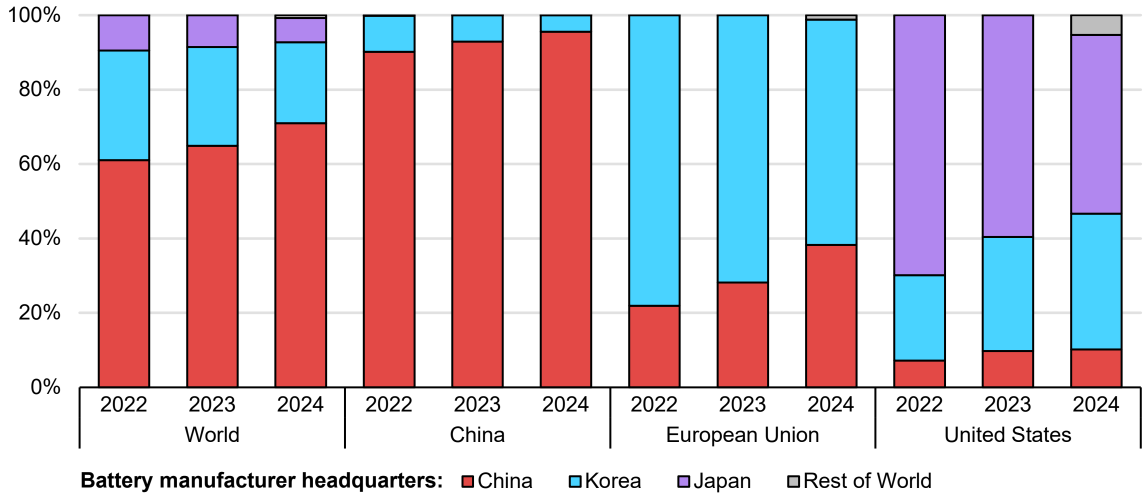
Korean companies, such as LG Energy Solution in Poland, are the largest battery producers in Europe, but their market share is also under pressure. Over the past 2 years, the market share of Korean manufacturers in the European Union has fallen from nearly 80% in 2022 to 60% in 2024, to the benefit of Chinese manufacturers. A key reason for this is the increased success of the LFP chemistry. In contrast, the share of Korean companies in the United States grew from about 20% in 2022 to over 35% in 2024, at the expense of Japanese manufacturers.

Korean manufacturers are rising to the challenge and are now investing in LFP, including through innovation efforts, and are scaling up LFP battery production, including in Europe and the United States. LFP battery development is also advancing in Japan: In early 2025, Nissan announced plans to build an LFP battery plant after receiving government certification in late 2024. Yet Chinese manufacturers are continuing to innovate LFP chemistry and performance simultaneously, further raising the bar for other producers. At the same time, the Chinese government's proposed export restrictions on advanced LFP technologies could limit technology transfer.

In the United States, Panasonic – historically Tesla's main battery partner – remained the country's largest battery producer in 2024, accounting for nearly half of the electric car market. However, its share is declining as Korean producers like LG Energy Solution, Samsung and SKI invest heavily in the US market. Tesla also ramped up its own battery production in 2024, primarily for use in the Cybertruck.

Battery production in the United States is expanding rapidly, spurred by the implementation of tax credits. Manufacturing capacity has doubled since 2022, reaching more than 200 GWh in 2024, with nearly 700 GWh of additional capacity under construction. Around 40% of existing and committed capacity is being operated or developed by established battery makers in close collaboration with automakers. Nevertheless, the cost of production remains higher than in Asia, if not accounting for incentives, and sudden policy shifts could affect the emerging US battery industry, increase production costs, or slow expansion in the near to medium term.

Share of electric car battery sales by battery manufacturer's headquarters, 2022-2024



Notes: Battery refers to battery cells. It reflects the batteries installed in vehicles sold in each region, and not the battery demand for vehicles manufactured in each region. Electric car and battery stockpiling are excluded from the analysis.
Sources: IEA analysis based on data from EV Volumes.

Battery innovation is accelerating, and it is not limited to new chemistries

Advanced battery technologies under development include solid-state, sodium-ion, lithium-sulphur, iron-air, and redox-flow batteries, among others. Some of them, like iron-air and redox-flow batteries, target different applications to established lithium-ion technologies, such as longer-duration storage for grid applications. Others, like sodium-ion batteries, aim to reduce dependence on lithium. Lastly, technologies like solid-state and lithium-sulphur batteries could also accelerate electrification in sectors that require or would benefit from higher energy densities, such as long-haul electric trucks or short-haul boats and planes. However, their deployment in these sectors will depend on meeting stringent safety requirements and on their total cost of ownership.

Sodium-ion batteries gained significant attention in 2022 as lithium prices surged, leading to the first EVs using the technology. Despite enthusiasm waxing and waning as a result of material supply chain challenges and falling lithium prices in 2023 and 2024, CATL – the world's largest battery producer – announced its second generation of sodium-ion batteries in 2025, alongside the launch of a dedicated sodium-ion battery brand. Meanwhile, BYD is also investing in sodium-ion battery production for EVs and battery storage. In March 2025, HiNa launched its new sodium-ion battery, which offers improved energy density and faster charging compared to the previous generation, heralding a promising year for this technology. However, recent analyses indicate that sodium-ion batteries will require either increased energy density or more favourable operating conditions – particularly higher lithium prices – to compete with LFP batteries on a price per kWh basis. Nevertheless, sodium-ion technologies could play a significant role during times of elevated lithium prices and may offer a cheaper option for batteries in cold climates, where LFP batteries typically perform less well.

In 2024, **solid-state batteries** moved closer to commercial reality with new large prototypes and manufacturing investments from Samsung SDI, Toyota, NIO, Honda, Quantum Scape, BASQUEVOLT, and Factorial, among others, and the creation of a government-led Chinese battery alliance, including large producers such as CATL, BYD, SAIC and Geely, to accelerate solid-state battery development. Despite this, their potential advantages, including enabling higher ranges and safety, still need to be demonstrated for battery packs manufactured at scale and tested under controlled, realistic and standardised conditions. The technology readiness level (TRL) of solid-state batteries therefore remains at large pilot stage (TRL 6), although this could change rapidly with companies like Toyota and BYD planning first mass production by 2027-2028. However, volumes will be limited initially, and it will take several years following roll-out for solid-state batteries to eventually become competitive with lithium-ion batteries. Additionally, "solid-state batteries" is often used as a generic term covering a range of options between fully solid-state and incumbent lithium-ion batteries, which creates some confusion. The first "solid-state batteries" to be commercialised might be semi- or quasi-solid-state batteries – for example using gel-like electrolyte[2] or incorporating small volumes of liquid electrolytes – as they could help address some scale-up challenges and reduce production costs.

Lithium-sulphur (Li-S) batteries, promising higher specific energy (Wh/kg) and lower reliance on critical minerals, have also gained momentum. The US start-up Lyten announced the world's first Li-S gigafactory, while Stellantis partnered with Zeta to commercialise this technology by 2030. However, several challenges remain, including improving volumetric energy density (Wh/L), enhancing

[2] French company Blue Solutions already markets a semi-solid-state battery using lithium metal anode and a gel electrolyte that requires the battery to be heated during use, and plans to invest more than EUR 2 billion in a factory in France by 2030.

durability, and addressing safety concerns related to the use of lithium metal anodes. Overcoming these hurdles will be key to enabling real-world applications.

Advances in battery **recycling** are also being made, for example combining pyrometallurgy and hydrometallurgy processes, increasing the recovery efficiency of reactive metals such as lithium, recycling the graphite in the anodes, or through the development of new recycling approaches, such as electrochemical extraction. However, recycling feedstock availability remains limited, restricting the impact of recycling in the short term (see Box below).

Options for **battery reuse** at the end of their first life for less demanding applications are also under development, with the majority of companies in the sector based in Europe. However, the economic viability of reuse is complicated by upstream competition from recyclers looking for access to end-of-life batteries, downstream competition from the falling prices of new batteries, and challenges associated with battery dismantling and repurposing while ensuring strict safety standards. Second-hand EV markets may play a larger role in supporting reuse and also increasing affordability.

Innovation extends far beyond battery chemistries, and the already broad landscape of battery innovation is getting even broader.[3] In 2023 and 2024, there was a remarkable surge in **improvements for incumbent lithium-ion batteries**, from superfast charging and "no-degradation" batteries to ultra-energy-dense batteries and new charging platforms, manufacturing processes, cell formats and pack designs, among others. Advances in manufacturing are also notable: for example, artificial intelligence for image analysis can enable the early detection of battery defects and their root causes, thereby improving production yields and reducing scrap rates. This capability is critical for scaling up production given the pace of modern gigafactories – a 50 GWh facility can produce up to 10 million (cylindrical) or hundreds of thousands (prismatic) EV battery cells per day.[4] The nature and pace of innovations in legacy technologies are already making a big impact on the market, posing a formidable challenge for emerging technologies to compete.

[3] See IEA (2025) State of Energy Innovation for deeper insights into how this landscape is evolving.
[4] Assuming an average plant utilisation factor of 85% over the year, a cell voltage of 4 volts, and a cell capacity of 60 ampere hours (prismatic) and 3 ampere hours (cylindrical).

Battery recycling is important, but its benefits will take time to materialise

Battery recycling is crucial for the battery industry's long-term sustainability, and is being promoted by industry organisations and governments through dedicated investments and regulations. For instance, the EU Batteries Regulation sets requirements for minimum recycling efficiency and recycled contents that will increase progressively. Recycled battery metals such as nickel, cobalt and lithium can incur 80% less GHG emissions than primary materials produced from mining and refining, while also reducing local environmental impacts, including water use and biodiversity loss near mines.

In addition to sustainability, governments are prioritising supply chain security. Recycling can enhance resilience for consumer countries without direct access to battery minerals, but only if there is a simultaneous development of the midstream battery supply chain, particularly the cathode active material (CAM) industry. To realise the security benefits, end-of-life batteries must be recycled, and the recovered minerals processed and utilised domestically, or in a partner country, to produce CAMs for batteries. However, the CAM industry is progressing more slowly than the battery industry in Europe and the United States. In the absence of a domestic industry, the recycled minerals would need to be exported for processing and then reimported as CAMs, or within batteries or EVs, thereby forfeiting the supply chain security advantage.

Recycling industries in Europe and North America have focused on NMC batteries – the main chemistry used for electric cars in these regions, but advances in LFP batteries are now making them more attractive outside of China, where LFP already leads the EV battery market. The rise of cheaper batteries such as LFP poses a challenge to the economic viability of battery recycling, which requires sufficiently high concentrations of valuable minerals in batteries to be profitable. Nevertheless, this does not preclude LFP battery recyclability, and NMC recycling facilities can be modified to process LFP batteries, though this might require different business models. Toll-based models – through the implementation of gate fees – can ensure the economic viability of LFP recycling, especially when lithium prices are low. Regulations would need to define how these toll fees are distributed to guarantee the proper management of all end-of-life batteries.

It will take time for the battery recycling industry to significantly affect primary mineral demand, as feedstock remains limited and EV batteries may last longer than previously expected. End-of-life EV and storage batteries are expected to account for only one-third of recyclable feedstock by 2030 and even less in the interim, with manufacturing scraps making up the rest. It will require about a decade for end-of-life batteries to become the main feedstock. In 2035, if countries fulfil their announced climate pledges, recycling would reduce global primary demand for cobalt by over 15% (40% in 2050), and for lithium and nickel by only about 5% (25% in 2050).

Battery production and trade

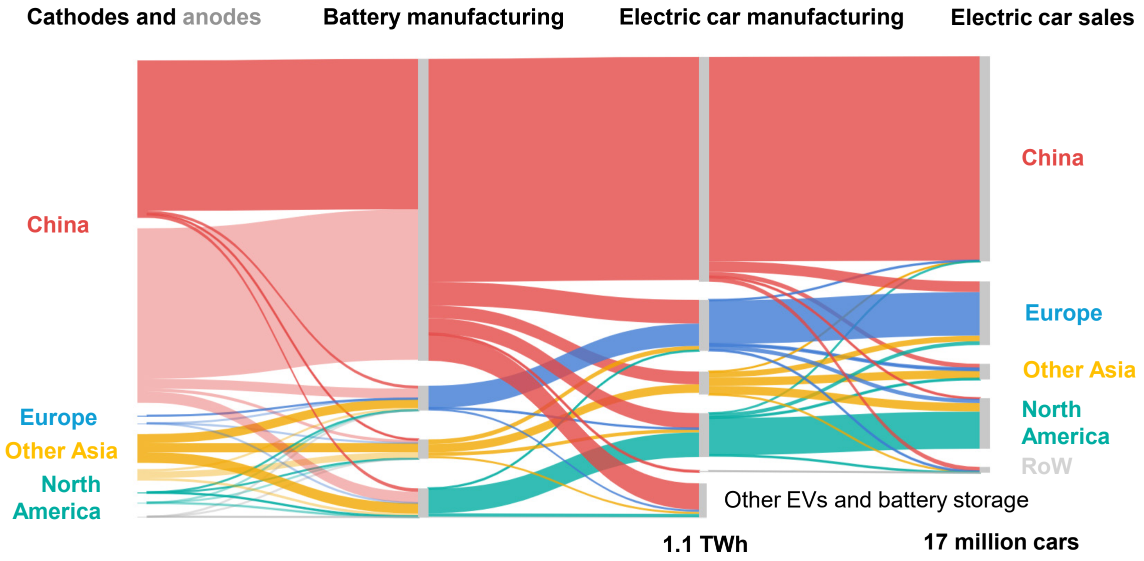
The battery market is being reshaped by two distinct trends: increasing consolidation, and government-led efforts to geographically diversify battery supply chains. Whereas markets used to be regionalised and small, they are now global and very large, and uncertainty over technological development is giving way to standardisation. In this new phase, economies of scale, partnerships along the supply chain, manufacturing efficiency, and the capacity to bring innovations swiftly to market will be even more crucial for manufacturers to remain competitive.

The battery supply chain remains geographically concentrated

The EV and battery supply chain becomes increasingly geographically concentrated when moving upstream from car manufacturing to battery cell and component production. China was responsible for 80% of global battery cell production in 2024, while the remainder was produced in the United States, the European Union, Korea and Japan. Importantly, the production of lithium-ion battery manufacturing equipment is also highly concentrated, with China, Korea, and Japan leading the market. China has also established a near monopoly on battery components production, supplying almost 85% of cathode active materials – including NMC and LFP chemistries – and over 90% of anode active material production, predominantly graphite. Outside of China, only Korea and Japan offer sizeable production capacity for cathode components. Korea also produces anodes, and Indonesia is expected to bring some diversification to the market. Nonetheless, China is set to remain the largest producer of batteries and their components by some distance in the medium term, based on announced projects and competitive advantages.

The geographical concentration of battery mineral mining and refining needed for battery cathodes and anodes is also a concern. In 2023, Australia, Chile and China mined about 85% of global lithium, with almost 65% refined in China and another 25% in Chile. Indonesia accounted for over half of nickel mining in 2023, while China and Indonesia together refined more than 60%. In the same year, the Democratic Republic of Congo was home to almost two-thirds of the world's cobalt mining, though three-quarters of all cobalt refining was handled in China. Graphite supply, the only critical mineral used for anodes today, is even more concentrated, with China responsible for 80% of mining and over 90% of refining.

Global manufacturing and trade flows of electric cars, lithium-ion batteries, and key components, 2024



Notes: RoW = Rest of World; EV = electric vehicle; Cathodes and anodes refer to cathode and anode active materials. Flows are normalised to the battery (cell) manufacturing step, with cathode and anode active materials normalised such that their sum is scaled to the battery cell volume. Numbers below the charts refer to the total demand, not only the traded volume. The lighter-colour version of the flows going to battery manufacturing represents the anodes (anode active materials). Battery applications different from EVs and battery storage are excluded from the analysis. Electric vehicle and battery stockpiling are excluded from the analysis.

Sources: IEA analysis based on EV Volumes, Benchmark Mineral Intelligence, and Bloomberg New Energy Finance.

Battery manufacturing capacity continues to grow

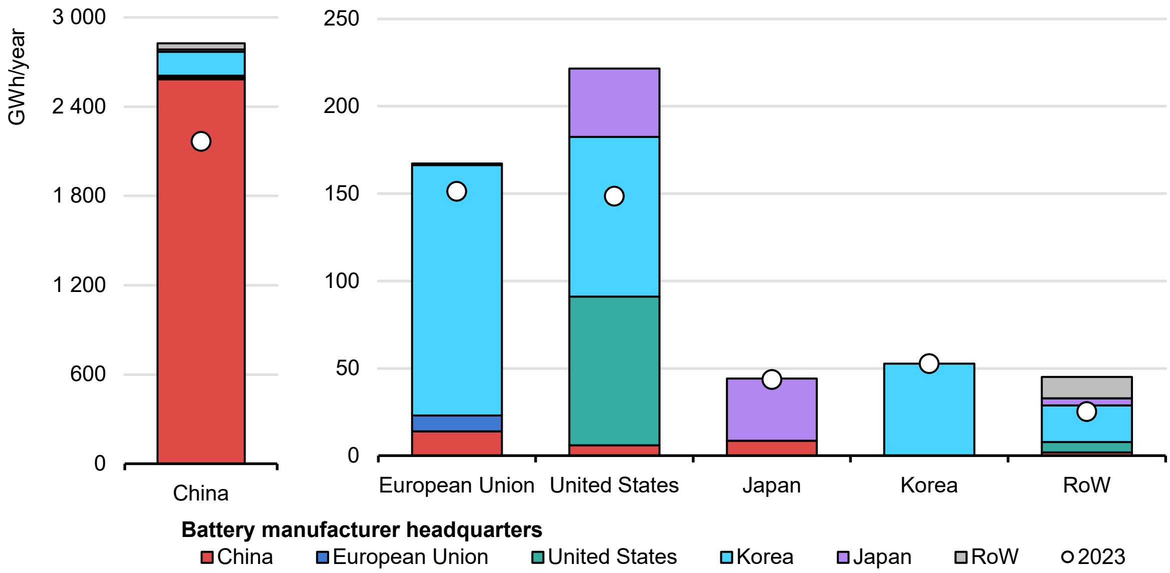
Global battery (cell) manufacturing capacity grew almost 30% in 2024 to reach more than 3 TWh – three times EV and battery storage demand in the same year. About 85% of global manufacturing capacity is in China, showing little change from 2023, and over 75% is owned by Chinese producers. Manufacturing capacity in the United States grew by almost 50%, led by Korean companies attracted by tax credits, which accounted for nearly 70% of the growth in 2024. This led installed capacity in the United States to surpass that in the European Union, which nonetheless increased by 10% in 2024 despite the Northvolt plant in Sweden being halted following its bankruptcy. The first Indian and Indonesian battery plants also opened in 2024, totalling more than 5 GWh/year and 10 GWh/year of manufacturing capacity, respectively.

Korean manufacturers remained the largest investors in overseas battery manufacturing capacity,[5] accounting for over 400 GWh globally, compared to 60 GWh for Japanese and 30 GWh for Chinese producers. Korean manufacturers, such as LG Energy Solution (with capacity in Poland), and

[5] This refers solely to existing manufacturing capacity as of 2024, and it accounts only for factories located outside the home country of the battery producer's headquarters.

Samsung and SKI (in Hungary), continue to be the main source of capacity in the European Union, and their importance is growing in the United States. If all announced projects are completed in full, the manufacturing capacity of Korean manufacturers outside of Korea would reach more than 1.1 TWh by 2030, 85% more than the announced overseas manufacturing capacity of Chinese battery producers.

Installed lithium-ion battery cell nameplate manufacturing capacity by region and location of manufacturer's headquarters, 2024

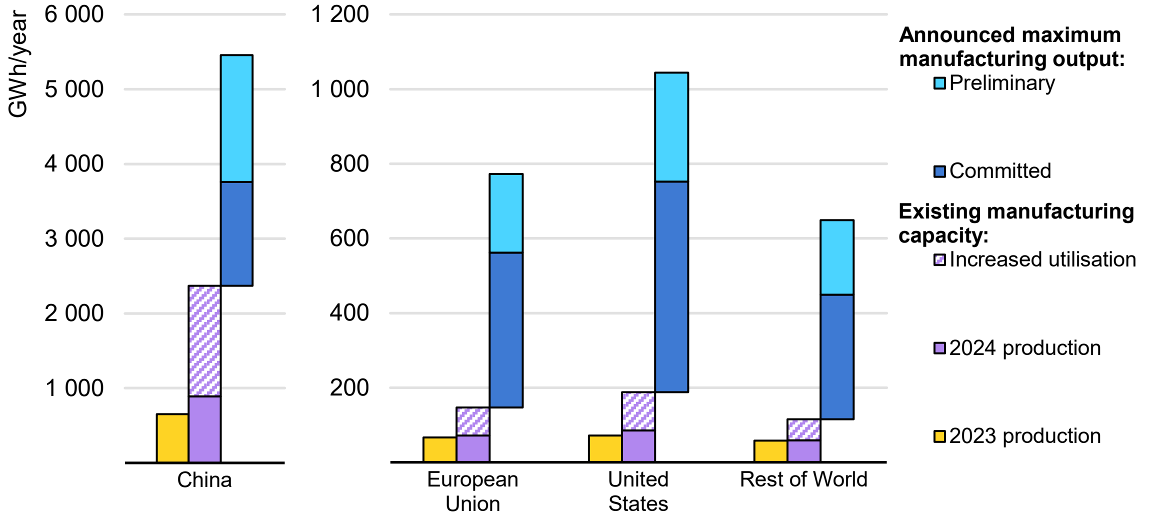


Notes: RoW = Rest of World. Lithium-ion battery manufacturing capacity installed in China, European Union, United States, Japan, Korea, and other countries sorted as a function of the company headquarters location (colours). For companies headquartered in a country but owned by companies headquartered in a second country, the headquarters of the owning company is considered for this analysis. The manufacturing capacity of joint ventures between automakers and battery producers is classified according to the battery producer headquarters.
Source: IEA analysis based on data from Benchmark Mineral Intelligence.

Asian manufacturers are leading battery market expansion

Expansion plans for manufacturing capacity can drive geographical diversification in the battery industry. Committed projects – i.e. those that are either under construction or have reached a final investment decision – would increase manufacturing capacity in China by nearly 60%, and almost quadruple capacity in the European Union and the United States. This expansion would lead global manufacturing capacity to grow to about 6.5 TWh (and more than 9 TWh if accounting for all announcements), up from 3.3 TWh in 2024, and reduce China's share of global manufacturing capacity to about two-thirds by 2030, down from 85% in 2024. Ownership distribution is expected to diversify less, given that capacity expansion is predominantly driven by established manufacturers headquartered in China, Korea or Japan, whose expertise in the battery sector provides a significant competitive edge.

Historical production and announced expansion of battery manufacturing maximum output by region, 2023, 2024 and 2030



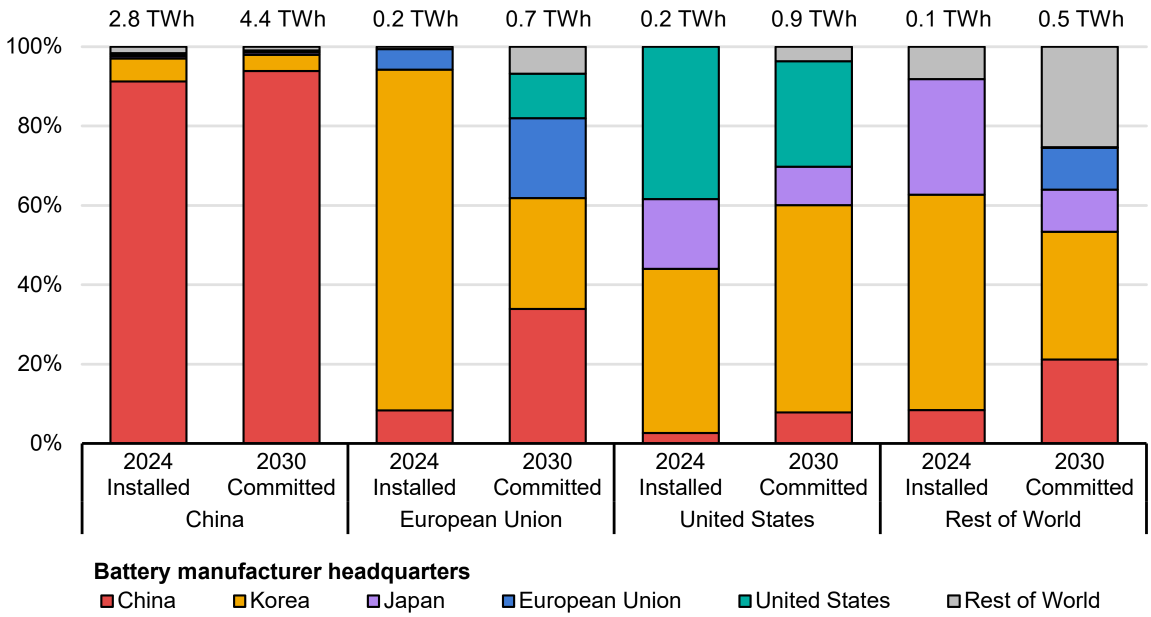
Notes: Increased utilisation refers to the gap between 2023 production levels and existing capacity being utilised at 85%, which is assumed to be the maximum average utilisation rate. A utilisation rate of 85% is also used for both committed and preliminary manufacturing capacity in 2030. Manufacturing capacity refers to companies already certified to serve both the EV and stationary storage markets and companies not yet certified to serve the EV market. Committed refers to plants that have reached a final investment decision and are starting or have already started construction works, and preliminary to plants that have been announced but are not yet being built. Production refers to EV battery and battery storage, and EV and battery stockpiling are excluded from the analysis. Data to end of Q1 2025.

Sources: IEA analysis based on data from Benchmark Mineral Intelligence, Bloomberg New Energy Finance, and EV Volumes.

The European Union is the largest single destination for overseas investments by Chinese battery producers, whose share of manufacturing capacity in the region could quadruple, rising from less than 10% in 2024 to more than 30% by 2030. These investments are an opportunity for technology transfer, bringing the expertise needed to scale up production in the region and drive down costs, which would benefit domestic automakers at a critical time for the industry. However, this may also create challenges for the region's established and emerging battery producers.

The share of battery manufacturing capacity in the European Union owned by Korean producers is expected to fall sharply from about 85% in 2024 to nearly 30% in 2030, while the share of EU-based companies could reach 20%, up from 5% at the end of 2024. However, this includes plants facing significant uncertainty, such as the Northvolt plant in Germany, for which Germany assumed over EUR 600 million in debt, and which is not directly affected Northvolt's bankruptcy. More generally, concerns are growing about the ability of smaller European producers to scale up production and compete with established global players, which may lead to a much smaller share of the future EU battery market being captured by domestic manufacturers.

Share of nameplate manufacturing capacity by region and location of battery producer's headquarters, 2024-2030



Notes: Committed refers to the sum of the installed manufacturing capacity (2024) and plants that have reached a final investment decision and are starting or have already started construction works. Manufacturing capacity refers to battery cells. For companies headquartered in a country but owned by companies headquartered in a second country, the headquarters of the owning company is considered for this analysis. The manufacturing capacity of joint ventures between automakers and battery producers is classified according to the battery producer headquarters. Numbers above each bar indicate the total nameplate manufacturing capacity in terawatt-hours (TWh) of batteries per year. Data to end of Q1 2025.

Sources: IEA analysis based on data from Benchmark Mineral Intelligence and Bloomberg New Energy Finance.

Collaboration between Korean or Japanese battery producers and OEMs operating in the United States is proving successful, with Korean companies leading investments in the country. They held or participated in 40% of the battery manufacturing capacity in the United States in 2024, and committed investments are expected to boost their share to over 50% by 2030. Meanwhile, based on committed projects, the share of Japanese companies would fall by almost half by 2030, and that of domestic companies like Tesla would drop from nearly 40% in 2024 to less than 30% in 2030. In addition, some companies primarily or fully owned by Chinese groups, such as Envision and Gotion, have also invested or announced plans to invest in the United States, but recent policies might lead to the cancellation of these plans.

Outside of today's three main EV markets, 60% of committed capacity is set to be added in other advanced economies thanks to growing demand and government support, including in Canada, other European countries, Korea, and Japan. The remaining more than 150 GWh of committed manufacturing capacity is being built in Southeast Asia, India and Morocco. Although these regions have attracted fewer investments to date due to limited domestic battery demand, they are increasingly generating interest from battery manufacturers.

Southeast Asia is attracting significant Chinese investments, which could speed up technology and innovation transfer. Indonesia, home to half the world's mined nickel needed for NMC batteries, is also investing heavily in battery component production – such as cathode and anode active materials – and its first graphite anode plants began production in 2024. India also has the potential to unlock a substantial battery market and is investing in domestic battery production, but realising its ambition to become a major battery manufacturer will require additional investments and clear policy signals supporting EV demand. In Morocco, abundant phosphate reserves – a mineral essential for LFP batteries – along with an established car manufacturing industry and free trade agreements with the European Union and the United States, have spurred over USD 15 billion in announced investments. These investments comprise lithium processing and battery and component manufacturing, including a large battery manufacturing plant of 100 GWh, the first in Africa.

8. Outlook for energy demand

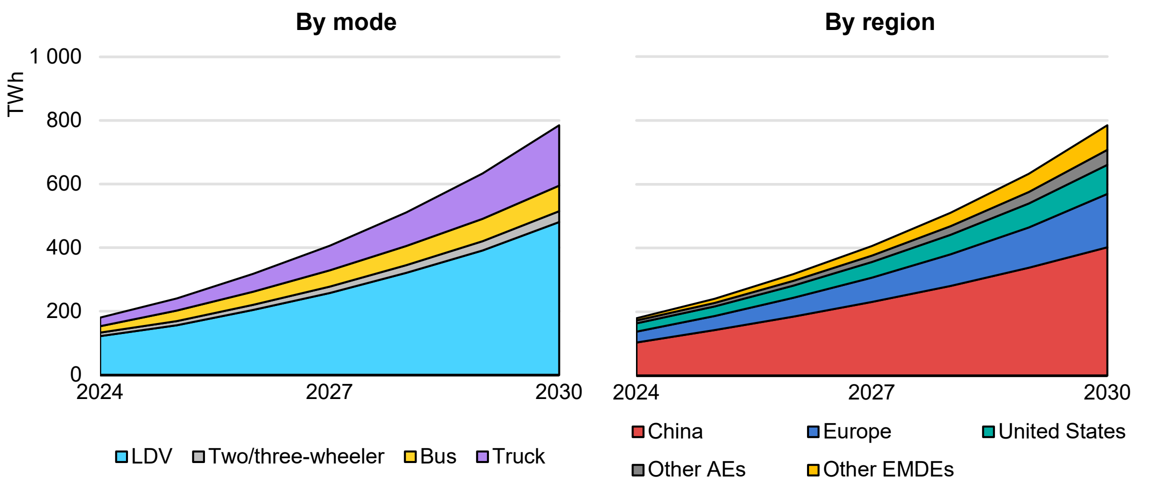
Electricity demand

Electric vehicles could account for more than 4% of European electricity demand by 2030

In 2024, the global fleet of EVs consumed around 180 TWh of electricity,[1] almost 60% more than the previous year. To put this in perspective, 180 TWh is more than the annual electricity consumption of Argentina. At the global level, EVs represented about 0.7% of final electricity consumption in 2024.

The stock of EVs is set to more than triple to 2030, but electricity demand could increase more than fourfold, reaching 780 TWh in the STEPS. This is driven by increasing consumption from electric trucks, as well as greater EV uptake in markets where people drive more per year. Total energy demand for road transport increases by only 5% in 2030 in the STEPS, while total road activity (in terms of vehicle kilometres travelled) increases by almost 20% during the same period, reflecting the greater energy efficiency of EVs.

Electricity demand by mode and by region in the Stated Policies Scenario, 2024-2030



Notes: LDV = light-duty vehicle; AEs = advanced economies; EMDEs = emerging markets and developing economies. 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. Regional data can be interactively explored via the Global EV Data Explorer.

[1] Electricity demand includes vehicle charging losses, which vary based on charging speed; it does not include transmission and distribution losses. For further information, see the model documentation.

Globally, electric LDVs remain the greatest consumer of electricity for road transport, though their share of road electricity demand falls by around 5 percentage points in 2024 to slightly above 60% in 2030 in the STEPS. In China in 2024, LDVs were responsible for only around 55% of road electricity demand, and this remains the same in 2030 in the STEPS, illustrating China's success in EV adoption across a range of applications. In contrast, over 90% of electricity demand for road in the United States came from electric cars in 2024, though this falls to around 75% in 2030 in the STEPS, as demand from electric buses and commercial vehicles picks up. In Europe, the increasing number of electric heavy-duty trucks means their share of road transport electricity demand increases from less than 5% to more than 20% in 2030 in the STEPS.

In both China and Europe, the share of electricity demand from EVs reached the milestone of 1% in 2024. By 2030 in the STEPS, the share of electricity for EVs in Europe exceeds the share in China, as electricity demand for other end uses, such as industry and buildings, grows faster in China than in Europe. Globally, EVs represent 2.5% of electricity demand in 2030 in the STEPS.

Share of electricity consumption from electric vehicles relative to final electricity consumption by region and scenario in the Stated Policies Scenario, 2024 and 2030

Country/region	2024	2030
China	1.2%	3.6%
Europe	1.0%	4.3%
United States	0.6%	2.2%
Japan	0.1%	0.5%
India	0.2%	1.1%
Southeast Asia	0.2%	1.0%
Latin America	0.1%	1.0%
Global	0.7%	2.5%

Notes: Total electricity consumption is taken from the IEA's Global Energy and Climate Model (GEC-Model). Regional data can be interactively explored via the Global EV Data Explorer.

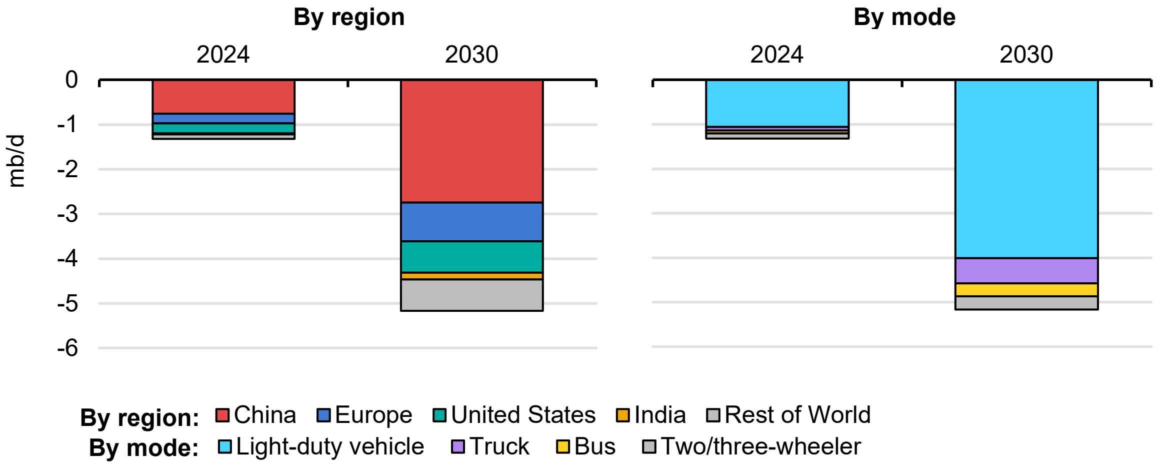
Oil displacement

Electric vehicles displace more than 5 mb/d by 2030

Expanding EV adoption continues to reduce oil demand, with oil displacement growing by 30% to over 1.3 mb/d in 2024 – equivalent to Japan's entire transport sector oil demand today. By the end of the decade, EVs are set to displace over 5 mb/d of diesel and gasoline in the STEPS, and China's EVs to account for half of displaced oil.

Electric LDVs drive most of the oil displacement, accounting for 80% today and around 77% by 2030. The relative impact of LDVs becomes smaller over time as technology developments and the expansion of charging infrastructure drive electrification in the heavy-duty segment, with electric trucks and buses together displacing nearly 1 mb/d in the STEPS by 2030.

Oil displacement by region and mode in the Stated Policies Scenario, 2024-2030



Notes: Oil displacement is based on internal combustion engine (ICE) vehicle fuel consumption to cover the same mileage as the electric vehicle (EV) fleet. Oil displacement is calculated by assuming that the distance (total kilometres) travelled by EVs by segment each year would have been otherwise travelled by ICE vehicles or hybrid electric vehicles (HEVs). In the case of plug-in hybrid electric vehicles (PHEVs), where the powertrain uses both oil-based fuel and electricity, only the distance covered by electricity is included. This method of estimation assumes that EVs replace ICE or hybrid vehicles of the same segment, and that these vehicles follow the same driving behaviour. The accuracy of this assumption is uncertain; there is some evidence to suggest that EVs are driven further than their ICE counterparts, for example.

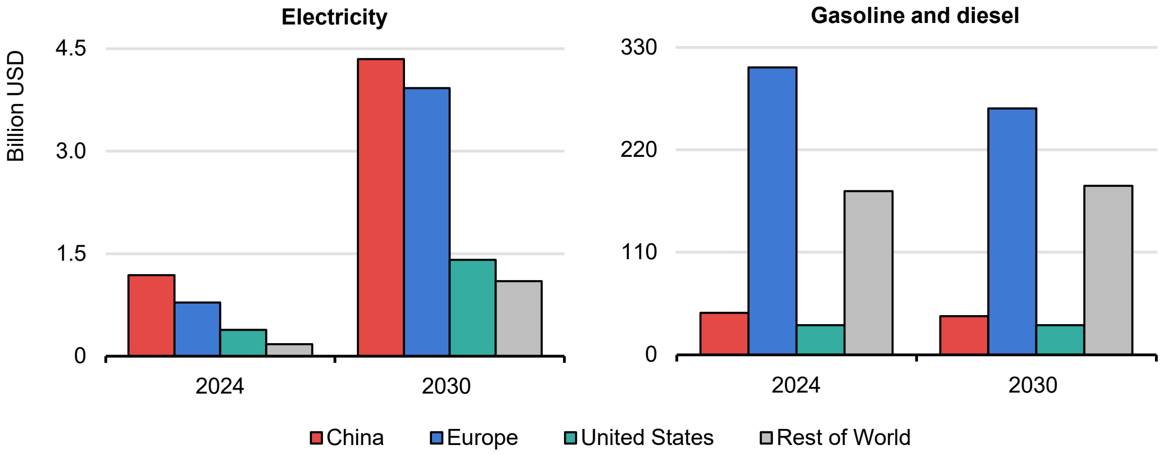
Governments will need to adapt tax policies to ensure both future revenues and growth of electrification

One of the primary financial challenges of vehicle electrification for governments is the resulting reduction in revenue from fossil fuel taxes. While efficiency improvements in ICEs have already had an impact on tax receipts, the fuel shift could lead to a further decline in tax income. Although EV drivers contribute to additional revenue through electricity taxes, this remains insufficient to fully compensate for the loss in gasoline and diesel tax income.

In 2024, electricity tax revenue increased by nearly 50% to reach more than USD 2.5 billion globally, while gasoline and diesel tax revenues accounted for USD 560 billion. As the global EV stock continues to rise, fossil fuel tax revenue is projected to decrease significantly to nearly USD 520 billion by 2030 in the STEPS, while electricity tax revenue grows to over USD 10 billion. If the decline in fossil fuel tax revenue is not compensated with alternative taxation measures, the effect of electrification displacing gasoline and diesel would result in a net tax shortfall for governments reaching more than USD 65 billion globally by 2030. In this scenario, Europe would account for 55% of net tax shortfall if no changes are made to fuel taxation.

China's fossil fuel tax revenues are projected to decrease from USD 45 billion to USD 41 billion as the share of electric cars in the total fleet rises to around 35% by 2030 in the STEPS. However, the increase in China's electricity tax revenue due to vehicle fleet electrification would nearly fully offset the loss. In Europe, which sees the largest decrease in fossil fuel tax revenue, the net impact of electrification is expected to result in a tax revenue decline of USD 40 billion in the STEPS by 2030. In the United States, fossil fuel tax revenue is projected to increase by USD 0.1 billion due to slow electrification and growth in the overall vehicle fleet. Meanwhile, the rest of the world is set to experience an increase in combined fossil fuel and electricity tax revenue totalling around USD 6.5 billion by the end of the decade, driven by expected growth in both ICEs and EVs.

Electricity, gasoline and diesel tax income by region, 2024, and in the Stated Policies Scenario, 2030



Notes: Fuel tax rates are assumed to remain constant. Only federal tax rates are included.
Source: Analysis based on tax rates from IEA Energy Prices.

Tax reforms to address tax income loss due to rising electromobility have tended to target three main areas: energy use (e.g. fuel excise duty), vehicle stock (e.g. registration tax) or road use (e.g. road tolls). For example, New Zealand ended its exemption for EVs from road use charges in 2024, and its new rate of NZD 76 (New Zealand dollars) (USD 46) per 1 000 km for BEVs is estimated to have generated tax revenue in the order of USD 50 million in 2024. To stabilise tax revenues, Norway, a world leader on electromobility, with nearly 90% share of car sales being battery electric in 2024, introduced a vehicle weight tax of NOK 12.08 Norwegian kroner (USD 1.1) per kilogramme on BEVs, generating around USD 0.15 billion in 2024. Prior to this, in 2023, Norway introduced a 25% VAT rate on BEVs priced at more than NOK 500 000 (around USD 46 000), and estimates having earned around (USD 0.14 billion) in 2024 from this new VAT tax measure. However, maintaining the VAT exemption for battery electric cars priced below NOK 500 000 resulted in revenue loss of around NOK 13 billion (USD 1.2 billion).

Prior to 2025, the United Kingdom waived vehicle excise duty (VED) for electric, zero, or low-emission cars, vans and motorcycles. From 1 April 2025, however, new electric cars are taxed GBP 10 (USD 13) in the first year and the standard rate, GBP 195 (around USD 255), in subsequent years. This measure boosts government coffers by nearly USD 3 billion by 2030 in the STEPS. Considering the gain from EV VED alongside the reduction in VED from ICE vehicles, the net tax increase from total car VED is projected to reach more than USD 1 billion by 2030.

Another option open to policy makers could be taxing vehicles based on efficiency, rather than imposing a flat rate, which would mean owners of less efficient, older vehicles bear a higher tax burden. While this could further incentivise EV growth, it might disproportionally affect people in lower-income demographics who are more likely to own an older vehicle, potentially reducing the public acceptance of electromobility in the long-term.

Similarly, there is a risk of public pushback in response to the introduction of taxes on EVs to cover fuel excise duty losses. To minimise this risk, any tax reform will need to be designed in a way that protects low-income households, while avoiding penalising early EV adopters. As the shift towards EVs continues, it will be essential for governments to introduce tax measures that gradually address the revenue gap while continuing to incentivise a just transition to a low-emissions transport system.

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Annex

Annex A: Total cost of ownership

The truck total cost of ownership (TCO) analysis uses the following inputs and assumptions.

Works consulted

General literature that contributed to developing the methodology and validating assumptions and values used in the total cost of ownership (TCO) analysis

Institution	Components	Includes estimates or references for
European Commission	HRS, EV charging	Capital and installation costs over time, for a variety of scales, operation and maintenance cost, lifetimes
NREL	EV charging	Capital and installation costs, maintenance and land costs, effect of scale
Ricardo	Diesel, battery electric and fuel cell trucks	Component costs for all three powertrains, low, average, high values for each, indirect costs and margins, component sizing
ICCT	Diesel, battery electric and fuel cell trucks	TCO analysis, residual value, truck retail price by class, component costs and sizing over time, financing assumptions, maintenance costs, Europe-focused
ICCT	Diesel, battery electric and fuel cell trucks, EV charging	TCO analysis, residual value, component costs and sizing over time, financing assumptions, maintenance costs, United States-focused
UC Davis	Diesel, battery electric and fuel cell trucks	TCO analysis, residual value, component costs and sizing, financing assumptions, maintenance costs, United States-focused
TNO	Diesel, battery electric and fuel cell trucks, HRS, EV charging	TCO analysis, residual value, component costs and sizing over time, margins, financing assumptions, maintenance costs, Europe-focused
NREL	Diesel, battery electric and fuel cell trucks	TCO analysis, dwell time considerations, residual value, component costs and sizing, financing assumptions, maintenance costs, various duty cycles, United States-focused
UC Davis	Diesel, battery electric and fuel cell trucks	Maintenance and repair costs for the three powertrains over time

Institution	Components	Includes estimates or references for
BNEF*	Battery electric truck	Battery pack prices for commercial BEVs in 2024
ITF	Diesel, battery electric and fuel cell trucks	Methodology, limitations, uncertainty analysis

Notes: HRS = Hydrogen refuelling station; EV = electric vehicle; BEV = battery electric vehicle; ICCT = International Council on Clean Transportation, ITF = International Transport Forum, NREL = National Renewable Energy Laboratory, TCO = Total cost of ownership, *the specific report from which the figures are derived is behind a paywall.

Vehicle production costs, specifications, and payload

Truck powertrain components in the United States, the European Union, and China used in the analysis

Powertrain type	Component	Value
Diesel	**Engine power**	325 kW
Battery electric	**Electric drive power**	350 kW
	Battery pack size	800 kWh
	On-board charger	44 kW
Fuel cell electric	**Electric drive power**	350 kW
	Fuel cell power	362 kW
	Battery pack size	70 kWh
	On-board charger	6.6 kW
	700 bar hydrogen tank size	60 kg

Notes: Powertrain sizing values are for a United States class 8 (or equivalent) tractor truck. The 60 kg hydrogen tank has a usable capacity of 50 kg. Fuel cell power is sized to provide 275 kW of power after 25 000 hours of operation.

Sources: Diesel engine power and battery electric battery pack size are adapted from National Renewable Energy Laboratory, fuel cell stack and fuel cell battery sizing are taken from US Department of Energy, electric drive power, on-board charger, and hydrogen tank sizes are taken from Riccardo.

Direct manufacturing costs of powertrain components in the United States, the European Union, and China used in the analysis, 2024 and 2030

	Units	United States		European Union		China	
Component	**2024 USD**	**2024**	**2030**	**2024**	**2030**	**2024**	**2030**
Electric drive	USD/kW	80	75	70	70	44	42
Power electronics (e-drive inverter box)	USD/kW	27	26	24	24	15	14
DC/DC converter	USD	540	525	485	470	295	290
Heating, Ventilation, and Air Conditioning; electrical and air brakes	USD	8555	8340	6590	6425	2995	2920

Component	Units 2024 USD	United States 2024	United States 2030	European Union 2024	European Union 2030	China 2024	China 2030
Battery and electronics thermal management (BEV)	USD/kW	19	17	17	16	11	10
Battery and electronics thermal management (FCEV)	USD/kW	8	7	7	7	5	4
Fuel cell system	USD/kW	365	230	330	210	200	130
Battery (FCEV)	USD/kWh	510	385	510	385	280	210
Battery (BEV)	USD/kWh	190	100	190	100	85	70
On-board charger	USD/kW	65	60	60	55	36	33
700-bar hydrogen tank	USD/kg	1220	1035	1095	930	670	570

Notes: "BEV" = battery electric vehicle; "FCEV" = fuel-cell electric vehicle. "Battery" includes battery cells, pack and the battery management system. In the case of BEVs the battery chemistry is assumed to be lithium iron phosphate (LFP), for FCEVs it is lithium nickel cobalt manganese oxide (NMC). "Fuel cell system" costs include economies of scale and learning effects equal to production volumes of 1 000 units and 20 000 units per year in 2024 and 2030, respectively. Values below USD 50 have been rounded to the nearest USD 1; values above USD 50 have been rounded to the nearest USD 5.

Sources: Battery costs are adapted from Bloomberg New Energy Finance, fuel cell system costs are adapted from US Department of Energy, electric drive, battery and electronics thermal management, on-board charger, DC/DC converter, hydrogen tank, and power electronics are adapted from Riccardo.

Estimated purchase price of a heavy-duty diesel truck in the United States, the European Union, and China used in the analysis, 2024 and 2030

	United States 2024	United States 2030	European Union 2024	European Union 2030	China 2024	China 2030
Driveline, cab, and chassis	40 400	39 300	31 100	30 300	14 100	13 800
Powertrain	66 000	69 300	48 400	53 400	23 100	24 300
Manufacturing and assembly	7 400	7 600	5 700	5 900	2 600	2 700
Indirect costs and margins	41 000	41 800	31 500	32 300	14 300	14 700
Total	**154 800**	**158 000**	**119 100**	**121 900**	**54 100**	**55 500**

Notes: Prices in 2024 USD for a United States class 8 (or equivalent) tractor truck with a 325 kW engine, as specified in the previous tables. "Powertrain" includes the engine and all balance of plant. Manufacturing and assembly costs are assumed to be 7% of production costs of the components, and indirect costs and margins are 36% of the total production cost, equally applied across all regions. All values are rounded to the nearest USD 100. The bottom-up calculated totals were validated against values from the California Air Resources Board (United States and Europe) and ICCT (China).

Sources: Values for the share of total costs from the driveline, cab and chassis; from manufacturing and assembly costs; and from indirect costs and margins are taken from Riccardo.

Estimated purchase price of a heavy-duty fuel cell electric truck in the United States, the European Union, and China used in the analysis, 2024 and 2030

	United States		European Union		China	
	2024	2030	2024	2030	2024	2030
Finished chassis and cab	40 400	39 300	31 100	30 300	14 100	13 800
Powertrain	41 200	39 200	37 000	35 300	22 600	21 500
Battery	35 800	26 800	35 800	26 800	19 700	14 800
Fuel cell	132 700	84 100	119 400	75 700	73 000	46 300
Hydrogen tank	73 100	62 100	65 800	55 900	40 200	34 200
Manufacturing and assembly	22 600	17 600	20 200	15 700	11 900	9 100
Indirect costs and margins	124 500	96 900	111 300	86 300	65 300	50 300
Total	**470 300**	**366 000**	**420 600**	**326 000**	**246 800**	**190 000**

Notes: Costs are for a United States class 8 (or equivalent) tractor truck with a 380 kW fuel cell system, hydrogen tank with 50 kg of usable capacity, and a 350 kW electric drive unit. Powertrain includes the electric drive unit, electronics and thermal management units, a 70 kWh battery, and all balance of plant. Manufacturing and assembly costs are assumed to be 3% of production costs of the components. with indirect costs and margins of 36% of the total production cost, equally applied across all regions. All values are rounded to the nearest USD 100. The bottom-up calculated totals were validated against values from the California Air Resources Board (United States and Europe) and ICCT (China).

Sources: Values for the share of total costs from the driveline, cab, and chassis; from manufacturing and assembly costs; and from indirect costs and margins are adapted from Riccardo.

Estimated purchase price of a heavy-duty battery electric truck in the United States, the European Union, and China used in the analysis, 2024 and 2030

	United States		European Union		China	
	2024	2030	2024	2030	2024	2030
Finished chassis and cab	40 400	39 300	31 100	30 300	14 100	13 800
Powertrain	47 500	44 900	42 700	40 400	26 100	24 700
Battery	152 000	78 900	152 000	78 900	69 700	55 600
Manufacturing and assembly	16 800	11 400	15 800	10 500	7 700	6 600
Indirect costs and margins	92 400	62 800	87 000	57 600	42 300	36 300
Total	**349 100**	**237 300**	**328 600**	**217 700**	**159 900**	**137 000**

Notes: Costs are for a United States class 8 (or equivalent) tractor truck with a 350 kW electric drive unit, and an 800 kWh battery. Powertrain includes the electric drive unit, electronics and thermal management units, on-board charger, and all balance of plant. Manufacturing and assembly costs are assumed to be 3% of production costs of the components, with indirect costs and margins of 36% of the total production cost, equally applied across all regions. All values are rounded to the nearest USD 100. The bottom-up calculated totals were validated against values from the California Air Resources Board (United States and Europe) and ICCT (China).

Sources: Values for the share of total costs from the driveline, cab, and chassis; from manufacturing and assembly costs; and from indirect costs and margins are adapted from Riccardo.

Estimated maintenance, insurance, and labour costs for battery electric, fuel cell electric, and diesel trucks 2024 and 2030

		Maintenance USD/km		Insurance %		Labour USD/hour	
		2024	2030	2024	2030	2024	2030
Diesel internal combustion engine vehicle	United States	0.26	0.26	3.0%	3.0%	42.1	44.3
	European Union	0.26	0.26	3.0%	3.0%	24.6	26.1
	China	0.18	0.18	3.0%	3.0%	11.6	14.0
Battery electric vehicle	United States	0.19	0.17	3.6%	3.2%	42.1	44.3
	European Union	0.19	0.17	3.6%	3.2%	24.6	26.1
	China	0.13	0.12	3.6%	3.2%	11.6	14.0
Fuel cell electric vehicle	United States	0.22	0.21	4.5%	4.1%	42.1	44.3
	European Union	0.22	0.21	4.5%	4.1%	24.6	26.1
	China	0.16	0.15	4.5%	4.1%	11.6	14.0

Notes: Maintenance costs are the same in years 1-5. Insurance costs are expressed as a share of the capital cost of the truck and represent the first year's premium, every year thereafter premiums fall by 2.5% for diesel vehicles, and 3.5% for battery electric vehicles and fuel cell electric; these figures are estimates derived from stakeholder engagement. Figures for labour cost are inclusive of employer's contributions.

Sources: Maintenance costs are adapted from UC Davis, labour costs are adapted from the International Labour Organization (United States and Europe) and from the Economic Research Institute (China).

Estimated unladen weight of a heavy-duty tractor-trailer, 2024 and 2030

	2024			2030		
	Diesel	BEV	FCEV	Diesel	BEV	FCEV
Truck chassis and cab	6 700	6 700	6 700	5 200	5 200	5 200
Powertrain or motors	2 200	600	600	2 200	600	600
Battery	-	4 200	300	-	3 500	300
Fuel cell	-	-	1 200	-	-	800
Hydrogen tank	-	-	1 800	-	-	1 800
Trailer	7 000	7 000	7 000	7 000	7 000	7 000
Total (kg)	**15 800**	**18 500**	**17 600**	**14 400**	**16 300**	**15 700**

Notes: Estimates are for a United States class 8 (or equivalent) tractor-trailer. The weight of the diesel battery is included in powertrain. Battery electric trucks are assumed to use lithium iron phosphate (LFP), and fuel cell electric trucks lithium nickel cobalt manganese oxide (NMC); in 2024 and 2030 these are assumed to have energy densities of 190 Wh/kg and 230 Wh/kg, and 250 Wh/kg and 280 Wh/kg. All values are rounded to the nearest 100 kg.

Sources: Values for the specific mass of diesel trucks, hydrogen tanks, fuel cells, powertrain or motors, and trailers come from the ICCT, and were validated against assumptions from Riccardo.

Gross maximum vehicle weight of a tractor-trailer combination, derogations, and resulting payload in the United States, the European Union, and China.

	United States		European Union		China	
	2024	2030	2024	2030	2024	2030
Maximum gross vehicle weight	36 300	36 300	40 000	40 000	49 000	49 000
Derogation (current)	900	900	2 000	2 000	0	0
Diesel payload	21 400	22 800	26 200	27 600	33 200	34 600
BEV payload	18 700	20 900	23 500	25 700	30 500	32 700
(penalty relative to diesel)	(12.6%)	(8.6%)	(10.2%)	(7.1%)	(8.1%)	(5.6%)
FCEV payload	19 600	21 400	24 400	26 300	31 400	33 300
(penalty relative to diesel)	(8.3%)	(5.9%)	(6.8%)	(4.9%)	(5.4%)	(3.9%)

Notes: “BEV” = battery electric vehicle; “FCEV” = fuel cell electric vehicle. Payloads are calculated as the maximum gross vehicle weight, minus the estimated unladen weights from the previous table, plus the derogation, if applicable. The US maximum gross vehicle weight is set to the 80 000 lb (36 288 kg) limit and does not include allowances for different configurations, the derogations refers to the 2 000 lb (907 kg) additional allowance for natural gas and electric vehicles but is assumed to also apply to FCEVs as per amendments made to several state laws. The proposed 4 000 kg (additional 2 000 kg on top of existing derogation) in the European Union is not included in the table but would reduce the penalty relative to diesel in 2024 to 2.6% and -0.8%, and in 2030 to -0.2% and -2.4% for BEV and FCEV respectively, with negative values implying they would, in theory, be permitted to run at a greater gross vehicle weight than their diesel counterparts. No derogation currently applies or is proposed for China.

Energy prices and fuel economy

Prices of diesel, electricity, and hydrogen, 2024 and 2030

	Units	United States		European Union		China	
Fuel	2024 USD	2024	2030	2024	2030	2024	2030
Diesel	USD/kWh	0.11	0.12	0.17	0.19	0.11	0.11
Diesel	USD/L	1.14	1.18	1.70	1.88	1.10	1.14
Electricity	USD/kWh	0.16	0.16	0.24	0.23	0.08	0.08
Hydrogen	USD/kWh	0.12	0.15	0.23	0.30	0.15	0.14
Hydrogen	USD/kg H_2	3.88	4.87	7.84	9.88	4.86	4.83

Notes: Hydrogen prices are composed of the weighted levelised cost of production and distribution, an assumed margin of 20%, and 10% tax. Underlying electricity prices are the same at both the depot and during en route charging, with the difference between them due exclusively to the differences in the infrastructure costs.

Fuel economy of diesel, battery electric and fuel cell heavy-duty trucks, 2024 and 2030

Powertrain	Units	2024	2030
Diesel ICEV	kWh/km	3.5	3.5
Diesel ICEV	L/100 km	35.2	34.5
BEV	kWh/km	1.6	1.5
FCEV	kWh/km	2.6	2.4
FCEV	kg H_2/100 km	7.7	7.3

Notes: "ICEV" = internal combustion engine vehicle; "BEV" = battery electric vehicle; "FCEV" = fuel cell electric vehicle. BEV fuel economy based on a charging efficiency of 97.5%.

Infrastructure costs and specifications

Capital and operating costs of a 50 kW and 350 kW heavy-duty electric fast charger, 2024 and 2030

		CAPEX (2023 USD)		OPEX	Utilisation factor
		50 kW	350 kW		(350 kW)
United States	**2024**	23 000	289 500	5%	5%
	2030	19 500	246 500	5%	10%
European Union	**2024**	22 000	218 500	5%	5%
	2030	19 000	185 500	5%	10%
China	**2024**	4 500	31 500	5%	5%
	2030	3 500	27 000	5%	10%

Notes: CAPEX = Capital expenditure and includes installation cost. OPEX = Operating expenditure, which is an annual cost expressed as a share of CAPEX. Utilisation factor refers to the share of hours in a day during which the charger is occupied. It is assumed that each battery electric vehicle requires the installation of one 50 kW charger at the depot, with a 15-year lifetime and 8% discount rate, and no additional land costs. For each year of operation one year of levelised cost of the depot charger is added to the infrastructure costs of the battery electric truck. For the 350 kW charger, vehicle footprint including 10% setback is assumed to be 54m^2 plus 20m^2 per charging pile for the pile itself, cabling, or other equipment. Industrial land values for the United States and Europe are assumed to be USD 1 642/m^2 and USD 242/m^2 in China and include a 23% markup for permitting and preparation. 350 kW charger costs are levelised assuming a 10-year lifetime and 8% discount rate. Diesel refuelling station infrastructure cost of 2% of the sale price of the fuel assumed throughout to account for both capital and operating costs.

Sources: The estimate for additional area required per charging pile is adapted from the ICCT, permitting and preparation costs associated with land purchase are taken from Argonne National Laboratory, industrial land values are adapted from CommercialEdge (United States and Europe) and CEIC (China).

Capital and operating costs of a 700 bar, 2 500 kg/day hydrogen refuelling station, 2024 and 2030

		CAPEX	OPEX		Utilisation factor	Average fill rate
		2023 USD	Fixed	Variable (kWh_e/kg_{H2})		(kg_{H2}/min)
United States	2024	8 840 000	4%	1.4	35%	2.5
	2030	8 030 000	4%	1.4	40%	3.6
European Union	2024	8 840 000	4%	1.4	35%	2.5
	2030	8 030 000	4%	1.4	40%	3.6
China	2024	2 660 000	4%	1.4	35%	2.5
	2030	2 480 000	4%	1.4	40%	3.6

Notes: CAPEX = Capital expenditure and includes installation cost; OPEX = Operating expenditure. "Fixed" is an annual cost expressed as a share of CAPEX, "Variable" is per unit of hydrogen dispensed. For a hydrogen refuelling station "utilisation factor" refers to the share of maximum daily hydrogen capacity which is dispensed each day. Hydrogen is delivered to the station and dispensed as a gas at 700 bar. Costs are levelised assuming a 10-year lifetime and 8% discount rate. A total station footprint of 1 759 m^2 is assumed. Industrial land values for the United States and Europe are assumed to be USD 1 642/m^2 and USD 242/m^2 in China, and include a 23% markup for permitting and preparation. Diesel refuelling station infrastructure cost of 2% of the sale price of the fuel assumed throughout to account for both capital and operating costs.

Sources: Station footprints, as well as permitting and preparation costs associated with land purchase, are taken from Argonne National Laboratory; industrial land values are adapted from CommercialEdge (United States and Europe) and CEIC (China); station costs are adapted from the European Commission.

Methodology

Total cost of ownership base and sensitivity case parameters by scenario, 2024 and 2030

		Parameters for EV chargers and HRS applied to all regions					
		Base case		High cost		Low cost	
		2024	2030	2024	2030	2024	2030
EV charger	UF	5%	10%	2.5%	5%	10%	20%
	Charging power	350 kW	350 kW	150 kW	150 kW	1 MW	1 MW
HRS	UF	35%	40%	17.5%	20%	70%	80%
	Fill rate	2.5 kg/min	3.6 kg/min	1.5 kg/min	1.5 kg/min	3.6 kg/min	5 kg/min
A payload penalty is only applied in the high-cost case							
Payload penalty		United States		European Union		China	
	BEV	12.6%	8.6%	10.2%	7.1%	8.1%	5.6%
	FCEV	8.3%	5.9%	4.9%	5.4%	5.4%	3.9%
Only the diesel fuel price was varied as part of the sensitivity analysis							
Diesel price		High	Low	High	Low	High	Low
	USD/litre	1.39	0.77	2.08	1.44	1.20	0.85

Notes: BEV = Battery electric vehicle; EV = Electric Vehicle; FCEV = Fuel cell electric vehicle; HRS = Hydrogen Refuelling Station; UF = Utilisation Factor. The "high cost" case corresponds to the scenario where the total cost of ownership is expected to be the highest. The "payload penalty" is calculated in a previous table of this Annex. HRS fill rate and charging power impact the total cost of ownership via the "dwell costs", which is the financial penalty incurred when refuelling takes longer than the minimum rest period. In the case of charging power the capital costs also vary.

Driving and refuelling profile

The daily driving range is assumed to be 500 km, where half of the daily distance is travelled before the driver's rest period and the other half afterwards. It is assumed that all truck types refuel during the rest periods. Regulations require rest periods durations of 20, 30, and 45 minutes in China, the United States, and the European Union, respectively. It is assumed that the diesel trucks can sufficiently refuel within the rest periods, and thus incur no dwell costs (see below for how dwell costs are calculated for battery electric and fuel cell electric trucks). En route charging is assumed to occur with 350 kW chargers. Battery electric trucks are also assumed to charge overnight, up to 10 hours, using a 50 kW (peak) charger. It is assumed that the trucks can operate seven days per week, forty-eight weeks per year for a total of 168 000 km travelled per year.

Dwell costs for battery electric trucks

Maximum and minimum charge levels of 20% and 80% are maintained to preserve battery health and for enhanced safety. Battery electric trucks are assumed to charge for the full length of their rest period and during their stay in depot. If required, the battery electric truck remains charging after the rest period until the state of charge is sufficient to complete the remaining 250 km to return to depot, charge overnight at the depot, and then complete the 250 km required to reach the rest period the following day. This additional daily charging, if required, is multiplied by labour cost to give the dwell cost.

Financing period and additional considerations

The truck is purchased with a 100% loan at 5% interest. A discount rate of 8% is applied throughout. The analysis takes into account the first 5 years after the purchase of the truck, equivalent to a total distance travelled of 840 000 km. Diesel trucks have a residual value of 26% throughout, BEV and FCEV trucks are assumed to also have a 26% residual value when purchased in 2024 and 33% if purchased in 2030, after haven driven comparable distances over that period to those modelled in this analysis.

Annex B: United States regional groupings

Mid West

Illinois, Indiana, Iowa, Kansas, Michigan, Minnesota, Missouri, Nebraska, North Dakota, Ohio, South Dakota, Wisconsin

Northeast

Connecticut, Delaware, District of Columbia, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, Vermont

Pacific

California, Oregon, Washington

Rocky Mountain

Colorado, Idaho, Montana, Nevada, Utah, Wyoming

Southeast

Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, South Carolina, Tennessee, Virginia, West Virginia

Southwest

Arizona, New Mexico, Oklahoma, Texas

Annex C: Regional and country groupings

Unless otherwise specified, regional groupings used in the Global EV Outlook and EV data explorers are as follows:

Africa

Algeria, Angola, Benin, Botswana, Cameroon, Côte d'Ivoire, Democratic Republic of the Congo, Egypt, Equatorial Guinea, Eritrea, Ethiopia, Gabon, Ghana, Kenya, Kingdom of Eswatini, Libya, Madagascar, Mauritius, Morocco, Mozambique, Namibia, Niger, Nigeria, Republic of the Congo (Congo), Rwanda, Senegal, South

Africa, South Sudan, Sudan, United Republic of Tanzania (Tanzania), Togo, Tunisia, Uganda, Zambia, Zimbabwe and other African countries and territories.[1]

Asia Pacific

Australia, Bangladesh, Democratic People's Republic of Korea (North Korea), India, Japan, Korea, Mongolia, Nepal, New Zealand, Pakistan, The People's Republic of China (China), Sri Lanka, Chinese Taipei, and other Asia Pacific countries and territories.[2]

Central and South America

Argentina, Plurinational State of Bolivia (Bolivia), Bolivarian Republic of Venezuela (Venezuela), Brazil, Chile, Colombia, Costa Rica, Cuba, Curaçao, Dominican Republic, Ecuador, El Salvador, Guatemala, Guyana, Haiti, Honduras, Jamaica, Nicaragua, Panama, Paraguay, Peru, Suriname, Trinidad and Tobago, Uruguay and other Central and South American countries and territories.[3]

Eurasia

Armenia, Azerbaijan, Georgia, Kazakhstan, Kyrgyzstan, the Russian Federation (Russia), Tajikistan, Turkmenistan and Uzbekistan.

Europe

European Union regional grouping and Albania, Belarus, Bosnia and Herzegovina, Gibraltar, Iceland, Israel,[4] Kosovo, Montenegro, North Macedonia, Norway, Republic of Moldova, Serbia, Switzerland, Türkiye, Ukraine and United Kingdom.

[1] Individual data are not available and are estimated in aggregate for: Burkina Faso, Burundi, Cabo Verde, Central African Republic, Chad, Comoros, Djibouti, Gambia, Guinea, Guinea-Bissau, Lesotho, Liberia, Malawi, Mali, Mauritania, Sao Tome and Principe, Seychelles, Sierra Leone and Somalia.

[2] Individual data are not available and are estimated in aggregate for: Afghanistan, Bhutan, Cook Islands, Fiji, French Polynesia, Kiribati, Macau (China), Maldives, New Caledonia, Palau, Papua New Guinea, Samoa, Solomon Islands, Timor-Leste, Tonga and Vanuatu.

[3] Individual data are not available and are estimated in aggregate for: Anguilla, Antigua and Barbuda, Aruba, Bahamas, Barbados, Belize, Bermuda, Bonaire, Sint Eustatius and Saba, British Virgin Islands, Cayman Islands, Dominica, Falkland Islands (Malvinas), Grenada, Montserrat, Saint Kitts and Nevis, Saint Lucia, Saint Pierre and Miquelon, Saint Vincent and Grenadines, Saint Maarten (Dutch part), Turks and Caicos Islands.

[4] 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 and/or the IEA 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.

European Union

Austria, Belgium, Bulgaria, Croatia, Cyprus,[5], [6] Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Romania, Slovak Republic, Slovenia, Spain and Sweden.

Latin America and the Caribbean (LAC)

Central and South America regional grouping and Mexico.

Middle East

Bahrain, Islamic Republic of Iran (Iran), Iraq, Jordan, Kuwait, Lebanon, Oman, Qatar, Saudi Arabia, Syrian Arab Republic (Syria), United Arab Emirates and Yemen.

North America

Canada, Mexico and United States.

Southeast Asia

Brunei Darussalam, Cambodia, Indonesia, Lao People's Democratic Republic (Lao PDR), Malaysia, Myanmar, Philippines, Singapore, Thailand and Viet Nam. These countries are all members of the Association of Southeast Asian Nations (ASEAN).

Annex D: Glossary

Abbreviations and acronyms

ACC	Advanced Clean Cars
ACEA	European Automobile Manufacturers Association
ACF	Advanced Clean Fleets
ACT	Advanced Clean Trucks
AFDC	Alternative Fuels Data Center
AFIR	Alternative Fuels Infrastructure Regulation
BEV	battery electric vehicle

[5] Note by 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".

[6] 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.

CAAM	China Association of Automobile Manufacturers
CAD	Canadian dollars
CAFE	Corporate average fuel efficiency
CAM	Cathode active material
CAPEX	capital expenditure
CATL	Contemporary Amperex Technology Co. Limited
CNY	Yuan renminbi
COP	Conference of the Parties
CO_2	carbon dioxide
DC	direct current
DSO	Distribution system operator
EAFO	European Alternative Fuels Observatory
EMDE	emerging market and developing economy
EPA	Environmental Protection Agency
EREV	extended range electric vehicle
ERS	electric road systems
EU	European Union
EV	electric vehicle
EVI	Electric Vehicle Initiative
EVSE	electric vehicle supply equipment
FAME	Faster Adoption and Manufacturing of Electric Vehicles
FCEV	fuel cell electric vehicle
GACC	General Administration of Customs of the People's Republic of China
GEC	Global Energy and Climate Model
GEVO	Global EV Outlook
GHG	greenhouse gases
HD	heavy duty
HDV	heavy-duty vehicle
HEV	hybrid electric vehicle
HRS	hydrogen refuelling station
H_2	hydrogen
ICCT	International Council on Clean Transportation
ICE	internal combustion engine
ICEV	internal combustion engine vehicle
IFC	International Finance Corporation
INR	Indian rupee
IRENA	International Renewable Energy Agency
ITF	International Transport Forum
KRW	Korean won
LCV	light commercial vehicle
LDV	light-duty vehicle
LEZ	Low emissions zone
LFMP	lithium iron manganese phosphate
LFP	lithium iron phosphate
Li-S	lithium sulphur

MD	medium-duty
MPV	multi-purpose vehicle
NCA	lithium nickel cobalt aluminium oxide
NEV	new energy vehicle
NEVI	National Electric Vehicle Infrastructure
NMC	nickel manganese cobalt oxide
NMCA	lithium nickel manganese cobalt aluminium oxide
NREL	National Renewable Energy Laboratory
NOK	Norwegian kroner
NZD	New Zealand dollars
OEM	original equipment manufacturer
OPEX	Operating expenditure
PHEV	plug-in hybrid electric vehicle
PLDV	passenger light-duty vehicle
PM-E-DRIVE	PM Electric Drive Revolution in Innovative Vehicle Enhancement
SEK	Swedish kronor
STEPS	Stated Policies Scenario
SUV	sports utility vehicle
TCO	total cost of ownership
TEN-T	Trans-European Transport Network
THB	Thai baht
TRL	technology readiness level
UNECE	United Nations Economic Commission for Europe
VAT	value added tax
VED	vehicle excise duty
VND	Vietnamese dong
V2G	vehicle-to-grid
WLTP	Worldwide Harmonised Light Vehicle Test Procedure
ZETI	Zero-Emission Technology Inventory
ZEVWISE	Zero-Emission Vehicle Infrastructure Support and Expansion
2/3W	two/three-wheeler

Units of measure

bar	bar
GWh	gigawatt-hour
kg	kilogramme
km	kilometre
km/hr	kilometres per hour
kW	kilowatt
kWh	kilowatt-hours
L	litre
lb	pounds
m	metre
mb/d	million barrels per day
MW	megawatt
m^2	metre squared
t	tonne

t CO_2	tonne of carbon dioxide
TWh	terawatt-hour
V	volt
W	watt
Wh/kg	watt-hour per kilogramme
Wh/L	watt-hour per litre

See the IEA glossary for a further explanation of many of the terms used in this report.

Currency conversion

Market exchange rates (2024)	1 US dollar (USD) equals:
British pound sterling	0.78
Canadian dollar	1.37
Chinese yuan renminbi	7.20
Euro	0.92
Korean won	1 363.37
New Zealand dollar	1.65
Indian rupee	84.60
Thai baht	35.29

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