EVO 24

Electric Vehicle Outlook 2024

BloombergNEF

Contents

Section 1. Executive summary

Electric vehicle markets around the world are not all traveling in the same direction or at the same speed in 2024. Sales of EVs continue to rise globally, but some markets are experiencing a significant slowdown and many automakers have pushed back their EV targets. Progress varies by segment, with electric commercial vehicles set for another blistering year and segments like buses and two- and three-wheelers already reaching very high levels of electrification.

Electric vehicles are no longer only a wealthy country phenomenon. Developing economies like Thailand, India, Turkey, Brazil and others are all experiencing record sales as more low-cost electric models are targeted at local buyers. Chinese automakers are expanding quickly abroad as they look for new markets for their EVs.

The transition to a clean transport system is also affected by growing geopolitical tension. Through strong, long-term planning and support, China has built up a formidable lead in batteries and the EV supply chain. Europe, the US, India and others are now pushing back against China's dominance with efforts to onshore manufacturing jobs and support domestic companies. Tariffs and further protectionist measures could slow down global EV adoption in the near term.

Policy support for EVs also looks less certain than it did a year ago. Several European governments slashed subsidies earlier than expected. The resulting slowdown has spurred calls to relax both the near-term vehicle CO2 targets, and the longer-term plan to phase out internal-combustion vehicle sales. Progress in the US will depend on the results of the presidential election later this year, leaving China as the only large auto market that has reached the point of consumer-led takeoff for EV sales.

Policymakers should not lose sight of long-term goals. While oil demand from transport is set to peak later this decade, only a couple of Nordic countries, and California, are currently on track for having a completely zero-emission passenger vehicle fleet by 2050. The rest of the globe is still lagging behind. The window for achieving net-zero emissions in road transport is closing quickly and there is no room left for complacency. EVs are still the most cost-effective and commercially viable route to fully decarbonizing transport.

The underlying technology for electrification continues to improve. Several next-generation battery technologies are reaching commercialization in the next few years and prices have fallen by 90% over the past decade. This trend looks set to continue, with early indications that prices are dropping sharply in 2024 due to lower raw-material prices, manufacturing advances, and overcapacity. This is good news for automakers and EV buyers but marks a challenging time ahead for new entrants to the battery industry.

Electrification is not the only vector of change in road transport. Shared mobility, vehicle connectivity and, eventually, autonomous vehicles are also set to reshape automotive and freight markets around the world in the decades ahead.

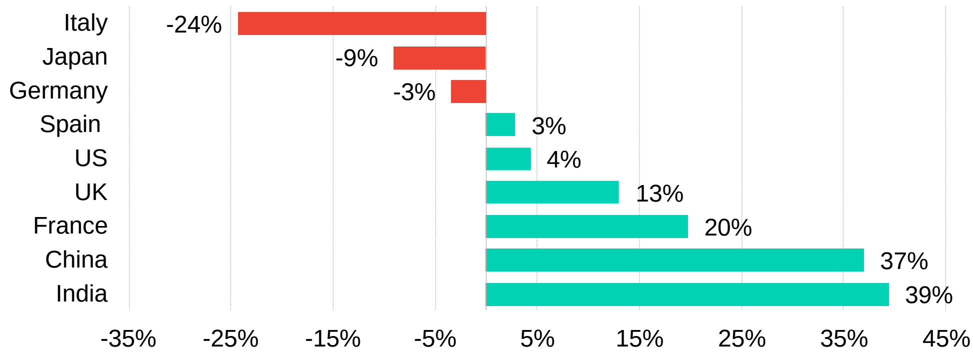
Against this increasingly complex backdrop, we are proud to present our 2024 Electric Vehicle Outlook, which examines each of the trends outlined above, and provides two updated scenarios for the future of road transport, drawing on BNEF's team of sectoral and regional experts around the world. Our Economic Transition Scenario describes how current techno-economic trends are expected to drive the EV transition, while the Net Zero Scenario examines what a path to a zero-emission global road fleet by 2050 could look like.

This report includes analysis on EV adoption in passenger vehicles, commercial vans and trucks, two- and three-wheeled vehicles and buses globally. It also looks at other drivetrains, including hybrids, natural gas and fuel cells, and then explores the resulting impacts of all of these on electricity markets, oil demand, battery materials, charging infrastructure and CO2 emissions.

The key findings are as follows:

- **The EV sales growth slowdown is real, but it is not the same everywhere in the world.** Countries like China, India and France are still showing healthy growth, but the latest data for Germany, Italy and the US is more concerning. In Japan, lack of EV commitment from the major domestic car makers, as well as no new models in the mini-car segment (kei-car) are holding the market back. Still, some slow-down was expected and the global growth rate in 2024 is broadly in line with BNEF forecasts from previous years.

Figure 1: Passenger EV sales year-on-year change in select countries, 1Q 2024



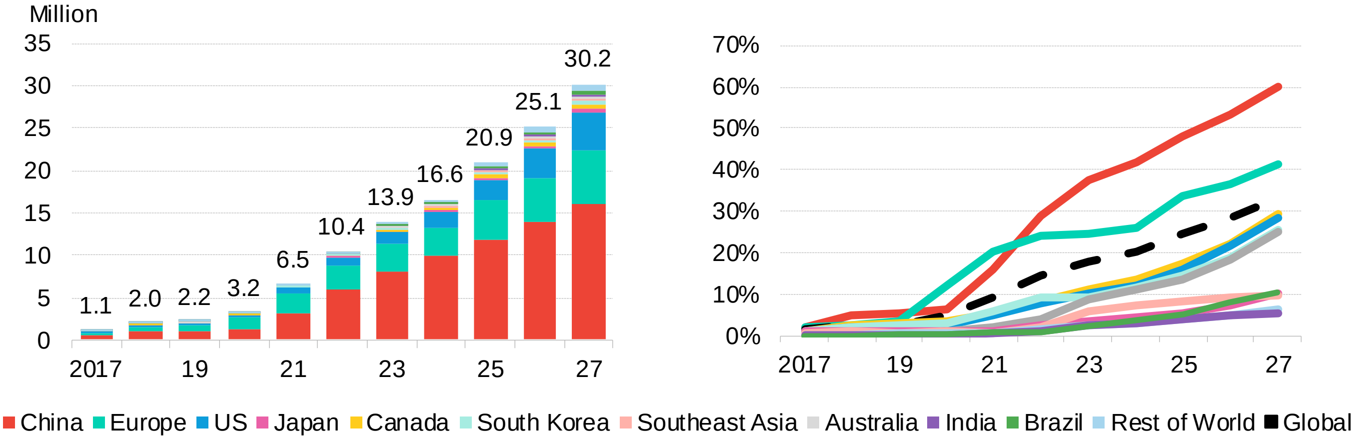
Source: BloombergNEF, MarkLines, Jato Dynamics. Note: Includes battery electric vehicles and plug-in hybrids.

- **More automakers are softening previous electrification targets.** Since 2023, several automakers – including Tesla, Mercedes-Benz, General Motors and Ford – have made cuts to their near-term goals for electric vehicles, often quoting their inability to manufacture EVs at as low a cost as internal-combustion cars. Yet, some automakers are holding their ground and achieving results. Kia, for example, targets all-electric vehicle sales of 1.6 million by 2030, or around 37% of the automaker's total sales. Against the slow-down rhetoric, the company is set to launch an affordable, all-electric SUV – the EV3 – later this year. At Volvo, global sales of electrified models (BEV and PHEVs) in April 2024 increased 53% compared with the same period last year, making up nearly half of all sales that month, according to a company statement. The newly released all electric compact SUV – the Volvo EX30 – was the driving force behind the year-on-year increase of 75% in the automaker's EV sales in Europe in April. Chinese automakers also continue to do well with their EV sales. A big gap is emerging between the automakers that are successful on EVs, and those that are not.
- **Global passenger EV sales continue to grow in the next few years, but the growth rate is visibly slower than before.** EV sales are set to rise from 13.9 million in 2023 to over 30 million in 2027 in our Economic Transition Scenario. In the next four years, electric car sales grow at an average of 21% per year, compared to the average of 61% between 2020 and 2023. The EV share of global new passenger vehicle sales jumps to 33% in 2027, from 17.8% in 2023. Only China (60%) and Europe (41%) are above that global average by then, but some European car markets move even faster, with the Nordics at 90% and Germany, the UK, and France all well above 40%. In the US, EV market jitters inflamed by the

upcoming presidential elections helped slow down adoption this year, and by 2027 only 29% of cars sold in the country are electric. Japan significantly lags other wealthy countries.

Still, the underlying technology for EVs continues to get better and cheaper, with many new, lower-cost EV models set for launch in the next few years. Some of the fastest growth rates are in emerging economies, with EV sales set to quintuple in Brazil by 2027 and triple in India. The fleet of electric cars grows fast, rising to over 132 million by 2027, from 41 million passenger EVs on the road at the end of 2023.

Figure 2: Global near-term passenger EV sales and share of new passenger vehicle sales by market



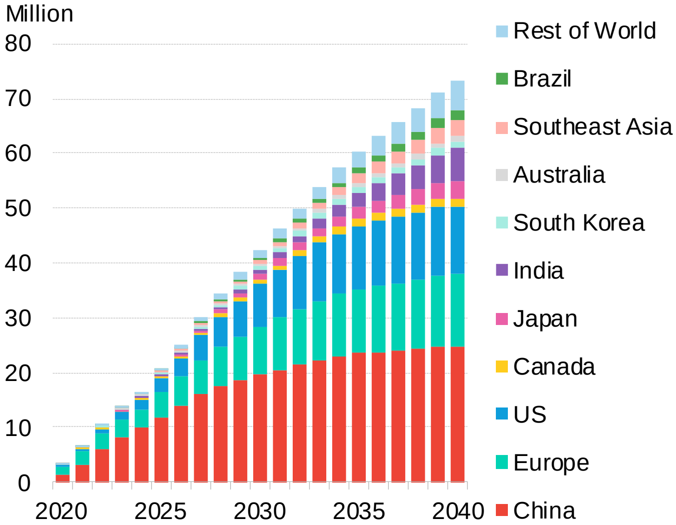
Source: BloombergNEF. Note: Europe includes the EU, the UK and EFTA countries. EV includes BEVs and PHEVs.

- **Sales of internal combustion vehicles have peaked and the fleet peaks soon.** Sales of internal combustion vehicles peaked in 2017. By 2027, sales of internal combustion vehicles are set to be 29% below their 2017 peak. The internal combustion vehicle fleet peaks in 2025. Hybrids experienced growing sales in 2023 in specific locations and segments of the passenger-vehicle market. Our economic analysis indicates that electric vehicles will be the primary method of decarbonizing road transport, however, hybrids can play a meaningful role. In Europe, the US, China, Japan and South Korea, we expect full hybrid sales to surpass 15 million units annually by 2030. Adoption rates can range between 20% and close to 50% in different markets. The main support for further hybrid penetration comes from the increasingly stringent fuel-efficiency rules. In the absence of those, we would expect relatively low passenger hybrid-vehicle sales, close to current levels in most markets.
- **Our long-term outlook for EVs remains bright, despite near-term challenges.** Improving economics of electric vehicles underpin the continued long-term growth in EV adoption. EVs reach 45% of global passenger-vehicle sales by 2030 and 73% by 2040 in BNEF's Economic Transition Scenario. Despite great progress and a steep growth trajectory, Southeast Asia, India and Brazil are still below the global average adoption by then. A stronger regulatory push is needed in these markets to help bridge the gap with the more developed EV markets. Still, by 2040 the three regions represent 15% of the global EV market, up from just 2% in 2023 and 4% in 2030.

While EV sales exhibit a traditional 'S-curve' for adoption, each country and region starts on this trajectory at different times. The varied start time and slowdown points between countries mean that the global average appears more linear than any individual country.

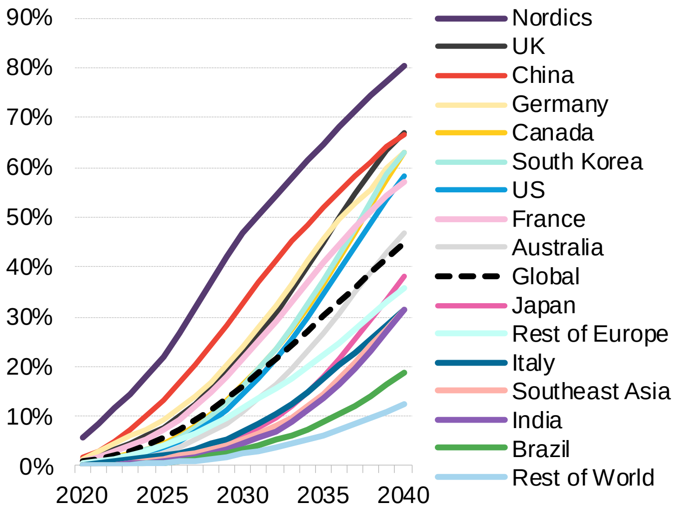
Despite rapid EV adoption, less than 50% of the global passenger-vehicle fleet is set to be electric by 2040.

Figure 3: Global long-term passenger EV sales by market – Economic Transition Scenario



Source: BloombergNEF

Figure 4: Global long-term EV share of passenger vehicle fleet by market – Economic Transition Scenario

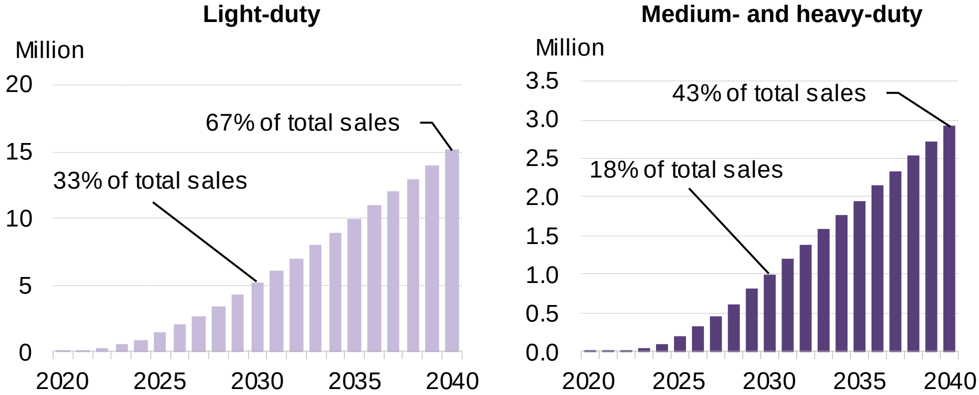


Source: BloombergNEF

- **The decarbonization of the commercial vehicle sector – including vans, trucks and buses – has already started and is set to accelerate.** The pace of zero-emission vehicle adoption differs across countries and segments: sales of electric light-duty delivery vans and trucks are spreading fast in China, South Korea, and several European countries, while sales in the US are weak for now. Still, on the back of good economics, the global e-van market approaches one third of sales by 2030 and two-thirds by 2040 (Figure 5).
- **Electric heavy trucks become economically viable for most use cases by 2030.** In heavier segments, battery electric trucks are mostly used in urban duty cycles initially. But their economics improve even for long-haul routes and around 2030 approach those of diesel powertrains. Fuel cell trucks remain a viable option for some duty cycles and in some countries, but their outlook is far less certain. Zero-emission technologies account for 18% of global truck sales by 2030, reaching 43% by 2040 (Figure 5).
- **New environmental policies are set to alter technology choices among truck makers.** Zero-emission powertrains are currently only slowly adopted within medium- and heavy-duty trucks. Still, newly enacted greenhouse gas rules in Europe and the US will push manufacturers to develop and sell large volumes of electric and fuel-cell trucks. The EU's CO_2 emissions targets imply high rates of electrification even by 2030. Municipal buses continue to electrify at a rapid pace and exceed 60% of sales already by 2030, reaching 83% by 2040.
- **Global road transport is still not on a net-zero trajectory, and protectionist policies risk knocking it further off course.** For the world to achieve a completely zero-emission vehicle fleet by 2050, sales of combustion vehicles need to stop around 2038 in our Net Zero Scenario, with leading markets phasing out combustion in the early 2030s. In the Economic Transition Scenario, only the Nordic countries reach a full phase-out of combustion vehicles before 2038.

  As more countries implement industrial strategies to capture value from the transition, there is a risk of some of these slowing adoption and climate goals falling further out of reach. Governments will need to carefully weigh up competing priorities and avoid policies that reduce competition or access to affordable EVs. The gap between BNEF's Economic Transition Scenario and the Net Zero Scenario is still significant and the need for a stronger regulatory push has not waned since the previous outlook.

Figure 5: Electric and fuel cell commercial van, truck, and bus sales near-term sales outlook – Economic Transition Scenario



Source: BloombergNEF, government agencies, China Automotive Technology and Research Center, EV-Volumes, Japan Automobile Dealers Association (JADA). Note: Electric vehicles include battery-electric and plug-in hybrid vehicles (for full list of sources see Figure 147).

- **Only the three-wheeled vehicle segment is on track to achieve a zero-emission fleet by 2050 without additional policy intervention**. Two- and three-wheeled vehicle sales continue to rise in emerging economies and electric sales are set to exceed 90% globally by 2040. Over 40% of two-wheelers and over 80% of the three-wheelers sold in 2023 were electric, leaving the latter as the only vehicle segment currently on track to achieve a net-zero fleet by 2050.

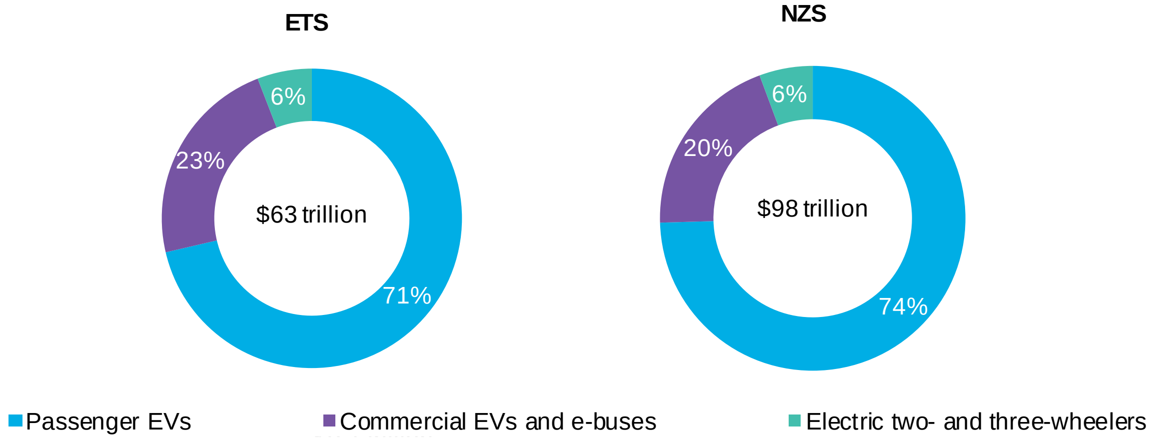
Table 1: Road transport segment progress toward net zero

Segment	Current share of road transport CO2 emissions	Current estimated global fleet size	Zero-emission vehicle (ZEV) fleet share in 2050 – Economic Transition Scenario	Level of policy intervention needed to hit Net Zero Scenario (100% ZEV share) by 2050
Three-wheeled vehicles	<1%	120 million	95%	On track
Two-wheeled vehicles	5%	1.1 billion	80%	Almost on track: minor additional measures needed
Municipal buses	1%	3.4 million	86%	Almost on track: minor additional measures needed
Light commercial vehicles	11%	170 million	77%	Positive trajectory: moderate additional measures needed
Passenger vehicles	53%	1.3 billion	69%	Positive trajectory: moderate additional measures needed
Medium + heavy commercial vehicles	30%	83 million	28%	Not on track: strong additional measures needed urgently

Source: BloombergNEF, various government sources. Note: Fleet size represents vehicles of all drivetrain types and are estimates based on various sources and BNEF data. Some values rounded. Current emissions and fleet size data are for 2023.

- **Massive spending is required in both scenarios.** The cumulative value of EV sales across all segments hits $9 trillion by 2030 and $63 trillion by 2050 in the Economic Transition Scenario. This jumps to over $98 trillion by 2050 in the Net Zero Scenario. There is already fierce competition among governments to ensure the development of local supply chains. EVs and batteries will remain a central part of many countries' industrial policy over the coming decades.

Figure 6: Estimated global EV market opportunity by 2050 – Economic Transition Scenario vs. Net Zero Scenario

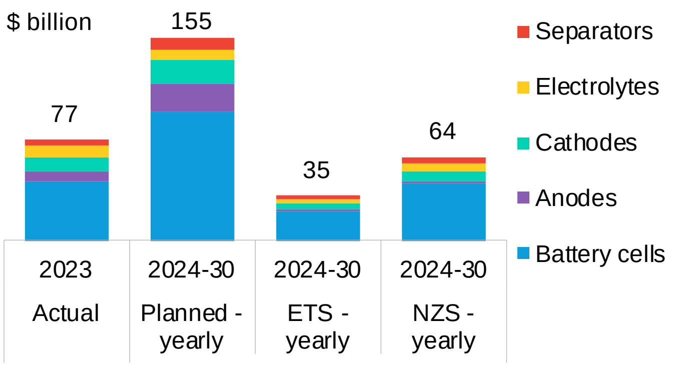


Source: BloombergNEF. Note: Includes battery electric and plug-in hybrid electric passenger and commercial vehicles, battery electric buses and electric two- and three-wheelers. Estimates are cumulative, spending starts in 2024. Dollars are in real 2023. 'ETS' is Economic Transition Scenario, and 'NZS' is Net Zero Scenario.

- **Large investments are needed in all areas of the battery supply chain, though planned investment would be more than enough should it materialize.** Annual lithium-battery demand grows rapidly in our Economic Transition Scenario, approaching 5.9 terawatt-hours annually by 2035. Meeting this demand requires large but achievable increases in materials, components, and cell production. At least $35 billion needs to be invested in battery-cell and component plants by the end of the decade, which is easily exceeded by the $155 billion already planned by companies (Figure 7). Over-investment is most apparent in battery-cell manufacturing, where planned lithium-ion cell manufacturing capacity by the end of 2025 is over five times the 1.5TWh global battery demand expected that year. Overcapacity is a big issue for battery makers, especially as many have ambitious plans to expand.

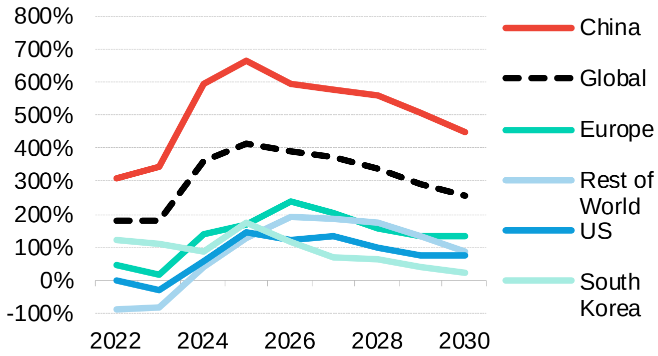
  Under BNEF's Net Zero Scenario, new demand for lithium-ion batteries from transport is 1.7 times that of our Economic Transition Scenario and reaches 218TWh cumulatively by 2050. New technologies that lower the footprint of resource extraction will become important, so will recycling. In lithium, for example, direct lithium extraction technologies could significantly lower the water and land-use in the extraction process, while improving metal recovery.

Figure 7: Annual battery factory investment by scenario



Source: BloombergNEF. Note: 'ETS' is Economic Transition Scenario. 'NZS' is Net Zero Scenario. Battery factory requirements include investment needed to meet EV and stationary energy storage demand. Planned investment based on company factory announcements benchmarked by respective regional capex. ETS and NZS based on China capex estimates.

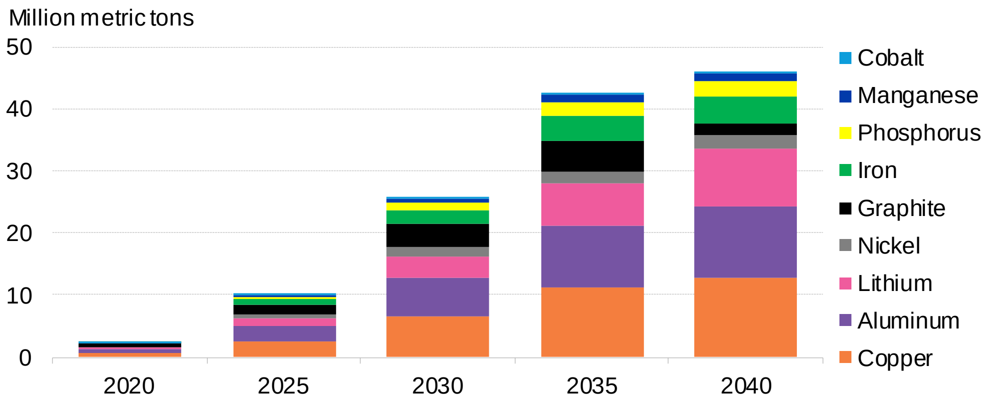
Figure 8: Lithium-ion battery cell manufacturing overcapacity ratio from 2022 to 2030, based on current announcements



Source: BloombergNEF. Note: Overcapacity ratio based on the manufacturing capacity over the same year's demand. Demand is based on BNEF's EVO 2024. Nameplate manufacturing capacity as of May 9, 2024, not de-risked. See Section 8.6 for details on methodology.

- **Lithium-iron-phosphate batteries are taking over the EV market, reducing the expected need for metals like nickel and manganese.** Fiercely competitive pricing strategies continue to put pressure on battery technology improvement. Improvements in lithium-iron-phosphate (LFP) technology, including super-fast-charging capabilities, cold temperature performance and higher energy densities, are increasing its market share, particularly in China, where many of the companies making LFP cells are based. LFP reaches over 50% of the global passenger EV market within the next two years. Nickel and manganese are among the biggest losers from the advancements in LFP batteries. Nickel consumption in lithium-ion batteries reaches 517,000 metric tons in 2025, while manganese reaches 131,000 metric tons. These are 25% and 38% lower than our previous estimates in EVO 2023 for nickel and manganese, respectively, due to the shift toward lower-cost chemistries.

Figure 9: Annual metals demand from lithium-ion batteries under the Net Zero Scenario

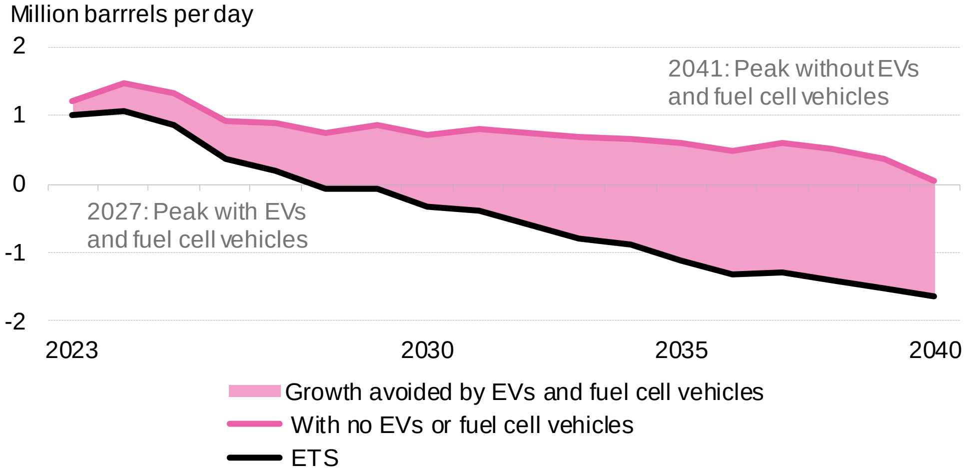


Source: BloombergNEF. Note: Lithium is expressed in million metric tons lithium carbonate equivalent (LCE). Note: Demand occurs at the mine mouth, one year before battery demand.

- **With 83 million electric cars, trucks, and buses on the road next year, and over 340 million electric two- and three-wheelers, oil demand displacement from EVs starts to ramp up.** In the next three years oil demand displaced by electric and fuel-cell vehicles of all types more than doubles from today, to almost 4 million barrels per day by 2027. This is slightly more than the volume Japan consumed in 2022.

  Rapid uptake of electric and fuel-cell vehicles across all segments drives the arrival of peak road fuel demand by 2027. Without EVs and fuel-cell vehicles, road fuel consumption would continue to grow until 2041 (Figure 10).

Figure 10: Year-on-year road fuel demand growth avoided by electric and fuel cell vehicles

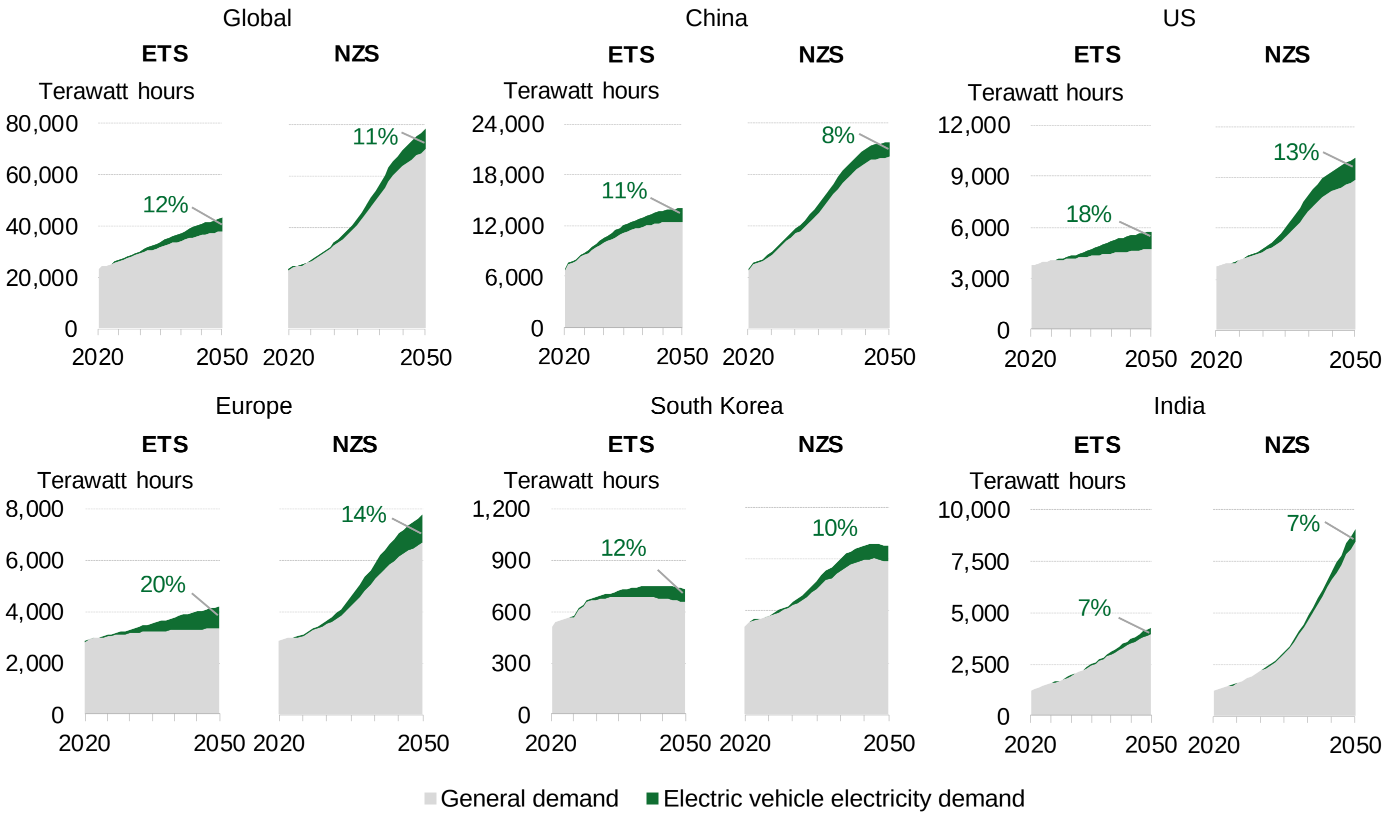


Source: BloombergNEF. Note: Includes biofuels. Alternative drivetrains include electric, fuel cell and natural gas vehicles. ETS is BNEF's Economic Transition Scenario.

- **A fully electric global fleet could consume twice the amount of electricity as the US did in 2023.** By 2050, in the Net Zero Scenario, some 8,313TWh of electricity is needed to power an all-electric vehicle fleet, double the amount of electricity consumed in the US in 2023. This drops to 5,290TWh in the ETS, and the demand accounts for between 11% and 12% of the global total in 2050, depending on the scenario. Despite the large growth in electricity demand, electric vehicles can aid the electrification of the energy system through smart charging, as grid operators apply variable pricing and other mechanisms to incentivize flexibility. The cost to upgrade the grid for EVs peaks at around 16% of annual grid expenditure in the mid-2030s in the ETS, before dropping soon after. The expenditure is equivalent to just $100 per battery electric vehicle in 2040.

  To supply all that electricity demand, the charging industry will need to mature rapidly over the next decade, creating opportunities for charging operators, manufacturers and developers. Between $1.6 trillion and $2.5 trillion in cumulative investment is required in charging infrastructure, installation, and maintenance by 2050, depending on the scenario. The size and distribution of power within the charging network is highly dependent on the assumed consumer charging preferences, business models and the prevalence of faster charging technology.

Figure 11: Electricity demand outlook for selected regions by scenario



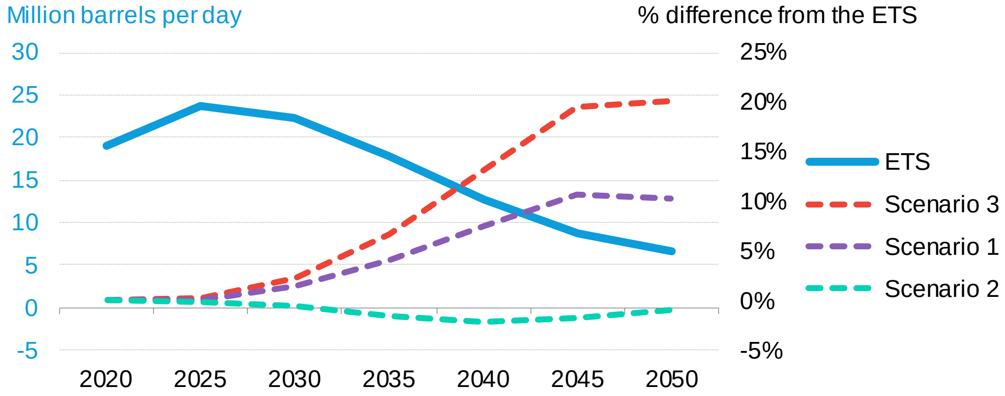
Source: BloombergNEF. Note: Uses general electricity demand projections from BNEF's New Energy Outlook 2024. This is the final energy consumption and excludes any losses in transmission. EV electricity demand includes demand from passenger EVs, commercial EVs, e-buses and electric two- and three-wheelers. Percentages refer to percentage of EV electricity demand of total in 2050.

- This year's EV Outlook includes three new Thematic Highlights, each of which explores a different part of the transition in vehicle markets around the world. The topics are:
  - The return of plug-in hybrids
  - EV driving distances are higher than expected
  - China's low-cost battery push
- **Plug-in hybrids are making a comeback, but it is still unclear whether it is a temporary trend,** or if PHEVs will remain an integral part of the transition for longer. The faster uptake of PHEVs is largely driven by China, which overtook Europe as the largest PHEV market in 2022 amid an influx of affordable models from automakers like BYD and Li Auto.

  The average electric range of PHEVs is rising and hit 80km in 2023, with some in China pushing well above 100km. PHEV battery pack sizes in China are almost twice the size of those deployed in the US and Europe, many of which were designed primarily to comply with fuel economy regulations.

  Although considered a bridge technology toward a zero-emission future, putting too much faith in plug-in hybrids comes with risks attached. Our meta-analysis of studies on the share of kilometers driven in electric mode by PHEVs shows a range of 11% to 54% depending on the country and owner type. If PHEVs are displacing BEV sales and are not utilizing their full electric driving potential, they add to oil demand in our analysis.

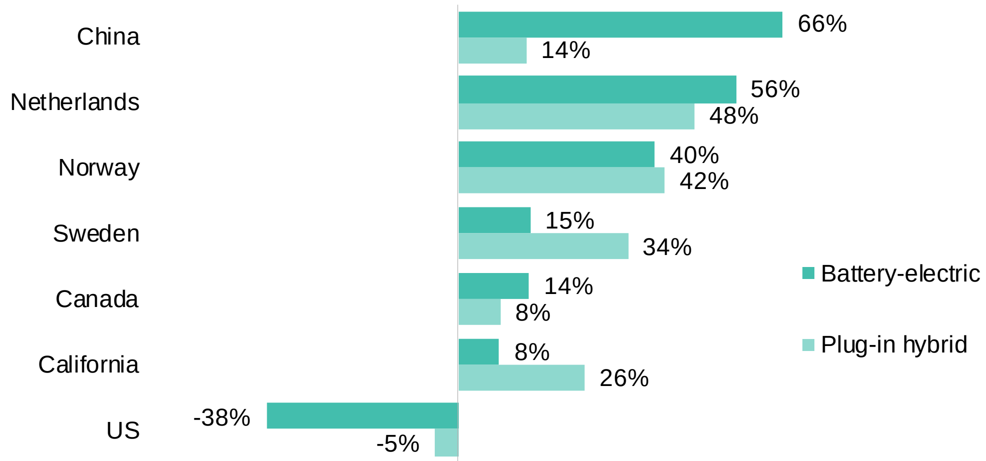
Figure 12: Global oil demand in the ETS and how it changes depending on the various PHEV adoption and electric-mode utilization scenarios



Source: BloombergNEF. Note: "Scenario 1" corresponds to high PHEV adoption, "Scenario 2" corresponds to high PHEV utilization and "Scenario 3" corresponds to high PHEV adoption and low PHEV utilization scenario; for more see Section 4.6.

- **Electric vehicle usage is on the rise.** In markets where EVs are developing an early foothold there is a growing body of evidence that they are winning over the most active drivers and are racking up more kilometers on an annual basis than ICE vehicles. In China and the Netherlands, the trend is particularly strong, with BEVs traveling 66% and 56% more than ICE vehicles, respectively. There is significant variation between geography and drivetrain. In the US, BEVs are driven about 40% less than ICE cars, and the mileage of PHEVs is 5% less. However, the standout EV adoption state in the US – California – has EV usage numbers that are closer to what can be observed in markets like Sweden.

Figure 13: Difference in annual vehicle kilometers traveled compared to internal combustion engine vehicles by drivetrain and market



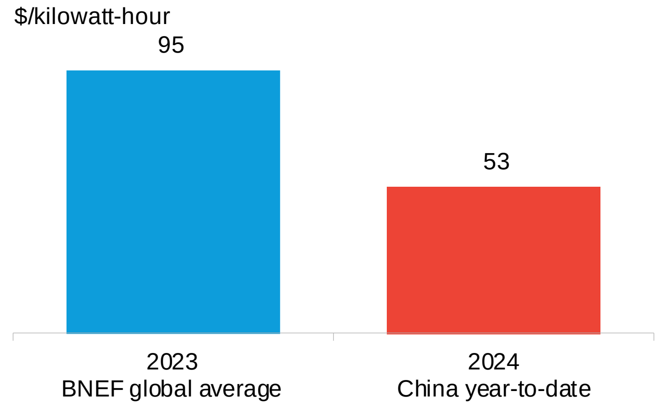
Source: BloombergNEF, National Big Data Alliance of New Energy Vehicles of China, Statistics Norway, Statistics Sweden, Statistics Netherlands, George Washington University, UC Davis, news reports. Note: Latest data available. California data is from a UC Davis study published in 2020. US data is from a study by George Washington University published in 2023. US data includes all states.

Automakers have an opportunity to shape their product portfolio to appeal to high-mileage drivers. High usage of EVs among working drivers is a strong signal that these vehicles are in demand. In some instances, automakers may need to tailor their vehicles to specific use cases. For example, Roewe vehicles, which are popular with ride-hailing drivers in China, have a lower range than many other EVs, but are offered at upfront price points that are attractive to ride-hailing drivers.

- **China's batteries are incredibly cheap**. While battery-cell manufacturing overcapacity is a phenomenon globally, it is most acute in China and is a major factor driving prices lower. In the domestic market, EV lithium-iron-phosphate (LFP) cell prices have averaged $53/kWh between January and April 2024, a 44% year-on-year drop (Figure 14). Planned battery production capacity in China is almost seven times demand by 2026. Sustained low prices could lead to an additional 23.9 million EVs being sold in China between 2024 and 2035, according to our scenario analysis. This averages 2 million additional BEVs and PHEVs per year over the next decade (Figure 15). That uptick, however, is not enough on its own to solve China's overcapacity. Actual excess supply will be lower due to varying utilization rates, commissioning delays and abandonments, but fierce competition is a trend that is likely to remain in the next couple of years, if raw material prices remain low.

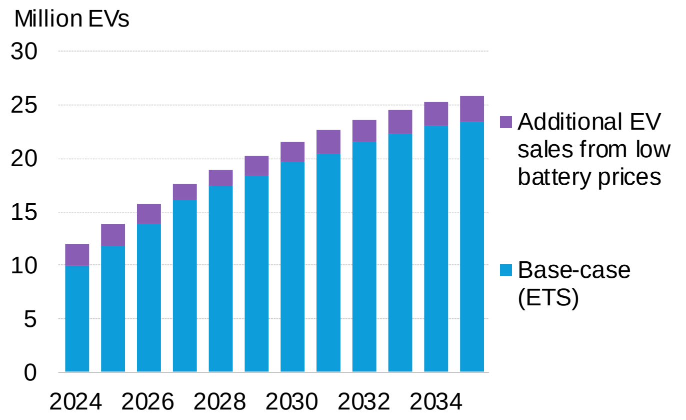
  Although low battery prices are a boon for demand, they put a strain on governments and automakers outside China that are seeking to localize their respective supply chains.

Figure 14: Lithium iron phosphate (LFP) battery cell prices



Source: BloombergNEF, ICC Battery. Note: 2023 price from BNEF's Lithium-ion Battery Price Survey. 2024 price from Jan-Apr from ICC Battery.

Figure 15: China EV sales by battery price scenario



Source: BloombergNEF. Note: The base-case uses BloombergNEF's Economic Transition Scenario (ETS) with battery prices from the BNEF's 2023 Lithium-Ion Battery Price Survey, the low-price scenario uses the same proprietary modeling with battery price data from ICC Battery averaged over January to April 2024 for the 2024 price and then the same year-on-year decreases expected in the price survey's long-term outlook.

Section 2. Introduction

2.1. What's new in EVO 2024

The important new areas of analysis in this year's EVO are the following:

- **New countries/regions covered.** This year's outlook adds Brazil to our list of modeled countries. Core countries and regions covered now include: US (with a breakout for California), China, Germany, Japan, India, Canada, South Korea, Australia, UK, France, Brazil, the Nordics, and South East Asia.
- We have also added a new 'Tier 2' country approach for each of the remaining EU and EFTA countries that allows us to model EV uptake beyond our core countries and regions.
- **New thematic highlights.** This year's outlook includes three new thematic highlights, each of which illustrates a different part of the transition in vehicle markets around the world. This year's topics are:
  - The return of plug-in hybrids
  - EV driving distances are higher than expected
  - China's low-cost battery push
- **More detailed near-term China electric and fuel-cell truck forecast** to reflect faster sales in this segment.
- **Larger role for plug-in hybrids in the near term.** Due to rising sales, we have re-assessed our view on plug-in hybrids, including their battery pack sizes and electric driving distances.
- **More detail on hybrids and compressed natural gas (CNG) vehicles.** Hybrid sales are rising and are now included in all our battery and material demand figures. CNG vehicles sales are growing in markets like India and are also discussed.
- **Faster Net Zero Scenario.** Our updated Net Zero Scenario has more rapid adoption than in previous years. Previous versions did not assume any overall carbon emissions target and therefore led to more than 2 degrees of warming in BNEF's long-term modeling. Our updated Net Zero Scenario is more closely aligned with BNEF's New Energy Outlook.
- **Updated lithium-ion battery price, volume and chemistry forecast based on our most recent market surveys:** We have developed a new battery cathode chemistry forecast for all vehicle segments that reflects rising deployment of lithium-iron phosphate (LFP) batteries.
- **Improved methodology for estimating investments needed in battery manufacturing** to better reflect capacity utilization factors.
- **Updated metals outlook and investment needs.** We have updated our near-term and long-term supply and demand balance for the critical metals and materials needed to scale up EV production. This includes lithium, cobalt, nickel and manganese. We have also refined our estimates for the investment needed to deliver this supply.
- **More regional charging analysis and granular inputs.** The electricity and charging outlook has been updated to reflect the latest utilization and roll-out data. This year the outlook also uses four regional modeling categories that allow more variations in the outlook across countries.
- **Improved visualization and charting tools on our flagship publication page.**

- Finally, we have re-run our vehicle economics and Bass-diffusion models using the most recent EV sales data and vehicle pricing for all segments. Each additional year of data helps calibrate results. Our passenger EV results in our Economic Transition Scenario are lower in some markets like the US and Germany in the near term due to a slowdown in sales, but they are higher in some emerging markets like India. The outlook is also slightly higher for electric trucks, while buses and two-/three-wheeler results are similar to last year.
- This year's outlook does not include full country level write-ups for the passenger vehicle market, but the full dataset and breakdown is still available to all clients. To download the country-level data and all other results from our models, click on the data icon on the insight record here, or the tableau data viewer here.

2.2. Scenarios and outlooks at BloombergNEF

This research forms part of the library of energy transition scenarios at BNEF.

The core scenario used in BNEF research is our Economic Transition Scenario (ETS). This employs a combination of near-term market analysis, least-cost modeling, consumer uptake and trend-based analysis to describe the deployment and diffusion of commercially available technologies in the absence of new policy regimes and to uncover the underlying economic fundamentals of the energy transition.

In addition to the ETS, BNEF develops a range of global, sector-based, and country-level scenarios. This includes a set of climate scenarios that investigate pathways to reduce greenhouse gas emissions in line with the Paris Climate Agreement.

Scenarios are future-focused simulations combining a number of uncertain parameters into an internally consistent narrative. They are predominantly used for medium- to long-term investigative studies and may also include sensitivities to key variables. Scenarios differ from forecasts which are usually shorter-term predictions of what we think will happen.

Scenarios in the *Electric Vehicle Outlook*

BNEF's *Long-Term Electric Vehicle Outlook* combines near-term forecasts with a long-term scenario. From 2024 to 2027 it includes a bottom-up forecast for each vehicle segment and country. This takes into account factors like current and upcoming EV models available, policy and incentive frameworks, historical growth rates, consumer adoption patterns and other factors.

BNEF's Net Zero Scenario (NZS) for road transport

Our Net Zero Scenario shows one possible pathway to achieving a global vehicle fleet with no direct tailpipe CO_2 emissions. The Net Zero Scenario does not explicitly bring upstream emissions from electricity generation, hydrogen production or vehicle manufacturing to zero. The results from this exercise are best viewed as a *net-zero-capable* fleet. For more on the decarbonization of the energy system, see BNEF's *New Energy Outlook* (web | terminal).

The Net Zero Scenario in this outlook does not correspond to any specific carbon budget or degree of warming target as set out in the Paris Agreement. While the scenario has the road-transport sector capable of reaching carbon neutrality by 2050, it exceeds the carbon budget required to stay on track for 1.5 degrees of warming. Staying within this will require an even more rapid switch to zero-emission vehicles, particularly in the late 2020s and early 2030s, as well as other measures.

The 2024 edition of BNEF's *New Energy Outlook* explores global and sector-level carbon budgets and the rate of energy transition needed for the transport sector to get on track by 2030, achieve net zero in 2050, and keep warming to 1.75 degrees above pre-industrial levels.

From 2028 onward, the *Electric Vehicle Outlook* splits into two long-term scenarios:

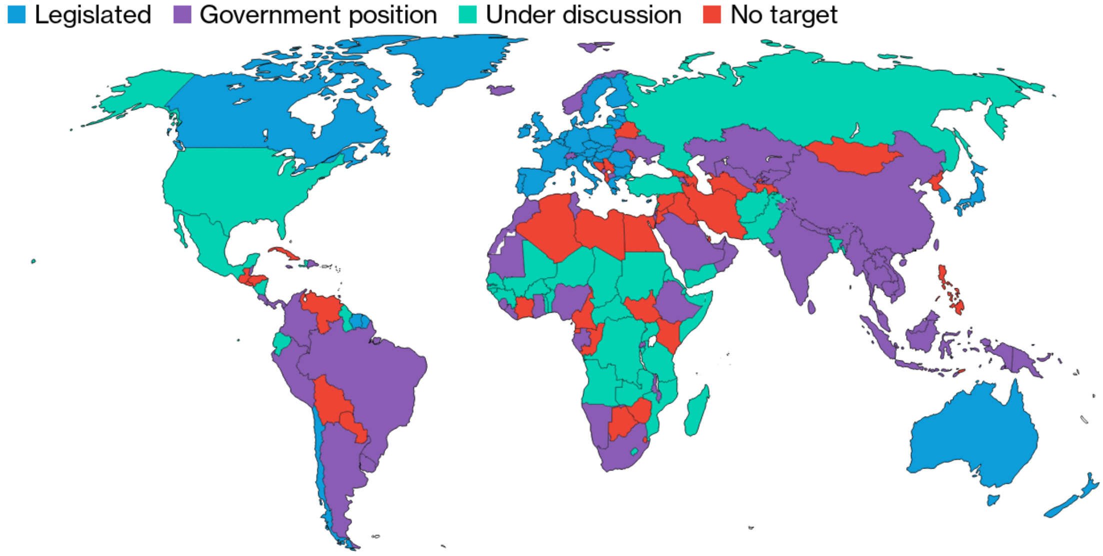
- **Economic Transition Scenario (ETS):** This is the main scenario described in this report. It assumes no new policies or regulations are enacted that impact the market. It also does not assume any long-term climate targets are hit, or that any combustion vehicle phase-out targets that have been announced by countries, states, cities or companies are achieved. Instead, adoption is primarily driven by techno-economic trends and market forces. Unless otherwise stated, charts and analysis in this report refer to the ETS. Most analysis in the ETS stops at 2040, but we have extended this to 2050 in some areas to compare with our Net Zero Scenario.

- **Net Zero Scenario (NZS):** This scenario investigates what a potential route to net-zero emissions by 2050 might look like for the road transport sector. This scenario looks primarily at economics as the deciding factor for which drivetrain technologies are implemented to hit the 2050 target. The Net Zero Scenario is one of a number of possible pathways that could meet this goal, and we are not claiming this is the most likely.

2.3. Summary recommendations for policy makers

Most of the governments around the world have a net-zero target in place or are considering one. Most are framed around hitting net-zero emissions by 2050, although China is aiming for 2060 and India for 2070. Despite these commitments, the road transport sector in most countries is not on track to meet net zero.

Figure 16: Markets by status of net-zero emissions targets



Source: United Nations, governments, BloombergNEF. Note: Targets as of May 14, 2024. Government position means that the government has official net-zero target but no plans to legislate it. Mapped data show policies in distinct economies.

EVO road transport emissions outlook

Road transport CO2 emissions continued to climb from their pandemic lows, reaching 6.26 gigatons of CO2 in 2023 and passing their previous 2019 high of 6.15 gtCO2. In our Economic Transition Scenario (ETS), road transport emissions do not peak until 2028 at 6.7 gtCO2 – 7% higher than 2023 levels. This is one year earlier than in last year's outlook (Figure 17).

Figure 17: Total global CO2 emissions from road transportation by energy source – Economic Transition Scenario

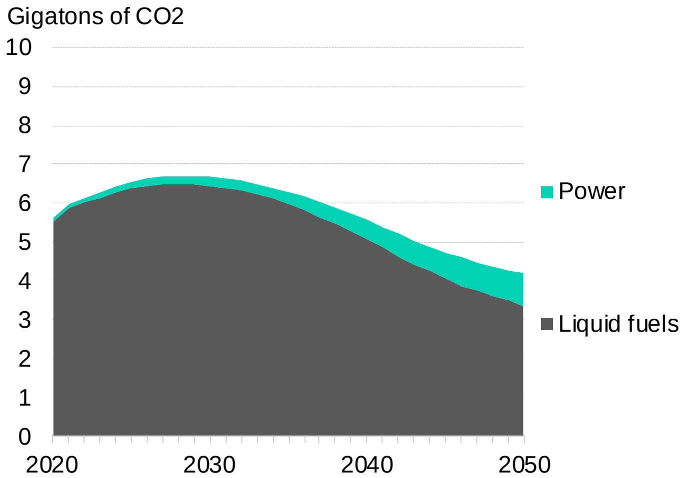
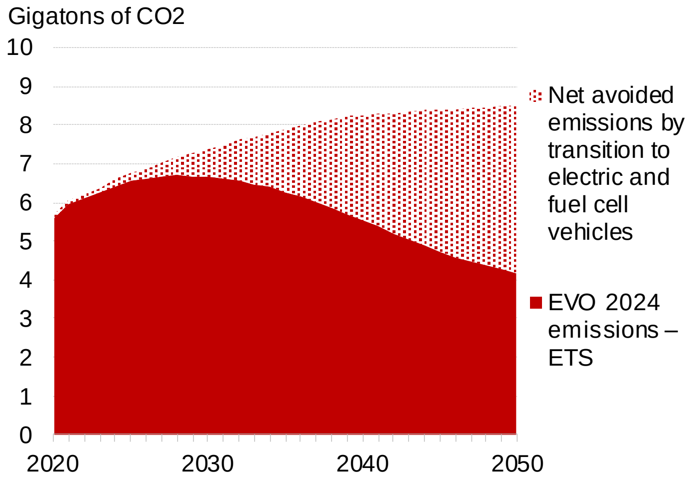
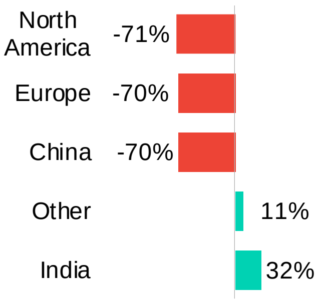


Figure 18: Road transport emissions avoided by the penetration of electric and fuel cell vehicles – Economic Transition Scenario



Source: BloombergNEF. Note: Liquid-fuel emissions include passenger vehicles, commercial vehicles and two-/three-wheelers. Power emissions include passenger vehicles, commercial vehicles, two-wheelers and electric buses. Net avoided emissions is avoided emissions subtracting the emissions that come from power. 'ETS' is the Economic Transition Scenario.

Figure 19: Change in road transport emissions between 2023 and 2050



Source: BloombergNEF

In our Economic Transition Scenario, annual direct CO2 emissions from road transport drop to 4.20 GtCO2 in 2050. This is similar to our previous outlook, with cleaner commercial vehicles becoming pivotal to lower emissions in the decade ahead.

Road transport CO2 emissions fall 37% by 2050 from their peak in 2028. However, that decrease does not fully reflect all the emissions that are avoided by the transition to electric vehicles. Actual emissions from road transport in 2050 would be nearly twice as high in 2050 in a world where electrification does not occur, and vehicles do not become more efficient (Figure 18).

Consistently, North America, Europe and China were the top emitters in 2023 as a share of overall road transport emissions. North America emitted about 26% of global road transport CO2 emissions that year, followed by Europe and China, both hovering around 15% of the total. Together, these three regions made up 55% of global road transport emissions last year.

Still, while the US, Europe and China see a sharp reduction in emissions in the future, India and the remaining countries see an increase over the next three decades (Figure 19) in our Economic Transition Scenario. By 2050, the US, Europe and China comprise only 24% of the world's road transport emissions, with India and rest of the world making up the rest. Still, by 2050 emissions from road transport are 33% lower than they were in 2023 (Figure 20).

Passenger vehicles made up 53% of road transport emissions in 2023 but drop to 43% by 2050 (Figure 21). Commercial vehicle and bus emissions rise from 42% of all road transport emissions in 2022 to 54% in 2050. Two- and three-wheelers comprise the remaining emissions.

Figure 20: Global CO2 emissions from road transport by region – Economic Transition Scenario

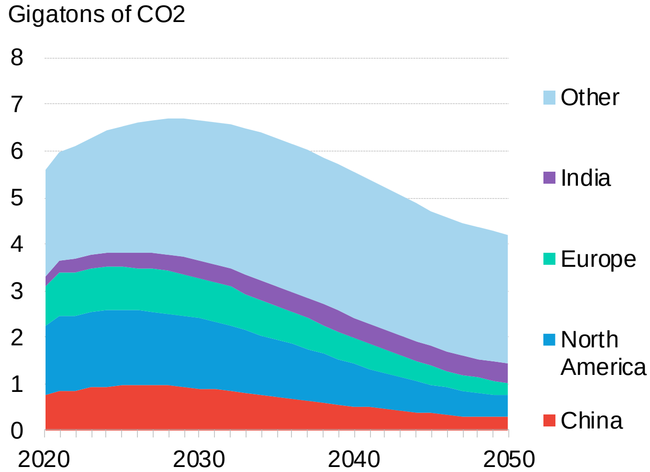
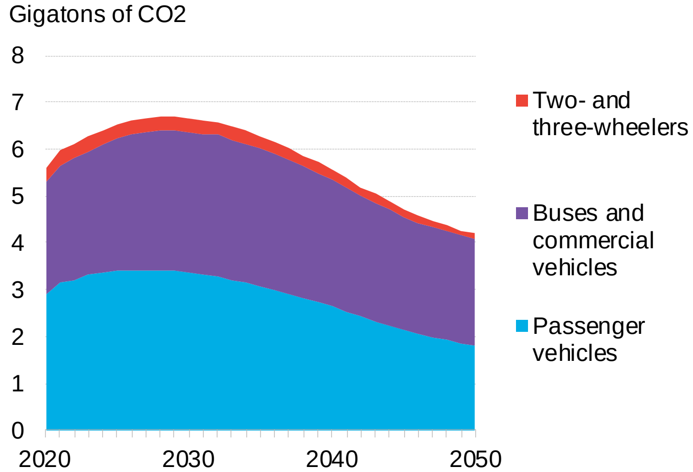


Figure 21: Global CO2 emissions from road transport by segment – Economic Transition Scenario

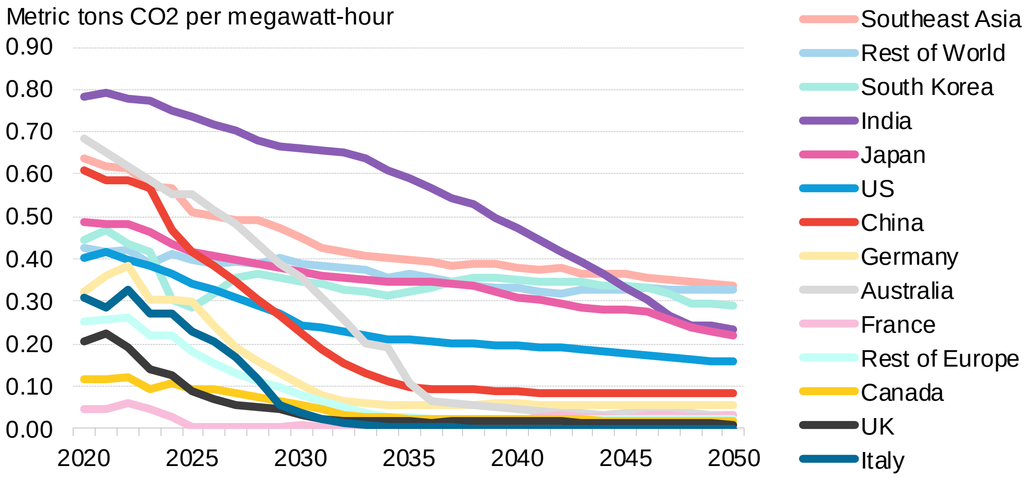


Source: BloombergNEF. Note: Liquid-fuel emissions include passenger vehicles, commercial vehicles and two-/three-wheelers. Power emissions include passenger EVs, commercial EVs, electric two-wheelers and e-buses.

Effectively cutting CO2 emissions from road transport through electrification needs to be coupled with increasing renewable generation in the power system. In the Economic Transition Scenario, we use carbon emissions intensity from BNEF's New Energy Outlook (Figure 22).

Globally, power generation from zero-emission sources is increasing every year. Some countries, like the UK and France, already have low-emission-intensity grids due to generation from wind and nuclear, respectively, meaning that EV charging in those countries is especially beneficial to mitigating carbon emissions.

Figure 22: CO2 emissions intensity of electricity generation – Economic Transition Scenario

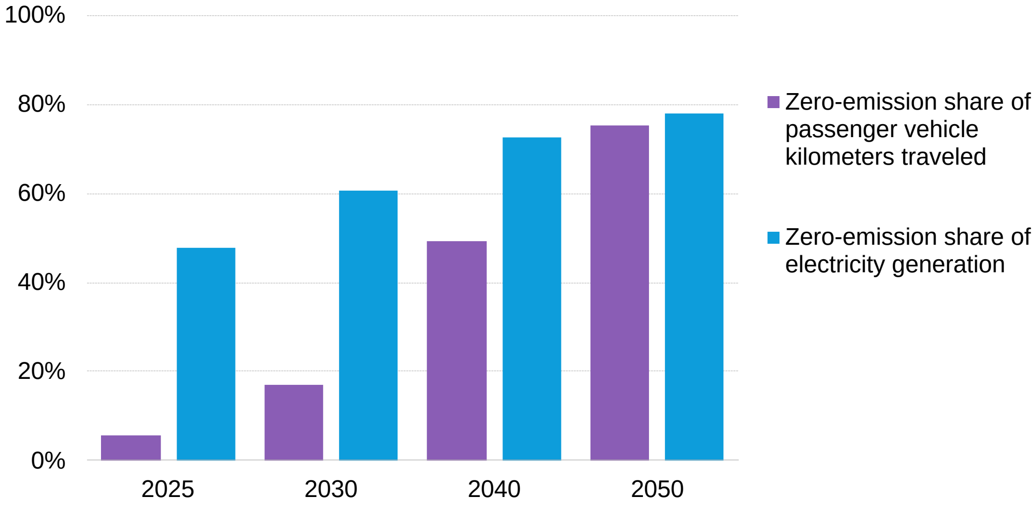


Source: BloombergNEF, New Energy Outlook 2024. Note: Economic Transition Scenario grid emissions from power generation in various regions. In this figure, Nordics are included in the Rest of Europe category.

According to BNEF's *New Energy Outlook 2024,* the global zero-emission share of electricity generation – which includes solar, wind, hydro, bioenergy, geothermal, nuclear, hydrogen and other renewables – reached 40% in 2023. By 2030, that share climbs to 60% under the Economic Transition Scenario, and 78% of all electricity generation by 2050.

At the same time, the electric share of global passenger vehicle kilometers travelled (VKT) grows from 3% of all kilometers traveled in 2023 to 17% in 2030, 49% in 2040 and 75% in 2050. As a result, more and more passenger kilometers will be drawing from an increasingly clean grid, though uptake of both EVs and clean power vary significantly by country (Figure 23).

Figure 23: Share of global power generation from zero-emission sources and share of passenger kilometers traveled in zero-emission vehicles – Economic Transition Scenario



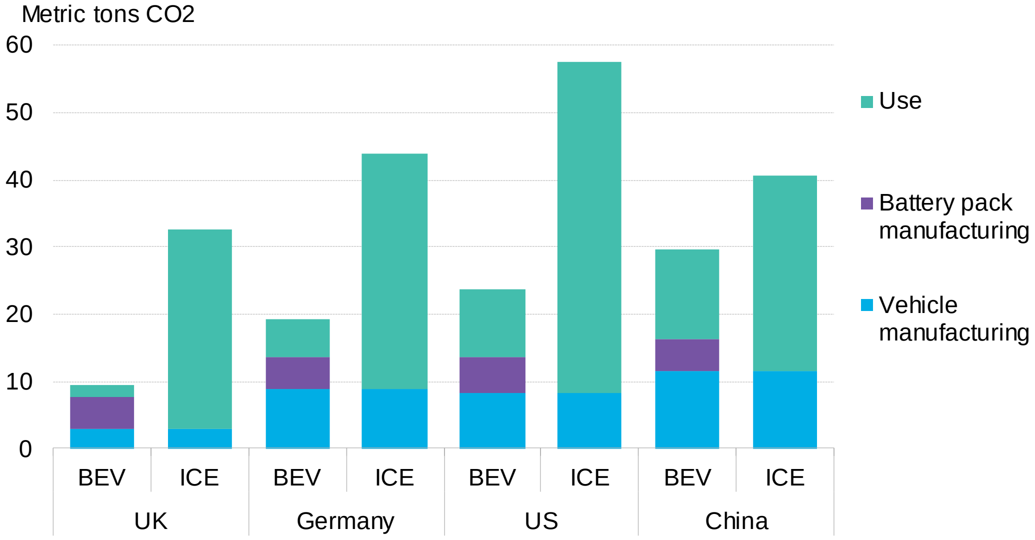
Source: BloombergNEF. Note: Zero-emission share of electricity generation is from BNEF's New Energy Outlook 2024.

Our emissions calculations assume an average CO_2 emissions intensity for each kilowatt hour (kWh) generated in each region. When EV charging occurs, we use a standard amount of CO_2 that is produced that represents an annual average for all hours of the day.

Manufacturing EVs is more carbon intensive than for combustion vehicles. However, once on the road, BEVs very quickly make up for that excess during the use phase. According to BNEF, in all analyzed countries, EVs have lower lifecycle CO_2 emissions than their combustion counterparts. How much cleaner EVs are than ICE depends not only on where the EV is used, but also where its manufacturing emissions occurred.

For a medium vehicle produced in 2023 and used for 250,000 kilometers, an electric car's lifecycle CO_2 emissions are around 70% lower than an ICE vehicle (Figure 24).

Figure 24: Total CO2 emissions of medium-segment ICEs and BEVs produced in 2023 and used for 250,000 kilometers



Source: BloombergNEF, New Energy Outlook 2022. Note: ICE is internal combustion engine, BEV is battery-electric vehicle. For methodology, see The Lifecycle of Electric Vehicles: 2024 edition (web | terminal).

The time it takes for an EV to have lower lifecycle CO2 emissions than an ICE car depends largely on the emissions intensity of the grid in the country where it charges. BNEF found that in the US, for an EV bought in 2023, it would take only 41,000 kilometers, or roughly 2.2 years of average driving, to reach that breakeven point. It would, however, take considerably longer in China, at 118,000 kilometers or roughly 10 years of driving, due to fossil-fuel-heavy grid in the country.

BNEF's EV lifecycle analysis and CO2 emissions analysis use the average emissions intensity per kWh. Encouraging charging during periods of high renewable energy generation could make EVs even cleaner. Such actions will also help use the excess power generated that would otherwise have to be curtailed.

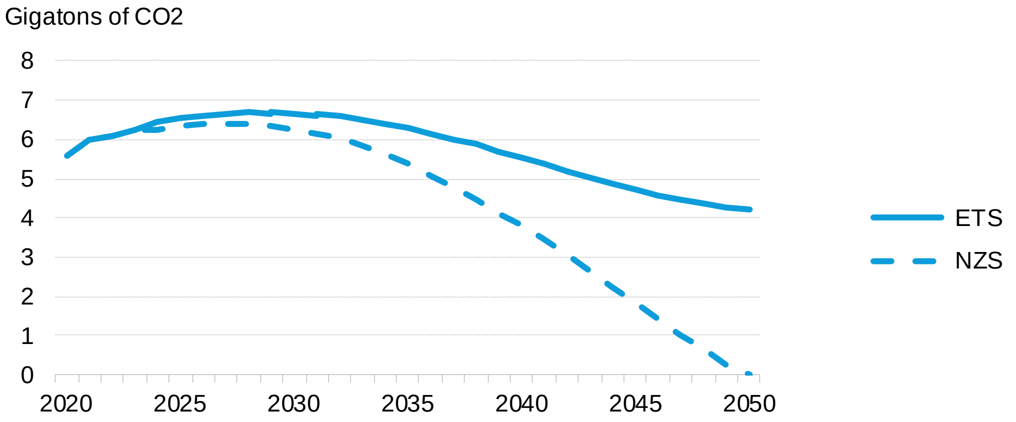
Reaching net zero

Reaching 2050 net-zero targets will require moving even faster on renewable generation and on adoption of zero-emission vehicles.

In our Net Zero Scenario, the number of zero-emission vehicles on the road grows much faster than in the Economic Transition Scenario. While in the ETS, the passenger zero-emission fleet reaches 11% of the total fleet in 2030, it climbs to 15% in the NZS – a difference of around 44 million vehicles. Under the NZS, tailpipe emissions peak in 2027, one year earlier than in the ETS, and continues to decline steeply in the 2030s as more ICE vehicles are retired from the fleet (Figure 25).

While the difference in tailpipe emissions between the two scenarios is initially minimal it expands quickly. By 2036, there is 1GtCO2 less emitted by road transport tailpipe emissions in the NZS compared to the ETS, and more than 4GtCO2 less in 2050.

Figure 25: CO2 tailpipe emissions from road transport – Economic Transition Scenario and Net Zero Scenario



Source: BloombergNEF. Note: Liquid-fuel emissions include passenger vehicles, commercial vehicles and two-/three-wheelers. 'ETS' is the Economic Transition Scenario, 'NZS' is the Net Zero Scenario.

The Net Zero Scenario in EVO 2024 achieves a net-zero-capable fleet and does not follow a specific carbon budget.

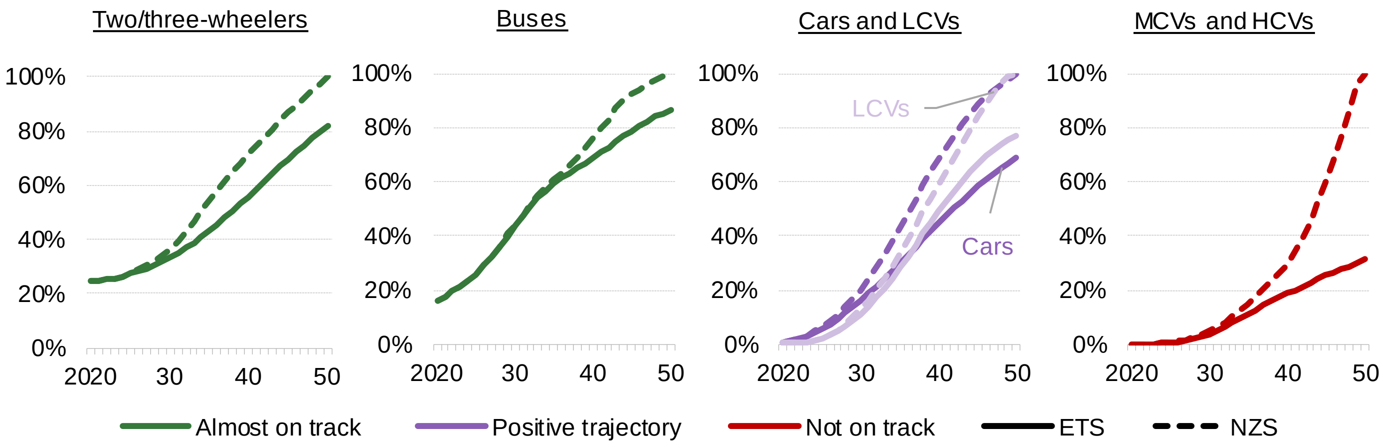
The New Energy Outlook 2024, which uses results from the Long-Term Electric Vehicle Outlook 2023 (see Section 11 for a comparison between EVO 2024 and EVO 2023 results), shows that the Economic Transition Scenario in road transport is consistent with a 2.6C temperature rise by 2050. Achieving a 1.75C-aligned carbon budget, which is the Net Zero Scenario in NEO 2024, will require a much steeper ramp in EV sales by the end of this decade and no more internal combustion engine vehicle sales after 2034. For more details, see the electric vehicles section of the New Energy Outlook 2024.

While BNEF's New Energy Outlook 2024 does not derive from the results in the Long-Term Electric Vehicle Outlook 2024, the overall principle remains the same: the ETS is on track for warming well over 2C. Reaching 1.75C or lower requires steep changes in the immediate future for global EV sales.

Segment trajectories

There is currently a large gap between the trajectory in our Economic Transition Scenario – which assumes no new policy intervention – and one consistent with the long-term emissions targets that governments have set. The window for achieving net zero in road transport is closing quickly, and the last internal combustion vehicle will need to be sold as early as 2036 for passenger vehicles, or in early 2040s for other segments, to stay on track for net zero.

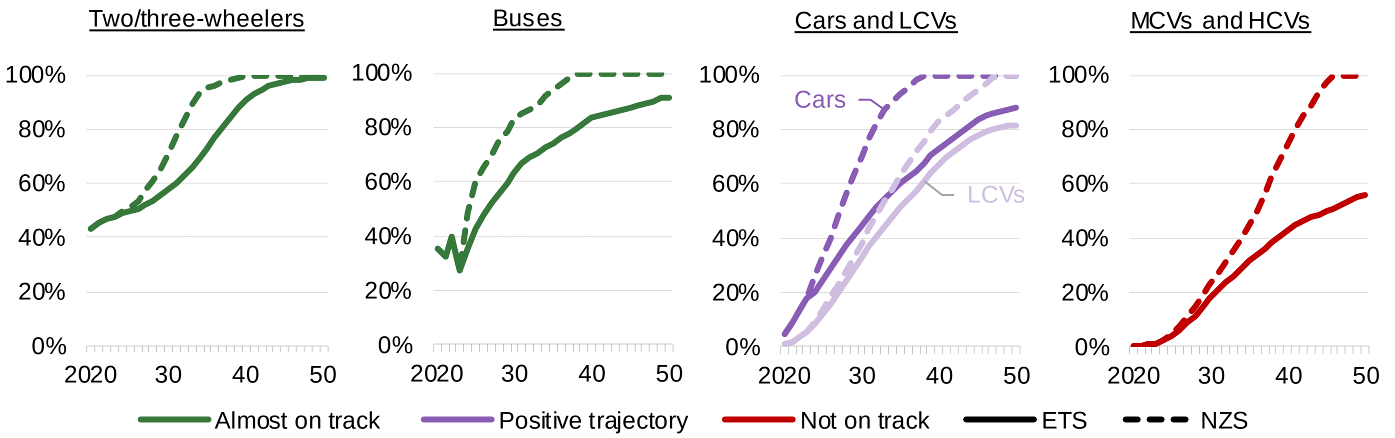
Figure 26: Zero-emission vehicle fleet share outlooks – ETS versus NZS



Source: BloombergNEF. Note: 'ETS' stands for Economic Transition Scenario and 'NZS' stands for Net Zero Scenario. 'LCVs, MCVs and HCVs' are light-, medium- and heavy-duty commercial vehicles. 'Zero-emission' includes battery-electric only for cars and two-/three-wheelers and also fuel-cell vehicles for buses, LCVs, MCVs and HCVs. All values global.

Progress varies and some segments of road transport are closer to achieving net zero by 2050 than others. Two-wheelers, three-wheelers and buses are the closest and may even be able to achieve an earlier target with a strong policy push. Passenger cars and light commercial vehicles are next, followed by heavier commercial vehicles, which will need more policy support urgently to remain on track for the Net Zero Scenario.

Figure 27: Zero-emission vehicle sales share outlooks – ETS versus NZS



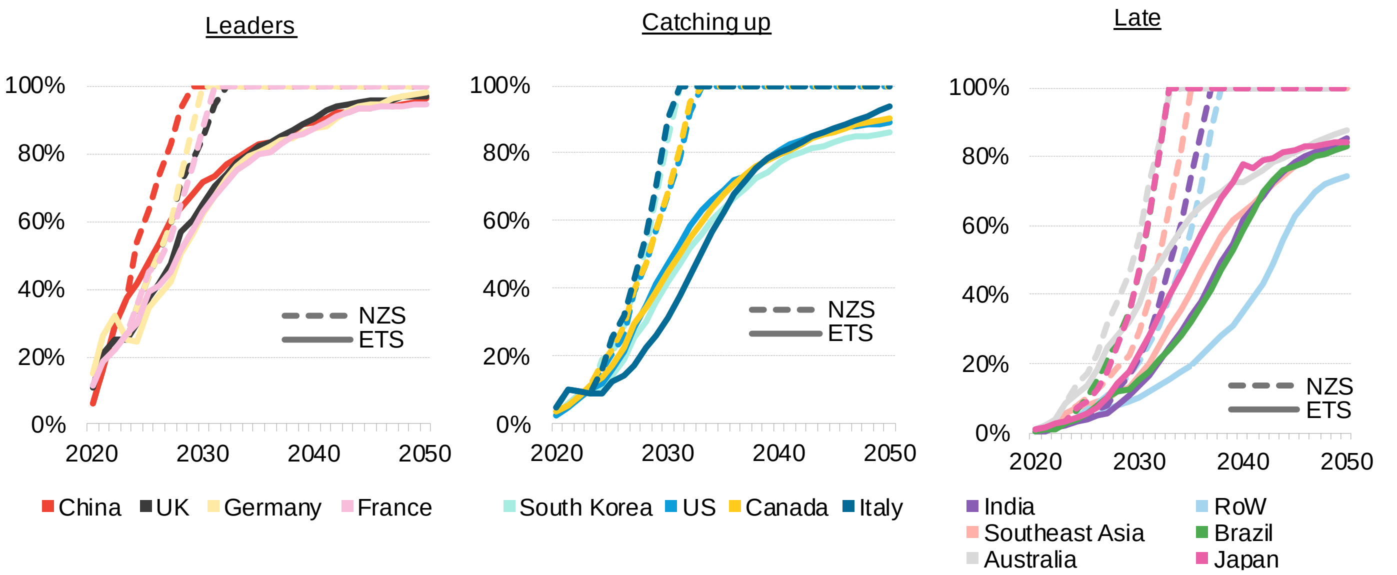
Source: BloombergNEF. Note: 'ETS' is Economic Transition Scenario and 'NZS' is Net Zero Scenario. 'LCVs, MCVs and HCVs' are light-, medium- and heavy-duty commercial vehicles. 'Zero-emission' includes battery-electric, plug-in hybrid electric and fuel-cell vehicles, depending on the vehicle segment. Some values rounded.

Regional trajectories

In the Economic Transition Scenario, only the Nordic countries reach a full phase-out of combustion vehicle sales before 2038. Some other countries – Germany, the UK, France and China – get close, as does California.

Some countries, like the US or South Korea, are on a positive trajectory, but all of the emerging EV economies – India, Southeast Asia, Brazil and Rest of World – despite making significant jumps in EV adoption in 2023, are still set to miss it by a lot, unless urgent policy action is taken today.

Figure 28: EV share of passenger vehicle sales, selected countries



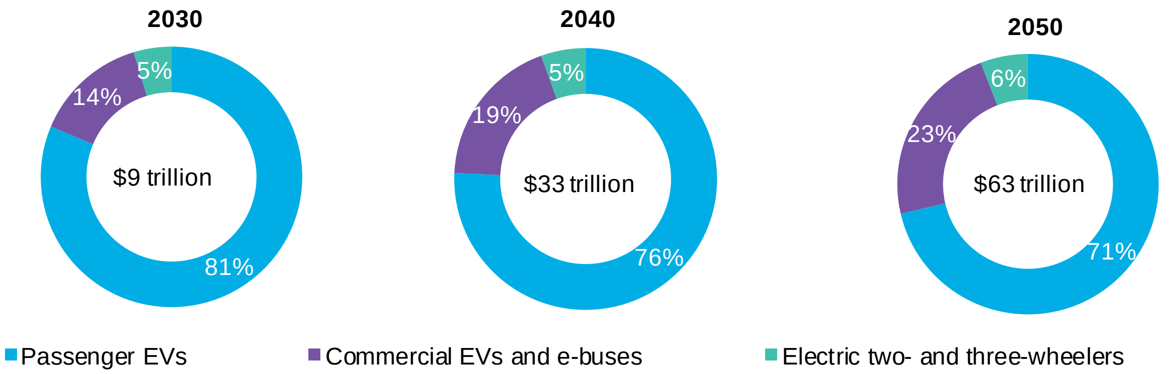
Source: BloombergNEF. Note: 'ETS' is Economic Transition Scenario and 'NZS' is Net Zero Scenario.

Impact and opportunities

EV sales between 2024 and 2030 are worth a cumulative $9 trillion, rising to $63 trillion by 2050

Electric vehicles represent trillions of dollars in potential market opportunity between today and 2050 – about $63 trillion in the Economic Transition Scenario. As EV adoption increases across the four segments covered in this report – passenger vehicles, commercial vehicles and buses, two-wheelers and three-wheelers – individual customers will be spending less per vehicle, but the volume of EVs sold rises quickly. These segments represent nearly $9 trillion between 2024 and 2030 in market size, increasing to $33 trillion by 2040 and $63 trillion by 2050.

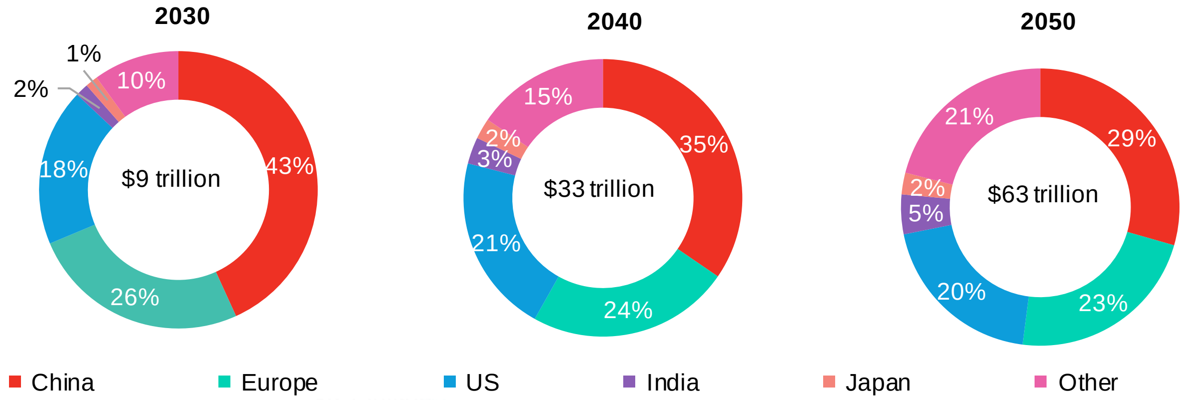
Figure 29: Cumulative global EV market opportunity by segment – Economic Transition Scenario



Source: BloombergNEF. Note: Includes battery electric and plug-in hybrid electric passenger and commercial vehicles, battery electric buses and electric two- and three-wheelers. Cumulative spending starts in 2024. Dollars are in real 2023.

Passenger EVs represent the vast majority of the value, which comprises 81% of spending by 2030, 76% by 2040 and 71% by 2050. Passenger EVs represent a $45 trillion market opportunity by 2050, followed by commercial EVs and buses, representing $14 trillion in EV spending by 2050. Electric two- and three-wheelers, though the largest in terms of absolute fleet, only account for 6% of cumulative spending by 2050 – or almost $4 trillion.

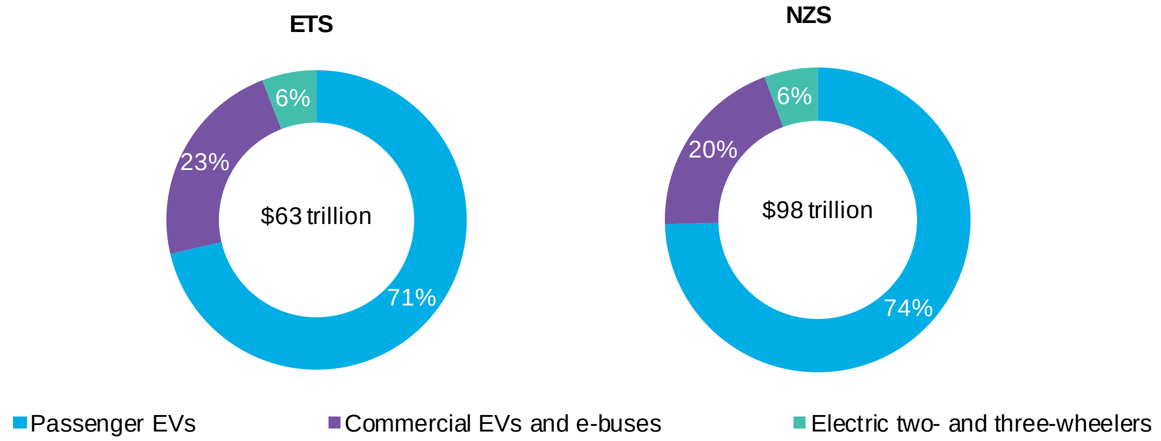
Figure 30: Cumulative global EV market opportunity by region – Economic Transition Scenario



Source: BloombergNEF. Note: Includes battery electric and plug-in hybrid electric passenger and commercial vehicles, battery electric buses and electric two- and three-wheelers. Estimates are cumulative spending starting in 2024. Dollars are in real 2023.

China represents almost half of the market between today and 2030 at $3.8 trillion. As other markets grow, China's share of global EV spending drops to 35% by 2040 and 29% by 2050. Still, China represents a nearly $19 trillion market opportunity between 2024 and 2050. It is followed by Europe and the US, valued at $14 trillion and $12 trillion by 2050, respectively. India and Japan are smaller in comparison, but still represent 7% of the cumulative EV spending by 2050 – at around $4.5 trillion. Remaining countries discussed in this report – including South Korea, Canada, Southeast Asia, Brazil, Australia, and the Rest of World – combined represent a roughly $13 trillion market opportunity by 2050.

Figure 31: Estimated global EV market opportunity by 2050 – Economic Transition Scenario vs. Net Zero Scenario



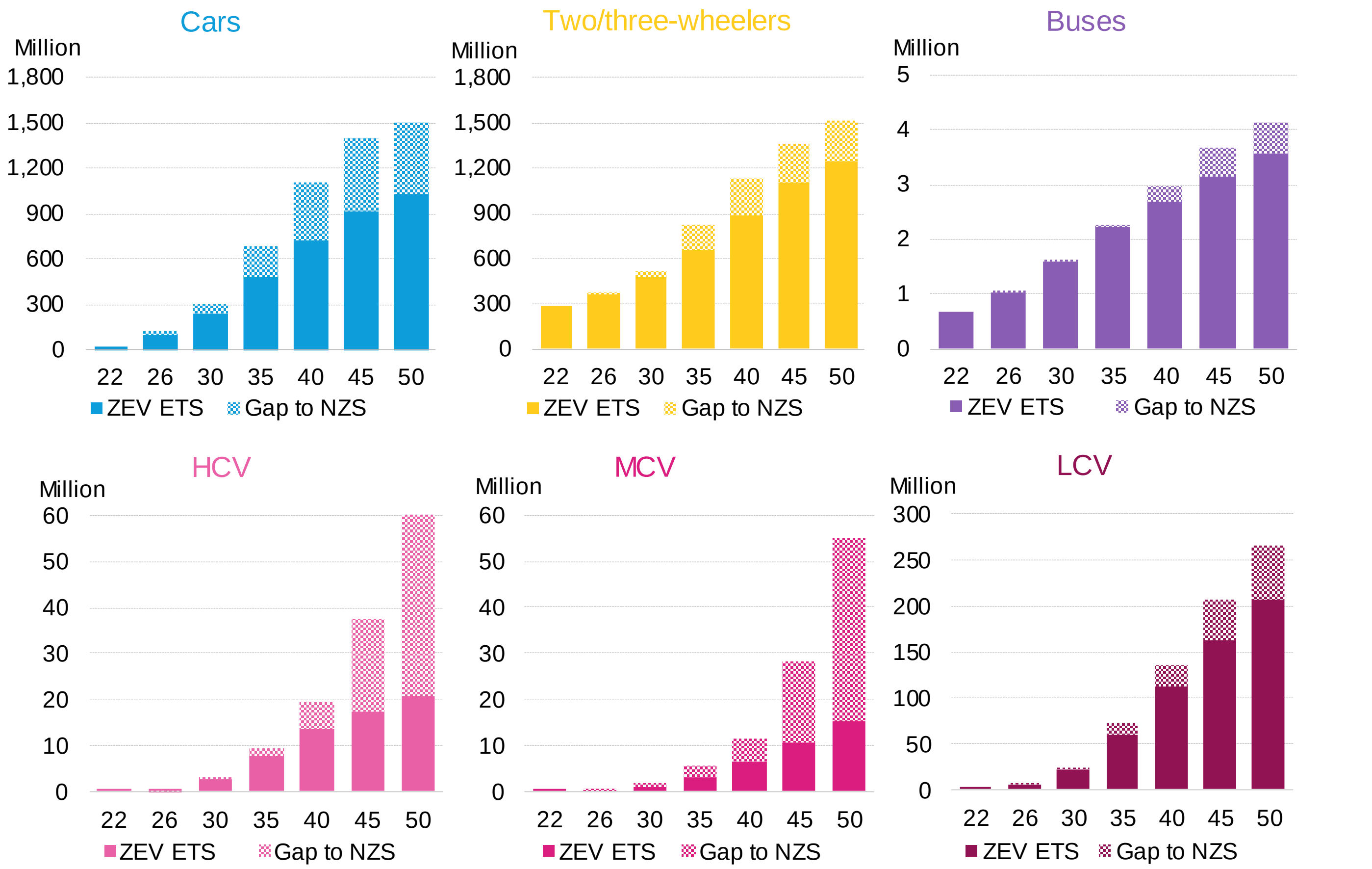
Source: BloombergNEF. Note: Includes battery electric and plug-in hybrid electric passenger and commercial vehicles, battery electric buses and electric two- and three-wheelers. Estimates are cumulative spending start in 2024. Dollars are in real 2023. 'ETS' is Economic Transition Scenario, and 'NZS' is Net Zero Scenario.

The Net Zero Scenario offers a world with much higher EV adoption, resulting in an investment opportunity of $98 trillion between today and 2050. While the size of the pie is larger, the composition of cumulative estimated EV spending by type does not drastically change. Under the NZS, 74% of total EV market opportunity by 2050 – or nearly $73 trillion – falls in the passenger vehicle category. Commercial EVs and e-buses represent about $19 trillion (21%), while electric two- and three-wheelers make up the remaining 6% and are valued at more than $5.5 trillion.

Another $1.7 trillion will be needed cumulatively between today and 2050 for charging infrastructure deployment in the Economic Transition Scenario, or $2.5 trillion in the Net Zero Scenario.

Although this is a massive opportunity, the rapid acceleration of EV deployment required for the net-zero trajectory comes with significant risks in supply chain. Reaching a net-zero fleet is equal to 470 million more zero-emission cars on the road by 2050 than in the ETS, and 280 million more electric two-/three-wheelers, 61 million more electric LCVs, 40 million more electric MCVs and nearly 39 million more zero-emission heavy-duty trucks on the road (Figure 32).

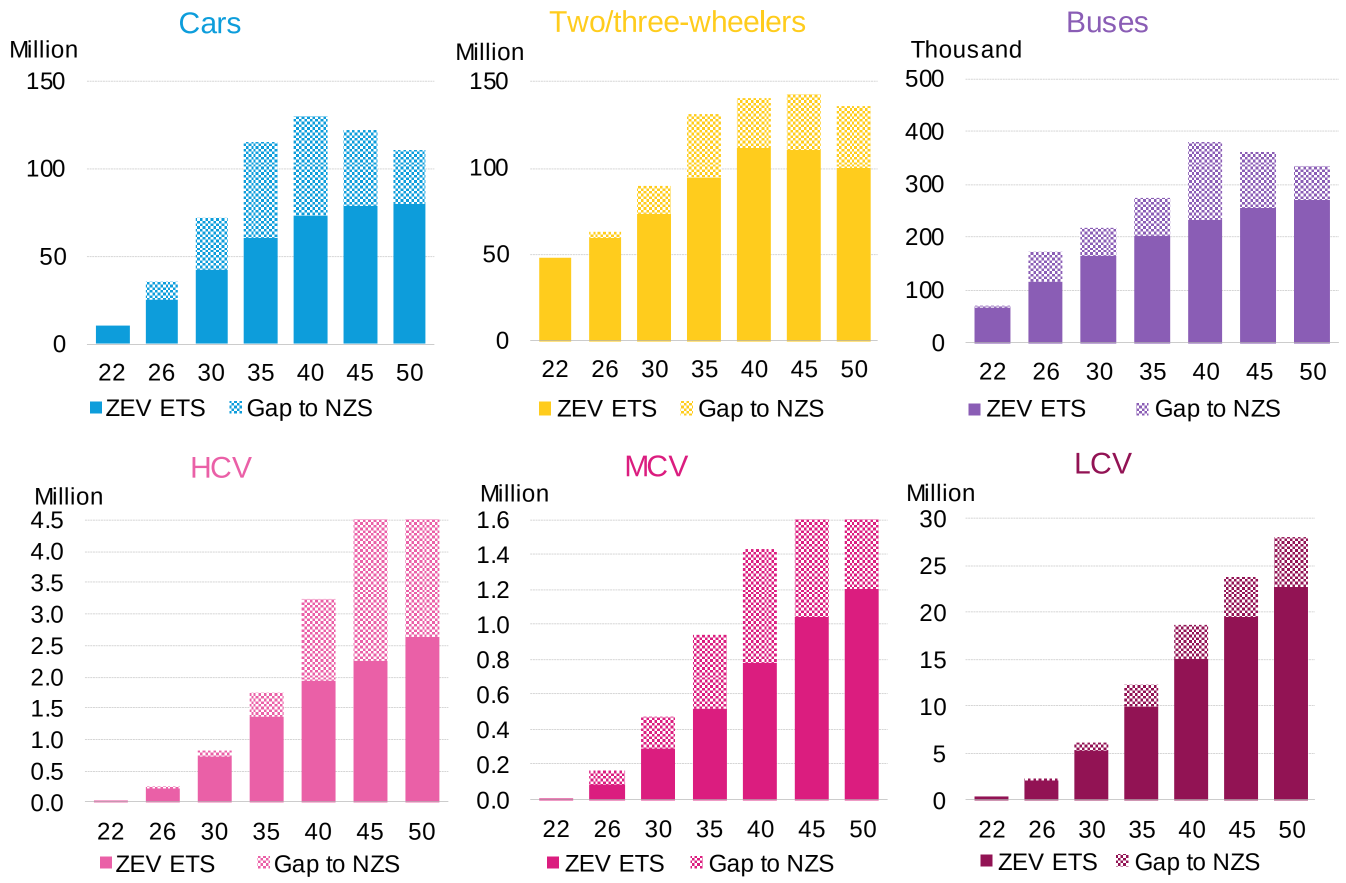
Figure 32: Global electric vehicle fleet in the Economic Transition Scenario and the gap to meet Net Zero Scenario



Source: BloombergNEF. Note: 'ETS' is the Economic Transition Scenario. 'NZS' is the Net Zero Scenario.

Bridging this gap in the fleet requires significant ramp up in sales in the next two decades. Some 55 million more electric cars need to find new buyers in 2035 in the NZS than in the ETS, and 37 million more electric two-/three-wheelers (Figure 33).

Figure 33: Global electric road vehicle sales in the Economic Transition Scenario and the gap to Net Zero Scenario



Source: BloombergNEF. Note: 'ETS' is the Economic Transition Scenario. 'NZS' is the Net Zero Scenario.

As a result of this significant ramp up, in the Net Zero Scenario, cumulative demand for lithium-ion batteries from all vehicle segments is 1.7 times that of our Economic Transition Scenario, reaching 226TWh by 2050. Demand peaks around 2043 and then slows as the market approaches saturation.

Under the Net Zero Scenario, the demand for raw materials is also set to skyrocket. Annual demand for metals needed for lithium-ion batteries rises from 3.7 million metric tons in 2022 to 52 million metric tons by 2050 in the Net Zero Scenario. Still, in this outlook, only lithium poses a supply-chain risk in 2050 under our Net Zero Scenario, if new discoveries are not made over the next two decades. This is an improvement compared to our results last year due to the increase in geological reserves and the introduction of battery chemistries that diversify the dependency on a few metals. This highlights the fact that combining demand-side response with that of the supply-side can prevent raw-material shortages in battery manufacturing.

Table 2: Batteries, materials, and investment impact

Sector	Current, 2023	2050 Economic Transition Scenario	2050 Net Zero Scenario
Batteries and materials			
Cumulative lithium-ion battery demand	2.4 TWh	131TWh	217TWh
Cumulative lithium demand (contained metal)	0.29 million metric tons	19.7 million metric tons	33.2 million metric tons
Cumulative cobalt demand (contained metal)	0.26 million metric tons	3.6 million metric tons	5.7 million metric tons
Cumulative class-1 nickel demand (contained metal)	1.14 million metric tons	28.9 million metric tons	47.4 million metric tons
Charging infrastructure			
Cumulative home and work charging infrastructure installed	17 million connectors	473 million connectors	670 million connectors
Cumulative public and e-bus/ truck charging infrastructure installed	4.5 million connectors	47.5 million connectors	75 million connectors
Investment			
Cumulative vehicle investment	$2 trillion	$63 trillion	$98 trillion
Cumulative charging-infrastructure investment	$114 billion	$1.7 trillion	$2.5 trillion

Source: BloombergNEF. Note: Lithium-ion batteries demand is from vehicles only and starts in 2015. Lithium, cobalt and nickel demand in BNEF's Net Zero Scenario refers to base chemistry mix which is explained in Section 8. Vehicle investment represents the total value of cars, trucks, buses and two- and three-wheelers sold.

Policy recommendations

To stay on track with the Net Zero Scenario across all segments, policymakers will need to step up and implement some or all of the measures discussed below. These vary depending on the segment and part of the supply chain, but there is some overlap as well and an opportunity to follow what worked elsewhere.

Passenger vehicles

- Introducing punitive import tariffs on electric vehicles manufactured in China could inadvertently slow down EV adoption by limiting the supply of affordable EVs. Countries that adopt such tariffs also risk shielding domestic automakers that have been slow to embrace the EV transition, removing some of the urgency that comes with exposure to competition on a more level playing field - and there is also the risk of retaliation and escalation in terms of trade policy. As such, countries should use trade policy carefully and, where tariffs are deemed necessary to support domestic industries, they should be carefully structured to encourage local investment without stalling the transition to lower-carbon transport.
- Governments with climate targets should set a phase-out date for sales of new internal combustion vehicles, to convey a clear, country level plan for transport decarbonization that automakers can then work toward. These targets need to be supported by policy measures with interim targets so that progress can be reviewed regularly. Progress on announcing new ICE phase-out goals has stalled in the last two years, while existing ones are facing stronger pushback.
- Fuel economy standards and/or tailpipe CO_2 emissions standards need to be made stricter and stretch further in time than current rules. Policymakers should not show leniency for non-compliance as the relevant deadlines approach.

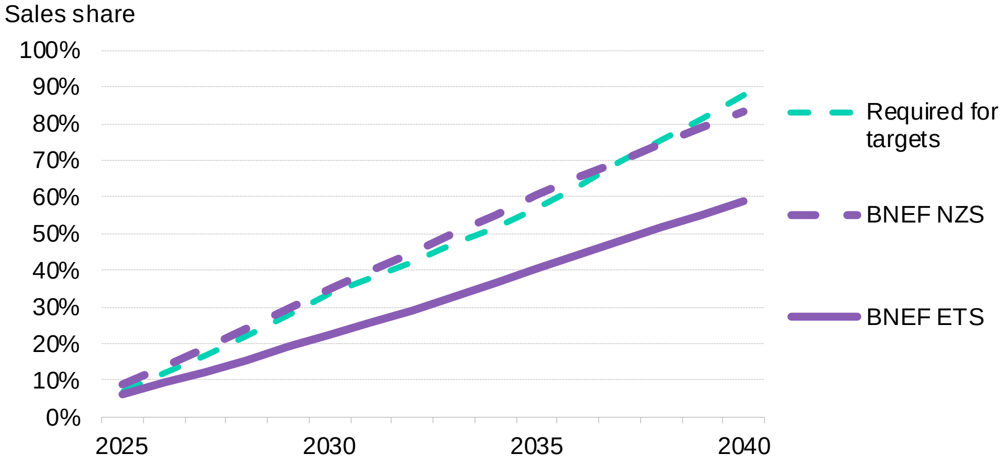
- Governments should consider mandates for the electrification of business fleets of passenger vehicles, including those of governments and transport operators, such as mobility-service providers.
- Additional consumer subsidies targeting low-priced and used EVs should be considered to help access the full range of buyers. EV subsidies should come with vehicle price caps that decline over time.
- Improving the relative economics of electric cars through CO2 emissions-based taxation of combustion cars should be put in place, especially in the more financially constrained markets unable to afford direct EV subsidies. Also, established EV markets should consider bonus-malus type approach to EV subsidies as this would allow for the support to last longer. Tightening these over time may be easier to implement politically than an outright ban on ICE sales.
- At the municipal level, tighter regulations for vehicles entering urban areas will help make the economics of zero-emissions vehicles more attractive, especially for commercial fleets.
- Stronger action is needed on regulating the use of plug-in hybrids. These are a useful transition tool, but only if actually used in their full electric capacity. The utility factor – the share of electric driving done by a PHEV – assumed in calculating cars' CO2 emissions in various testing cycles has to be brought closer to real-world values.
- Access to affordable finance will be crucial for accelerating EV adoption across passenger vehicles, especially in emerging EV markets. Interest rates subvention could be one way of subsidizing electric vehicle sales in markets facing high borrowing costs. Inclusion of EVs under priority sector lending could be another, as it increases the pool of money allocated by banks for financing EV purchases.
- Policymakers should consider enforcing a stronger regulatory environment around battery warranties and repairs, as the uncertainties in this area are one of the reasons for faster depreciation of electric cars. Support and investment in building out after-sales services, and skilled-labor training are also crucial.

Commercial vehicles

Light electric vans and trucks are already being adopted in several countries. The Net Zero Scenario for such vehicles still demands faster adoption, but looks more achievable than for the heavier vehicle segments. For these, the zero-emission share of the fleet reaches only around 30% by 2050 in the ETS. Closing that gap requires starting now to address the whole ecosystem of regulatory support, including purchasing, manufacturing and operational subsidies, with different focus in each category and at various times during the market's development. More detailed measures could include the following:

- Establish simple and long-term CO2 and pollutant emissions targets for commercial vehicles, without segment and technology exceptions. Those should be stringent enough to bring the industry closer to the net-zero trajectory, similar to the proposed targets in Europe (Figure 34).
- Simplify funding processes, for example, with set funding cycles, encourage the use of point-of-sales vouchers for zero-emission truck purchases, and separate infrastructure from vehicle purchase subsidies.
- Introduce subsidies and fiscal incentives specifically for small fleets purchasing zero-emission trucks.

Figure 34: Required electric and fuel-cell medium- and heavy-duty truck adoption for proposed emissions targets in Europe



Source: BloombergNEF. Note: 'ETS' is Economic Transition Scenario, and 'NZS' is Net Zero Scenario.

- Vary operational charges for trucks, such as road tolls, depending on a vehicle's CO2 emissions, and penalize emissions from heavy vehicles.
- Promote demand aggregation for zero-emission trucks and refueling infrastructure by providing regulatory and financial support to help manufacturers and station operators to scale up.

Batteries

- Governments should set requirements and standards for the recycling of EV batteries and continue to support research into next-generation battery technologies. Funding and streamlined permitting processes can help encourage new supply of raw materials.
- Advancements like sodium-ion batteries, solid-state batteries and next-generation anodes are now entering commercialization. Governments should look at ways to support domestic development of these areas and continue to support R&D into emerging battery technologies that reduce dependance on critical raw materials.

Charging infrastructure

- Support for charging infrastructure needs to be expanded dramatically, including for remote and otherwise under-served locations. Governments should also review cost recovery mechanisms for grid upgrades and grid connections to enable more charging points, and consider if these can be included in the rate base of relevant grid operators in a given area.
- Extensive investments will be needed in high-powered charging for trucking fleets, including local grid network reinforcements. Governments should fast track grid connection and permitting processes for these facilities wherever possible. In some cases, reductions in peak demand charges may be needed.

Industry

- Governments need to develop detailed transition strategies for the industries affected by the shift to zero-emissions vehicles. This includes developing plans to recoup lost tax revenue from the sale of liquid transport fuels. The politically acceptable solutions for this will vary by region. Retrofits and early retirement of older vehicles will also need to be explored, particularly in the heavy-commercial-vehicle segment.
- Policymakers need to ensure enough renewable generation is commissioned to maximize the benefit of road transport electrification. Investment in renewable generation should not slow down and should go hand in hand with road-transport electrification investment.

Mobility

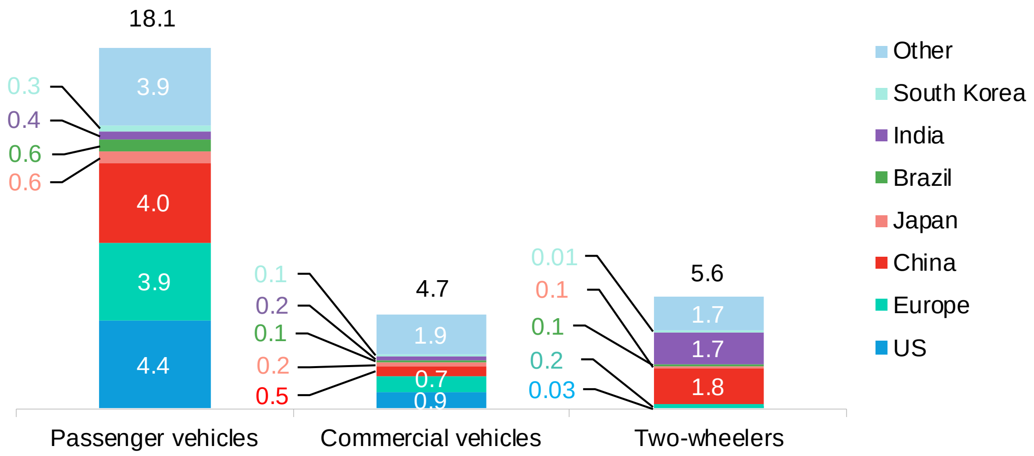
- Most of the above measures target vehicle adoption, but governments should also push to reduce overall demand for vehicle usage and ownership. Higher-density zoning in urban areas, active transport options such as cycling and walking, and investment in mass public transit all have an important role to play.

Section 3. Road transport today

The global passenger-vehicle fleet traveled around 18 trillion kilometers in 2023 (Figure 35), up from 17.1 trillion in 2022. Cars are the dominant segment of road transport by a wide margin. Two-wheelers traveled just 5.6 trillion kilometers and commercial vehicles only 4.7 trillion kilometers. The US accounted for over 24% of total passenger vehicle kilometers traveled in 2023 and Europe and China each made up about 22% of the global total.

Despite having 18% of the world's population, India accounted for just 2.5% of total passenger vehicle kilometers and 4.5% of commercial vehicle kilometers. Two-wheelers (mopeds, scooters and motorcycles) are the primary modes of transport in the country.

Figure 35: Global kilometers traveled by select vehicle segments, 2023



Source: BloombergNEF, government agencies. Note: 'Other' includes Canada, Australia, Southeast Asia (Indonesia, Thailand, Malaysia, the Philippines, Vietnam and Singapore) and rest of the world.

There are more than 1.3 billion passenger vehicles on the road globally (Figure 36). Europe has 302 million. The fleet in China grew from around 280 million vehicles in 2022 to nearly 296 million vehicles in 2023. The US has approximately 249 million passenger vehicles. Japan has more than 62 million, Southeast Asia has 46 million, Brazil 45 million and India 43 million, while Australia, Canada and South Korea each have about 24 million. The other 223 million passenger vehicles in our 'Rest of World' (RoW) category represent all other markets, notably Russia, Mexico and Turkey. Internal combustion engines still power the vast majority of passenger vehicles. At the end of 2023, there were about 41 million passenger EVs on the road, making up 3.1% of the global fleet.

New sales of passenger vehicles are similarly distributed. Consumers bought 78 million in 2023 (Figure 37), up from 75 million in 2022. Despite a decline in sales from the previous year, China was again the largest passenger vehicle market in 2023 with sales just under 22 million units, followed by the US and Europe with 14.5 million units and 13 million units, respectively. Both markets grew from 2022 levels but are still well below historic highs. About 18% of passenger vehicles sold globally in 2023 were battery-electric or plug-in hybrid vehicles.

Figure 36: Global passenger vehicle fleet, 2023

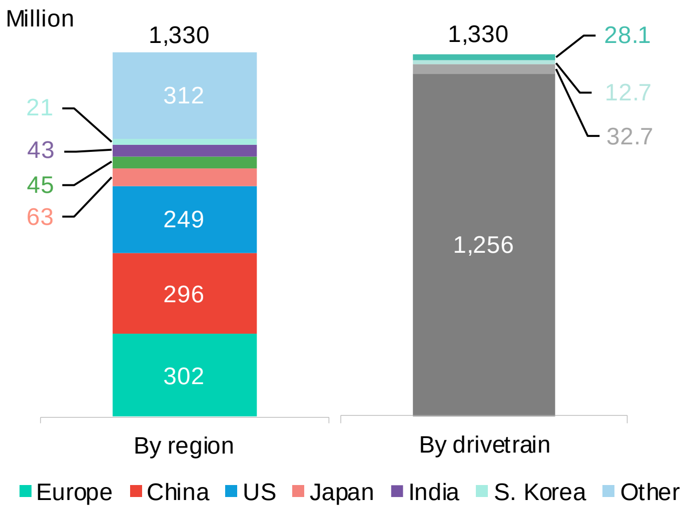
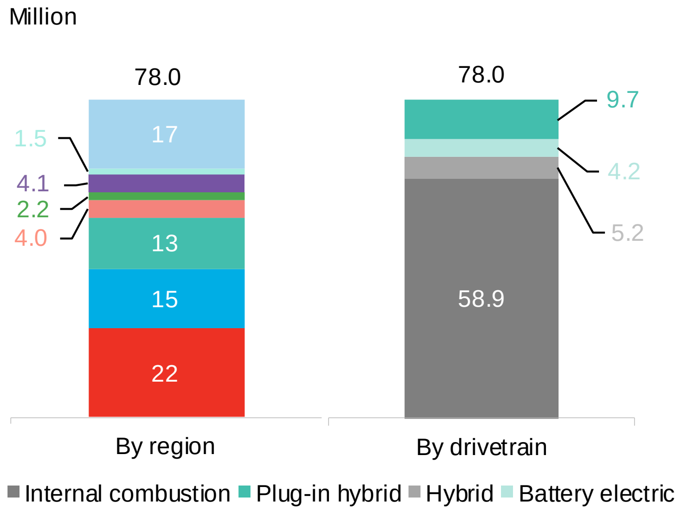


Figure 37: Global passenger vehicle sales, 2023



Source: BloombergNEF, government agencies, MarkLines. Note: 'Other' includes Canada, Australia, Southeast Asia and rest of the world.

There were about 14 million more two-wheelers sold in 2023 than passenger vehicles (Figure 38). China accounts for 53% of global two-wheeler sales, with two-wheelers outselling passenger cars in the country at a rate of nearly two-to-one. The growing two-wheeler market of India is the second largest in the world, four-times higher than that for passenger vehicles. Commercial-vehicle sales amounted to 15 million units in 2023 (Figure 39). China, Europe and the US were the largest markets, accounting for over 48% of global annual sales.

Figure 38: Global two-wheeler sales, 2023

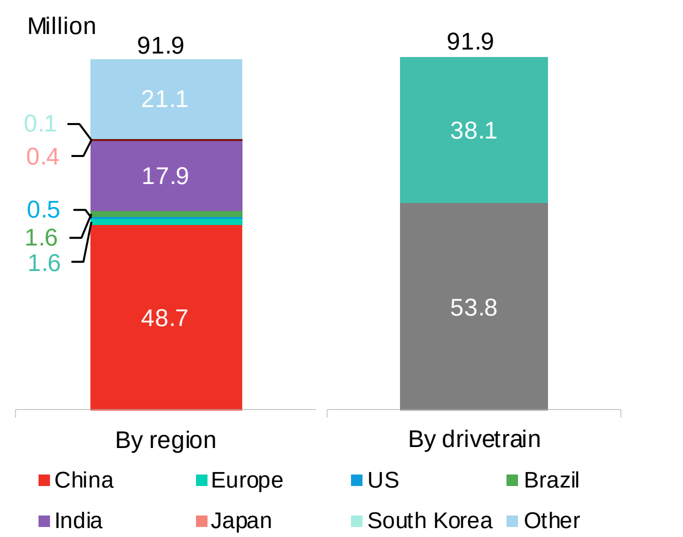
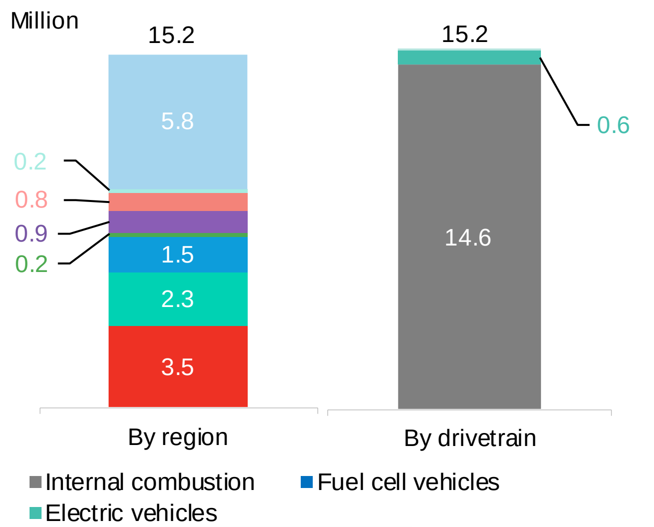


Figure 39: Global commercial vehicle sales, 2023



Source: BloombergNEF, government agencies. 'Note: 'Other' includes Canada, Australia, Southeast Asia and rest of the world.

3.1. The EV market today

Passenger and commercial EV sales

In 2023, some 13.9 million passenger EVs were sold globally, up from 10.4 million in 2022 (Figure 40). China was the leading market last year and represented over half (59%) of global passenger EV sales, with just under 8.2 million EVs sold in the country.

Figure 40: Global passenger EV sales by market

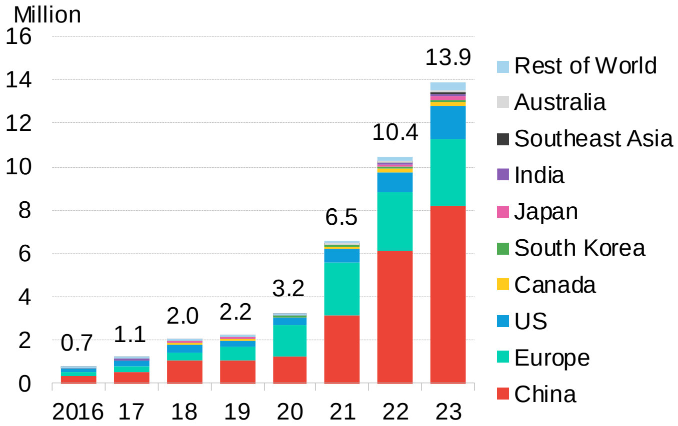
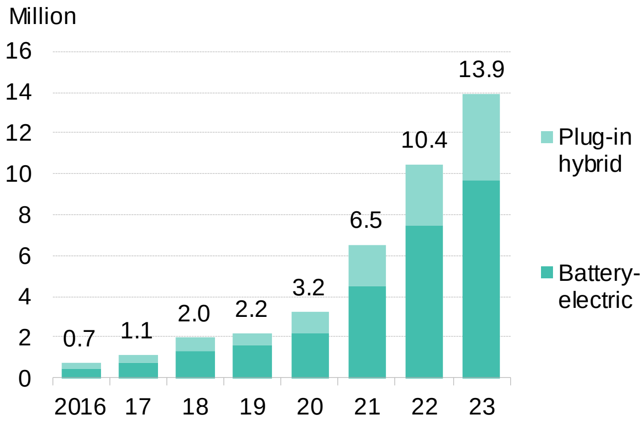


Figure 41: Global passenger EV sales by drivetrain



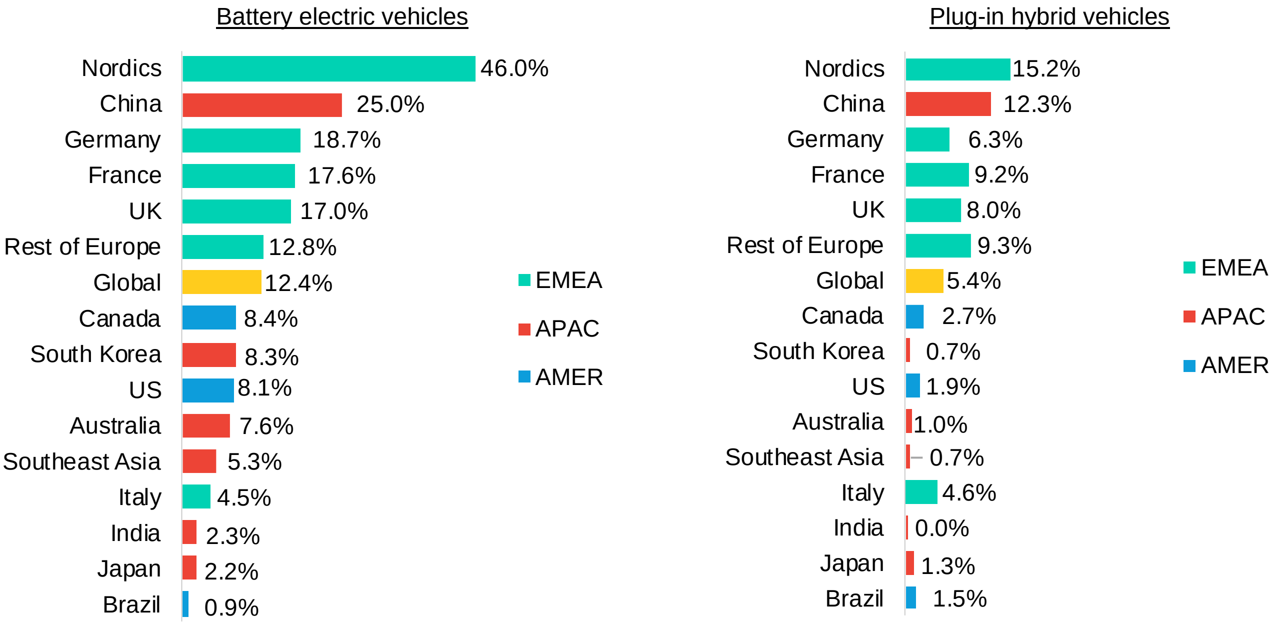
Source: BloombergNEF, MarkLines, Jato. Note: EVs include battery electric and plug-in hybrid vehicles. Includes highway-capable passenger EVs. Excludes low-speed EVs, e-buses and commercial EVs.

Battery electric vehicles represented 70% of the plug-in market in 2023, down from 72% in 2022, with plug-in hybrids increasing their share of the overall passenger electric vehicle market slightly. The increase in the market share of plug-in hybrids comes from China, where sales of cars with this drivetrain were up 82% year-over-year in 2023 (Figure 41).

Plug-in hybrids accounted for 33% of all EVs sold in China last year, up from 24% in 2022, as demand for plug-in hybrids is rising quickly outside of megacities where consumers are more price-sensitive and still find it more difficult to access charging infrastructure. In 2023, in the compact-car segment – which makes up nearly a quarter of total passenger vehicles sales in China – an average fully electric car was still priced roughly 18% higher than a comparable ICE model. The price gap between an average plug-in hybrid car in the same segment and a combustion car was near zero.

In 2023, electric vehicles accounted for 17.8% of all passenger vehicle sales globally and a record 61% in the Nordics (Figure 42). Outside of the Nordics, several countries are moving faster than the global average: in China, over 37% of all cars sold were electric, followed by Germany, France and the UK, which all surpassed 25%.

Figure 42: Passenger BEV and PHEV share of total car sales in select markets, 2023

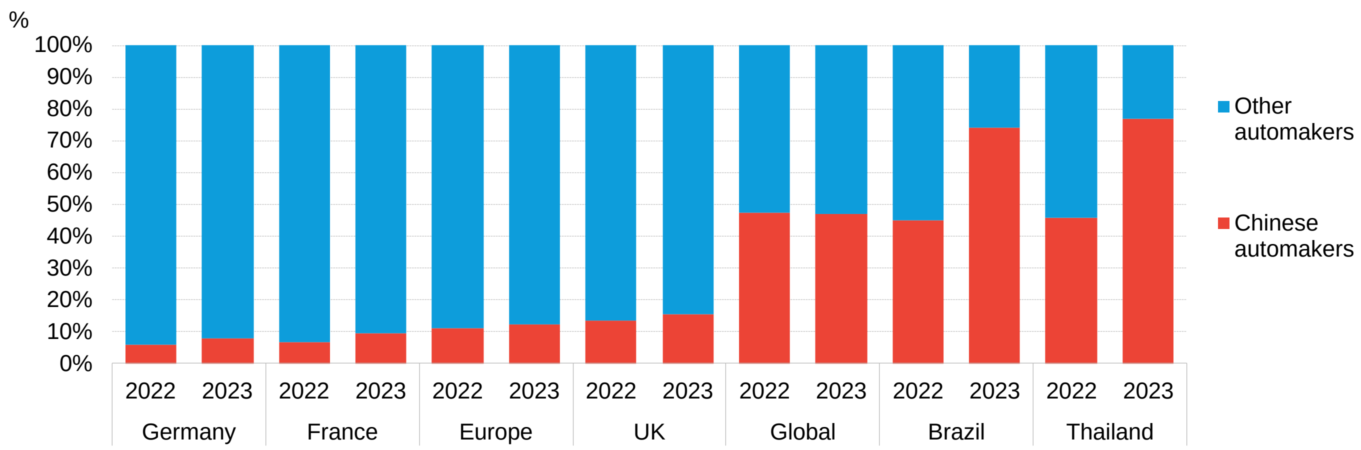


Source: BloombergNEF, MarkLines.

The fleet of passenger EVs, e-bus and commercial EVs reached 43 million at the end of 2023

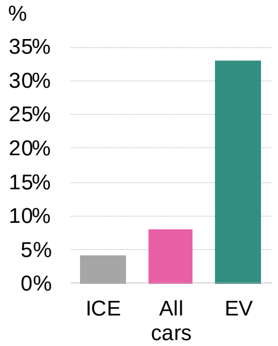
While China accounted for over 59% of global passenger EV sales in 2023, Chinese automakers provided 47% of all electric cars sold globally. This remained unchanged from 2022, but the importance of Chinese automakers grew significantly in a number of emerging EV markets. In Brazil, where passenger EV sales nearly tripled in 2023, China-based automakers were behind 76% of all EVs sold that year – in large part due to the rapidly growing sales from BYD. In Thailand, the share of Chinese automakers in total electric car sales grew to 77% in 2023, from 46% in 2022 (Figure 43).

Figure 43: Automakers' share of total passenger EV sales



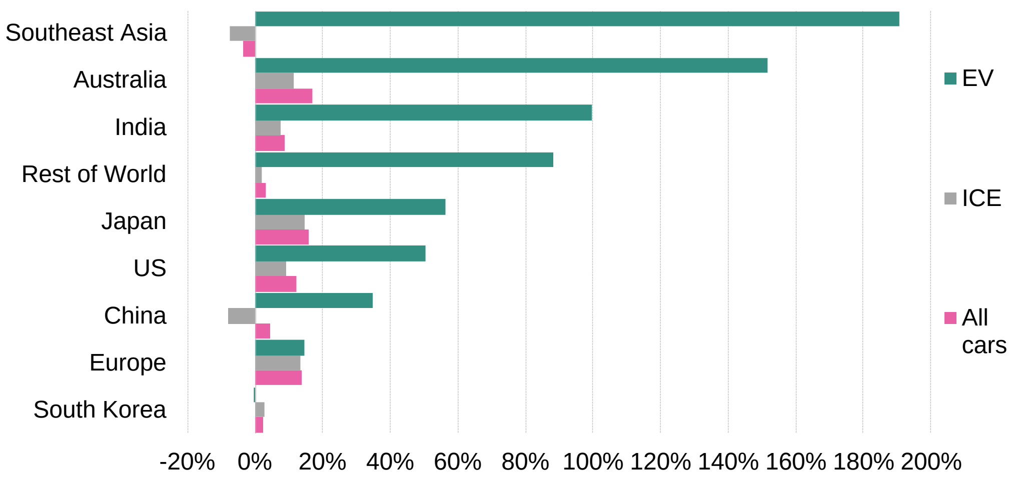
Source: BloombergNEF

Figure 44: Global annual growth rate for passenger vehicle sales, 2022 to 2023



Source: BloombergNEF. Note: EV includes battery-electric and plug-in hybrid vehicles. ICE stands for internal combustion engine.

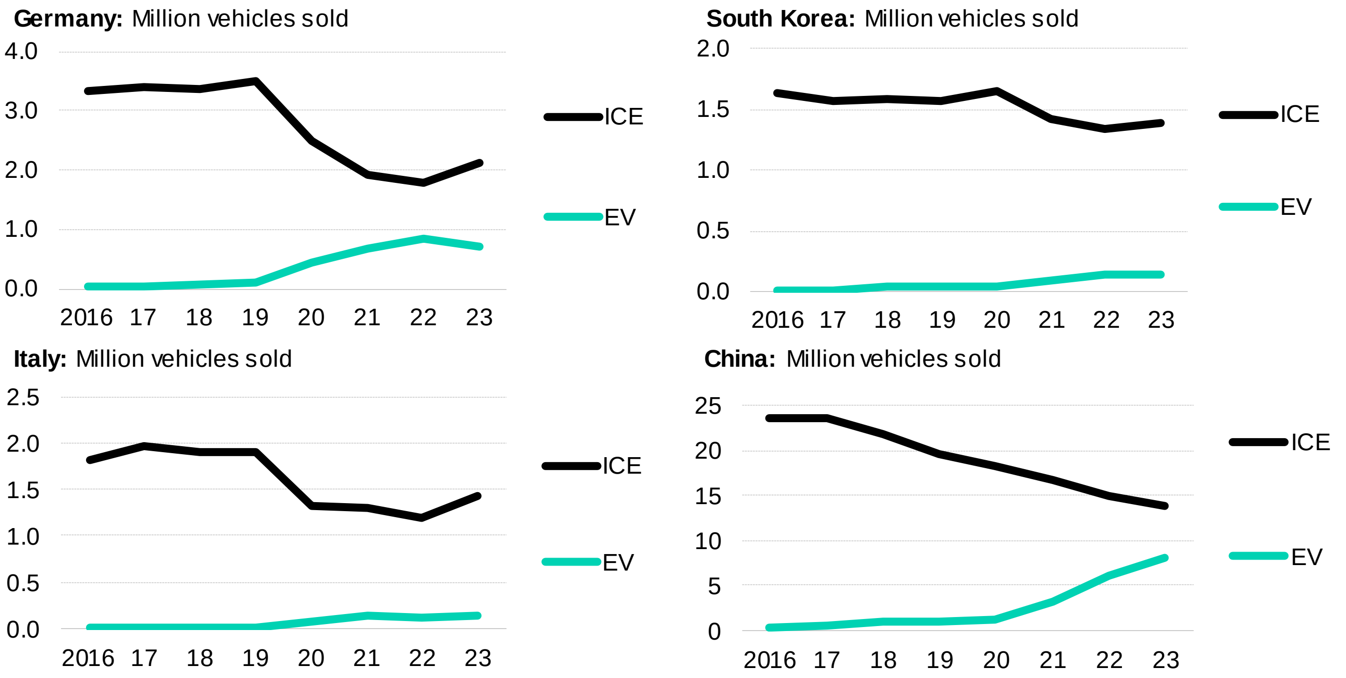
Figure 45: Annual growth rate for passenger vehicle sales, 2022 to 2023



Source: BloombergNEF. Note: EV includes battery-electric and plug-in hybrid vehicles. ICE stands for internal combustion engine.

Global passenger vehicle sales jumped 8% in 2023. Within that category, electric car sales grew much faster than those of combustion vehicles, at 33% compared to just 4% year-on-year, respectively. There were only a couple of countries where EV sales were either down – Germany (-16%) – or where combustion vehicle sales grew faster than EVs – South Korea and Italy (Figure 45, Figure 46).

Figure 46: Passenger vehicle sales by drivetrain



Source: BloombergNEF. Note: EV includes battery-electric and plug-in hybrid vehicles. ICE stands for internal combustion engine.

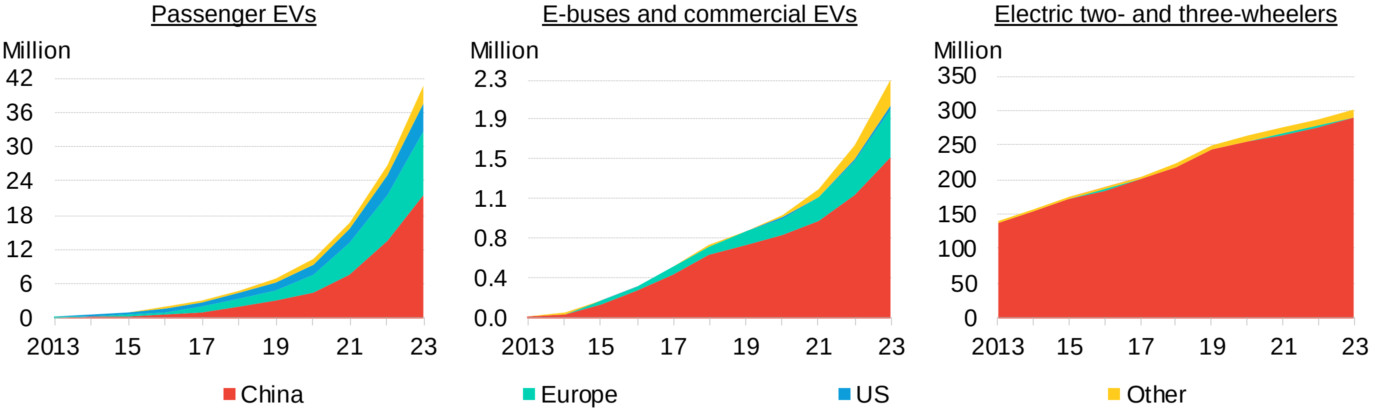
In total, just over 64 million internal combustion vehicles were sold in 2023. Although this represents a 4% increase from a year earlier, it continues to be significantly lower than the 86 million sold six years earlier in 2017.

There are now more electric trucks on the roads in China than there are e-buses

The fleet of passenger electric vehicles reached 41 million at the end of 2023 (Figure 47). Another 2.3 million electric buses and commercial vehicles made it onto the roads globally by the end of last year. China now has over 670,000 e-buses in use, and the second largest e-bus fleet is in Europe, with over 23,000 e-buses in circulation. Commercial EV truck sales have picked up last year, and there are now almost 859,000 of those on the road in China, 432,000 in Europe, 118,000 in South Korea and over 36,000 in the US. For the first time, there are now more electric commercial vehicles on the road in China than e-buses.

The global fleet of electric two-/three-wheelers is seven times larger than the worldwide fleet of passenger and commercial EVs combined. At the end of 2023, there were nearly 302 million electric two-/three-wheelers globally, with 96% of that fleet in China.

Figure 47: Global EV fleet sizes by segment and market

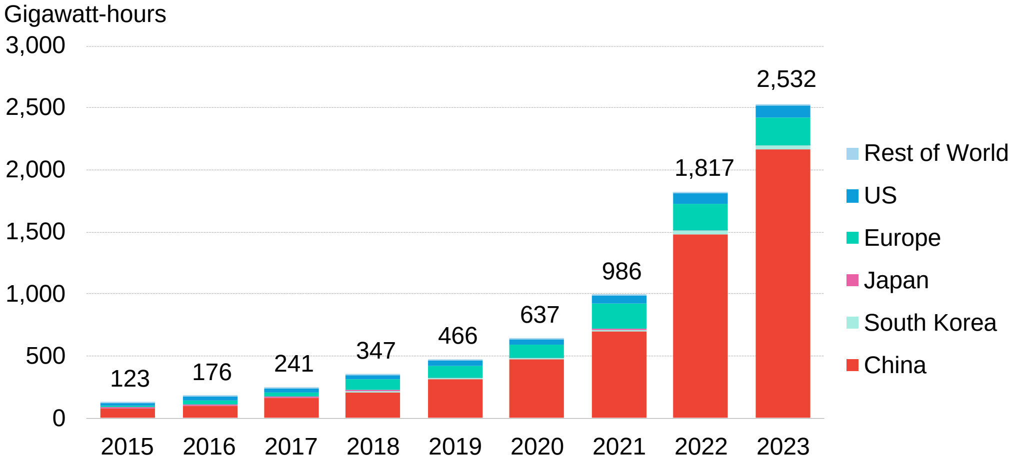


Source: BloombergNEF, MarkLines. Note: Includes battery electrics and plug-in hybrids.

3.2. Current battery demand, prices and capacity

At the end of 2023 there was 2.5 terawatt-hours/year (TWh/year) of commissioned lithium-ion battery manufacturing capacity globally, more than 20 times that online in 2015 (Figure 48). If all additional planned plants are built, total capacity would increase to 9.4TWh/year by the end of 2026. While capacity is heavily concentrated in China, new cell-manufacturing capacity in Europe, and increasingly in the US, is beginning to ramp up to support growing demand in those regions.

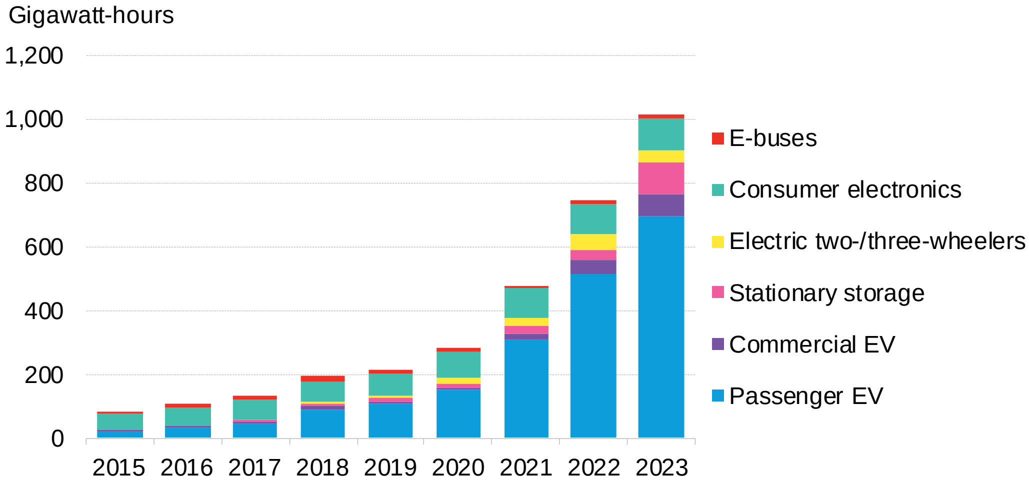
Figure 48: Cumulative lithium-ion battery cell manufacturing capacity



Source: BloombergNEF. Note: Data up to 2023 includes fully commissioned nameplate capacity.

Demand for lithium-ion batteries in passenger EVs was 698GWh in 2023, up from 514GWh in 2022 (Figure 49). Passenger EVs accounted for 69% of total lithium-ion battery demand in 2023, versus 53% in 2020 and compared with 26% in 2015.

Figure 49: Annual lithium-ion battery demand by application

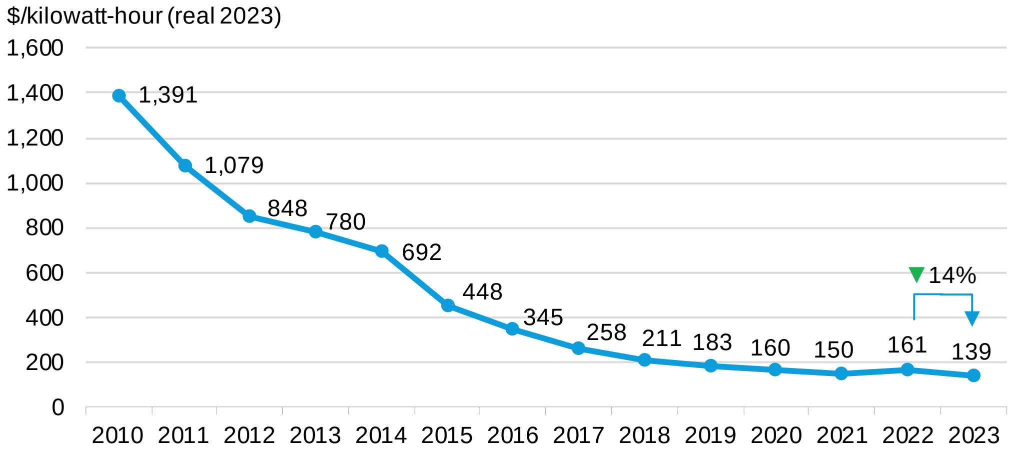


Source: BloombergNEF, Avicenne. Note: The demand outlook for consumer electronics comes from Avicenne.

Battery prices

Battery prices fell again in 2023, after an unprecedented year of increases in 2022. BNEF's annual battery price survey found that the volume-weighted average price for lithium-ion battery packs dropped to $139 per kilowatt-hour (kWh) in 2023, a 14% decline from 2022 (Figure 50). Drivers include falling raw-material and component prices due to significant growth in production capacity across all parts of the battery value chain. Meanwhile, demand may have fallen short of industry expectations, even as it continued to grow. Since 2010, battery prices have fallen 89% and are nearing levels where the upfront costs of EVs can start to be competitive with internal combustion engine vehicles (ICE) without subsidies.

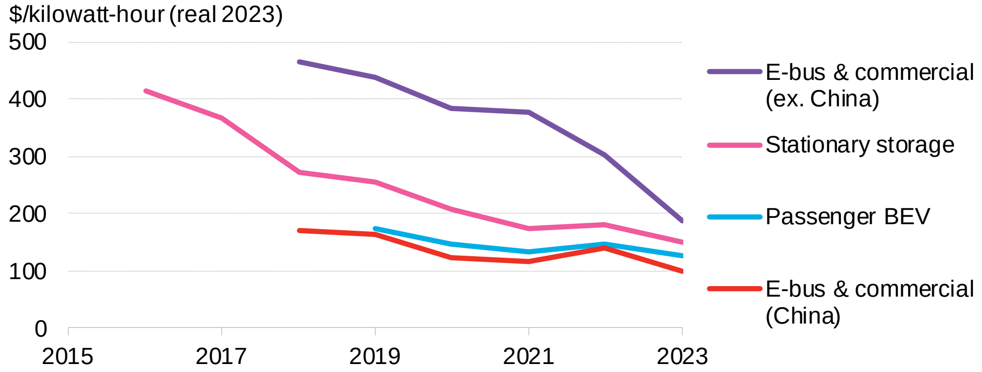
Figure 50: Volume-weighted average lithium-ion pack price



Source: BloombergNEF

In 2023, the cheapest packs delivered on a volume-weighted average basis were in China, coming in at $126/kWh. Chinese electric buses and commercial vehicles continue to have the lowest average battery pack prices, at $100/kWh. Cell prices for these applications were $89/kWh on average, but these were for relatively large lithium-iron-phosphate (LFP) packs. Prices for e-buses and commercial vehicles outside China dropped significantly and are now closer than ever to industry average (Figure 51). Prices across segments start converging as demand and related economies of scale drive prices down.

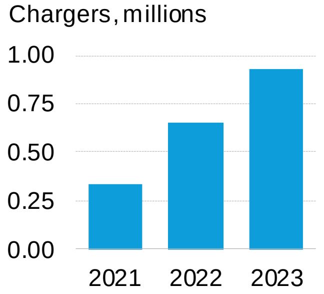
Figure 51: Historical volume-weighted average pack prices by sector



Source: BloombergNEF

3.3. EV charging infrastructure

Figure 52: Annual public charging installations in China



Source: BloombergNEF, EVCIPA

The global public charging network consisted of close to 4 million chargers at the end of 2023, with annual installations growing 40% year-on-year, below the 85% growth in 2022 (Figure 53). China continued to dominate the global public charging network with 69% of the total number installed at the end of 2023. This was after installing 929,000 new chargers in the year, which was 43% higher from the number added in 2022 (Figure 52).

South Korea almost doubled the number of chargers installed in 2023, reaching 47,000 new chargers. France and Germany also made notable progress, each bringing online 36,000 chargers (Figure 54). Annual installations fell in both the US and the Netherlands.

The US and Netherlands are very different charging markets. The Netherlands has benefited from strong government incentives and consistent growth in its charging infrastructure. Whilst still a leading market for public charging, the slowing installations could be down to saturation, reduction in subsidies and a move toward faster chargers. Fewer slow chargers are required to serve the same size EV fleet. The US has been bereft of competition and the main federal funding scheme – the NEVI grant – is taking time to turn funds into chargers in the ground. Tesla lowering its ambitions will be a challenge for the market, as it is the dominant operator in the US, even though new entrants are popping up. As the US sector matures, it may start to mirror Europe, where there are hundreds rather than tens of operators vying for market share.

Figure 53 : Cumulative global public charging connectors

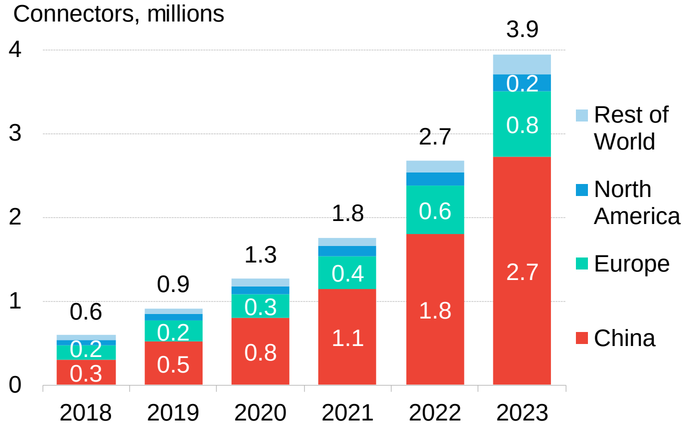
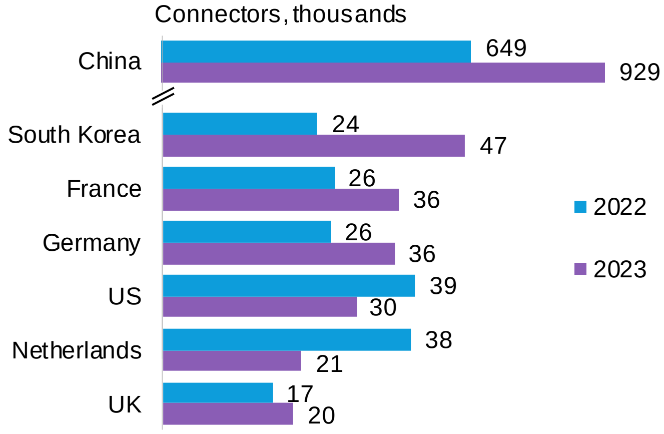


Figure 54: Annual public charging installations by country



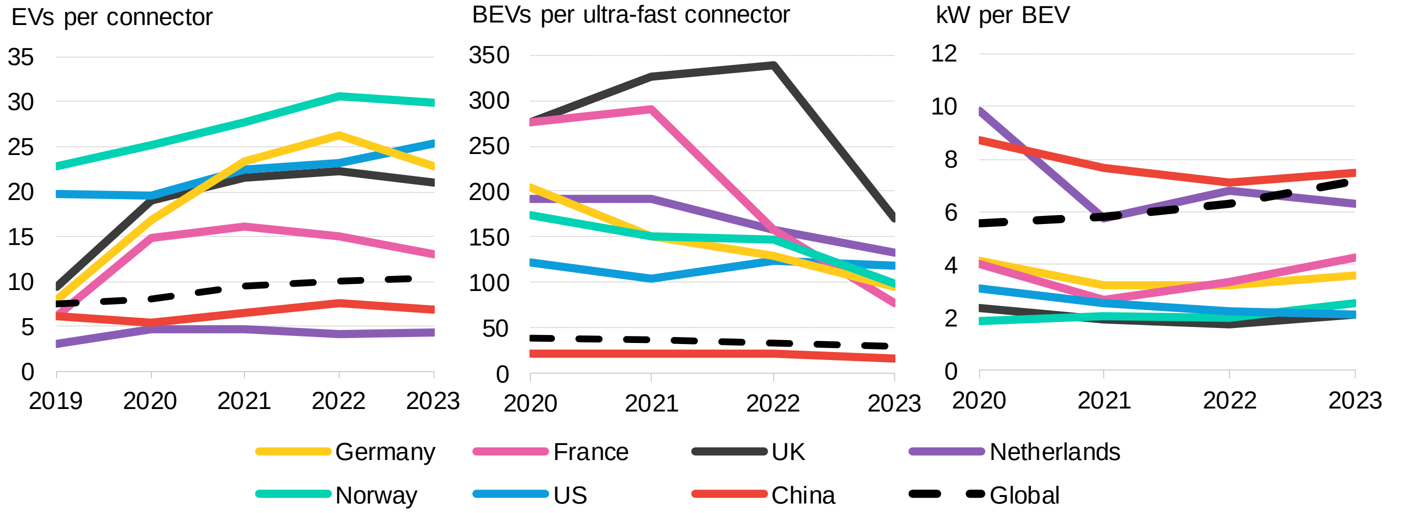
Source: BloombergNEF, China Electric Vehicle Infrastructure Promotion Alliance (EVCIPA), US Alternative Fuels Data Center, Tesla, Chargehub, a range of public and private sources.

Some 31% of public chargers installed in 2023 were ultra-fast, but they accounted for 86% of investment

Globally, the number of EVs per charger rose slightly to 10.3 to 1 in 2023 (Figure 55), but it fell in many major markets outside the US. The ratio of BEVs to ultra-fast chargers also plummeted, which means there are many more fast chargers per electric vehicle. This counters the narrative from automotive associations such as ACEA (European Automobile Manufacturers' Association) which have been critical of EV adoption targets, claiming that growth in EVs is significantly outstripping the growth in public chargers.

There is also more charging power in the network per BEV than there was a year before, growing from 6.3kW globally in 2022 to 7.1kW per BEV in 2023. Europe is the first market to legislate on this metric – the Alternative Fuel Infrastructure Regulation sets a target of 1.3kW of public charging power per battery electric vehicle on the road. Many countries are above this. Germany had 3.6kW per BEV and France reached 4.2kW. Norway is lower than most markets with just 2.5kW per BEV and the UK is similarly lagging at just 2.1kW.

Figure 55: Density of public charging per electric vehicle across selected countries



Source: BloombergNEF. Note: Ratio of kW per BEV calculated based on full network power and no removal of power for PHEVs.

The move to ultra-fast chargers is impressive. France dropped from 157 BEVs per ultra-fast charger in 2022 to 77 in 2023, Germany from 129 to 95, and the UK from 338 to 170. These chargers can deliver more power in shorter charging sessions, which reduces the total number of chargers needed. They accounted for 86% of the $24 billion invested in public charging in 2023, despite making up a third of new chargers. China has had a focus on the availability of fast charging for some time and there are just 17 BEVs per ultra-fast connector. The emphasis can in part be attributed to the lack of home charging.

Figure 56: Share of public charging network power by power category in 2023

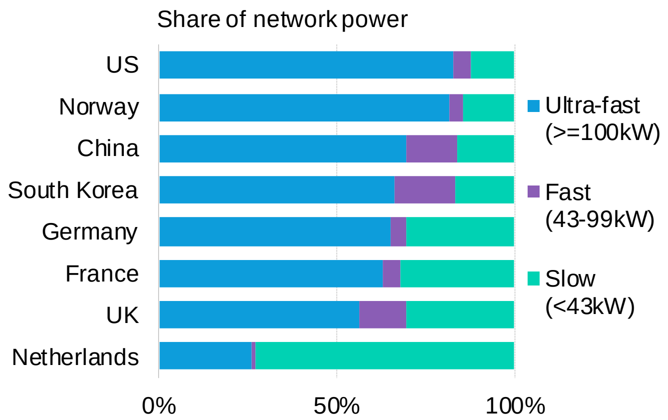
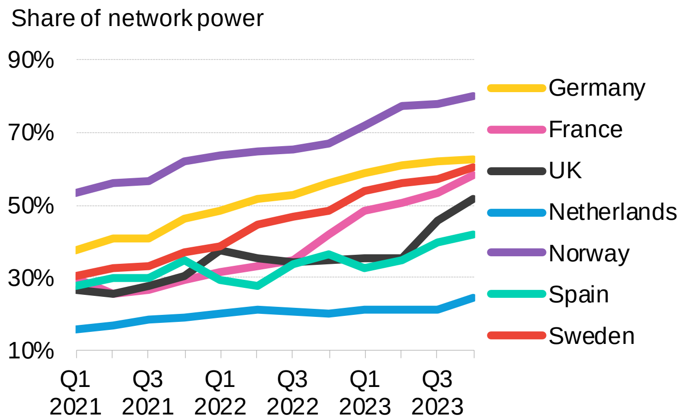


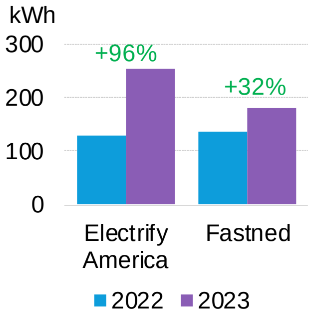
Figure 57: Share of public charging network power capacity from ultra-fast chargers



Source: BloombergNEF, Eco-Movement and China Electric Vehicle Infrastructure Promotion Alliance (EVCIPA).

The move to ultra-fast charging can be seen based on how much share of network power it accounts for. In Norway, the US and China, they deliver 80% of the network's power (Figure 56),

Figure 58: Energy delivered per charger per day on fast networks



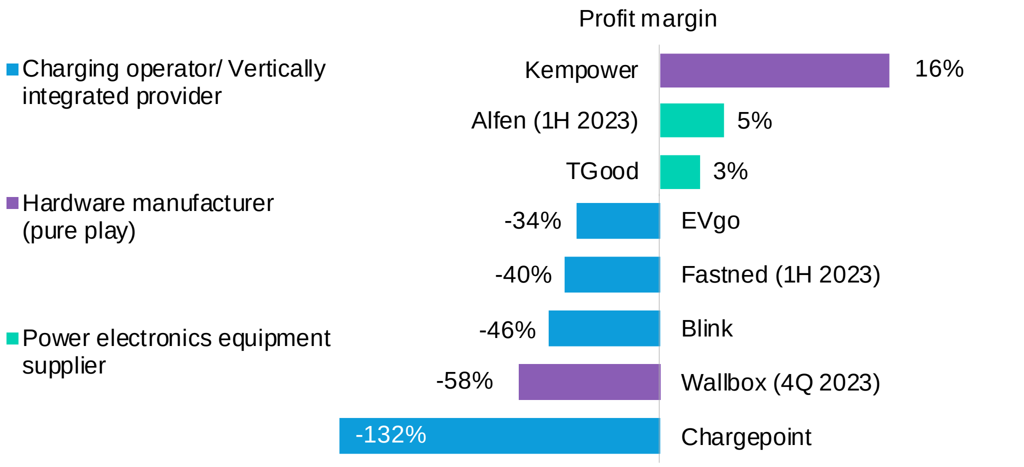
Source: Electrify America, Fastned, BloombergNEF

whilst they also account for between 50 and 75% in UK, France, Germany and South Korea. The chargers have been taking up an increasing share over time (Figure 57). In Norway they have grown from 50% of network power to 80% in four years.

It is not clear that ultra-fast chargers will account for such high shares in all markets. In the Netherlands, close to 75% of network power is provided by slow chargers, although the ultra-fast share of network power has also increased in recent years. Legislators across countries are also starting to focus on funding truck charging, which will also require more fast charging. From a network-operator perspective, ultra-fast chargers offer the potential to deliver large amounts of energy and increase charger utilization. This strategy is coming to fruition for Fastned and Electrify America, both of which delivered much more energy per charger per day in 2023 than 2022. Electrify America delivered 38GWh of electricity last year, almost double the 2022 value (Figure 58). Data on slow chargers is limited but this is closer to 7 kWh per day on Scandinavian operator Recharge's network.

While improving utilization is essential for the networks to operate profitably, the industry is facing challenges. As of the third quarter of 2023, all the charging operators that make money from selling electricity, as tracked by BNEF, had a negative profit margin (Figure 59). Fastned was Ebitda positive in 2023, however.

Figure 59: Profit margin for select charging companies in 3Q 2023



Source: BloombergNEF, Bloomberg Terminal {FA<GO>}, company filings. Note: Profit margin uses net income margin, adjusted from Bloomberg Terminal and if this is unavailable, chart takes the value from company presentations

To increase profitability, operators have increased the price of fast charging (Figure 60). The average price per kWh rose by 21% in the UK over the course of 2023, and by 12% in Germany. There is a big spread in prices though and competition may cause operators to decrease prices in the future. In the UK, the most expensive price for fast charging is $1.29/kWh and cheapest is just $0.19/kWh. Slow charging was 30% cheaper than fast charging across UK operators (Figure 61).

Monthly subscriptions that attract customer loyalty are common, and operators are also reducing subscription pricing to attract customers. Automaker-led Ionity halved the price of its monthly subscription in January 2024 from €11.99 to €5.99. Subscribers get a €0.20 per kWh discount.

Figure 60: Average public charging price for fast and ultra-fast chargers in select countries

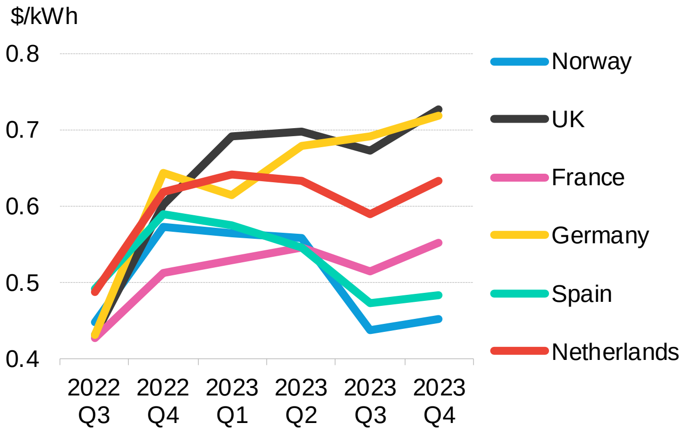
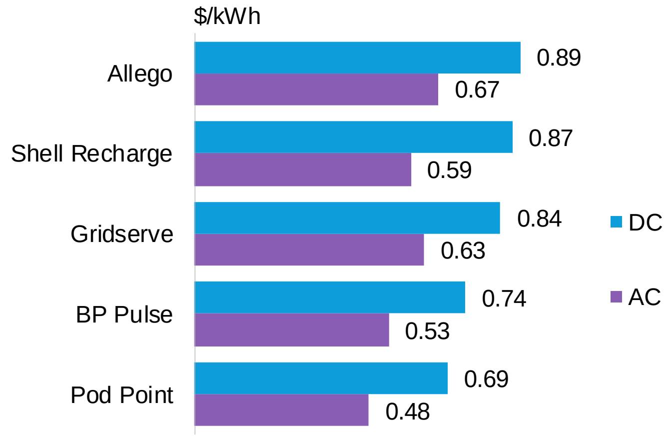
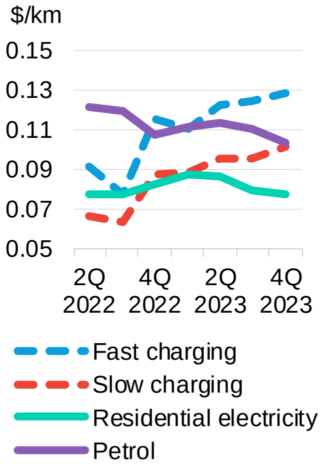


Figure 61: Average price of AC and DC public charging on select UK charging networks in December 2023



Source: BloombergNEF, Eco-movement. Note: Prices converted to US dollars. Shows price of energy before applicable VAT.

Figure 62: Price per kilometer by fuel type in Germany



Source: BloombergNEF, Ecomovement. Note: Fast and slow charging average price from Ecomovement data.

It is important to note that public charging prices are mostly lower than that of gasoline, particularly on slower chargers, but fast charging is proving to be an expensive option in some markets (Figure 62). Home charging is still significantly cheaper than petrol driving per kilometer though and smart charging tariffs, where energy is cheaper at low demand times, make this difference even more pronounced. Utilities are increasingly offering special tariffs to EV drivers and EV charging is one of the biggest winners of UK local flexibility tenders.

Data on home charging is still lacking, but Shell Recharge's survey points to high levels of home charging in Europe and North America. Around 71% of 25,000 European EV drivers surveyed in 2021 charged at home, but only 56% of the total had a home charger with 15% using a standard socket. The number of drivers without a home charger has risen over time with 44% of surveyed drivers stating they did not have a home charger in 2023, against 39% in the previous year's survey.

Companies in the home-charging industry are facing challenges, including increasing competition, commoditization and lower government subsidies. This has led to faltering revenues and negative profit margins for companies such as ChargePoint and Wallbox. Companies are looking to software to manage wider energy demands of homes and businesses as a differentiator. With 25 EV models now offering bi-directional charging functionality, many are looking to offer bi-directional charging.

3.4. Automaker commitments to EVs

Despite electric vehicle sales increasing globally, in 2023 and in 2024, several automakers scaled down their near-term electrification targets made earlier this decade, quoting lower-than-expected demand and a slow-down in the EV market. No automakers announced new long-term EV commitments in the last two years.

Long-term targets stagnant

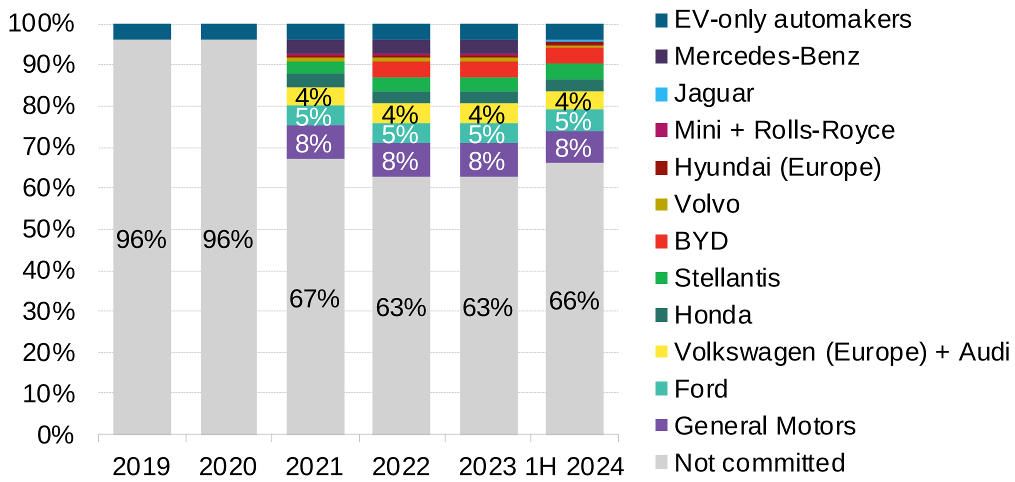
Automaker targets give a sense of the level of commitment to the zero-emission vehicle transition. Long-term pledges take many shapes and forms, but broadly fall into three categories: automakers committing to end new investment in internal combustion vehicles, those committing to phasing out ICE sales, and those committing to long-term net-zero emissions targets (Figure 64).

Automakers have not announced any new targets to phase out internal combustion engine vehicles since 2022

Over the past two years, no major automakers have announced plans to phase out internal combustion engine vehicles. While 17 automakers have announced ICE phase-outs since 2020, the vast majority of announcements were made in 2021. Automakers who have made such targets span high-volume sellers, such as GM, to smaller brands like Rolls-Royce and Maserati. Four automakers – Stellantis, Volkswagen, Ford and VW – have set an end date for ICE vehicle sales in Europe specifically but have been vague as it pertains to their global ambitions.

Mercedes-Benz was the first automaker to rethink its ICE phase-out target, highlighting vulnerability of existing commitments

Figure 63: Share of global passenger vehicles sold by automakers with an ICE phase-out announcement and electric-vehicle only automakers

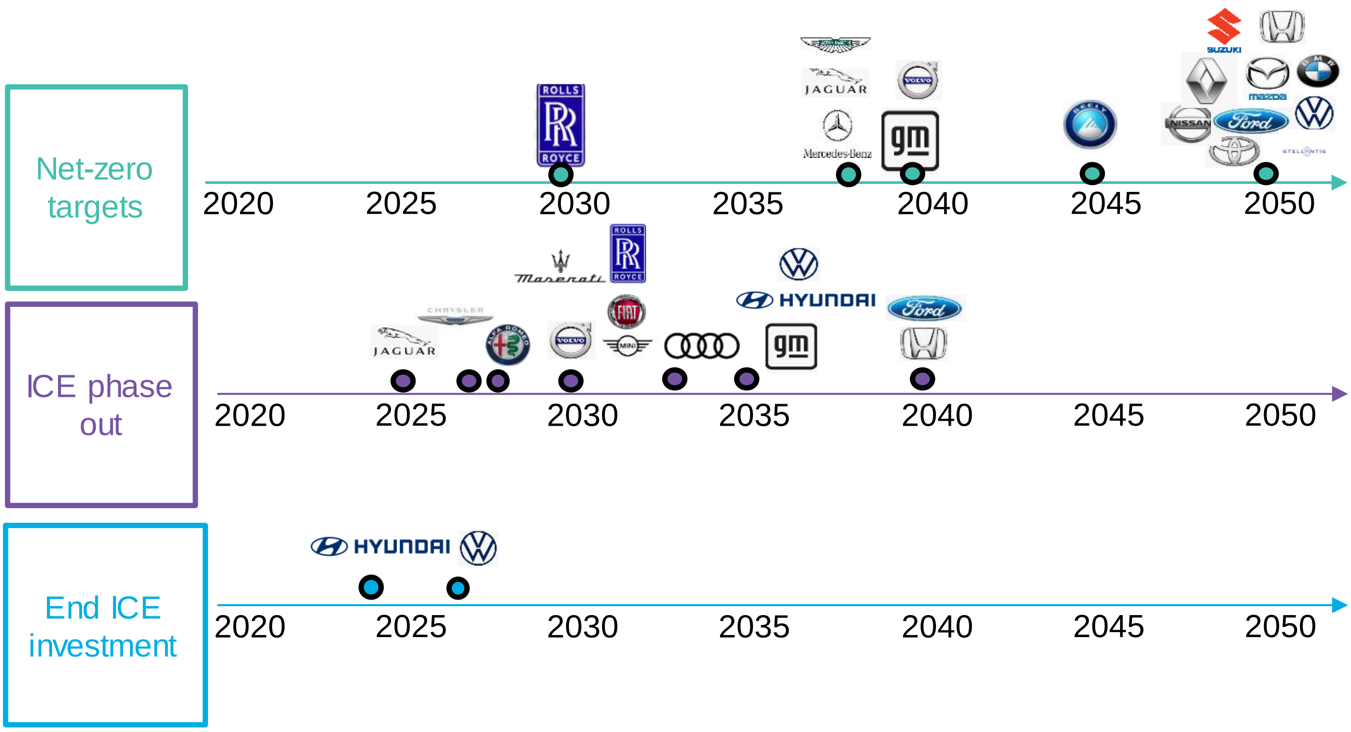


Source: BloombergNEF, MarkLines, various automakers. Note: Share of 2023 passenger vehicle sales. Announcements made through May 15, 2024. Stellantis brands included: Peugeot, Fiat, Chrysler, Alfa Romeo and Maserati. Ford signed the Zero Emission Vehicles, or ZEV, Declaration at COP 26, indicating its willingness to go fully zero-emission by 2040 globally, but it has not repeated that commitment in reports to investors.

Automakers that have announced ICE phase-out targets represented 33% of global passenger vehicle sales in 2023 (Figure 63). Additional EV-only automakers (like Tesla, Nio and Rivian) made up nearly 4% of last year's passenger car sales. Still, cracks have begun to appear in the commitments already made. In the first half of 2024, Mercedes-Benz announced it had shifted back its 2025 electrification target of 50% of sales to 2030 while also opening the door to conventional hybrids. It also indicated it was no longer holding to its ICE phase-out policy, originally set for 2030. Ford announced it was thinking of revising its all-electric goal for 2030 in Europe and broadening it to include PHEV sales. GM's Cadillac brand also cast doubts about its 2030 all-electric target.

Several automakers, like Hyundai and VW, have announced they will cease investment in new combustion engine vehicles. Hyundai has indicated it is transitioning to fully electric development, while VW says its last ICE platform will come out in 2026. Ending ICE investment can be a more radical step than ending new sales of these models, because it suggests a rapid move to EVs in the near term versus a target further out that can be postponed or modified. Still, until a financial decision is made it is always possible automakers could change course (Figure 64).

Figure 64: Automakers' drivetrain development targets



Source: BloombergNEF. Note: Hyundai, Stellantis and VW ICE phase-out target is for Europe only. On November 9, 2021, Ford signed the COP26 declaration on accelerating the transition to 100% zero-emission cars and vans, which called for working toward an ICE phase-out globally by 2040 and in leading markets by 2035. Excludes interim targets. Net-zero target scope varies by company, as some only cover Scope 1 and 2 emissions. For more details, see BNEF's Net-Zero Assessment Tool (web).

As of early 2024, some 17 automakers have also set a 'net-zero' or carbon-neutrality target ranging between 2039 and 2050. More than half of these companies have also established an ICE phase-out goal, with Toyota, BMW, Nissan and Renault among the exceptions. These net-zero targets vary by timing, the scope of emissions addressed, regions included and other criteria.

Some of the ICE phase-out targets automakers have set are getting close. For example, brands like Jaguar have set phase-outs for 2025 and Chrysler in 2028. The year 2030 is now less than six years away. Given the time needed to go all-electric, the viability of these targets is likely to come under increased scrutiny as once-distant goals meet present day production realities.

Delayed or altered near-term targets

Since 2023, several automakers – including Tesla, Mercedes-Benz, GM, VW, Ford and Jaguar – have made cuts to their near-term goals for electric vehicles, often quoting their inability to manufacture EVs at as low a cost as gasoline cars. Some have also cited macroeconomic conditions as reasons for pushing back targets. Table 3 below summarizes some of the announcements made over the past year and their implications.

Table 3: Reduction in near-term EV targets by selected automakers

Automaker	Announcement date	Action	Original target	New target	Comments
Ford	July 27, 2023	Delaying EV production target	600,000 EV run-rate by 2023	600,000 EV run-rate by 2024	Ford has also reduced output for the Mustang Mach-E and F-150 Lightning
	October 30, 2023	Plant delays at Marshall plant, 2nd Kentucky factory	Mid-decade	TBD	Pushed back $12 billion in investment to better align with the markets. Reduces investment in the Marshall, Michigan, plant with CATL.
VW	September 30, 2023	EV plant cancellation	2026	Canceled	$2 billion facility canceled; vehicles will be re-oriented
GM	October 24, 2023	Canceling EV production target	400,000 vehicles produced from 2022 – 2024 1H	Canceled	GM maintains a run-rate target of 1 million vehicles in the US for 2025
	October 24, 2023	Model delays	2023	2024	GM delayed the Chevy Silverado EV and Equinox EV to 2024
	May 1, 2024	GM's Cadillac suggests all-electric 2030 target is up in the air	2030 target for going "fully electric."	TBD	Cadillac's global vice-president hinted that electric and gasoline vehicles could co-exist beyond 2030
TOYOTA	November 1, 2023	2023 sales target cut by 40%	202,000	123,000	Blamed on weakening standing in China market
TESLA	January 26, 2024	CEO Elon Musk argued that Tesla is between "two waves" and expected growth will not arrive in 2024. No specific growth target mentioned in 1Q 2024 earnings call.	50% compound-annual growth-rate (CAGR) from 2020 to 2030	Not stated	Tesla was aiming to achieve 50% CAGR in production in the 2020s but shifted stances in recent months as it embraced other areas of focus – like autonomous vehicles.
JLR	February 9, 2024	Jaguar reduced the number of fully electric models coming by 2026	Six full-electric Land Rovers and two electric Jaguars	Four BEV Land Rovers	JLR has reduced its plan for the number of BEVs coming onto market in the near-term. It hopes to make plug-in hybrids a part of its strategy moving forward.
Mercedes-Benz	February 22, 2024	Delaying and changing EV share of sales 50% target from 2025 to 2030	50% EV share of sales by 2025	50% EV share of sales by 2030 (potentially inclusive of conventional hybrids).	Mercedes-Benz argued that variable cost parity between EVs and gasoline cars is years away.

Source: BloombergNEF, automaker targets. Note: TBD stands for to-be-determined.

Further reading

- *Tesla's Cloudy Pipeline May Spell Danger for US EV Leader* (*web* | *terminal*)
- *Rivian Aims to Recreate Tesla's Model 3 Magic With New R2* (*web* | *terminal*)
- *Legacy Automakers Betting on EV Platforms for an Edge* (*web* | *terminal*)
- 2023 Lithium-Ion Battery Price Survey (*web* | *terminal*)
- *Zero-Emission Vehicle Factbook* (*web* | *terminal*)
- *Electric Vehicles: a Primer* (web | terminal)

Light duty passenger vehicles

Section 4. Global passenger vehicle outlook

Global demand for passenger vehicles increases every year in the Economic Transition Scenario at an average of 3% between now and 2030, driven in large part by emerging economies, like India or Southeast Asia. Electrification of passenger vehicles is under way, despite near-term struggles in some of the major EV markets, with over 45 million passenger EVs on the road as of mid-2024. EV adoption hits 33% of global passenger vehicle sales by 2027, 45% by 2030 and 73% by 2040 in BNEF’s Economic Transition Scenario.

Some markets are moving faster than others. China, Europe, and the US continue to speed ahead, fueled by years of supportive policy, model availability and access to charging infrastructure. EVs reach 71% of sales in China, 56% in Europe and 48% in the US by 2030. However, sales are now rapidly increasing in the more price-sensitive markets, like India and Southeast Asia, where either new effort from domestic car manufacturers or strengthening relationship with Chinese and Korean automakers, combined with supportive policies, have helped uncover EV demand.

Passenger EV adoption hits 33% of sales by 2027 and 73% by 2040 in BNEF’s Economic Transition Scenario

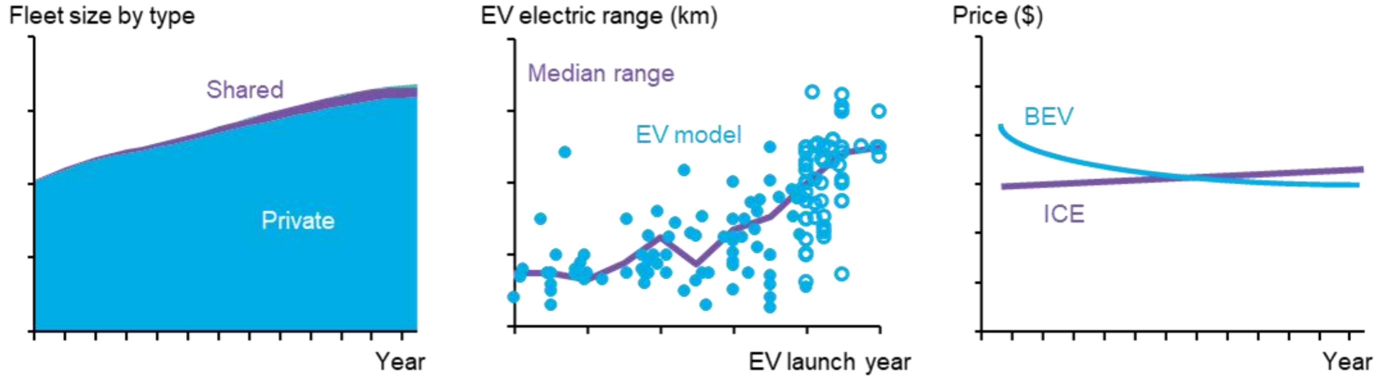
Sales of internal combustion vehicles peaked in 2017, and the fleet grows until 2025 then starts to decline from 2026. The global fleet of passenger electric vehicles grows from 41 million on the road at the end of 2023 to 132 million in 2027 (9.2% of the fleet) to 242 million in 2030 (16% of the fleet) and 722 million by 2040 (45% of the fleet) in the Economic Transition scenario.

As in the previous outlook, the world is still not on track to have a 100% zero-emission passenger-vehicle fleet by 2050, achieving just 69% by then in the Economic Transition Scenario. Much faster EV adoption is needed to hit our Net Zero Scenario trajectory. To get on track for the net-zero fleet trajectory, EV sales need to contribute 70% to the total car sales globally by 2030, compared with EVs reaching 45% adoption by then in the Economic Transition Scenario. The sales of combustion passenger vehicles need to end by 2038 in most countries to stay on track for the Net Zero Scenario, and only the Nordics are currently set to achieve this.

4.1. Vehicle sales and EV adoption: brief methodology

A simplified version of our passenger-vehicle sales outlook and EV adoption methodology is shown in Figure 65. For the detailed methodology please see Section 12.

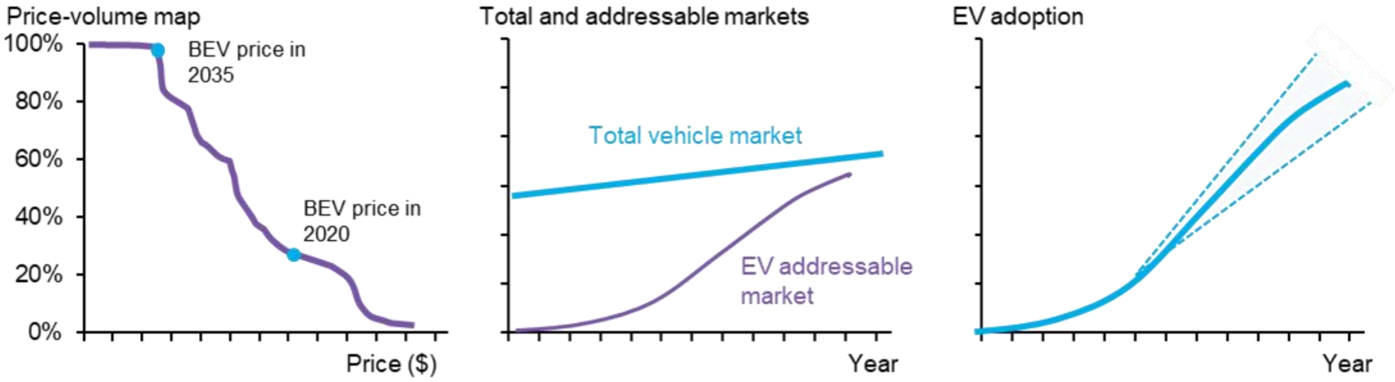
Figure 65: Simplified passenger EV outlook methodology



1. Taking into account the impact of **GDP, demographics, shared mobility services, autonomous vehicles and other factors** on kilometers traveled, we estimate the size of future car fleet and sales by country

2. Examining current **country-level policies, purchasing behavior and upcoming EV model launches**, we estimate EV sales over the short term (2024-2027).

3. Using our **lithium-ion battery experience curve and other cost data**, we estimate when the **retail prices and cost of ownership of EVs** become cheaper than those of combustion engine vehicles.



4. By creating **'price-volume maps'** for each country, we analyze how different consumer segments spend their money on cars in every region and market segment.

5. By adjusting country-level vehicle markets by EV retail prices in a given year, we estimate the **total addressable market** for EVs over the long term (2028-2040).

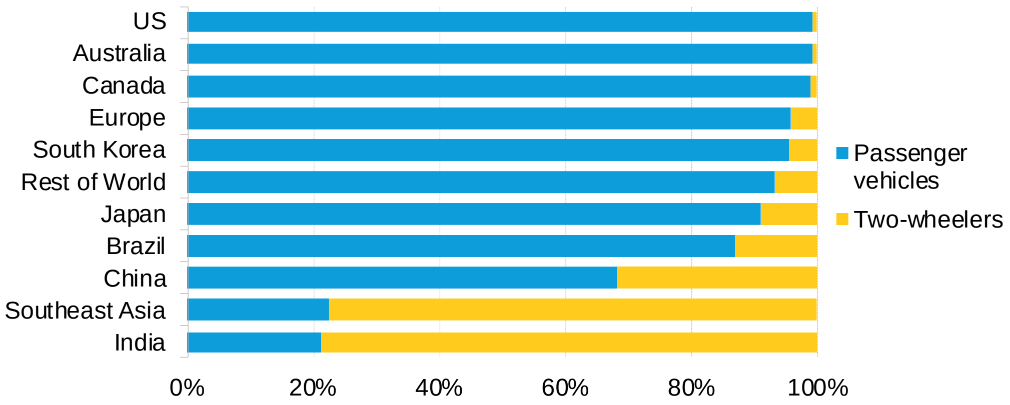
6. Using a cost-based total addressable market, short-term trajectory and historic market dynamics, we calibrate adoption parameters for a **Generalized Bass Diffusion** model to create the long-term outlook.

Source: BloombergNEF. Note: Charts are only illustrative.

4.2. Global passenger vehicle kilometers, fleet and sales

The overall demand for mobility forms the basis of our outlook. We focus on the annual vehicle kilometers covered by the passenger vehicle fleet because it accounts for the vast majority of annual vehicle kilometers traveled in major auto markets (Figure 66). The year 2023 continued the long-standing trend of markets where two-wheelers dominate the passenger transport mix, such as Southeast Asia and India, increasing the share of kilometers covered by passenger cars at the expense of two-wheelers.

Figure 66: Breakdown of vehicle-kilometers traveled by segment and market, 2023



Source: BloombergNEF. Note: Includes passenger vehicle and two-wheelers only.

Global passenger-vehicle kilometers traveled exceed 25 trillion annually by 2040

In our outlook, the annual distance traveled by the global passenger-vehicle fleet increases by 7.6 trillion kilometers between 2023 and 2040 (Figure 67), with most growth occurring in developing markets. China's annual vehicle-kilometers traveled (VKT) increase 48% by 2040, exceeding the annual distance traveled in the US and Europe from 2028 onward. India sees its annual VKT rise by around 140% over the same period, from less than 400 billion to over 1 trillion kilometers. Growth is also strong in the rest of the world, with annual vehicle-kilometers driven increasing 60%. Southeast Asia, for example, sees its annual VKT rise by 166% from 2023 levels, while Brazil's VKT grows 93%.

Defining shared vehicles

In our definition, "shared vehicles" are taxis, ride-hailing vehicles and fleet-based car-sharing vehicles. This grouping is meaningful in our modeling as these vehicles have significantly different usage patterns to vehicles that are primarily used by a single owner or family. We gave strong consideration to counting rental cars as shared vehicles, however, there are two reasons why they are included as private vehicles:

1. Rental vehicles are driven more than private vehicles on an annual basis – about double the distance – but this usage is not as much as ride-hailing and taxis, which are driven about three to five times that of private vehicles.

2. Rental vehicles are only part of the rental fleet for approximately one to two years, after which they are sold into the private fleet. These vehicles are in the private vehicle fleet for far longer than they are rental cars, and ultimately are driven more as private vehicles.

We estimate that shared mobility services accounted for about 4% of total kilometers traveled by the global passenger-vehicle fleet in 2023, slowly rebounding to the pre-Covid-19 pandemic levels in 2019 of about 5% (Figure 68). In countries with low levels of private vehicle ownership and inadequate public transit, the contribution of shared mobility services is higher. In India, for example, we estimate shared vehicles from taxis and companies like Ola and Uber, accounted for about 25% of total kilometers traveled by the passenger vehicle fleet in 2023. About 5.6% of passenger-vehicle kilometers in China in 2023 were in shared vehicles, still lower than prior to the Covid-19 pandemic but higher than the 3.8% of 2022.

The share of kilometers traveled by shared mobility in our outlook rises to 8.6% globally by 2035. From 2032, human-driven shared services begin to feel the impact of the rise of shared autonomous vehicles (referred to here as robotaxis). From 2038, human-driven shared mobility services cease to grow in our outlook, as shared, autonomous vehicles start replacing them in many cities.

Figure 67: Outlook for annual kilometers traveled by the global passenger-vehicle fleet by market

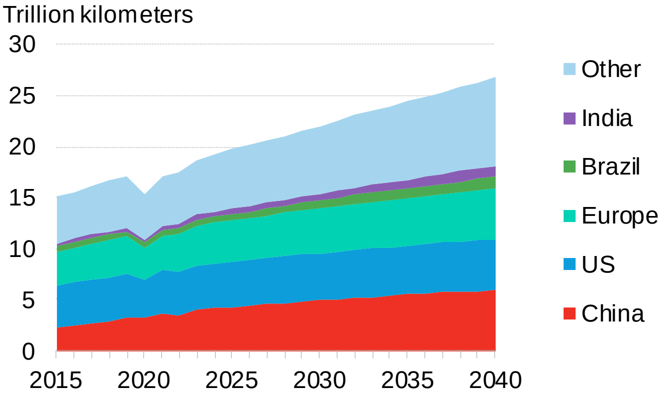
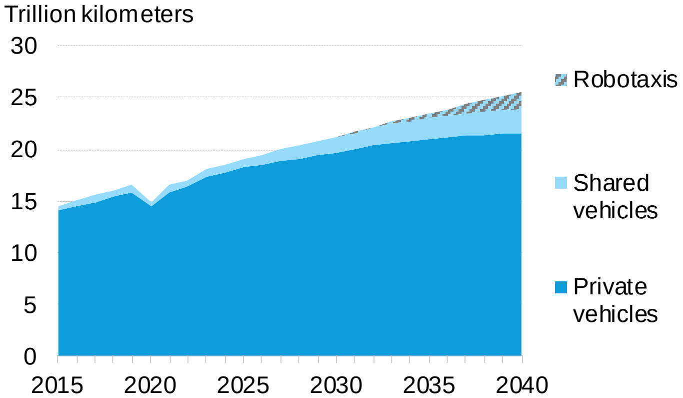


Figure 68: Outlook for annual kilometers traveled by the global passenger-vehicle fleet by type



Source: BloombergNEF. Note: 'Other' includes Japan, South Korea, Australia, Southeast Asia, Canada and Rest of World. Shared vehicles are taxis as well as car-sharing and ride-hailing vehicles. Robotaxis are highly autonomous (Level-4) ride-hailing vehicles.

Our outlook sees the global passenger vehicle fleet rising to 1.6 billion units by 2040

Our outlook for annual kilometers traveled implies the passenger-vehicle fleet expands to 1.6 billion cars in 2040 from around 1.3 billion cars in 2023 (Figure 69). While the global fleet grows, it peaks locally in the early 2030s in Japan and South Korea due to their declining and aging populations, and peaks in the mid/late 2030s in the US, Europe and China due to robotaxis supplanting private vehicle ownership. In India, the fleet more than doubles over this period.

By 2030, the global robotaxi fleet reaches 500,000 vehicles, or just 0.03% of the 1.5 billion passenger vehicles on the road in that year. After that, growth accelerates quickly, with the fleet almost reaching 22.9 million and accounting for 1.4% of the global passenger vehicle fleet in 2040 (Figure 70). In countries such as India, that have complex road environments and ample availability of labor for human-driven shared mobility services, we expect robotaxis to have a very limited impact.

Figure 69: Global passenger-vehicle fleet outlook by market

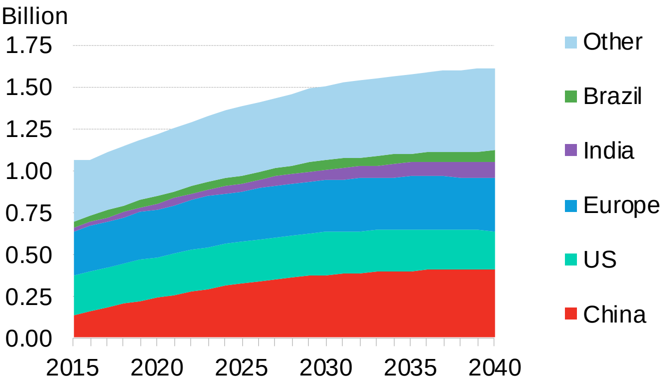
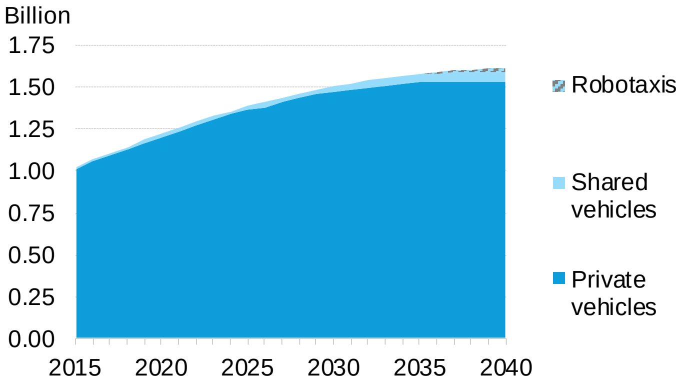


Figure 70: Global passenger-vehicle fleet outlook by type



Source: BloombergNEF. Note: 'Other' includes Japan, South Korea, Australia, Southeast Asia, Canada and Rest of World. Shared vehicles are taxis as well as car-sharing and ride-hailing vehicles. Robotaxis are highly autonomous (Level-4) ride-hailing vehicles.

Global passenger-vehicle sales have endured several tumultuous years that involved the Covid-19 pandemic, a semiconductor supply shortage, war in Europe and the Middle East and a high inflation environment. In 2023, as many as 78 million passenger vehicles were sold globally, up from 75 million in 2022 (Figure 71). In our outlook, the passenger-vehicle market continues its upward trajectory in 2024, coming close but ultimately falling short of pre-pandemic levels. In our outlook, passenger-vehicle sales reach a new all-time high in 2026. Annual sales grow to a peak of just over 101 million in 2037, before declining.

Figure 71: Global annual passenger-vehicle sales outlook by market

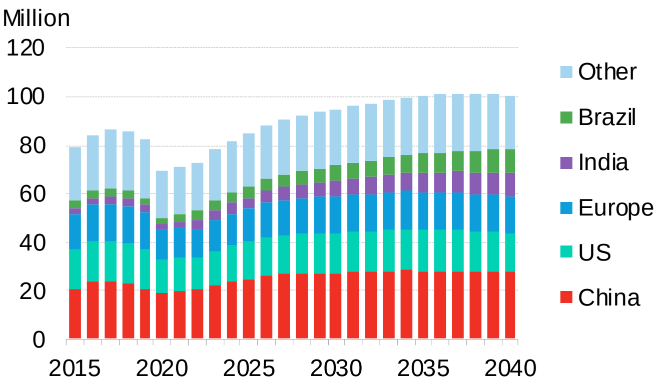
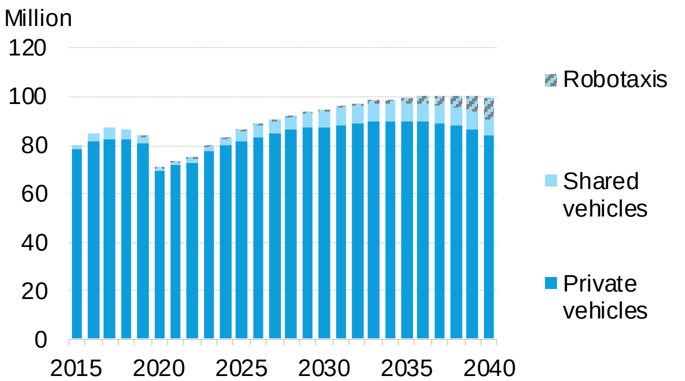


Figure 72: Global annual passenger-vehicle sales outlook by type



Source: BloombergNEF. Note: 'Other' includes Japan, South Korea, Australia, Southeast Asia, Canada and Rest of World. Shared vehicles are taxis as well as car-sharing and ride-hailing vehicles. Robotaxis are highly autonomous (Level-4) ride-hailing vehicles.

4.3. Passenger EV adoption outlook – Economic Transition Scenario

Note on data availability by country

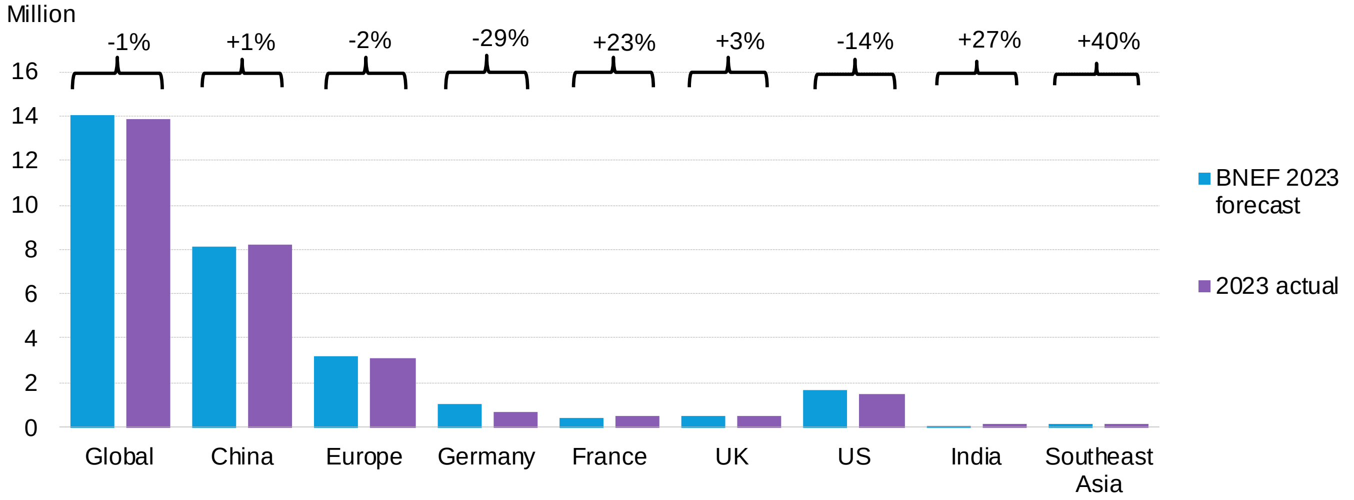
In a similar way to last year, this year's outlook does not include full country-level write-ups for the passenger-vehicle market, but the full dataset and breakdown are still available to all clients. To download the country-level data and all other results from our models, simply click on the data icon on the insight record here, or the tableau data viewer here.

Are near-term EV sales slowing in comparison to our expectations?

Global EV sales growth rates are slowing down, but in line with our expectations in last year's outlook

Toward the end of 2023 and early 2024, the EV market was dominated by headlines about a global decline in EV sales and "below expectations" EV sales. There is an undisputable slow-down in global EV sales, with annual growth rates moving from 102% in 2021 to just 33% in 2023. However, this slow-down was in line with our expectations – in our previous Long-Term Electric Vehicle Outlook (EVO), we expected global annual growth rate to reach 34% last year.

Figure 73: Passenger EV sales in 2023 compared to forecast in BNEF's 2023 EV Outlook



Source: BloombergNEF. Note: Percentages in the figure show the difference between actual 2023 sales and the 2023 forecast.

In the previous Long-Term Electric Vehicle Outlook (EVO) we projected passenger EV sales would reach 14.1 million globally in 2023. Actual global 2023 EV sales came in at around 13.9 million, within 1% of our forecasted value.

There were, however, some regional and country level differences. Although Europe's forecast for 2023 was within 2% of the actual value, we overestimated EV sales in Germany by around 29% – mostly a result of the country abruptly ending EV subsidies in mid-December 2023 and shaving off the previously expected peak in EV sales in the last month of the year.

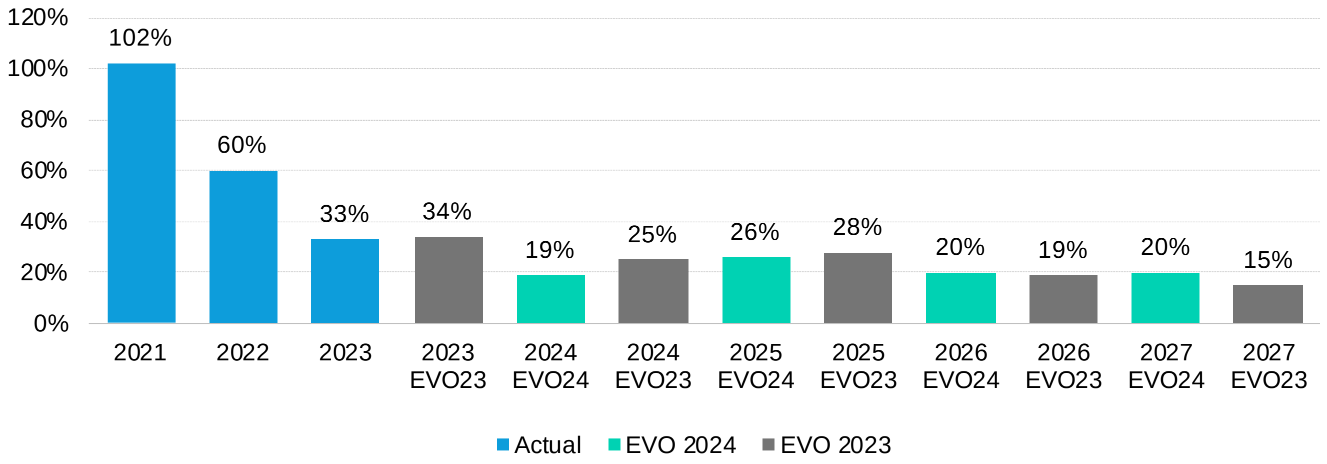
Similarly in the US, actual 2023 passenger EV sales came in 14% lower than what we previously forecasted. Lackluster performance from Ford and GM, combined with an ageing EV model lineup from Tesla and the effects of the support offered under the Inflation Reduction Act not becoming tangible for manufacturers until 2025 were behind that missed projection.

The European Union's CO2 targets will not become more stringent until 2025, keeping EV market growth in the region muted until then

The above, combined with the uncertainty around the potential impact of the presidential elections in the US and the diluted electrification commitment of a few of the key European automakers, impact our near-term forecast for Europe and the US. The slow-down in these two EV markets impacts our global near-term EV growth rates.

We now expect global EV sales to grow 19% in 2024, against 25% in the previous outlook. The difference in the expected growth rates become small afterward, with some of the lost demand in 2024 being picked up in 2027 (Figure 74). By then, most of the low-cost, mass market EVs from major automakers – VW, Stellantis, Tesla, Hyundai and others – are set to be available.

Figure 74: Global annual passenger EV sales growth rates – actual results compared to BNEF's 2023 and 2024 forecasts



Source: BloombergNEF. Note: EVO is Electric Vehicle Outlook.

Near-term sales

EV sales are set to continue rising in 2024 in this year's outlook, reaching 16.6 million globally, despite the high inflation and with several automakers scaling down their EV production and electrification targets. This is up 19% from 2023 and is driven primarily by China, which takes an even bigger chunk of global sales in 2023.

After tripling in 2023, passenger EV sales in Southeast Asia increase to 209,000 in 2024, over 40% higher than in 2023

China's passenger EV sales reach 9.9 million units in 2024, up 21% from 2023. Sales are driven by a new wave of demand-boosting pricing cuts, kicked off by a number of automakers, including BYD. Additionally, on June 1 this year China implemented tougher technical requirements on EVs exempted from the purchase tax. This brings some demand forward to the first half of 2024, as BEVs with a range below 200 kilometers and battery energy density below 125 watt-hours per kilogram are no longer eligible for tax exemptions. Some entry-level variants of Wuling Hongguang Mini, Changan Lumin, Geely Panda Mini and Wuling Bingo – the top-four mini BEVs in 2023 – are affected.

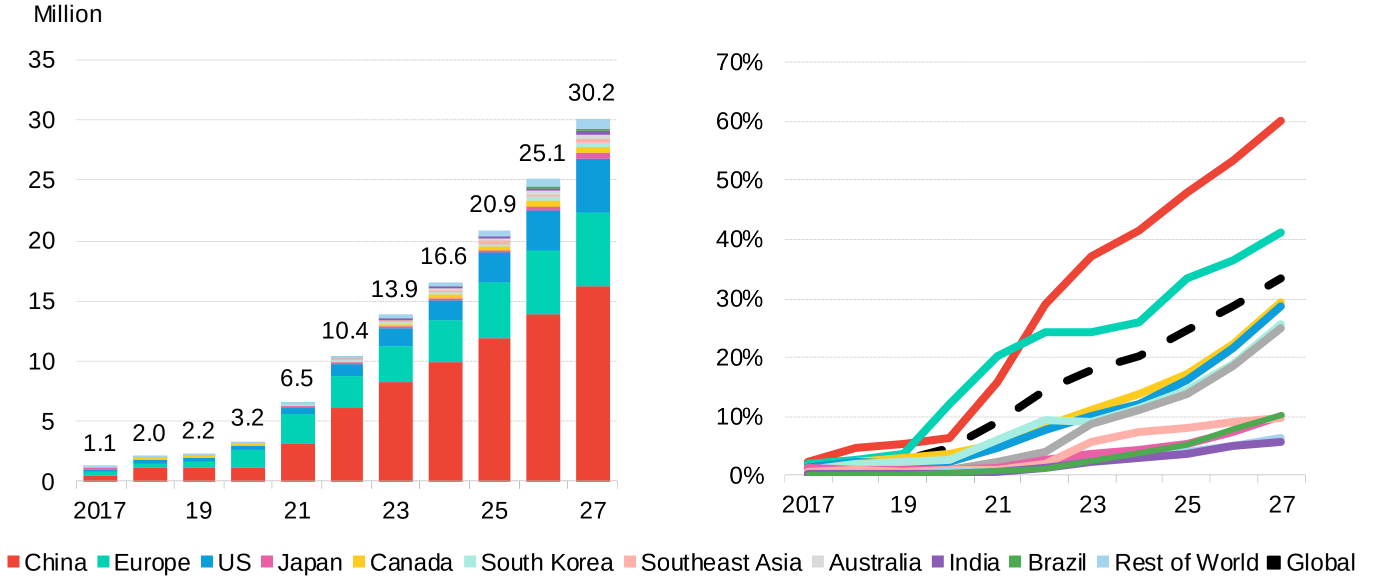
EV sales in Europe come in at just under 3.5 million in 2024 – some 10% higher than in 2023. The underwhelming growth is mainly down to weaker pressure from fuel-economy targets this year. The European Union's CO2 targets will not become more stringent until 2025, keeping EV market growth in the region muted until then. The lower pace of growth reflects the increasing uncertainty over EV sales in Germany, where the removal of the EV purchase incentives combined with tough economic conditions could put off EV buyers in a more meaningful way. Still, not all is lost in Europe in 2024, and there is a chance that countries like France or the UK will pick up some of that lost demand in Germany. Several potentially very popular, low-cost EVs, like the Citroen E-C3 (priced at €23,300) and the Renault 5 E-TECH (priced at around €25,000) are set to be released this year – with both addressing the popular small vehicle segment. In the UK, 2024 is the first year of the Zero Emission Vehicle (ZEV) mandate, with 22% of car sales in the country mandated to be zero-emission this year.

Passenger EV sales in the US grow 20% in 2024, compared to 2023, to just under 1.8 million. This marks a slowdown from 2023 growth rate (49%) as some of the major automakers, like Ford and General Motors, continue to struggle with production and sales ramp up, and as Tesla failed to refresh its model line-up in a meaningful way. Remaining key automakers, like Hyundai, Kia or Volvo, continue to increase their EV sales in 2024, albeit from a low base.

Passenger EV sales in India grow 41% in 2024, compared to 2023, to over 134,000

In Japan, passenger EV sales reach 180,000 units in 2024, just 28% higher than in 2023, amid sluggish electrification efforts from domestic automakers, and the lack of new electric models in the mini-car segment (kei cars). Passenger EV sales in Australia top 127,000 in 2024, up 29% compared with 2023, driven by healthy sales of Tesla and BYD vehicles.

Figure 75: Global near-term passenger EV sales and EV share of new passenger-vehicle sales by market



Source: BloombergNEF. Note: Europe includes the EU, the UK and European Free Trade Association (EFTA) countries. EV includes battery EVs and plug-in hybrid EVs.

After tripling in 2023, passenger EV sales in Southeast Asia increase to 209,000 in 2024, over 40% higher than in 2023. Purchase subsidies introduced for EVs in Thailand in 2022 have improved the affordability of such vehicles in the country. Malaysia has also exempted import duties on EVs through 2025, while Indonesia, Singapore and Vietnam now offer tax incentives for battery-electric vehicles. Additionally, the governments in Indonesia and Thailand offer manufacturing incentives, including income-tax holidays and import-duty exemptions, to manufacturers setting up local factories to build EVs and batteries. This is not only improving model availability in these markets, but is also attracting manufacturers from China to establish a presence. SAIC Motor and Great Wall Motor are currently refurbishing their existing auto plants in Thailand to EV plants, while BYD, GAC Aion and Chery Automobile plan to start EV production in Thailand this year.

Passenger EV sales in India grow 41% in 2024, compared with 2023, to just over 134,000. The jump in sales is first spurred by the rush for subsidies offered to EVs used for commercial purposes under the FAME scheme, which is phased out in March 2024. However, demand in this segment continues to be strong even after the subsidies expire, as India's leading EV cab operators are pursue ambitious expansion plans. Our forecast also hinges on Uber making steady progress on its plan to deploy 25,000 EVs in its fleet. Private demand on the other hand is supported by new models launched in 2024, mostly in the SUV segment. Battery-electric vehicles are the dominant electric drivetrain in India, making up almost all EVs sold in the country through the duration of our near-term forecast.

Outlook to 2027

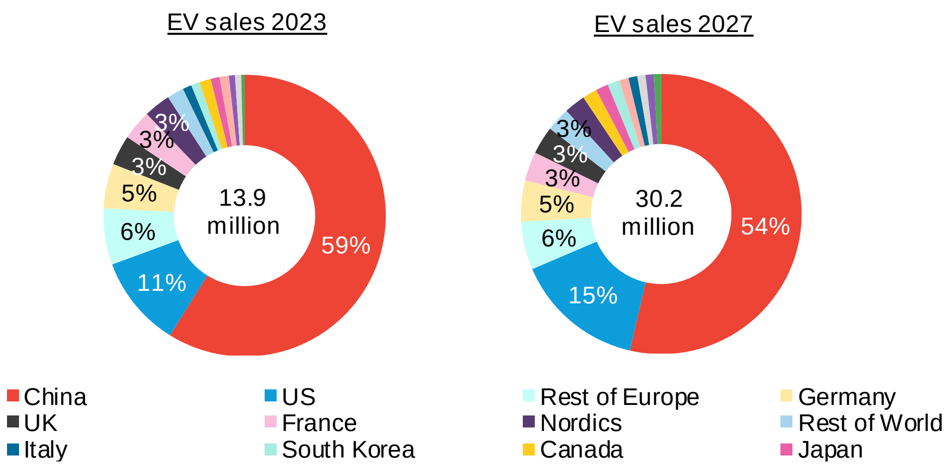
Things slow down slightly in Europe in 2024 but pick up again in 2025 – the year which marks the change in the region's fuel-economy targets

Global passenger EV sales rise from 13.9 million in 2023 to 30.2 million in 2027 – including 22.4 million BEVs and 7.8 million plug-in hybrid EVs (PHEVs). China, the US and Europe account for 89% of global passenger EV sales in 2027 (Figure 76). The EV share of new passenger-vehicle sales jumps from 18% in 2023 to 33% in 2027. Adoption in some markets is much higher, with EVs reaching 60% of sales in China and 41% in Europe. Some major European car markets move even faster, with the Nordics at 90%, the UK at 47% and France at 45% (Figure 75).

After 2024, passenger EV sales in China continue to grow at an average 18% annually until 2027. China lacks a strong regulatory push as both the fuel-economy goal and New Energy Vehicle (NEV) credit scheme targets for 2025 were already met or exceeded in 2022, and the longer-term objective of NEVs making up 40% of new car sales by 2030 will most likely be met this year. China's EV market is now shaped primarily by consumer demand and sales will be slowed down by market saturation and a tougher economic outlook.

China, Europe, and the US together account for 89% of global EV sales in 2027 in this year's outlook

Figure 76: Global passenger-vehicle sales by market



Source: BloombergNEF

Things slow down slightly in Europe in 2024 but pick up again in 2025, which marks the change for the region's fuel economy targets. The 2025 goal calls for CO2 emissions of passenger cars to be reduced by 15% compared with 2021, when more than 20% of new cars sold in the region were already electric. By 2027, over 41% of new passenger vehicle sales in the region are electric.

In the US, EVs make up nearly 29% of passenger vehicle sales by 2027, up from 10% in 2023. As a result, the US accounts for 15% of global passenger EV sales in 2027, up from 11% in 2023

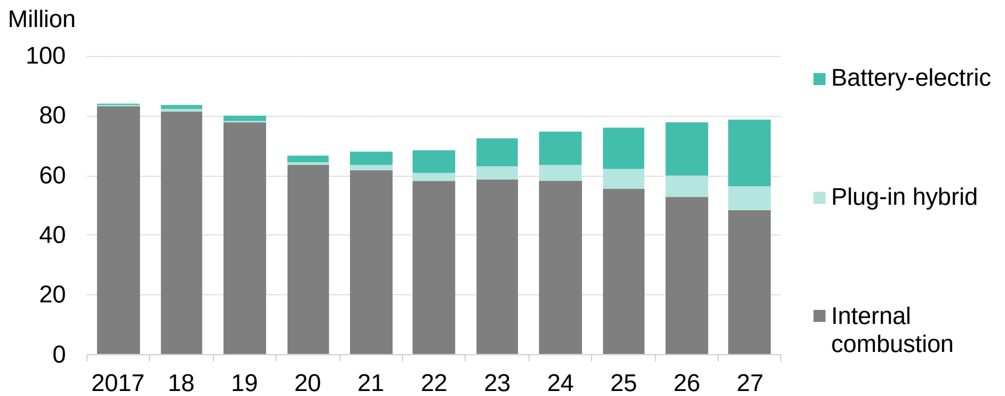
(Figure 76). Following a sluggish 2024, some moderate optimism in the EV market arrives already in 2025 as a few new EV models are launched, and as the Inflation Reduction Act increases manufacturing capacity of automakers like Hyundai, BMW or Toyota. This is followed by more affordable, mass market EVs arriving in 2026 from companies like Ford.

This year we have added Brazil to our list of core countries. The electric vehicle market in Brazil is still nascent but growing very fast, largely due to the expanding availability of competitively priced models, especially from Chinese automakers. Over half of the battery-electric electric cars sold in Brazil in 2023 were from BYD. After tripling in 2023, passenger EV sales in the country increase at an average 49% per year to reach just under 256,000 units in 2027. One in 10 cars sold in the country is electric by then.

Over 60% of cars sold in China in 2027 are electric

Global sales of internal-combustion passenger vehicles peaked in 2017 in our outlook. By 2027, sales of combustion vehicles (including hybrids, but excluding PHEVs) are 42% lower than at their highest point in 2017 (Figure 77).

Figure 77: Global passenger-vehicle sales by drivetrain



Source: BloombergNEF

Near-term fleet

The global fleet of passenger electric vehicles grows from 41 million on the road at the end of 2023 to 132 million in 2027. Over half of that fleet is in China (55%) in 2027, with the rest being driven on the roads of Europe (23%), the US (13%) and the rest of the world (9%) (Figure 78).

Despite the rapid increase in EV sales globally and the decline in combustion vehicle sales, it takes time for this to flow through to the fleet. Combustion vehicles still make up 91% of the global fleet in 2027. The transition moves faster in China and Europe, where at the end of the near-term outlook, EVs account for nearly 21% and 10% of the fleet, respectively.

Adoption is much slower in our Rest of World category, as well as in Brazil, India, Southeast Asia, and Japan. These countries together were responsible for 31% of global passenger-vehicle sales in 2023, and this effectively drags down the average global EV share of fleet (Figure 79).

Figure 78: Global near-term passenger EV fleet by market

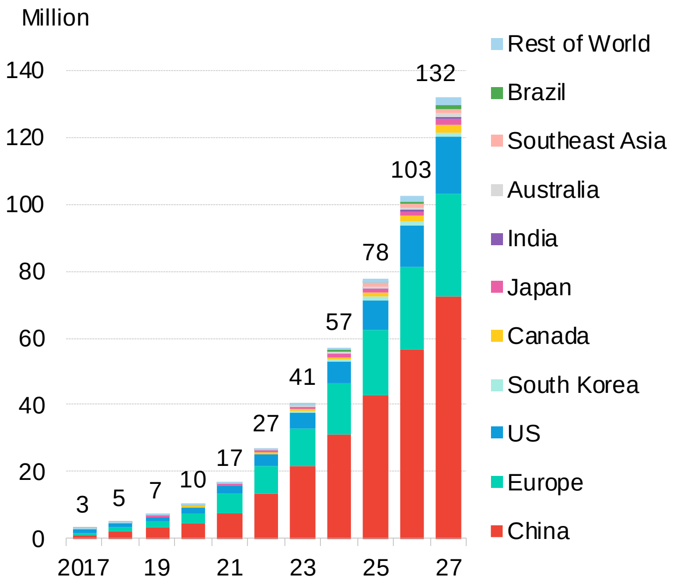
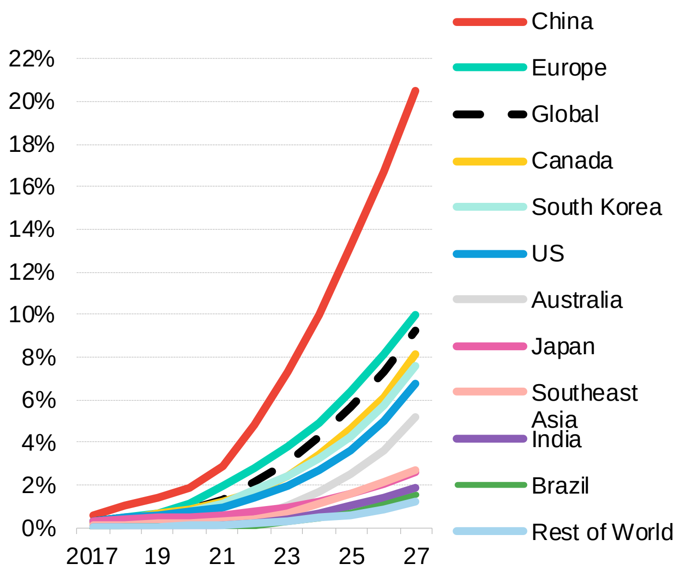


Figure 79: Global near-term EV share of passenger-vehicle fleet by market

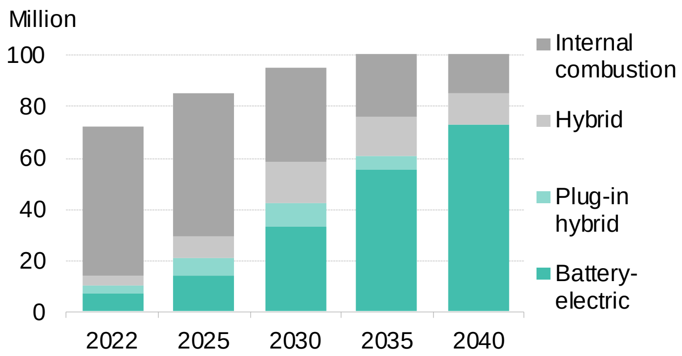


Source: BloombergNEF. Note: Europe includes the EU, the UK and European Free Trade Association (EFTA) countries. EV includes battery EVs and plug-in hybrid EVs.

Long-term sales outlook

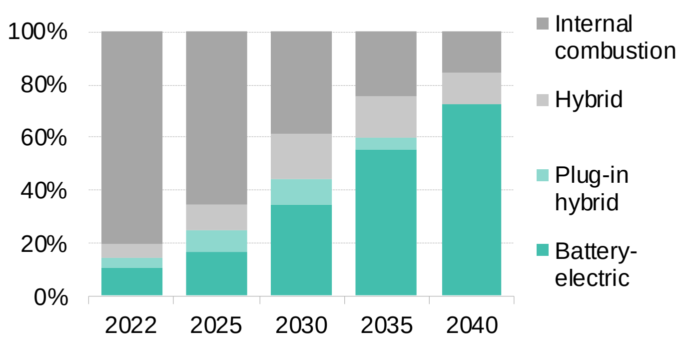
In this year's Economic Transition Scenario, EV sales rise from 13.9 million in 2023 to 21 million in 2025 (25% of sales), 42 million in 2030 (45% of sales) and 73 million in 2040 (73% of sales) (Figure 80 and Figure 81).

Figure 80: Global passenger-vehicle sales by drivetrain – Economic Transition Scenario



Source: BloombergNEF

Figure 81: Global passenger-vehicle share of sales by drivetrain – Economic Transition Scenario



Source: BloombergNEF

ICE vehicle sales never return to their 2017 peak, while BEVs exceed half of total sales by 2034. This is two years later than in last year's outlook, mostly due to slower adoption in the US and Europe, and also due to PHEVs staying around for longer in China (Figure 80 and Figure 81).

Figure 82: Global long-term passenger EV sales by market – Economic Transition Scenario

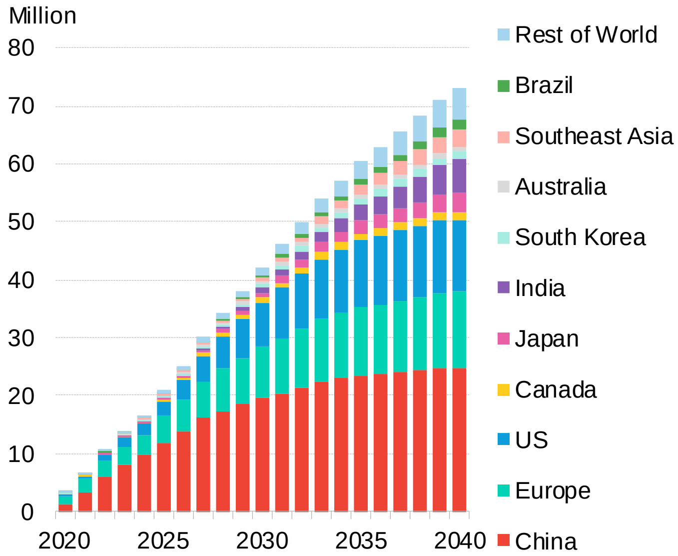
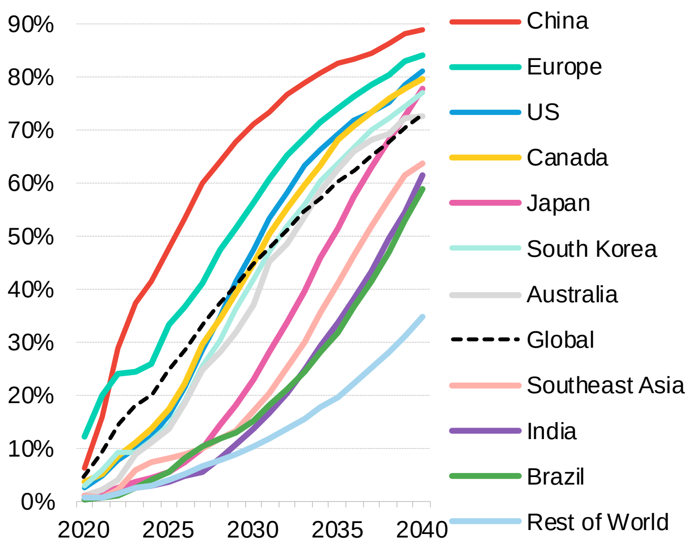


Figure 83: Global long-term EV share of new passenger-vehicle sales by market – Economic Transition Scenario



Source: BloombergNEF. Note: Europe includes the EU, the UK and European Free Trade Association (EFTA) countries. EV includes battery EVs and plug-in hybrid EVs.

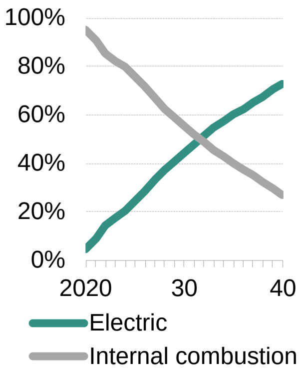
After increasing rapidly this decade, EV sales growth slows down from 2030 in China and from the mid-2030s in Europe and the US as they begin to saturate. Although public charging infrastructure is growing at pace globally, it still presents a barrier to electrifying the last 10% to 20% of the market in many countries. For further details, refer to Section 10 on charging infrastructure (Figure 82, Figure 83).

While EV sales follow a consumer adoption curve, each country and region starts on this trajectory at a different time. Most countries exhibit a traditional 'S-curve' shape for EV share of new sales, but the varied start time and slowdown points between countries means that the global average appears somewhat linear.

The global view hides a highly varied rate of adoption between countries:

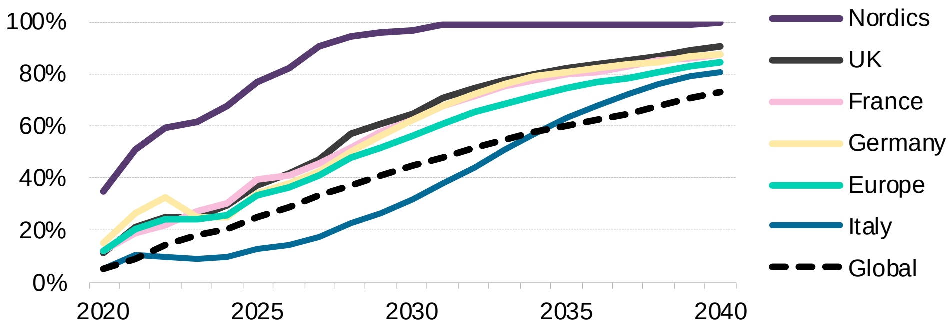
- In terms of EV sales penetration, Europe and China remain ahead of other markets for the entirety of the analyzed period. However, as adoption slows down in the near-term outlook in Europe – due to Germany and some of the domestic automakers backing off their earlier targets – China stays ahead for the entirety of our outlook.
- Still, the Nordics and the UK, move faster than Europe as whole, or China. The Nordics reach 99% BEV share of sales in 2034 (Figure 85). UK reaches 91% BEV share of sales by 2040.
- Due to the size of its passenger vehicle market, China leads globally in terms of absolute EV sales. EVs reach 68% of sales in China in 2030, 83% by 2035, and 89% in 2040. However, unlike in the last year's outlook, where PHEV sales in China phased out by 2035, in this year's outlook, those continue until 2039. PHEV sales peak in 2030, at around 6 million, reaching roughly 31% of all EVs sold in China that year. For more details on the return of PHEVs please see Section 4.6.

Figure 84: Global EV share of new passenger vehicle sales – Economic Transition Scenario



Source: BloombergNEF. Note: Electric includes battery-electric and plug-in hybrid vehicles. Internal combustion includes hybrids.

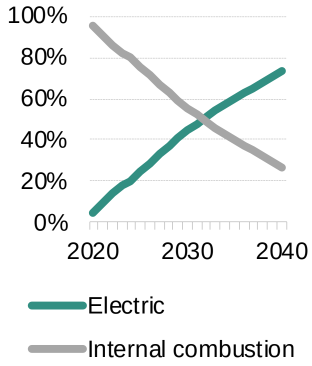
Figure 85: EV share of new passenger-vehicle sales in selected European countries – Economic Transition Scenario



Source: BloombergNEF

- Despite near-term hiccups, Japan and South Korea are the only countries in Asia, except for China, with EV adoption above the global average, at 78% and 77% by 2040, respectively. Strong policy support, compelling models from domestic automakers in South Korea, and electric *kei* cars in Japan, are supporting the electrification of passenger vehicles in the two countries in the long term. Australia is next, with EV adoption at 73% by 2040 – the same as the global average and a 3-percentage-point improvement from last year's 70%.
- EV adoption takes longer in India and Southeast Asia, but sales grow rapidly in the 2030s – at an average 23% and 19% per year, respectively – as the relative economics of electric cars and ICEs improve in those price-sensitive markets. In India, EV adoption reaches 61% by 2040, with the country becoming the fourth largest EV market globally (in absolute terms) contributing 8% to global EV sales by then – up from just 1% in 2025. Strong policy support, a growing domestic manufacturing base and increasing availability of low-cost EV models in markets like Singapore, Thailand, Indonesia, and Vietnam, lift EV sales in Southeast Asia. These rise from 148,000 in 2023 to 612,000 in 2030 and 3 million in 2040. EVs form 17% and 64% of all passenger vehicles sold in Southeast Asia in 2030 and 2040, respectively.
- While the US continues to lag China and Europe, and despite growth that is slower than previously expected in the near-term forecast, it makes up considerable ground between 2027 and 2031, pushed by the incentives in the IRA, increase in mass-market EV model availability and more stringent fuel-economy standards. EVs reach 48% of US passenger vehicle sales by 2030 (just below President Biden's target), 69% by 2035 and 81% by 2040 (Figure 88). This progress assumes that Biden's policies remain in place.
- California continues to outpace the rest of the US, with nearly one in four cars sold in the state in 2023 being electric already. The Golden State's specific EV policies enshrined in the Advanced Clean Cars II policy, begin to take effect for model year 2026 and drive growth in the end of the near-term forecast. California's 2035 target to have 100% of all new sales be electric by 2035, remains unchanged and continues to push automakers to grow EV sales in the state in the long-term. EVs reach 65% of California's passenger vehicle sales by 2030, 80% by 2035 and 88% by 2040 (Figure 88).

Figure 86: US EV share of new passenger-vehicle sales – Economic Transition Scenario



Source: BloombergNEF. Note: Electric includes both battery-electric and plug-in hybrid vehicles. Internal combustion includes hybrids.

The impact of the 2024 presidential election on US EV adoption

The US EV market is at a sensitive juncture ahead of the 2024 presidential election. If Biden were to win, many of the EV policies in place, from the provisions in the Inflation Reduction Act (IRA) to fuel-economy standards, are likely to continue uninterrupted.

If Donald Trump were to return to the presidency, major changes to federal EV policy are likely. Almost immediately, a Trump administration could cancel Biden's executive order to achieve between 40-50% EV share of sales in the US by 2030. The Trump administration could also return to its previous playbook of softening fuel-economy standards, which would ease the pressure on automakers to sell EVs in the US market. The changes could begin almost immediately upon taking office but would take potentially years to fully play out. While such actions would likely end up in legal suits – most likely led by the State of California – it would add yet another layer of uncertainty for US automakers and other stakeholders involved in the EV transition.

Repealing provisions within laws like the IRA or the Bipartisan Infrastructure Law would prove more difficult as it would require approval from both Houses of Congress. Still, the rule-making process will allow a Trump administration to re-write guidance – without Congressional approval – around specific interpretations of the IRA EV tax credit by the Biden administration. This could include restricting EV leasing or tightening of the 'foreign entities of concern' group to further limit access to the clean-car tax.

As many of the EV factories and battery manufacturing plants being planned are in the red (Republican) and purple (swing) states[1], it could be more difficult politically for a full Republican government to repeal the various IRA credits, including the EV tax credit and the battery-production tax credit. Still, Republican members of Congress have already introduced legislation to target the $7,500 EV tax credit.

All of these actions, if successfully delivered, would harm the near-term growth in the US. Automakers that are invested in the growth of electric vehicles will continue making some investments in the US market, but without the pressure of tightening fuel-economy standards in the US, it would likely occur at a much slower pace. As with the previous Trump presidency, states would have to put in policies to stem the gap. This time around, state governments are unlikely to offer as generous subsidies as they did in the past but would likely continue to support their local EV markets. It would still remain a heavy lift for the Section 177 states[2] to carry the entire US market.

In the near-term, the US would likely fall further behind Europe and China in EV adoption. There is also a long-term risk that US domestic automakers fall further behind their international peers on electrification under a Trump presidency.

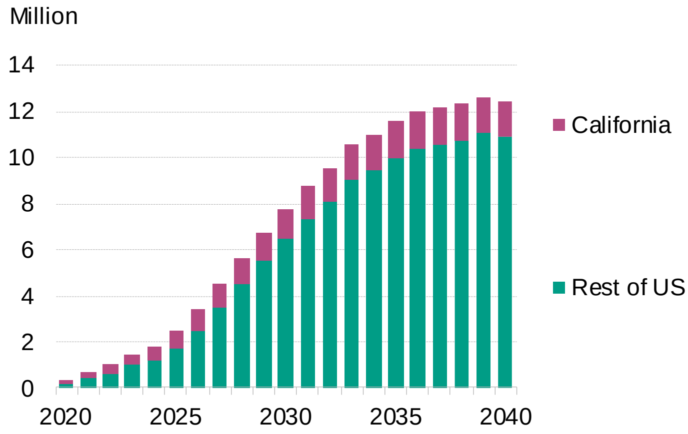
- EV adoption in the rest of the US takes longer, and closely tracks the national EV adoption trajectory. However, the so-called Section 177 states – states that follow California's fuel-economy policies – are likely to see higher adoption in the near-term than the remaining states in the Rest of the US category. The EV share of passenger vehicle sales was just

[1] Red states refer to those won by Republican candidates, typically in the last presidential election. Purple states (like Georgia) are competitive states that often swing an election and have recently been contested by both Democratic and Republican candidates in the US.

[2] The Section 177 states are those that follow some or all of California's fuel economy-related policies. These states include New York, Massachusetts, Vermont, Maine, Pennsylvania, Connecticut, Rhode Island, Washington, Oregon, New Jersey, Maryland, Delaware, Colorado, Minnesota, Nevada, Virginia and New Mexico.

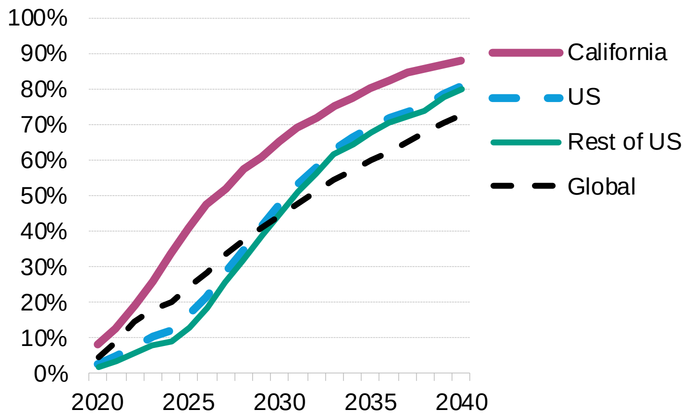
under 8% in 2023 for the Rest of the US, and reaches 45% by 2030, 68% in 2035 and 80% in 2040.

Figure 87: Passenger EV sales in the US – Economic Transition Scenario



Source: BloombergNEF

Figure 88: EV share of new passenger-vehicle sales in the US – Economic Transition Scenario

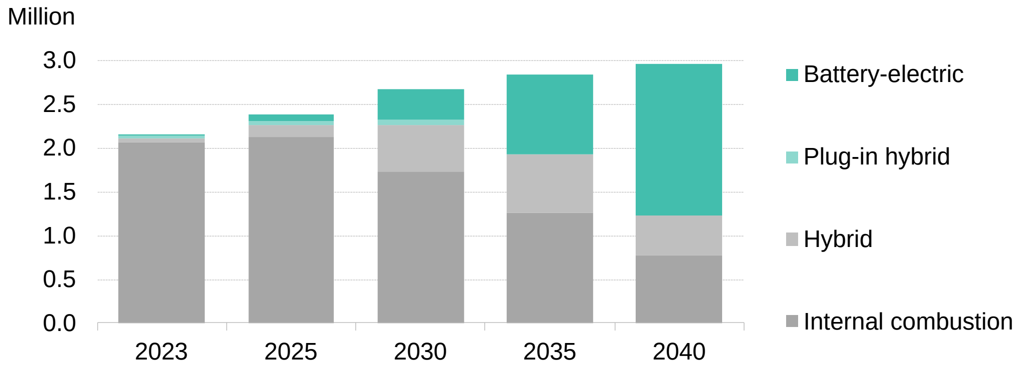


Source: BloombergNEF

California continues to outpace the rest of the US, with already nearly one in four cars sold in the state in 2023 being electric

- Brazil has a strong automotive industry producing most of its passenger vehicles domestically. Automakers including BYD, Great Wall Motor and Stellantis aim to kick off EV production in Brazil starting this year, but with 2025 being more likely. Local EV manufacturing will be crucial in keeping the momentum going by bringing upfront price parity in Brazil sooner. However, Brazil is the second-biggest producer of ethanol globally. It has high blending mandates for gasoline, and most passenger vehicles are “flex fuel”, meaning they can run on gasoline and very high blends of ethanol. As such, there is still a debate among the industry and the government over whether space should now be made for transport electrification.

Figure 89: Brazil passenger-vehicle fleet by drivetrain – Economic Transition Scenario

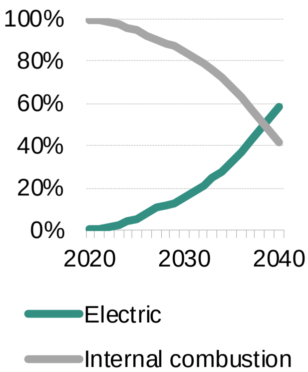


Source: BloombergNEF

- One possible way to circumvent the ethanol industry’s resistance is flex-fuel plug-in hybrids. Although they do not exist yet, BYD already hinted it would look to develop its first flex-fuel PHEV vehicle, capable of running on both gasoline and ethanol. Stellantis also revealed plans to start producing flex-fuel PHEVs. When these would be available, for both BYD and

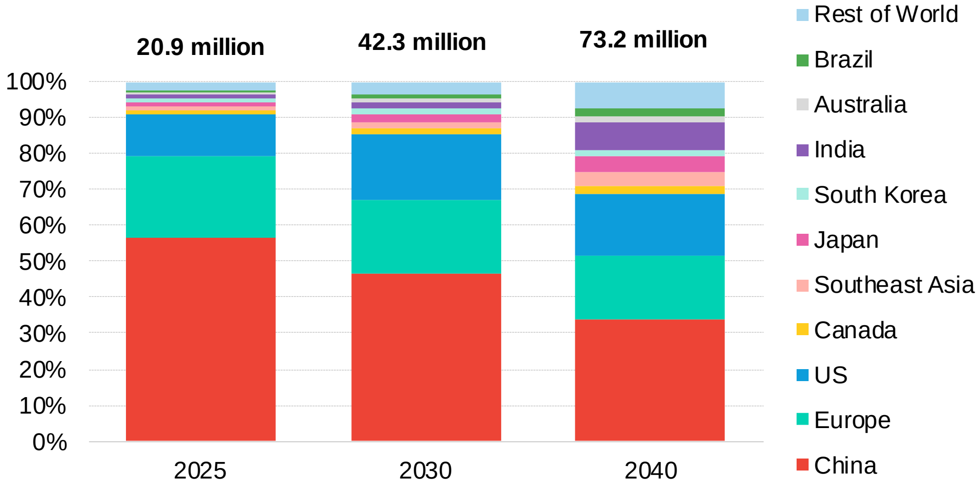
Stellantis, remains unclear. The EV share of passenger-vehicle sales in Brazil was just over 2% in 2023, but it reaches 15% by 2030, 32% in 2035 and 59% in 2040 (Figure 90).

Figure 90: Brazil EV share of new passenger-vehicle sales – Economic Transition Scenario



Source: BloombergNEF. Note: Electric includes both battery-electric and plug-in hybrid vehicles. Internal combustion includes hybrids.

Figure 91: Global passenger EV sales by market – Economic Transition Scenario



Source: BloombergNEF

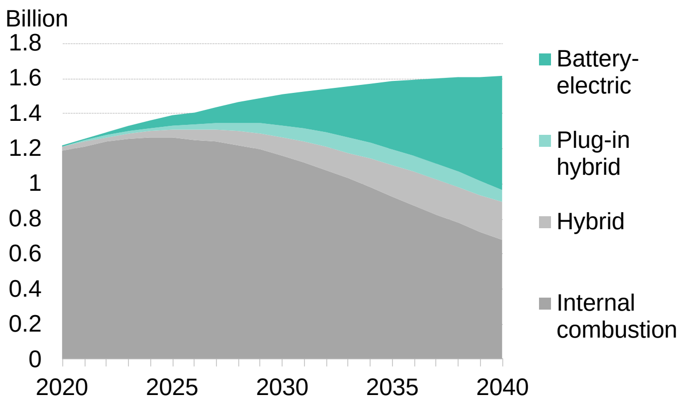
Long-term fleet outlook

The global fleet of passenger EVs grows from 41 million on the road at the end of 2023 to 78 million in 2025 (5.6% of the fleet), 242 million in 2030 (16% of the fleet) and 722 million by 2040 (45% of the fleet) (Figure 92, Figure 93, Figure 94 and Figure 95).

The global fleet of internal combustion vehicles, including hybrids, is set to peak in 2025

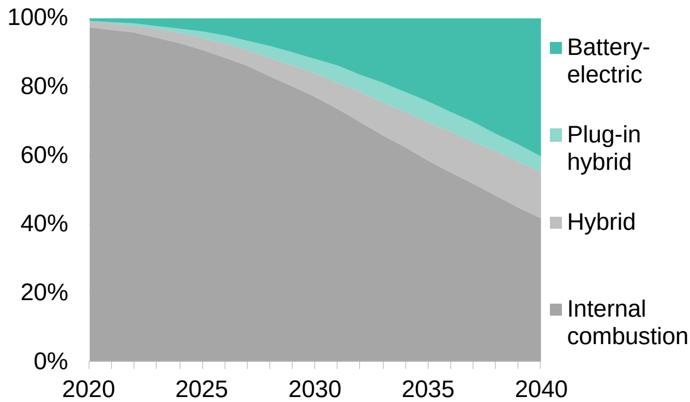
The fleet of internal combustion passenger vehicles (including hybrids) is very close to its peak, which comes in 2025. Still, despite the relatively rapid growth of EV sales, there are still 894 million ICE vehicles (including hybrids) on the road in 2040, down from 1.3 billion in 2023.

Figure 92: Global passenger-vehicle fleet by drivetrain – Economic Transition Scenario



Source: BloombergNEF

Figure 93: Global passenger-vehicle share of fleet by drivetrain – Economic Transition Scenario



Source: BloombergNEF

Figure 94: Global long-term passenger EV fleet by market – Economic Transition Scenario

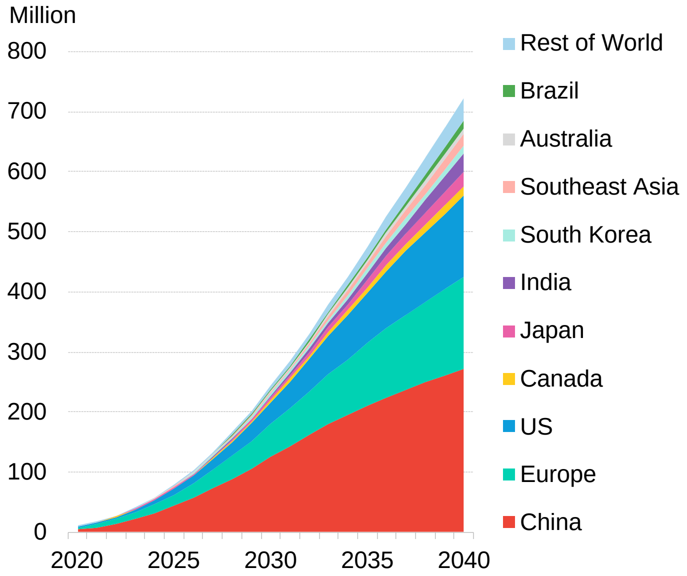
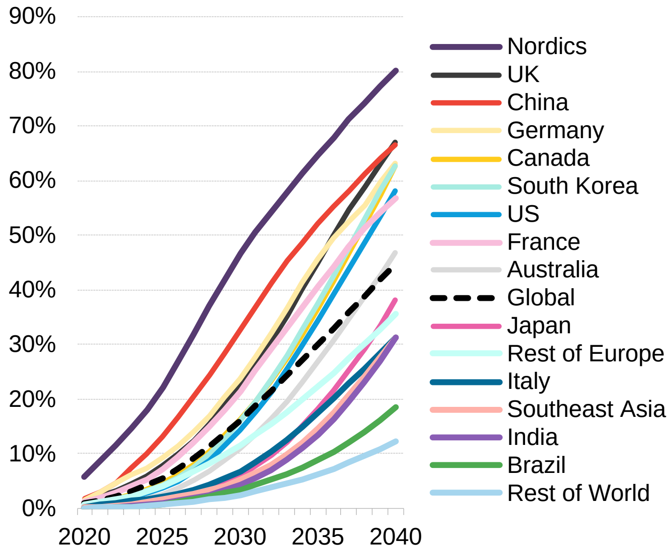


Figure 95: Global long-term EV share of passenger-vehicle fleet by market – Economic Transition Scenario



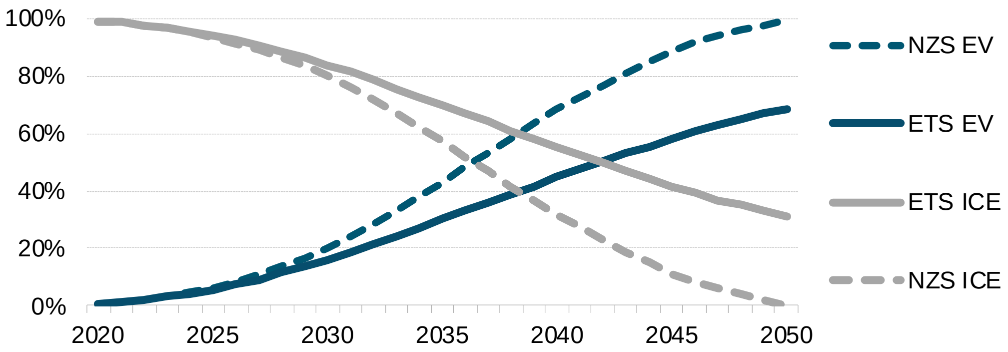
Source: BloombergNEF. Note: Europe includes the EU, the UK and European Free Trade Association (EFTA) countries. EV includes battery EVs and plug-in hybrid EVs.

4.4. Passenger EV adoption outlook – Net Zero Scenario

Global sales of new internal combustion vehicles need to stop by 2038 at the latest to stay on track for the Net Zero Scenario

In 2040, the electric-vehicle share of the global fleet reaches 45% in our Economic Transition Scenario, increasing to 69% by 2050. This is still far from the target of a fully zero-emission fleet by 2050. Over 67% of the vehicles on the road by 2050 are BEVs, followed by a small number of PHEVs. In the Net Zero Scenario, the EV share of the global passenger vehicle fleet reaches 100% in 2050. All the EVs are BEVs by then (Figure 96).

Figure 96: Passenger-vehicle fleet split outlooks by drivetrain – Economic Transition Scenario and Net Zero Scenario



Source: BloombergNEF. Note: 'ETS' stands for Economic Transition Scenario and 'NZS' for Net Zero Scenario.

Figure 97: Passenger-vehicle fleet outlook by drivetrain – Economic Transition Scenario

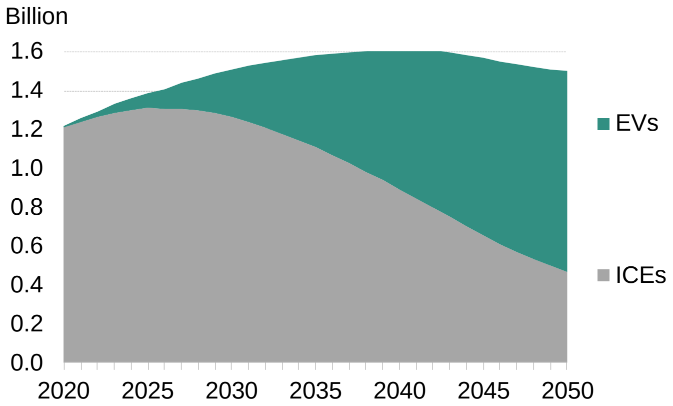
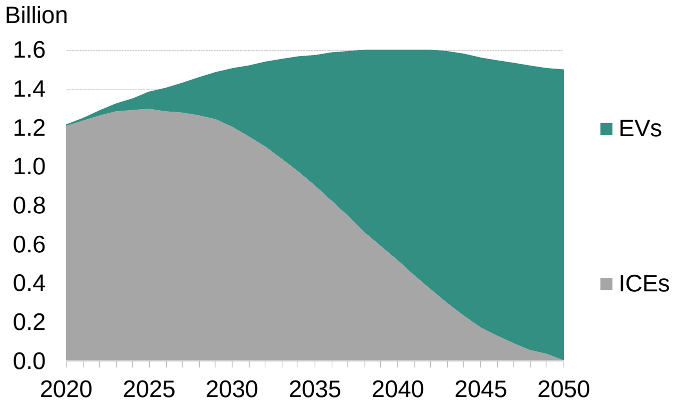


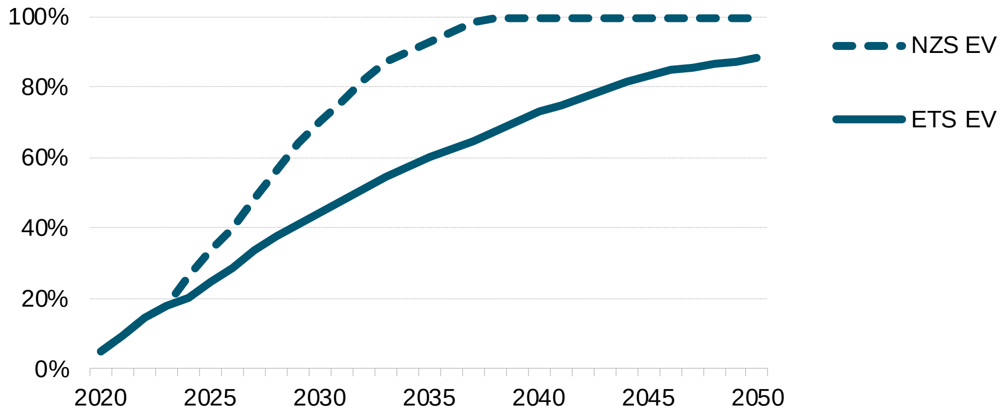
Figure 98: Passenger-vehicle fleet outlook by drivetrain – Net Zero Scenario



Source: BloombergNEF. Note: EV includes battery-electric vehicles (BEV) and plug-in hybrid vehicles (PHEV). ICE includes traditional hybrids.

In absolute terms, the EV fleet increases from 476 million in 2035 to 1 billion in 2050 in the Economic Transition Scenario, and from 678 million in 2035 to 1.5 billion in 2050 in the Net Zero Scenario. In both scenarios, the internal-combustion passenger-vehicle fleet peaks in 2025, but the following decline is much steeper in the Net Zero Scenario (Figure 97, Figure 98).

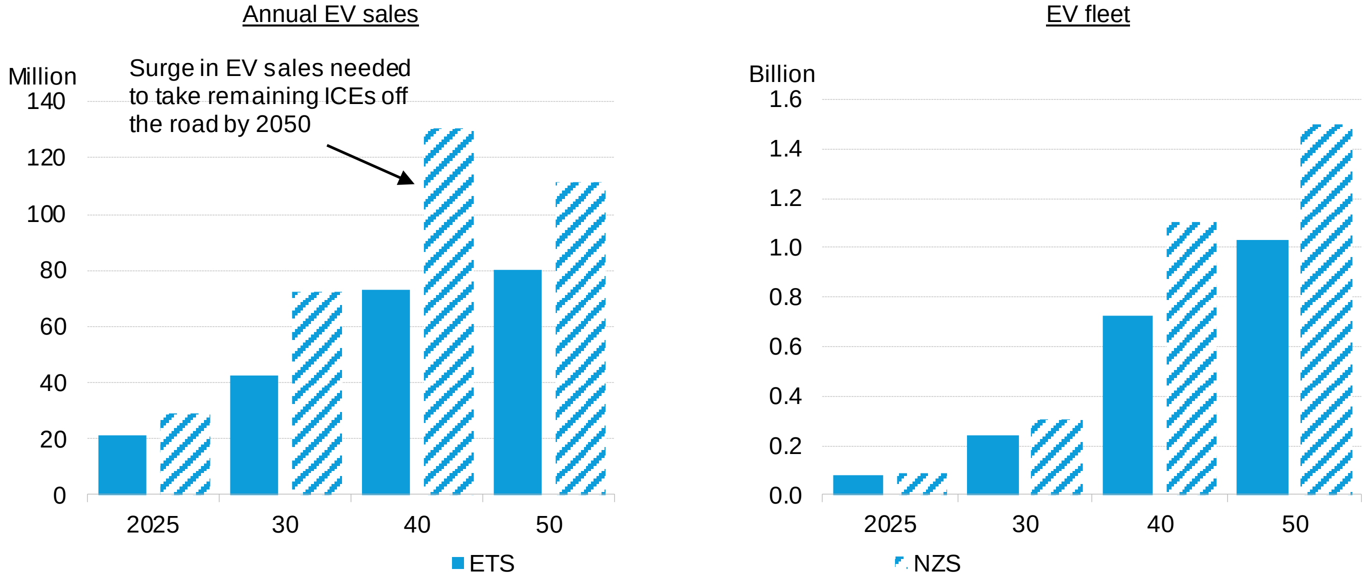
Figure 99: Electric vehicle share of total passenger vehicle sales – Economic Transition Scenario and Net Zero Scenario



Source: BloombergNEF. Note: 'ETS' is Economic Transition Scenario and 'NZS' is Net Zero Scenario.

Such a rapid turnover in the passenger-vehicle fleet has significant implications for new vehicle sales. In order to achieve a net-zero fleet of passenger vehicles, sales of zero-emission vehicles need to significantly accelerate already from 2024, compared with the Economic Transition Scenario. All new passenger vehicles sold globally have to be zero-emissions by 2038, while adoption reaches only 68% by then in our Economic Transition Scenario (Figure 99 and Figure 100).

Figure 100: New passenger EV sales and fleet in the Economic Transition Scenario and Net Zero Scenario

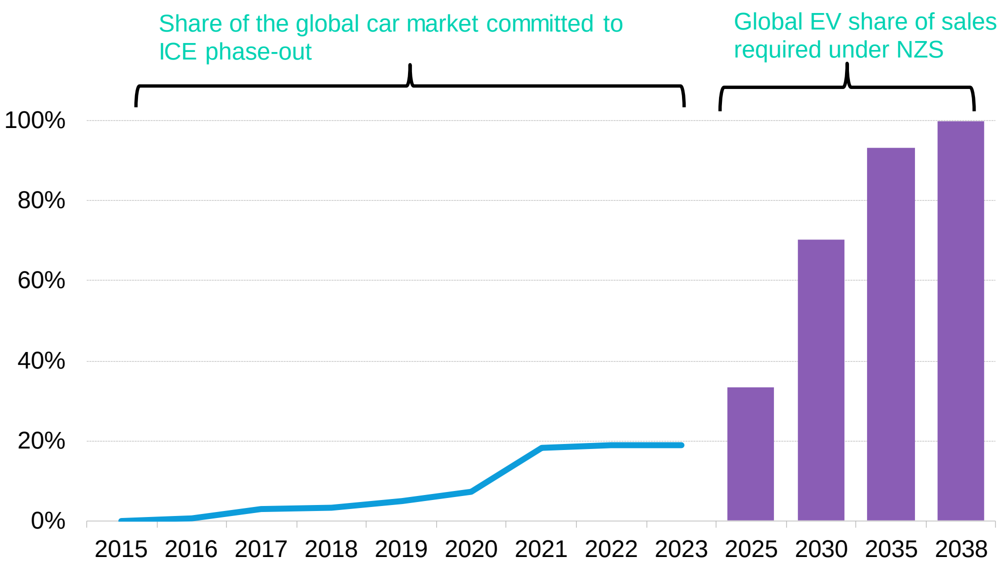


Source: BloombergNEF. Note: 'ETS' is Economic Transition Scenario and 'NZS' is Net Zero Scenario.

Country results and long-term policy targets

There are now 38 national targets to phase out sales of ICE vehicles. This includes the EU27 countries that are obliged to stop selling ICE cars by 2035. However, there has been a noticeable slow-down in countries announcing new plans to phase out internal-combustion vehicle sales. The last country to announce an ICE phase-out target was Vietnam, in 2022

Figure 101: Share of global passenger vehicle sales covered by national phase-out targets and the share required to stay on track for Net Zero Scenario



Source: BloombergNEF. Note: 'NZS' is Net Zero Scenario.

Italy is moving slower in this outlook than last year, highlighting the need for consistent regulatory support

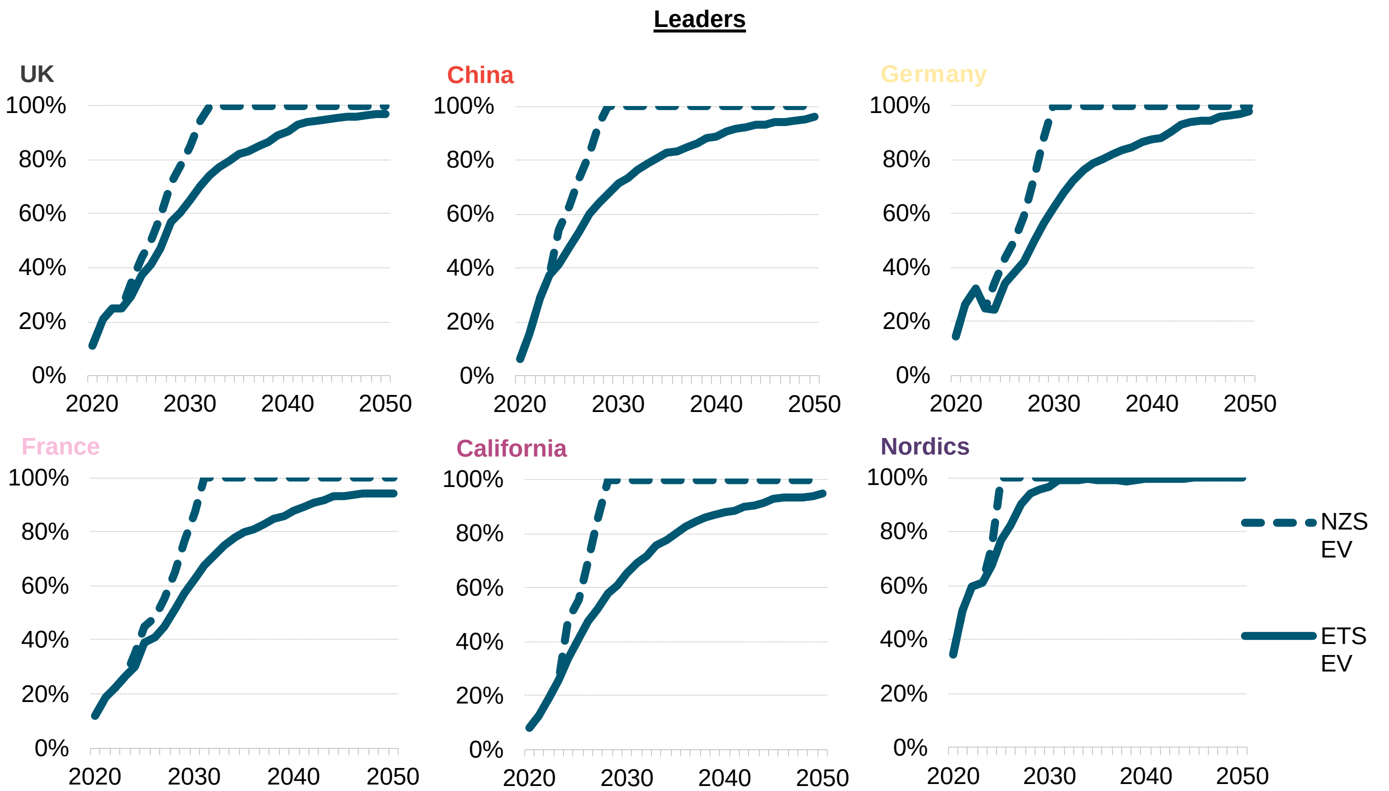
The slow-down in country-level commitments undermines broader net-zero ambitions. Countries with already-existing ICE phase-out targets together represented only 19% of global new passenger car sales in 2023. Some of the major automotive markets like the US, China or India have no national level ICE phase-out plans, though they do have ambitious interim electrification goals. Still, this is not enough for the world to reach net-zero emissions in road transport by 2050 (Figure 101).

In our outlook, none of the analyzed countries achieves a full phase-out of combustion vehicle sales by 2038 in the Economic Transition Scenario. Some get close, such as the UK, China, Germany, and France with 87%, 87%, 85% and 85% EV share of passenger vehicle sales by 2038, respectively. The Nordics already achieve 90% EV adoption in 2027. Those countries together are responsible for 36% of global car sales by 2038.

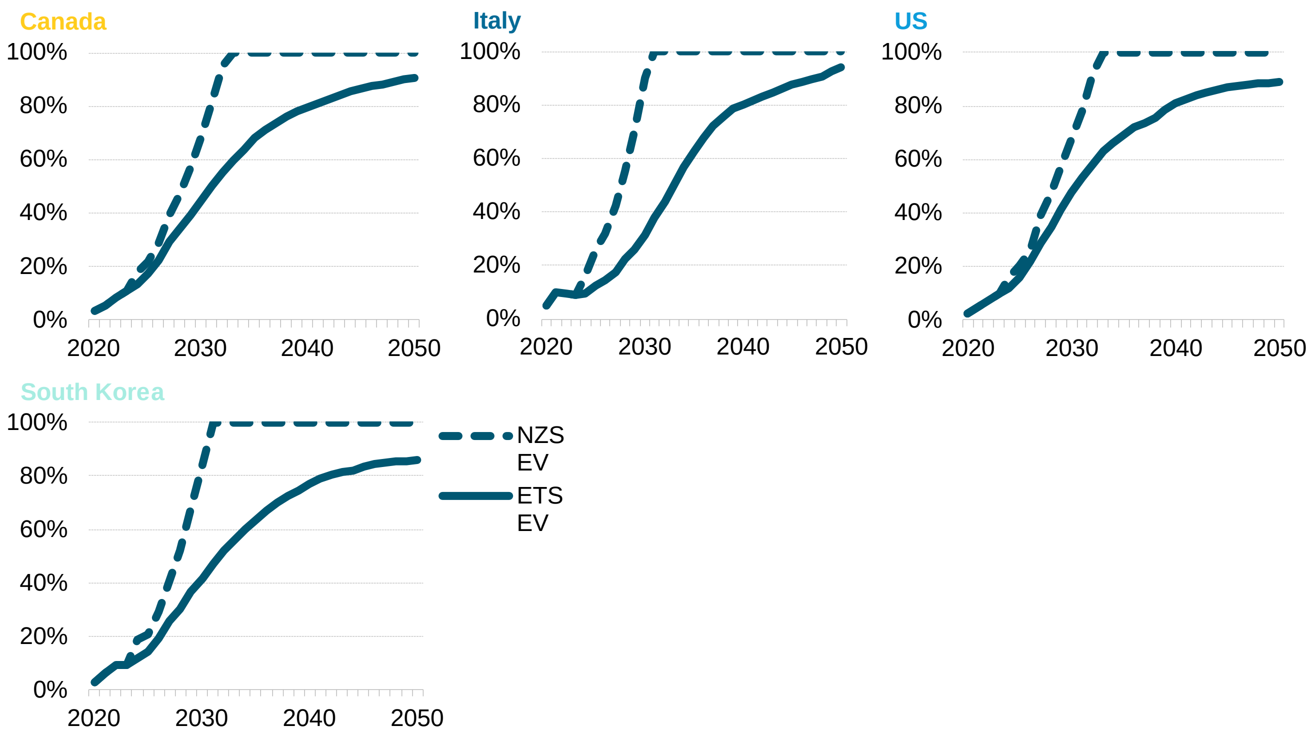
The US, alongside Canada, Italy and South Korea, exceed 70% EV share of sales by 2038, suggesting these countries may be quickly catching up with the leading countries. Roughly 22% of global car sales in 2038 take place in these four countries. Still, in this year's outlook, Italy dropped from the 'leaders' group to 'catching up' category, due to sluggish and slower-than-expected EV adoption. This highlights the importance of consistent regulatory support, as even one bumpy year in EV sales can affect the long-term trajectory.

Some 37% of the global car market in 2038 comes from countries currently not on track for net-zero emissions in the passenger vehicle segment by 2050 (Figure 102). This includes India, Southeast Asia and countries in the Rest of World group (which includes markets like Russia and Mexico).

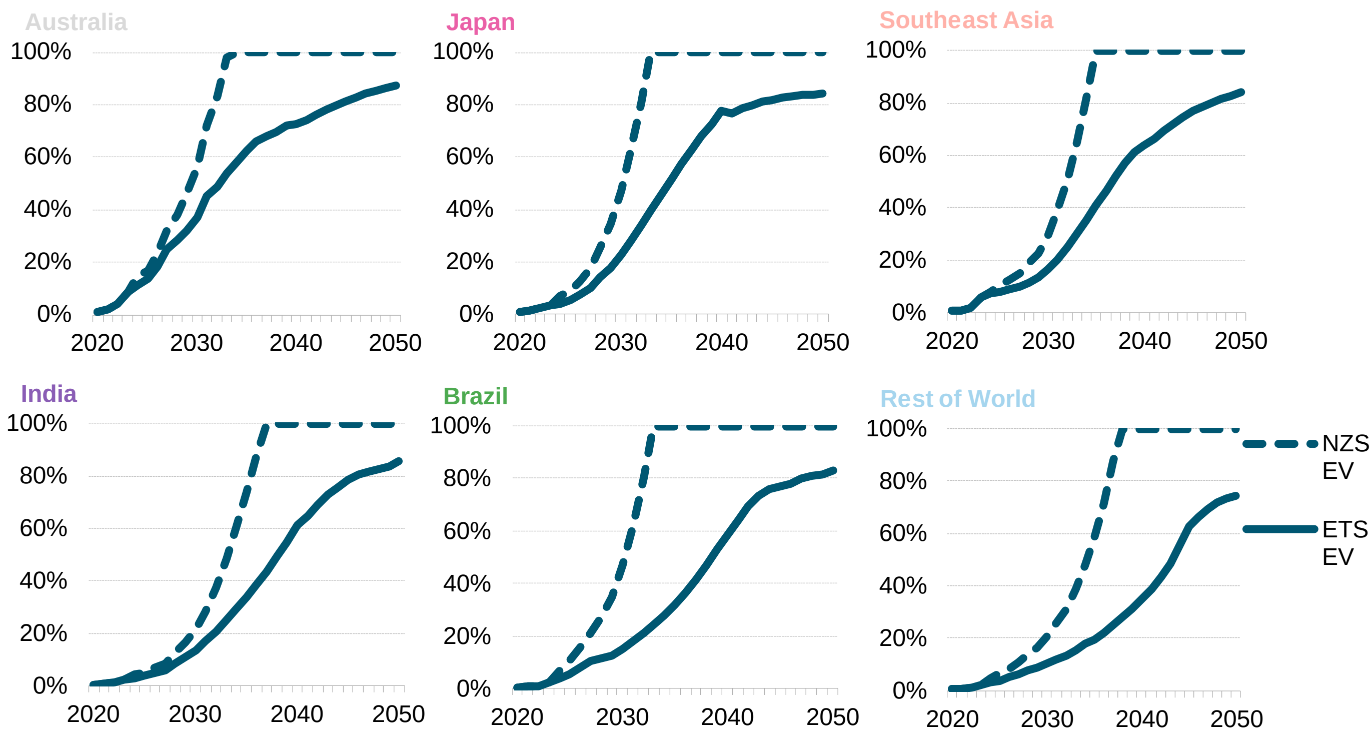
Figure 102: Country-level EV share of sales – Economic Transition Scenario and Net Zero Scenario



Catching up



Late

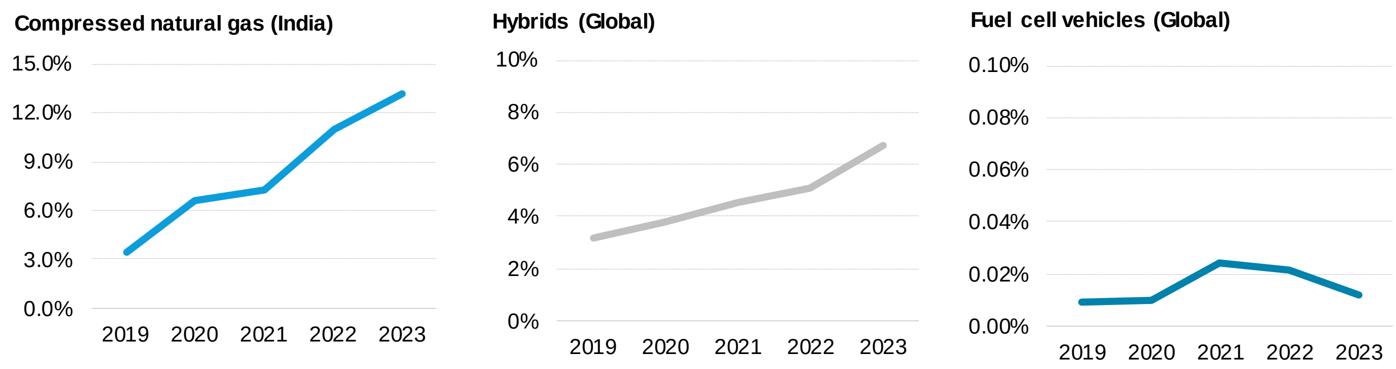


Source: BloombergNEF

4.5. Other drivetrains

Hybrids and compressed natural gas (CNG) vehicles experienced growing sales in specific locations and segments of the passenger-vehicle market. Our economic analysis indicates that electric vehicles will be the primary method of decarbonizing road transport, however, hybrids and CNG vehicles can play a meaningful role. We are less optimistic on the future for hydrogen fuel-cell technologies in passenger vehicles (Figure 103).

Figure 103: Passenger car share of sales for hybrid, compressed natural gas and fuel-cell vehicles



Source: BloombergNEF, India's Ministry of Road Transport and Highways.

Hybrids

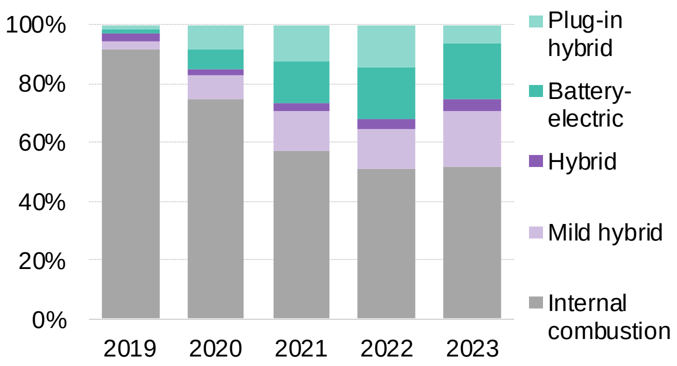
Stringent fuel efficiency regulations are the main factor driving up hybrid vehicle sales in major car markets. One exception is Japan, where consumer demand for HEVs has been strong for several years, driven mostly by consumer loyalty to the domestic car manufacturer Toyota (Figure 105). Hybrids are a central part of Toyota's powertrain strategy.

Hybridization can reduce the CO2 output of a vehicle by 10-30% – depending on the vehicle segment and the current engine technology. Hybrid components can also be integrated in current engineering platforms without major redevelopment. Unlike battery electric vehicles (BEVs), HEVs offer a similar consumer experience to a traditional internal combustion engine (ICE) vehicle, and do not require substantial behavioral changes from the user.

Full hybrid powertrains are parallel or series-parallel systems, whereby an internal combustion engine and an electric motor are both connected to the car's drive system and can provide traction. They can also capture braking energy, charge the on-board battery, and start-stop the ICE as needed.

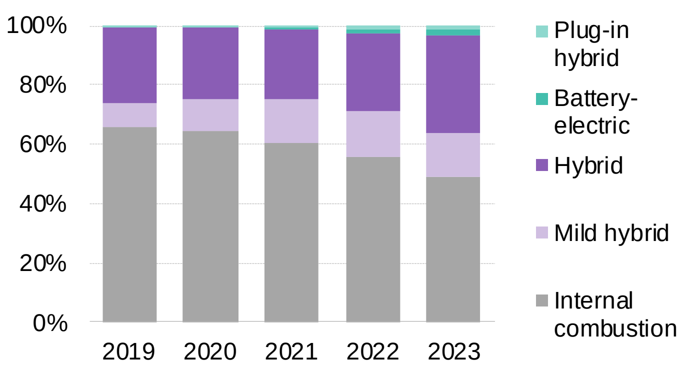
In markets such as Germany, there are high numbers often quoted for hybrid sales but many of these are mild hybrids (Figure 104). Mild hybrids have smaller motors and batteries, and can typically only assist the operation of the ICE. At a minimum, these systems offer regenerative braking and start-stop functions. When using 48 Volts, they can also electrify some other components in the car, such as pumps and the air-conditioning unit for further efficiency gains. These higher-voltage designs can also use electric turbos to enhance drivability and efficiency. Depending on configuration, some systems may provide coasting functions as well.

Figure 104: Share of passenger-vehicle sales in Germany by drivetrain



Source: BloombergNEF, MarkLines, Germany Federal Motor Transport Authority.

Figure 105: Share of passenger-vehicle sales in Japan by drivetrain

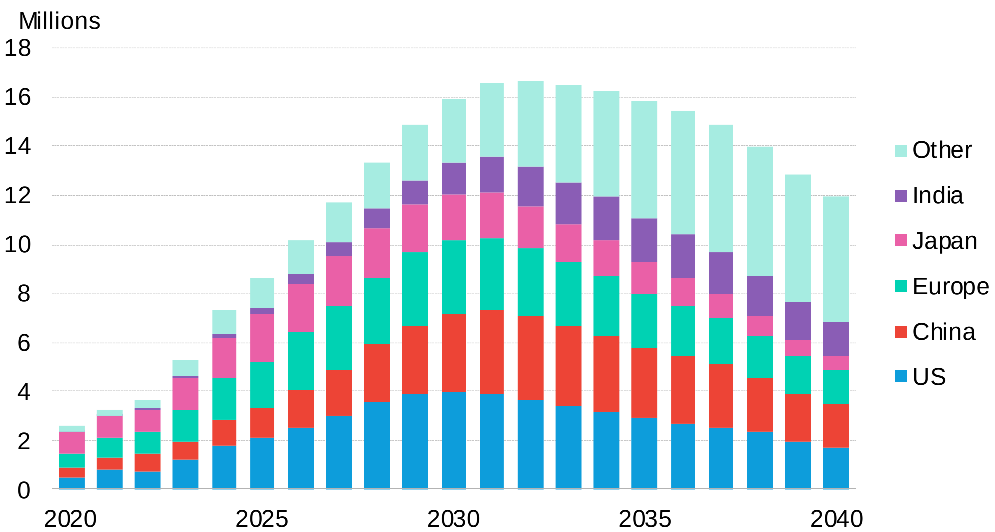


Source: BloombergNEF, MarkLines, Japan Automobile Dealers Association.

In Europe, the US, China, Japan and South Korea, we expect full hybrid sales to surpass 15 million units annually by 2030 (Figure 106). Adoption rates can range between 20% and close to 50% in different markets. The main support for further HEV technology penetration comes from the increasingly stringent fuel-efficiency rules. In the absence of those, we would expect relatively low passenger hybrid-vehicle sales, close to current levels – or lower – in most markets.

Rising electric vehicle sales and mild hybridization are the principal barriers for higher adoption of full hybrids. These technologies could allow particular automakers to focus on electric cars for growth, while keeping compliance costs for their ICE models relatively low. Hybrid sales begin to decline post 2030 in our outlook, as EVs take a larger share of the total car market.

Figure 106: Outlook for hybrid-vehicle sales by market in the Economic Transition Scenario



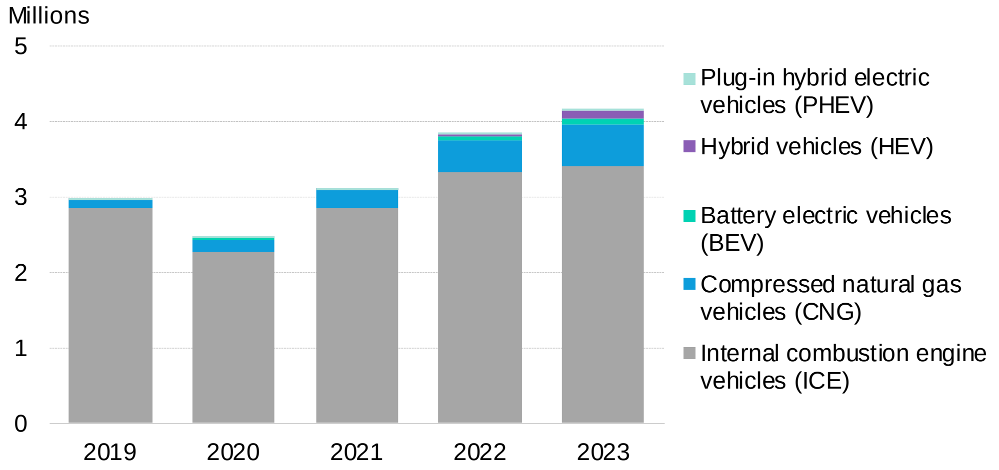
Source: BloombergNEF. Note: Passenger vehicles only. Excludes mild hybrids and plug-in hybrids.

Compressed natural gas (CNG) vehicles

India is home to more than 6,200 CNG fueling stations with nearly half owned or managed by state-owned energy company, GAIL, and its subsidiaries. The availability of this infrastructure combined with increasing petrol and diesel prices led to sales of compressed natural gas (CNG) cars growing 30% in 2023 from 2022 levels to nearly 548,000 units (Figure 107).

Besides being more economical than gasoline and diesel models, CNG has a lower carbon footprint, which automakers are using to transition to a low-emissions product portfolio. Six new CNG models were introduced in India last year, taking the total to 25. Despite impressive growth of CNG passenger vehicles in India, there is little evidence of a similar trend in other countries. Passenger CNG vehicles are part of our outlook at present but will be monitored for consideration in future iterations of this report.

Figure 107: Sales of passenger vehicles in India by drivetrain



Source: BloombergNEF, India's Ministry of Road Transport and Highways.

Hydrogen fuel-cell vehicles

Passenger fuel-cell vehicles (FCVs) can in theory offer faster refueling and longer driving ranges than BEVs. They can also potentially alleviate some of the pressure on raw material supply for batteries.

Passenger FCVs continue to face three major challenges:

1. **There are currently no other mass-market applications for fuel-cell systems**, so to reduce costs by increasing scale, FCV sales have to rise. In contrast, BEV manufacturers have benefited from decades of prior investment in the lithium-ion battery supply chain serving consumer-electronics applications. Demand for batteries in stationary storage applications is also now increasing very quickly.
2. **There is limited existing hydrogen refueling infrastructure,** and the price of hydrogen at the pump remains significantly higher than other transport fuels. While we expect the cost of hydrogen production from renewables to fall, there will be many other hard-to-abate sectors such, as fertilizer production, which will be vying to use green hydrogen. Transportation and distribution of hydrogen to refueling stations is also a challenge due to its low volumetric density. Shell and other groups have started closing hydrogen refueling stations, and consumers in markets like California are facing very high costs to refuel.

There were more Lamborghinis sold last year than fuel-cell vehicles from all manufacturers

3. **The value proposition of FCVs for consumers is getting weaker**. Experience with consumer adoption shows that products need to be both cost-competitive and offer a better experience to gain popularity. As BEV technology continues to improve, it is becoming increasingly hard to convince consumers that FCVs offer advantages over BEVs. Range has become less of an advantage in recent years, with the longest-range BEVs now offering more range than FCV models.

   Even in a scenario in which BEVs did not take off, it is not certain that FCVs would succeed. Many consumers may simply opt to continue buying or using gasoline-powered vehicles. PHEVs are also able to offer many of the near-term benefits of FCVs in terms of range and refueling time. Some of the latest PHEVs launched in China have 100-200 kilometers of electric range, further narrowing any advantage that FCVs might have.

We removed FCVs from our passenger-vehicle outlook in 2023 due to very low volumes of sales, little consumer interest, high geographic concentration, limited model availability and a lack of commitment to high-volume manufacturing from automakers.

Falling sales

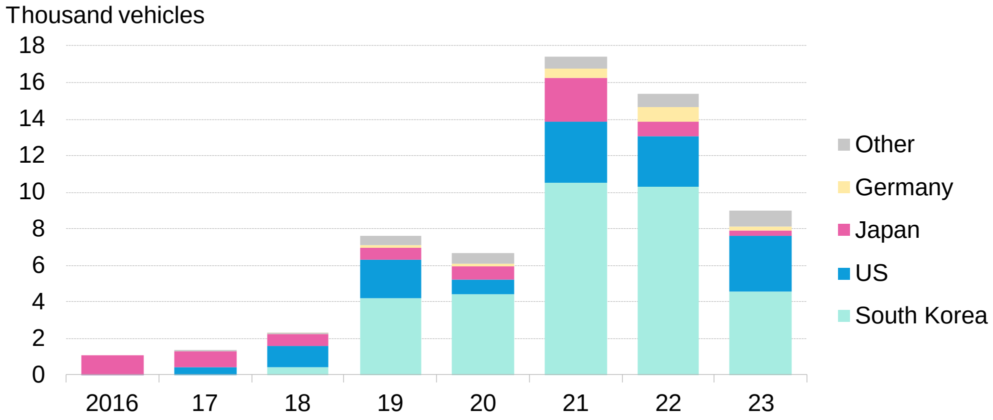
With just 9,000 units sold in 2023 BNEF has stopped forecasting passenger fuel-cell vehicles. We will resume this if they reach 0.1% of global vehicle sales

There were just 9,000 passenger FCVs sold last year, down significantly from more than 15,000 sold in 2022 and the second consecutive year of declines (Figure 108). Sales in markets like Japan and South Korea – both of which have been pushing the technology – fell dramatically. Only 318 fuel-cell vehicles were sold in Japan last year, down from 2,438 in 2021. More Lamborghinis were sold in 2023 than fuel-cell cars from all manufacturers.

Geographic and model concentration

Most of the global passenger FCV market is now concentrated in South Korea, where the government provides generous purchase subsidies and hydrogen fuel subsidies for these vehicles. In 2023, over 50% of all passenger FCV sales were in South Korea.

Figure 108: Passenger fuel-cell vehicle sales



Source: BloombergNEF, MarkLines. Note: Includes passenger FCVs only.

Toyota aimed to sell 30,000 FCVs a year by 2020 but sold just 3,736 in 2023, likely at a significant loss

Virtually all passenger FCV sales are from the Toyota Mirai and the Hyundai Nexo. Various other companies, including Stellantis, have announced plans to launch more vehicles sometime in the 2020s, but none have signaled any significant volume intent, and several have pushed back timelines. Toyota initially claimed it would sell 30,000 units per year of its Mirai FCV by 2020 before going on to higher volumes. It sold just 3,736 in 2023 despite offering steep discounts of up to $30,000 on the model.

In some markets like the UK, passenger FCV refueling stations have been removed due to low usage and challenging economics. Hydrogen refueling stations in California have also suffered from a lack of available hydrogen, high costs and poor reliability. Average retail hydrogen costs in California are now over $30/kg, meaning a Toyota Mirai costs around $150 to fill up.

Outlook

FCVs represented just over 0.01% of global passenger vehicles sales last year and will likely be in a similar range in 2024, if not lower. We are not able to make a long-term outlook for passenger FCVs while sales are so low, show limited momentum, and are highly concentrated in a few markets and models.

We will revisit our passenger FCV outlook if and when these vehicles reach 0.1% of total vehicle sales globally. This would require annual volumes of around 80,000 passenger FCVs.

FCVs still play a role in our commercial vehicle and bus outlook. For more on this see Section 5**.**

Further reading

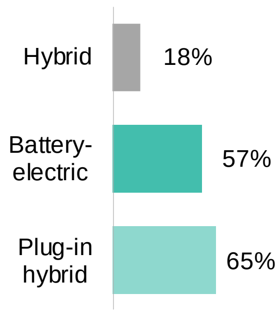
- *Zero-Emission Vehicle Factbook* (web | terminal)
- *Latin America EV Market Outlook 2023: Value Chain Builds* (web | terminal)
- *The Lifecycle Emissions of Electric Vehicles: 2024 Edition* (web | terminal)
- *Rivian Aims to Recreate Tesla's Model 3 Magic With New R2* (web | terminal)
- *India EVs Cost Less Over Lifetime But Face Uptake Hurdles* (web | terminal)
- *Electrified Transport Market Outlook 1Q 2024* (web | terminal)
- *China's EV Growth Still Leans on Cities, Not Rural Markets* (web | terminal)
- *US States Embrace EVs at Very Different Speeds* (web | terminal)
- *Long-Term Electric Vehicle Outlook 2023* (web | terminal)

Thematic Highlight
The Return of Plug-in Hybrids

Plug-in hybrid electric vehicles (better known as PHEVs) are often considered a bridge technology for a zero-emissions future. Critics argue PHEVs are not only more complicated to build and costlier to run than battery-electric vehicles, but are also at odds with climate goals because they consume fossil fuels. Proponents argue PHEVs can still benefit the climate if powered mainly by electricity. With a resurgence in China and growing automaker commitments to this technology in the US, the debate over PHEVs' impact on transport decarbonization is back on the table.

This Thematic Highlight offers a deep dive into the role PHEVs could play over the next few decades, and factors that could shape their trajectory, including public policy, cost, model availability and technology improvements. We then offer scenarios on what higher PHEV penetration and utilization may look like, and what effect PHEV growth could have on global demand for batteries and electricity, as well as efforts to reduce oil consumption. We find that increasing the electric mileage of PHEVs could have a more significant climate impact than simply selling more of them.

Figure 109: Compound annual growth rate for global passenger-vehicle sales from 2019 to 2023, by drivetrain



Source: BloombergNEF, MarkLines, JATO Dynamics, auto associations.

The current plug-in hybrid market

In the race against battery-electric vehicles (BEVs), plug-in hybrids appear to be in a weaker position than a decade ago due to policies favoring pure electric cars, rapid improvements in battery technology and charging infrastructure deployment.

However, over the past five years, PHEV sales have been rising faster than other alternative drivetrains. Annual sales of PHEVs reached 4.2 million globally in 2023, rising at a compound annual growth rate of 65% from 2019, compared to 57% for BEVs and 18% for hybrid vehicles that can't be plugged in (Figure 109).

Figure 110: Passenger plug-in hybrid-vehicle sales, by region

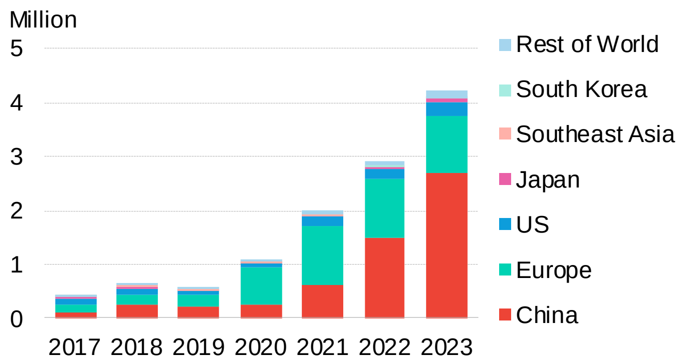
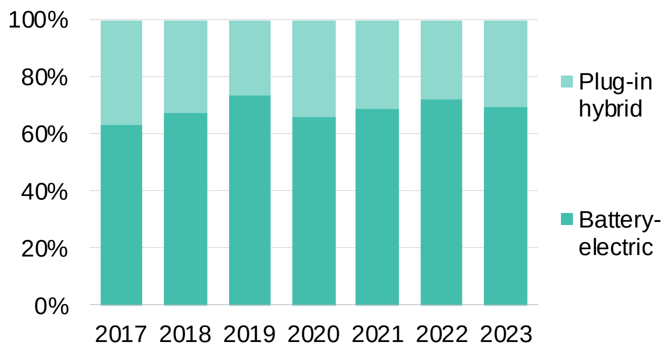


Figure 111: Global passenger EV sales, by drivetrain

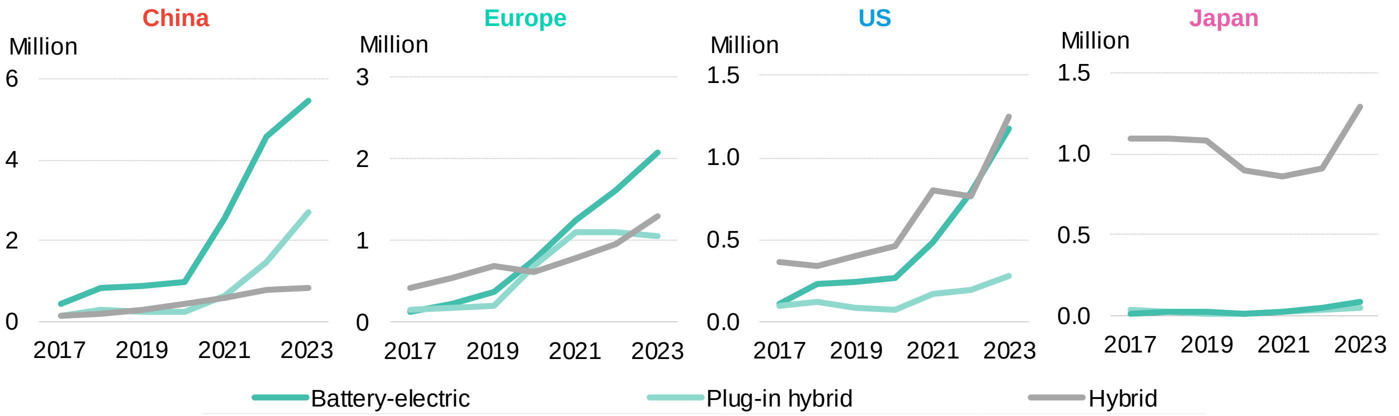


Source: BloombergNEF, MarkLines, JATO Dynamics.

Europe and China represented around 90% of global plug-in hybrid sales in 2023

The faster uptake of PHEVs across 2019 to 2023 was largely driven by Europe and China, which together represented nearly 90% of sales last year. Historically, the bulk of sales were concentrated in Europe as automakers saw plug-in hybrids as an important part of their strategy to comply with fuel-economy targets. However, China became the largest market in 2022 thanks to an influx of affordable models from the likes of BYD and Li Auto (Figure 110). The surge in China pushed plug-in hybrids to 30% of new passenger EV sales globally last year, slightly up from 2022 levels (Figure 111). PHEV sales in other countries are still relatively small, both in absolute terms and in their share of the total EV market (Figure 112). Outside of China and some European countries, PHEVs surpassed 30% of local EV sales in just two markets last year: Japan at 37% and Brazil at 63%. In the US, they only hit 19%.

Figure 112: Passenger-vehicle sales in selected markets, by drivetrain



Source: BloombergNEF, MarkLines, Bloomberg Intelligence, auto associations. Note: Hybrid vehicles exclude mild hybrids, which electrify some vehicle systems and may provide limited traction.

Factors affecting the plug-in hybrid market

Public policy, automakers' strategies, advancements in PHEV technology and competing drivetrains will continue to affect consumer demand for plug-in hybrids across the world. This section summarizes the benefits of and challenges facing PHEVs.

Table 4: Pros and cons of plug-in hybrids versus battery-electric vehicles

Topic	Pros	Cons
Cost of ownership and ease of use	Less range anxiety due to ability to use both gasoline and electricity to power the vehicle.	Total cost of ownership for PHEVs is the highest among ICE, BEV and hybrids in most cases, due to limited use of electricity.
Policy and testing	Effective way to comply with fuel economy and emission requirements.	Studies show that, at most, only 55% of average driving mileage occurs in all-electric mode in real-world cases. Real-world fuel economy is often worse than in government testing, meaning the climate benefits are less than advertised.
Scale-up	Some automakers like BYD and Stellantis have mastered PHEVs and are able to manufacture at high volume, using less battery material for each vehicle than for BEVs.	BEV architecture is simpler and over time has proven to be less costly on a dollar-per-kilowatt-hour basis, which also means a scale-up could be achieved more quickly.
Batteries and technology	PHEVs have outpaced BEVs in terms of how fast their batteries are increasing in capacity,	PHEV batteries mostly use slower chargers, so public charging could remain a challenge.

Topic	Pros	Cons
	suggesting automakers are responding to consumers looking for better all-electric range.	

Source: BloombergNEF. Note: PHEV refers to plug-in hybrid electric vehicle; BEV is battery-electric vehicle; ICE is internal combustion engine vehicle.

Policies

The US has taken a drivetrain-neutral approach to EV support, while China and Europe offer more benefits for battery-electric vehicles

Incentives and tax benefits are an important driver of EV demand, especially in the early stages of adoption, and can also play a critical role in shaping manufacturers' drivetrain choices.

Most countries have traditionally provided higher purchase subsidies for BEVs than PHEVs, aiming to tip the scales toward the lower-emitting drivetrain. However, Germany, China and the UK have already phased out direct purchase subsidies and now rely more on supply-side mandates. Although CO2 emissions and fuel-economy rules tend to benefit BEVs more than PHEVs, in the near term, plug-in hybrids will remain an important compliance tool for many automakers. The US and Canada have taken a drivetrain-neutral approach in their EV support schemes, which could spur domestic PHEV sales as automakers reconsider the technology to reach new potential consumers who are unsure about going fully electric. Table 5 highlights some of these policies.

Table 5: Selected regional and national public policies that drive EV adoption

Market	Key EV policies	Drivetrain preference	Impact
US	Inflation Reduction Act's (IRA) EV tax credits	No preference	The clean-car tax credit offers the same amount of incentive for plug-in hybrids and battery-electric vehicles, as long as the IRA's battery component and critical mineral requirements are met. Therefore, the tax credit will not swing consumers' preferences much.
	Corporate Average Fuel Economy (CAFE) standards	No preference	Fuel economy standards give automakers the ability to choose their own drivetrain pathway to reduce CO2 emissions moving forward. This could arguably benefit PHEVs, given that the US government makes assumptions around efficiency and utilization. While automakers that sell only BEVs will have to sell fewer vehicles overall, they can also use PHEVs so long as the average emissions profile across all new car sales meets each year's target.
Europe	CO2 emissions performance standards for cars and vans	No preference until 2035, when BEVs and fuel-cell vehicles are preferred	From 2035 onward, the European Union's fleet-wide CO2 emissions target is zero grams of CO2 per kilometer, corresponding to a 100% reduction, effectively excluding PHEVs. Although there are some loopholes for e-fuels, PHEVs will be at a disadvantage. While they can potentially emit as little as 30-50gCO2/km on the WLTP cycle, relying on PHEVs alone for compliance would require more than eight out of 10 cars sold in 2030 to be PHEVs and that number would fall to zero just five years later.
China	New Energy Vehicle (NEV) credit mandate	Battery-electric	An average BEV can generate two to six times more NEV credits than a PHEV in the 2024-25 period. However, the NEV targets are easily achievable across the industry, which undermines the policy's effect on drivetrain selection.
	Corporate Average Fuel Consumption requirements	Battery-electric	BEVs are assigned a lower fuel-consumption value (zero) than PHEVs. Still, the EV share of sales needed to meet the targets with all BEVs or all PHEVs is very close. The current stage of fuel efficiency rules (2024-25) is unlikely to have a material impact on automakers' drivetrain strategies.
Japan	Clean EV subsidy	Battery-electric	The government offers a maximum subsidy of 850,000 yen ($5,400) for BEVs and 550,000 yen ($3,500) for PHEVs.
Brazil	Biofuel blending mandate	Plug-in hybrid	Brazil has a biofuel blending mandate of 22% of ethanol in gasoline and a vast fleet of flex-fuel vehicles. The government aims to bolster biofuel support by

Market	Key EV policies	Drivetrain preference	Impact
			increasing the blending mandate to 27%. Strong ethanol support runs counter to BEVs but would benefit flex-fuel PHEVs – once produced.

Source: BloombergNEF, government websites. Note: Values are rounded. WLTP refers to the Worldwide Harmonized Light Vehicles Test Procedure.

Model availability

Current market dynamics suggest only a few automakers are well positioned to expand their plug-in hybrid portfolio and scale up production.

The 10 manufacturers with the highest PHEV sales in 2023 made up over 80% of the global PHEV market. The top seller was BYD, with about half its EV sales being plug-in hybrids. Several other automakers, like Stellantis, Changan and Toyota, are also more reliant on plug-in hybrid technologies, with their EV sales last year almost evenly split between BEV and PHEVs as well.

Stellantis is the top seller of plug-in hybrids in the US, while BYD dominates in China. Europe's market is more fragmented.

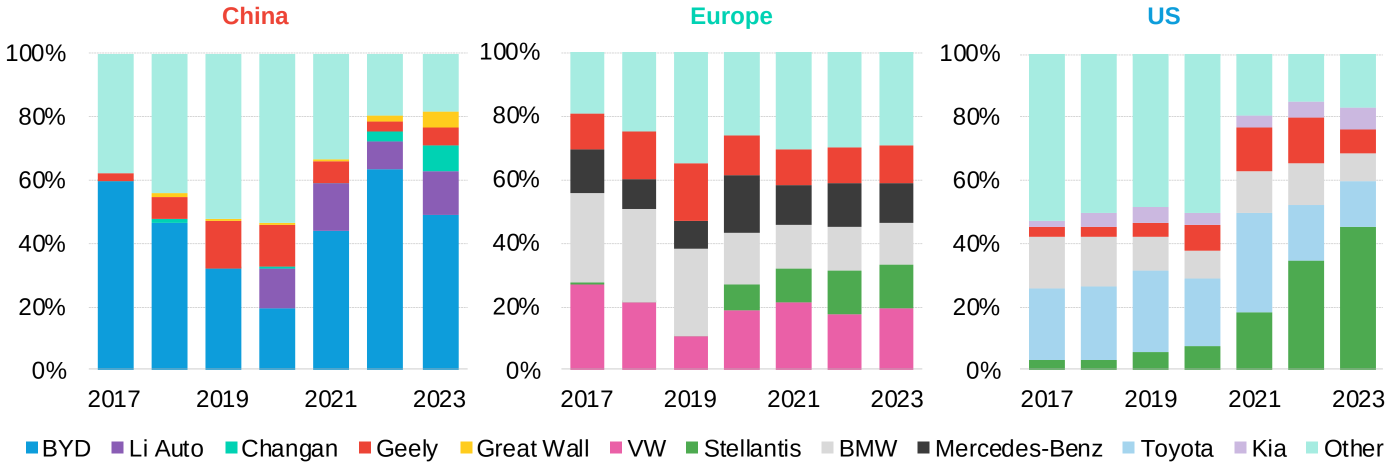
Together, automakers across the world had roughly 200 PHEV models on offer in the first quarter of 2024, with 35% only available in China. BYD is the dominant player in China, representing nearly half of all new PHEV sales last year, although that share is down from 63% in 2022.

While the models sold in China span a wide spread of prices and segments, more than 40% of PHEVs sold in Europe last year were from premium brands like Volvo, Audi, Mercedes-Benz and BMW. More affordable models from Hyundai-Kia, Toyota and Stellantis accounted for just 28% of PHEVs sold in Europe, while they enjoyed a much larger 70% share in the US.

Stellantis was the main supplier in the US in 2023, representing around 45% of sales. Its momentum was driven by the plug-in hybrid versions of the Jeep Wrangler and Chrysler Pacifica.

Europe's PHEV market is more fragmented, with no automaker yet capturing more than a fifth of the market. VW led last year with a 20% share of sales, followed by Stellantis, BMW, Mercedes-Benz and Geely, all of which are closer to the 10% mark.

Figure 113: Breakdown of passenger plug-in hybrid electric vehicle market, by region and automaker



Source: BloombergNEF, MarkLines, JATO Dynamics.

Technology improvements

Automakers are increasing the electric range of their plug-in hybrid models to meet consumer needs. Globally, the volume-weighted average range of PHEVs rose from 53 kilometers in 2017 to 80 kilometers in 2023 (Figure 114).

The higher ranges are a result of larger and more energy-dense batteries. The volume-weighted average PHEV battery pack size reached around 15 kilowatt-hours (kWh) in the US and Europe in 2023, compared to 26kWh in China (Figure 115). Overall, PHEV battery pack sizes expanded at a compound annual growth rate of 20% in the US and 11% in China between 2017 and 2023 – faster than the 1.5% rate in the US for BEVs and 6.5% in China. In Europe, PHEV and BEV battery pack sizes stayed relatively flat across this period, with a compound annual growth rate of -2% and 1.8%, respectively.

Figure 114: Volume-weighted average electric range of plug-in hybrid vehicles, by market

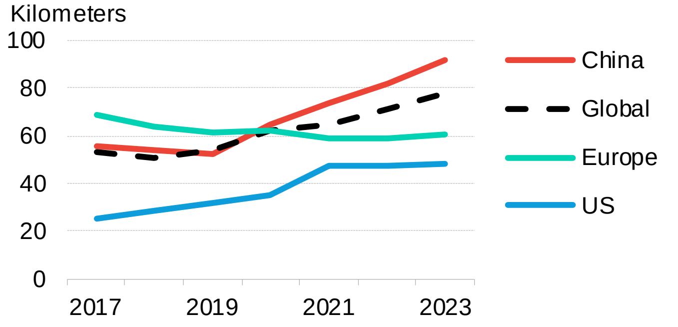
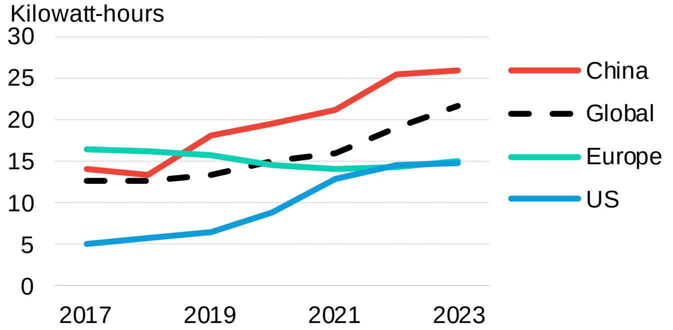
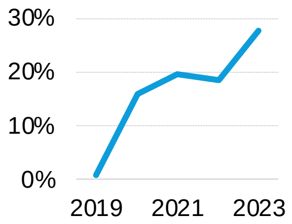


Figure 115: Volume-weighted average battery pack size of plug-in hybrid vehicles, by market



Source: BloombergNEF, MarkLines, JATO. Note: Ranges are measured in Worldwide Harmonized Light Vehicle Test Procedure.

Figure 116: Share of extended-range models in China's plug-in hybrid vehicle sales



Source: BloombergNEF, China Automotive Technology and Research Center.

Plug-in hybrids in the US have the lowest electric range. New model launches led to a big jump in 2021 but since then, ranges have remained relatively stable, at around 48 kilometers. In Europe, the average PHEV electric range is lower than back in 2017, at 61 kilometers. Even so, sales in the region increased almost ninefold across this period, hitting 1.06 million in 2023. While the European PHEV market has expanded dramatically, consumers purchased models that delivered a relatively similar range.

What is an extended-range electric vehicle?

An extended-range electric vehicle (EREV), also known as a range-extended electric vehicle, is a battery-powered EV that has a secondary onboard power generator. The range extender is usually a small gasoline engine.

EREVs are a version of plug-in hybrids but differ from 'standard' PHEVs in the way the engine is connected to the electric motor. EREVs are designed using a series powertrain layout, meaning they rely only on the electric motor to drive the wheels. When the battery is depleted to a certain level, the gasoline engine is switched on to charge the battery and/or power the electric motor. 'Standard' PHEVs have a parallel or a combined series-parallel powertrain architecture, in which both the gasoline engine and electric motor can directly propel the wheels.

In China, plug-in hybrids have surpassed 92 kilometers of all-electric range on average, nearly double what is available in the US. This difference was driven by rising sales of extended-range EVs in China – from automakers like Li Auto and Seres Group – and automakers' push for longer-range PHEVs. Nearly 30% of China's PHEV sales were extended-range models in 2023 (Figure 116), which have an average range of 127 kilometers (Figure 117). For extended-range EVs alone, battery pack sizes averaged 39kWh in 2023, while the rest of the Chinese PHEV market reached around 21kWh (Figure 118).

With two propulsion systems, PHEVs remain more complex to engineer than other drivetrains when it comes to architecture design, component sizing and control strategy. To enable longer electric range, manufacturers are increasingly using larger battery packs, further increasing vehicle weight and body size.

Figure 117: Volume-weighted average electric range in China, by vehicle type

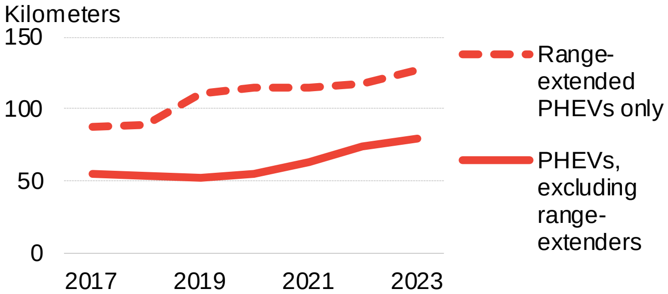
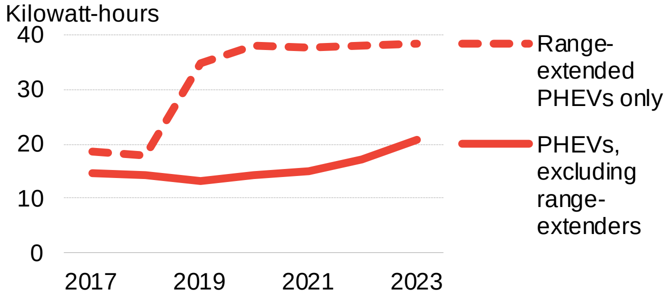


Figure 118: Volume-weighted average battery pack size in China, by vehicle type



Source: BloombergNEF, MarkLines, JATO. Note: Ranges are measured in Worldwide Harmonized Light Vehicle Test Procedure.

Costs

Plug-in hybrids have a lower transaction price than internal combustion engine vehicles in China but cost more in the US and Europe

The average transaction price for a PHEV in China fell below the average internal combustion engine vehicle price in 2023 (Figure 119). But PHEVs remain more expensive than their ICE and BEV counterparts in most other major markets (Figure 120).

In China, the average transaction price for BEVs was also lower than for ICEs, but largely because battery-electric vehicle sales in the country are skewed toward smaller vehicles. In the US, the average transaction price for a BEV undercut a PHEV for the first time last year as a result of Tesla's aggressive price cuts.

Figure 119: Average vehicle transaction price in China, by drivetrain

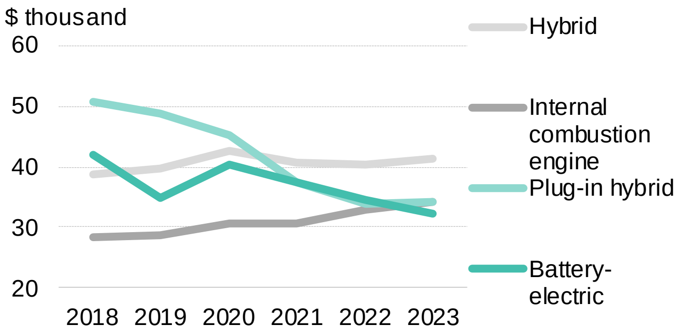
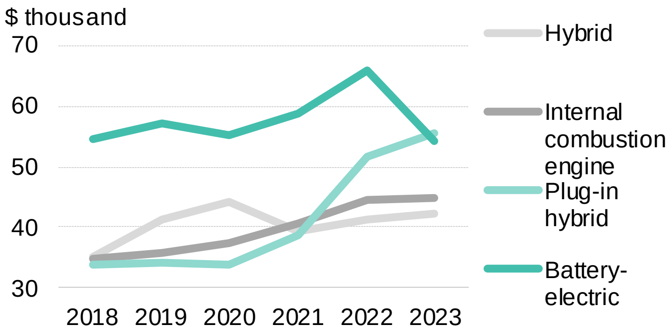


Figure 120: Average vehicle transaction price in US, by drivetrain



Source: BloombergNEF, China Automotive Technology and Research Center. Note: Battery-electric vehicles exclude mini cars.

Source: BloombergNEF, Edmunds. Note: Charts use different scales for y-axes.

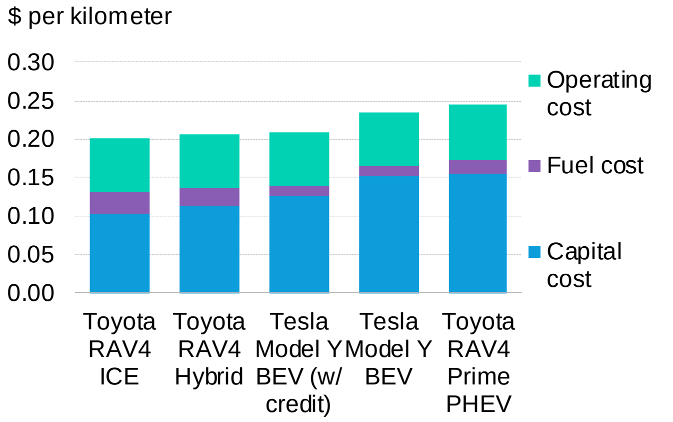
The total cost of ownership (TCO) of PHEVs depends on how much they are driven in electric mode. If electric mileage is low, or even moderate, these vehicles currently have a higher TCO than comparable ICE, BEV or hybrid models. This remains true even for the most efficient PHEVs.

The Toyota RAV4 Prime, a popular longer-range PHEV in the US, also comes in ICE and hybrid variants and competes directly with the Tesla Model Y, the best-selling battery-electric vehicle in the US. On a TCO basis, the RAV4 Prime is the most expensive option, followed by the Model Y, RAV4 HEV and RAV4 ICE (Figure 121). For this TCO calculation, we assumed a 50% utilization rate, meaning the PHEV model runs only on electricity for half the assumed annual distance traveled. Detailed assumptions behind this analysis can be found in Appendix F.

In China, both BEVs and PHEVs trail gasoline vehicles in terms of TCO, but BYD's Song Plus PHEV comes out slightly ahead of its BEV counterparts (Figure 122). The ICE version of Great Wall Motor's Haval H6 has the lowest TCO, but the comparable EV models from BYD cost only $0.02-0.03 more per kilometer.

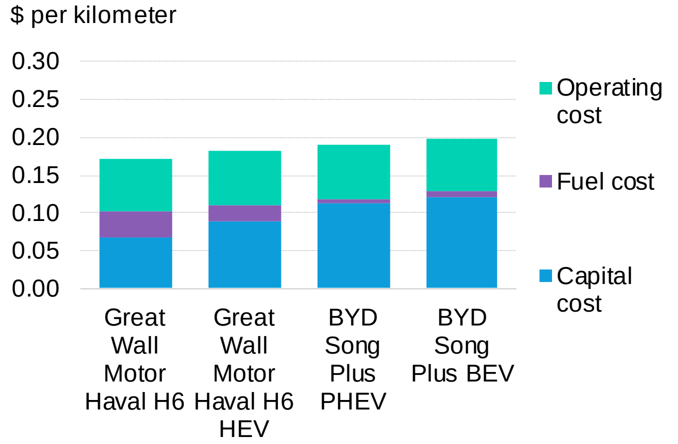
Although the results in these two regions do not currently look encouraging for either BEVs or PHEVs, a lack of potential for further cost reductions and limited electric-only driving make for a gloomier outlook for PHEVs. BEVs, meanwhile, should see continued improvements in battery costs and efficiency that can help improve their TCO.

Figure 121: Total cost of ownership of selected SUVs in the US



Source: BloombergNEF, Toyota, Tesla. Note: Includes upfront price as of April 26, 2024. Assumes gas price of $2.93 per gallon and electricity cost of $0.14 per kilowatt-hour. Credit refers to the $7,500 US federal EV subsidy under the Inflation Reduction Act. Full inputs in Appendix F.

Figure 122: Total cost of ownership of selected SUVs in China



Source: BloombergNEF, MarkLines, BYD, CarsGuide. Note: Includes upfront price as of April 26, 2024. Assumes gas price of $3.66 per gallon and electricity cost of $0.09 per kilowatt-hour. Full inputs in Appendix F.

How often are plug-in hybrids driven in electric mode?

The travel patterns of PHEV drivers vary across countries, both in terms of the total distance driven and how much the pure-electric mode is used. For example, PHEVs in Norway, Sweden and the Netherlands have higher annual mileage than ICE vehicles, while the mileage of US PHEVs is slightly lower than their ICE counterparts. We discuss the total kilometers driven for various vehicle types in further detail in Section 4.7.

Fuel economy ratings of plug-in hybrids and real-world results do not line up

Studies suggest PHEVs may not be as efficient as fuel-economy testing suggests. The International Council on Clean Transportation found in 2020 that "PHEV fuel consumption and tail-pipe CO2 emissions in real-world driving, on average, are approximately two to four times higher than type-approval values".

Other studies have backed up the ICCT's claim of a discrepancy between the test range of PHEVs and real-world results. A Transport & Environment report from 2022 found that while the Worldwide Harmonized Light Vehicle Test Procedure rated CO2 emissions of three PHEVs – the BMW 3 series, Peugeot 308 and Renault Megane – were in the range of 27-36 grams per kilometer, the real-world CO2 emissions were up to three times higher at 85-114 grams per kilometer.

New fuel-economy standards often make assumptions around the grams of CO2 per kilometer traveled and electric range utilization. Drawing from real-world data as PHEV penetration grows can help deliver more realistic policy design and tangible climate benefits.

For PHEVs' utilization of electric mode, literature and empirical studies show that between 10-55% of total distance traveled for PHEVs is powered by electricity (Table 6). The results vary across regions and user types, although the electric share in most countries is trending upward. A comprehensive report from the International Council on Clean Transportation surveyed 100,000 vehicles across a number of regions and found that PHEV drivers in Norway and the US had the highest electric motor utilization rates, with far lower results for drivers in China and Germany. Private car owners in Europe were also shown to use the all-electric mode for a larger share of daily kilometers, compared to those who used company cars.

Table 6: Share of plug-in hybrids' daily kilometers driven in different modes

Market	Electric mode	Year	Sample size	Sources
China	26%	2019-2020	6,870 private cars surveyed	ICCT
	40.6-45.6%	2021	1.1 million PHEVs connected	National Big Data Alliance of NEVs
	43.2-47.7%	2022	2.2 million PHEVs connected	National Big Data Alliance of NEVs
US	47%	2010-2016	13,000 PHEVs in California	UC Davis
	54%	2014-2020	84,068 private cars surveyed	ICCT
Norway	53%	2016	1,514 private cars surveyed	Figenbaum & Kolbenstvendt
Germany	43%	2019-2020	1,385 private cars surveyed	ICCT
Netherlands	24%	2014-2018	10,800 company cars surveyed	Ligterink & Eijk; Van Gijlswijk & Ligterink
Europe	45-49%	2012-2021	3,661 private cars surveyed	ICCT
	11-15%	2017-2021	2,273 company cars surveyed	ICCT

Source: BloombergNEF, NEV Alliance, International Council on Clean Transportation (ICCT). Notes: In electric mode, plug-in hybrid electric vehicles (PHEVs) are only propelled by their electric motor and consume electricity. In other modes, both the combustion engine and electric motor are used, consuming gasoline and electricity.

Impacts on oil, battery and electricity demand

The adoption of PHEVs will depend on a multitude of factors, including automakers' buy-in, policy, consumer appetite, availability of charging infrastructure and the technological advances of competing drivetrains. The scenario analysis below investigates the potential impacts of higher

PHEV adoption versus our base-case Economic Transition Scenario, and higher or lower utilization of electric driving in PHEVs, on upstream and downstream sectors.

Table 7: Main findings of scenarios

Scenario	Description	Variables		Highlights
		Share of PHEV kilometers traveled in electric mode	**PHEV share of EV sales**	
Economic Transition Scenario	Base case in EVO 2024	65% in 2040	Peaks at 33% in 2025 and phase-out by 2040	In our ETS, all EVs sold are pure-electric cars by 2040. The volume of oil displaced is 12.7 million barrels per day and electricity consumed exceeds 2 terawatt-hours.
Scenario 1	**High PHEV adoption** (base-case electric distance driven)	65% in 2040	Peaks at 50% in 2027 and drops to 8% in 2040	Increasing PHEV sales but keeping the utilization of electric mode unchanged would move the world further away from net-zero targets. In this scenario, while battery demand by 2040 is roughly 7% lower than in the ETS, fuel demand is around 7% higher.
Scenario 2	**High electric distance driven** (base-case PHEV adoption)	90% in 2040	Peaks at 33% in 2025 and phase-out by 2040	Increasing the amount of electric driving of PHEVs but keeping their sales the same as in the ETS, could help decarbonize passenger transport slightly faster. In this scenario, oil consumption from passenger vehicles is roughly 2% lower than in the ETS by 2040.
Scenario 3	**High PHEV adoption, low electric distance driven**	45% in 2040	Peaks at 50% in 2027 and drops to 8% in 2040	The real risk of putting too much faith in PHEVs and their drivers comes to light in this scenario. PHEV sales increase in line with scenario 1, but electric-mode utilization is far lower. As a result, while demand for electricity, charging and batteries falls compared to the ETS, oil demand is 13% higher by 2040 than in our base case.

Source: BloombergNEF

Scenario inputs

We consider the impacts of two variables – the share of plug-in hybrids in EV sales and the electric share of vehicle kilometers traveled – on oil displacement, electricity consumption and battery materials demand, by building three additional scenarios. Each scenario is compared to the Economic Transition Scenario (ETS), which represents our base case for PHEV adoption and utilization.

- Scenario 1: **High PHEV adoption,** where total EV sales remain the same as in ETS, but the share of plug-in hybrids in EV sales is much higher, surging this decade and peaking at 50% in 2027. The electric share of kilometers driven for PHEVs remains the same.
- Scenario 2: **High PHEV utilization scenario,** where plug-in hybrids are used more in electric mode. This scenario uses the same PHEV sales outlook as the ETS, but electric utilization grows to 90% in 2040 for all PHEVs.
- Scenario 3: **High PHEV adoption and low utilization scenario,** where plug-in hybrid sales increase and only 45% of daily kilometers driven are done in electric mode.

We assume higher plug-in hybrid sales come at the expense of battery-electric vehicles, but in reality they could displace any drivetrain

Plug-in hybrid adoption

In the high PHEV adoption scenarios (Scenario 1 and Scenario 3), we assume plug-in hybrid sales peak at 50% of all passenger EV sales in 2027 (Figure 123). There are two recent examples that make this a realistic assumption:

- In Norway, the world's leading electric vehicle market, plug-in hybrids reached that pinnacle in 2017-18, before falling away. Our high PHEV adoption scenarios follow Norway's general pattern, with a quick rise to make up 50% of EV sales before tapering off.
- BYD, the leading global seller of electric vehicles, still relies heavily on plug-in hybrids. Since 2017, about 46% of the company's annual sales have been PHEVs. Given BYD's swift increase in EV volumes and plans for international expansion, it could have an outsized influence on global plug-in hybrid sales moving forward.

Each of our scenarios assume higher PHEV sales come at the expense of BEVs. In reality, plug-in hybrids could also be displacing ICE vehicles or hybrids.

Plug-in hybrid electric mode utilization

In Scenario 1, the share of a plug-in hybrid's kilometers driven in electric mode rises from 40% of kilometers traveled in 2015 to 65% in 2040 and 75% in 2050 (Figure 124). Scenario 2 assumes PHEVs use electric mode more, leading the electric share of their kilometers driven to grow rapidly from 40% in 2015 to 90% in 2040. In Scenario 3, the share of electric mode use starts at 40% in 2015 and rises to just 45% for all other years.

Figure 123: Plug-in hybrid share of global EV sales, by scenario

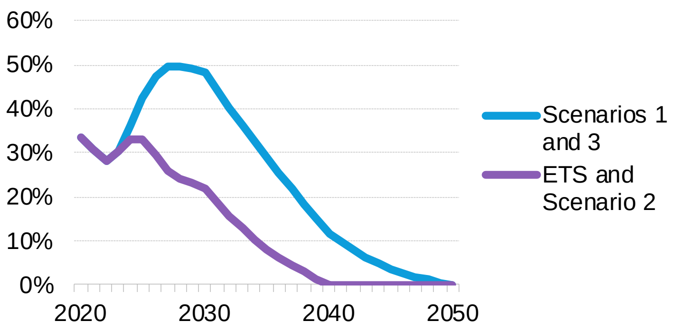
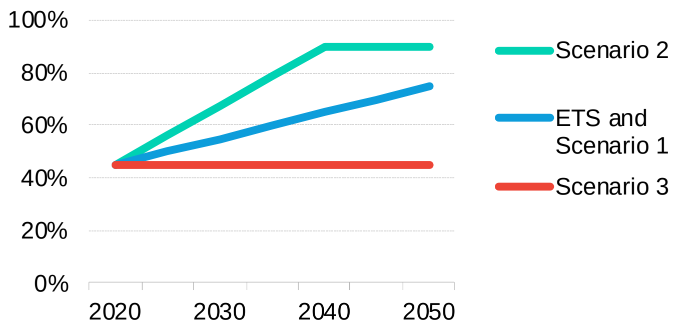


Figure 124: Share of plug-in hybrid kilometers driven in electric mode



Source: BloombergNEF. Note: ETS is Economic Transition Scenario.

Results

Each of these scenarios has a different impact on the electric share of global vehicle-kilometers traveled and demand for batteries, electricity and oil.

How plug-in hybrids are used matters for reaching emissions targets as much as how many PHEVs there will be

While just having more plug-in hybrids on the road will play a factor in battery demand, electric-mode utilization is more critical for electric vehicle kilometers traveled and electricity and oil consumption.

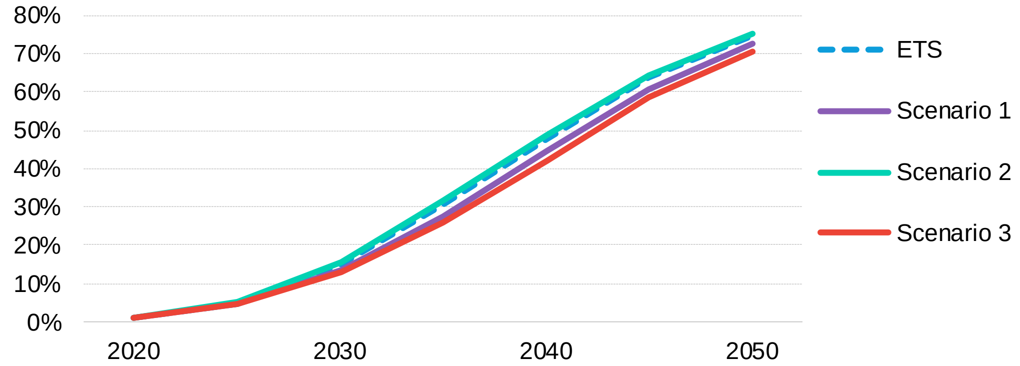
In Scenario 2, where PHEV sales are the same as in the ETS but electric mode utilization reaches 90% by 2040, the impact on electric vehicle kilometers traveled and demand for batteries, electricity and oil is relatively limited. On the other hand, increasing PHEV sales – Scenario 1 – has a visible impact on oil demand, lifting it by 7% by 2040 over ETS.

Scenario 3 is the most detrimental to the EV transition and meeting climate mitigation targets, with 1.7 million more barrels of oil consumed per day by 2040 than in the ETS, equal to the daily oil consumption of Indonesia in 2022.

Vehicle kilometers driven

The biggest differences between our scenarios occur in 2030 and 2040, before plug-in hybrids phase out of the fleet in the 2040s. In 2040, some 49% of all vehicle-kilometers traveled globally are electric in Scenario 2, compared to 48% in the ETS, 44% in Scenario 1 and 42% in Scenario 3 (Figure 125).

Figure 125: Global electric passenger vehicle kilometers traveled, by scenario



Source: BloombergNEF

Electricity and charging infrastructure demand

Some 22 million more public charging connectors are needed in 2030 for Scenario 2 compared to Scenario 3, but only 4 million more than in the ETS

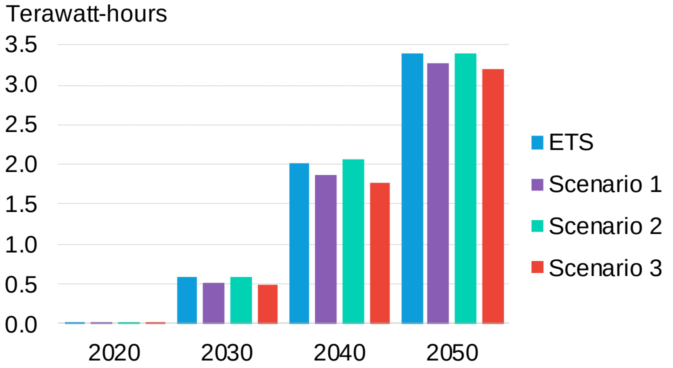
The results for the global electric share of vehicle-kilometers traveled have a direct impact on both the amount of electricity used by EVs, and the charging infrastructure needed to support an EV fleet of that size.

Electricity demand from EVs is lower than in the ETS in both Scenario 1 and Scenario 3. Only in Scenario 2 does electricity demand increase over the base case, by about 4% in 2030 (Figure 126). Given that we assume PHEVs displace BEVs across all scenarios, there is limited change in global electricity demand since the vehicles we removed rely on electricity for 100% of their vehicle-kilometers traveled.

Unsurprisingly, driving plug-in hybrids more in electric mode has a greater effect on the demand for charging infrastructure than just higher PHEV adoption (Figure 127). The number of charging connectors needed to support the fleet of electric cars in 2030 ranges from 88.6 million in Scenario 3 to 110.6 million in Scenario 2, compared to 106.4 million in the ETS. This means that in Scenario 3 (which assumes higher PHEV sales), the demand for charging infrastructure is about 17% lower than in the ETS, while in Scenario 2 (which is based on higher utilization) it is 4% higher than the ETS. Scenario 3 needs 6% less charging infrastructure – or around 6 million fewer charging connectors – than Scenario 1 in 2030, highlighting the real-world impact of lower all-electric mode utilization.

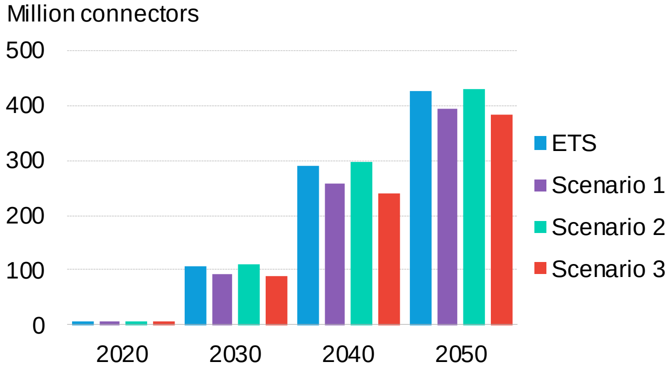
By 2050, around 44.6 million more charging connectors are needed in Scenario 2 compared to Scenario 3, the low-electrification case. In Scenario 2, where PHEV utilization is higher, there are 428.7 million charging connectors by 2050, roughly the same as the ETS.

Figure 126: Global electricity demand from passenger EVs, by scenario



Source: BloombergNEF

Figure 127: Global charging infrastructure demand, by scenario



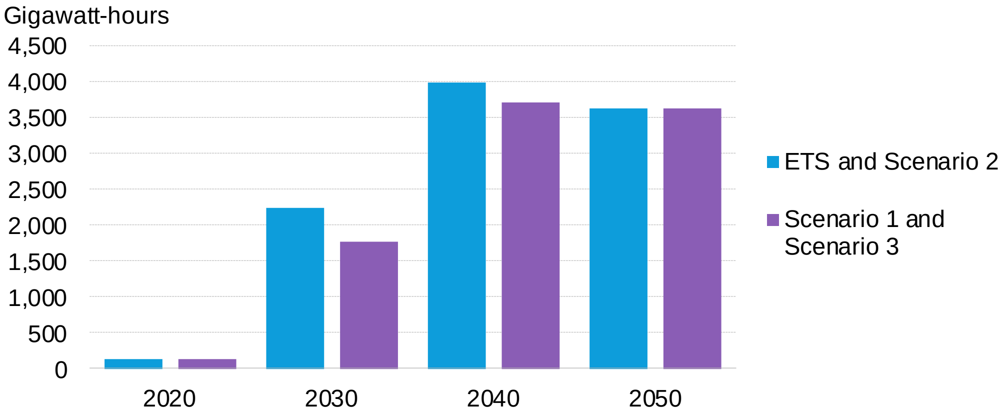
Battery and oil demand

Plug-in hybrids do help to reduce battery demand, easing the need for critical battery materials – but could come at the cost of higher global oil demand

Plug-in hybrid proponents argue that one of the strongest reasons for adopting this drivetrain is the potential to reduce demand for battery materials. According to BNEF analysis, and assuming the additional PHEVs displace BEVs and not ICE vehicles, plug-in hybrids do help reduce battery demand from EVs and, as a result, ease the need for critical battery materials. However, this comes at the cost of oil demand reductions, as low utilization of plug-in hybrids in electric mode translates to higher oil consumption, pushing the world further away from a net-zero trajectory for road transport.

In the ETS and Scenario 2, where PHEV adoption is the same, global battery demand hits 2,256 gigawatt-hours in 2030, about 485GWh (27%) more than in Scenario 1 and Scenario 3 (Figure 128). By 2040, battery demand in the ETS and Scenario 2 is just 7% higher than the other two pathways, and as PHEV sales slow in all scenarios, battery demand converges by 2050.

Figure 128: Global passenger EV battery demand, by scenario



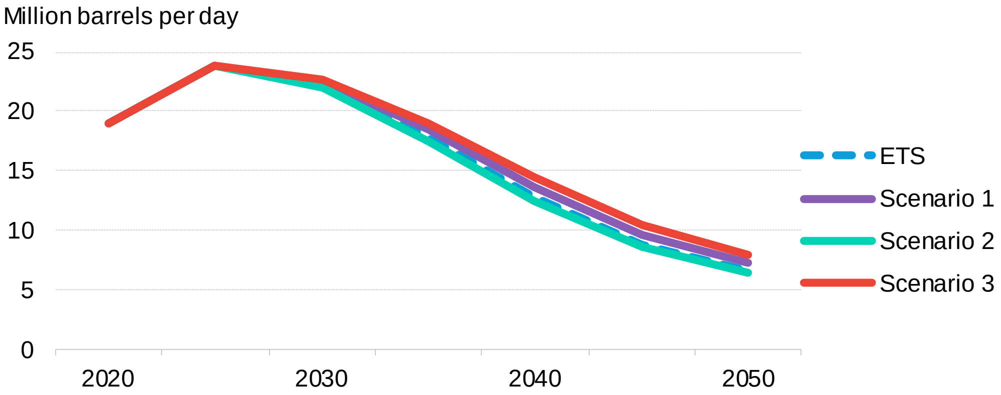
Source: BloombergNEF

Oil demand varies depending on how often plug-in hybrids are utilized in all-electric mode, but the differences between the scenarios are not significant in the near term. This is because all the pathways, except Scenario 3, see utilization rates increase over time. By 2030, oil demand from passenger vehicles in the ETS reaches 22.2 million barrels per day (Figure 129). Despite higher PHEV adoption, oil consumption in Scenario 1 is only 1% higher than the ETS due to unchanged utilization rates. In Scenario 3, oil demand increases by 2% by 2030, compared to the ETS.

The difference in oil demand use between a low PHEV electric mode scenario and the ETS is 1.7 million barrels of oil per day in 2040, equivalent to the current daily oil use of Indonesia.

By 2040, however, the scenarios diverge, and about 1.7 million more barrels of oil are used per day in Scenario 3 compared to the ETS – a difference of about 13%. The demand for oil is 7% higher by 2040 in Scenario 1 than in the ETS, but 2% lower in Scenario 2 than the base case.

Figure 129: Global oil demand from passenger vehicles, by scenario



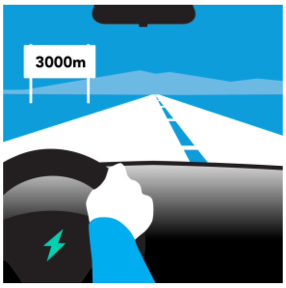
Source: BloombergNEF

The greater use of oil each day in Scenario 3 highlights the potential risk of pursuing a global plug-in hybrid strategy to achieve climate mitigation targets. Simply selling more PHEVs is not a viable strategy if all-electric mode utilization does not increase at the same time.

Pure electric vehicles can avoid CO2 emissions not only by displacing ICE sales, but also due to using a less carbon-intensive grid to meet charging needs. Moving toward scenarios where less electric-mode use occurs and more oil is consumed due to higher PHEV adoption would move the planet further away from emission reduction goals.

Further reading

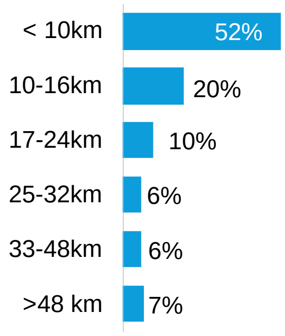
- *Hype Won't Help Plug-In Hybrid Cars Win the US EV Race* (terminal)
- *Surging Plug-In Hybrids in China Won't Save the Drivetrain* (web | terminal)
- *Plug-In Hybrids Run Out of Road as EVs Take Off, Policies Shift* (terminal)



Thematic Highlight

EV Driving Distances are Higher than Expected

Figure 130: Share of vehicle trips by trip length in the US



Source: US National Household Travel Survey 2022

Electric vehicle (EV) detractors often point to the range limitations of EVs compared to internal combustion engine (ICE) vehicles, and the still-limited access to charging infrastructure in many markets. So-called ‘range anxiety’ and ‘charging anxiety’ may sway the vehicle purchase decisions of drivers who are concerned about taking longer trips. However, the majority of passenger vehicle journeys are over short distances. Some 52% of vehicle trips completed each day in the US are under 10 kilometers (6 miles) and 93% are shorter than 48 kilometers (30 miles) (Figure 130).

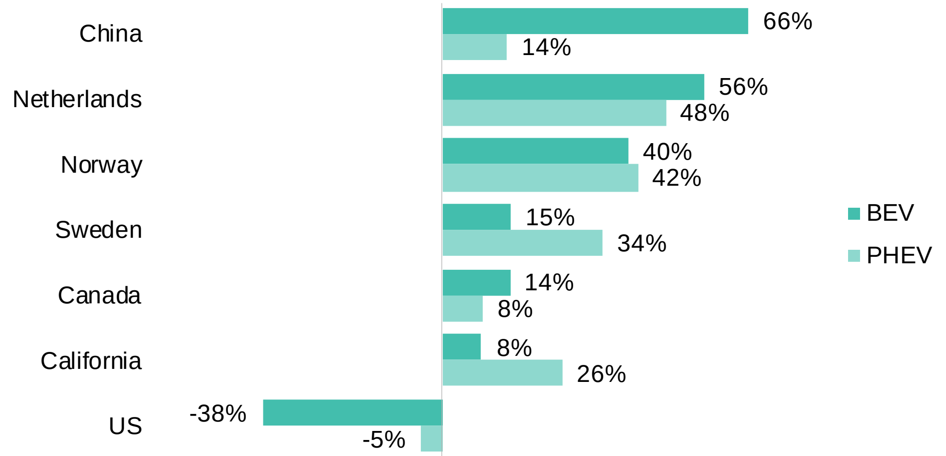
In markets where EVs are establishing an early foothold, all these shorter trips are adding up. There is strong evidence that EVs are winning over the most active drivers and are racking up more kilometers on an annual basis than ICE vehicles. If this trend is sustained and applies globally, it would have major implications for how EVs are able to contribute to the decarbonization of road transport.

Electric vehicle usage by market

The average electric vehicle, including battery-electric vehicles (BEVs) and plug-in hybrid electric vehicles (PHEVs), is driven more than the average internal combustion engine (ICE) car in leading EV markets, based on data collated by BNEF (Figure 131). In China and the Netherlands, the trend is particularly strong, with BEVs traveling 66% and 56% more than ICE vehicles, respectively. There is significant variation by geography and drivetrain. In less mature EV markets like North America, the trend is not as clear. In the US, BEVs are driven about 40% less than ICE cars, while PHEVs do 5% fewer kilometers, according to a 2023 study by George Washington University. However, the standout EV adoption state in the US – California – has EV usage numbers closer to what can be observed in markets like Sweden.

For the better part of a decade, BEVs and PHEVs in Norway, Sweden and the Netherlands have consistently outdriven gasoline (petrol) vehicles on an annual basis (Figure 132). Diesel vehicles, however, are covering about the same annual distances as EVs, according to the latest available data. Diesel vehicles are usually larger and are generally preferred by corporate car fleets – factors which partly explain their higher annual mileage – but they also account for a smaller share of the total vehicle fleet compared to gasoline vehicles.

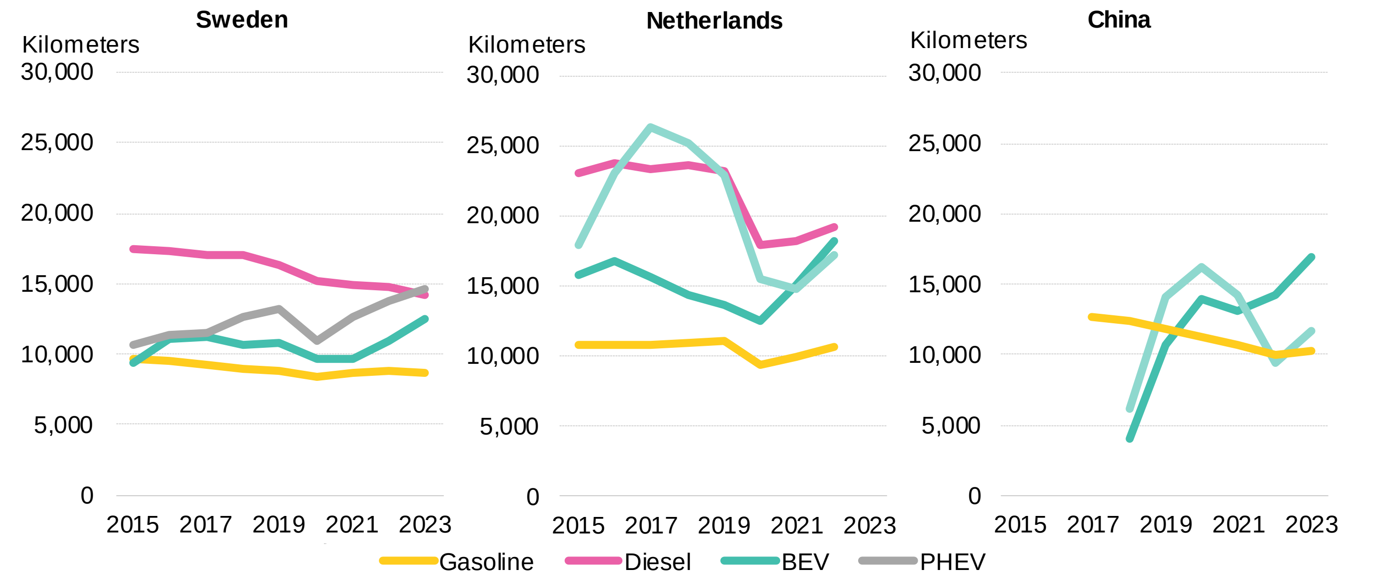
Figure 131: Difference in annual vehicle-kilometers traveled compared to internal combustion engine vehicles by drivetrain and market



Source: BloombergNEF, National Big Data Alliance of New Energy Vehicles of China, Statistics Norway, Statistics Sweden, Statistics Netherlands, George Washington University, UC Davis, news reports. Note: Latest data available. California data is from a UC Davis study published in 2020. US data is from a study by George Washington University published in 2023. US data includes all states. BEV = battery-electric vehicle. PHEV = plug-in hybrid electric vehicle.

In China, the average BEV and PHEV has been driven more than ICE vehicles since 2020. Around 16% of EVs in China are registered for ride-hailing services and the popularity of smart EVs in the market are major reasons for them driving longer distances. Far higher EV sales, range improvements and the entry of locally manufactured Tesla vehicles can explain China's jump in the average annual mileage of BEVs and PHEVs in 2019.

Figure 132: Annual vehicle-kilometers traveled by drivetrain and market



Source: BloombergNEF, National Big Data Alliance of New Energy Vehicles of China, Statistics Sweden, Statistics Netherlands. Note: BEV = battery-electric vehicle. PHEV = plug-in hybrid electric vehicle.

Factors affecting EV driving distance

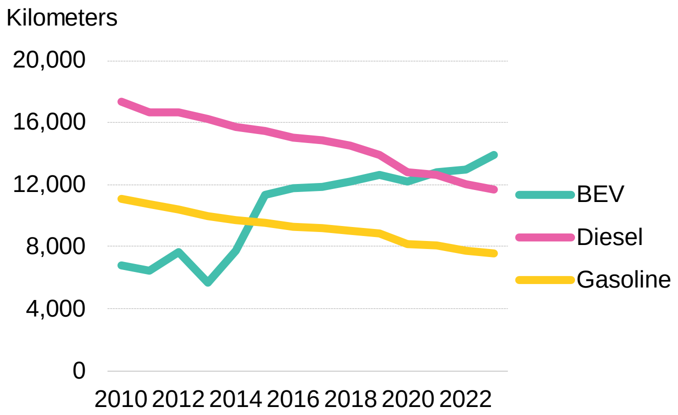
The rising utilization of EVs is driven by an increase in driving ranges on a single charge, the growing availability of charging infrastructure, the relative cost savings of operating an EV over an ICE vehicle, and policies that have made it easier and cheaper for working drivers to operate EVs in urban areas.

Improvement in maximum driving range

The average BEV annual distance traveled in Norway jumped 47% to 11,800 kilometers in 2015, from less than 8,000 kilometers a year earlier, as the first long-range mass-market model (Tesla Model S, ~422 kilometers) made its entry (Figure 133). EVs available before the entry of the Tesla Model S were mainly short-range models such as the Nissan Leaf, Volkswagen e-Golf and Ford Focus Electric (~200 kilometers based on the world harmonized light-duty vehicle test procedure or WLTP).

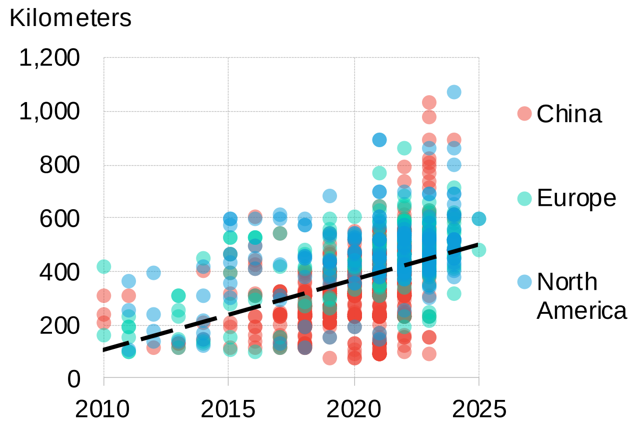
As range increases, drivers in a multi-car family may utilize EVs more and potentially use them for longer trips previously completed with ICE vehicles. The average BEV range from available models has increased to around 500 kilometers as of 2023 in China, Europe and North America, from 100-200 kilometers in 2013 (Figure 134), according to BNEF's *EV Model database* (tool).

Figure 133: Annual vehicle kilometers traveled by drivetrain in Norway



Source: BloombergNEF, Statistics Norway. Note: BEV = battery-electric vehicle. PHEV = plug-in hybrid electric vehicle.

Figure 134: BEV model range by market available



Source: BloombergNEF. Note: Uses range measured based on the world harmonized light-duty vehicle test procedure (WLTP).

An enhanced driving experience

The average driving distance of Tesla vehicles and those from comparable high-performance EV brands stand out from the general EV population. Models under these brands usually offer impressive acceleration, longer maximum range and, in the case of Tesla, access to a well-established fast charging network. Tesla vehicles such as the Model 3 and Model Y were driven on average around 27,000 kilometers in 2023 in the UK and the US, almost double the average annual distance of all other EVs (Table 8), according to energy demand data monitored by ev.energy. Tesla cars and vehicles that are comparable on price and features – such as the Audi e-tron and Ford Mustang Mach-E – were driven 40% more than ICE cars in the UK (Figure 135). Only Tesla and Audi EVs outdrove ICE vehicles in the US (Figure 136). This is likely due to a higher average annual driving distance in the US and a less dense charging network.

Table 8: Kilometers traveled of BEVs by make in 2023

	UK	US
Tesla	27,808	27,069
Non-Tesla	15,714	14,929

Source: BloombergNEF, ev.energy.

These brands also tend to deploy the latest driving automation and infotainment technology in their vehicles. In China, for instance, the average annual mileage of vehicles which are marketed as 'smart' EV brands, such as NIO, Xpeng and Li Auto, is around 20,000 kilometers per year, or 60% more than ICE vehicles. Studies have also found that drivers may travel more in partially automated EVs due to increased comfort and less stress from not having to focus on certain driving tasks (web | terminal).

Figure 135: Vehicle-kilometers traveled by BEVs by make in 2023, in the UK

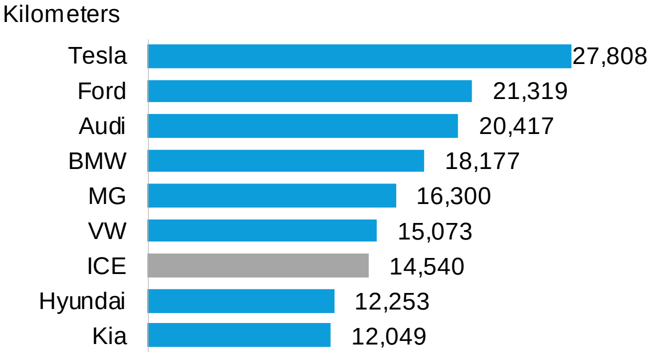
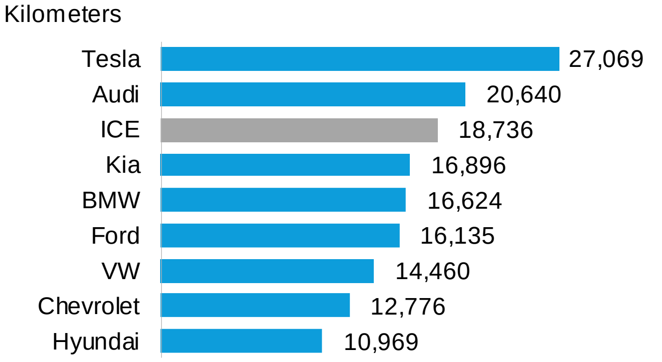


Figure 136: Vehicle-kilometers traveled of BEVs by make in 2023, in the US

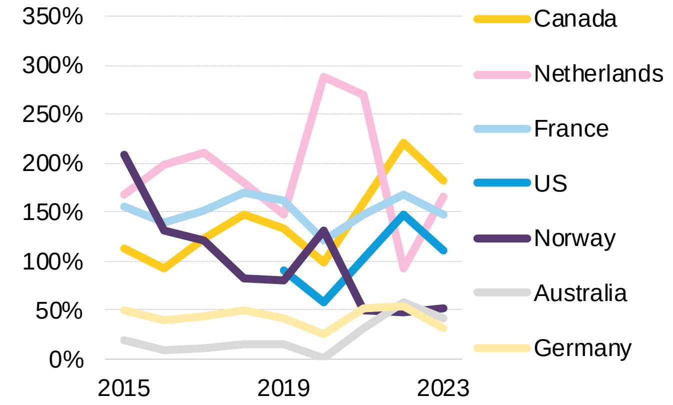


Source: BloombergNEF, ev.energy. Note: Annual vehicle-kilometers traveled, based on energy delivery data provided by ev.energy and energy consumption data by model. ICE represents the average annual vehicle-kilometers traveled by internal combustion engine vehicles in the market. VW = Volkswagen.

Better charging networks and favorable economics

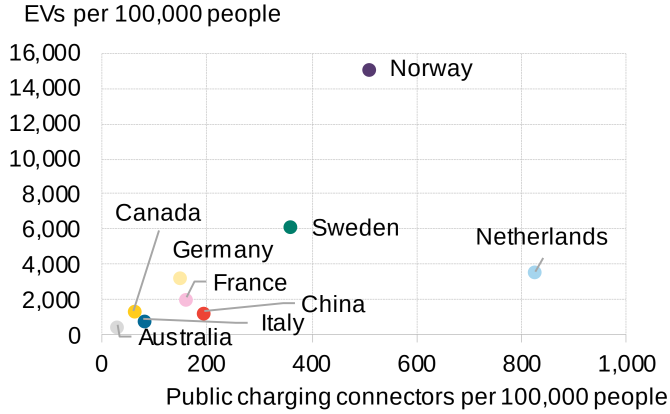
Lower operating costs and easier access to charging infrastructure could be encouraging EV owners to drive more. EV drivers have a variety of ways to access charging for their vehicles, with high-speed public charging being the most expensive and off-peak charging at home being the cheapest. The split of all these charging methods will vary from driver to driver, but on aggregate there is a cost saving for using an EV. The cost per kilometer traveled in an ICE passenger car fueled by gasoline can be over 150% more than an EV powered with residential electricity in markets like Canada, the Netherlands and France (Figure 137). While factors like volatile oil prices cause fluctuations, electricity on average has an advantage in operating costs over traditional road fuel.

Figure 137: Relative additional cost of a gasoline-powered kilometer traveled versus residential electricity



Source: BloombergNEF, Bloomberg. Note: The ratio shown is calculated as the difference between the cost of gasoline per kilometer traveled and the cost of electricity per kilometer traveled compared to the latter.

Figure 138: EV public charging connector density



Source: BloombergNEF compiled from multiple sources including Eco Movement, EVCIPA, KECO, Tesla, EVgogo. Note: Data as of December 2023.

Combining this cost advantage with a dense public charging network can lead to increased EV usage. The Netherlands, Norway and Sweden have some of the densest public charging networks in the world (Figure 138). The Netherlands, in particular, offers more than 800 public charging connectors for every 100,000 residents.

Preferential access to urban areas

Limitations on the use of ICE cars – particularly in urban areas – has increased the relative utility of EVs. These measures often influence the ability of working drivers to do their jobs, but also impact drivers who commute to work in an urban area by car.

Table 9: Selected types of policies on reducing vehicle-kilometers traveled

Policy type	Application	Markets	EV exemption
Increase the cost of car ownership	Congestion charge	London, Stockholm, Singapore	Yes
Diminish the utility of car ownership	Low Emission Zones	London, Oslo, Milan	Yes
	License plate-based driving ban	Beijing, Tianjin, Hangzhou	Yes
Limit the growth of passenger car fleet	Vehicle purchase restriction with a bidding system	Singapore, Shanghai, Beijing, Guangzhou, Tianjin, Shijiazhuang, Shenzhen, Hangzhou, Hainan	Yes in Shanghai, Shenzhen and Hangzhou
Reduce the need for car ownership	Investment in public transit and active transport such as walking and cycling	France, UK, Canada, Norway	Not applicable

Source: BloombergNEF

Typical disincentives include increasing the cost of car ownership through tolling or taxation, or diminishing the utility of ICE vehicles through driving bans and purchase restrictions (Table 9). The adoption of these measures is region-, country- and city-specific. For example, limited access areas like low-emission zones (LEZs) are in place in more than 400 European cities, while license plate-based driving bans are only seen in a few Chinese cities like Beijing, Tianjin and Hangzhou. EVs enjoy exemptions from many of these restrictions in a wide selection of markets.

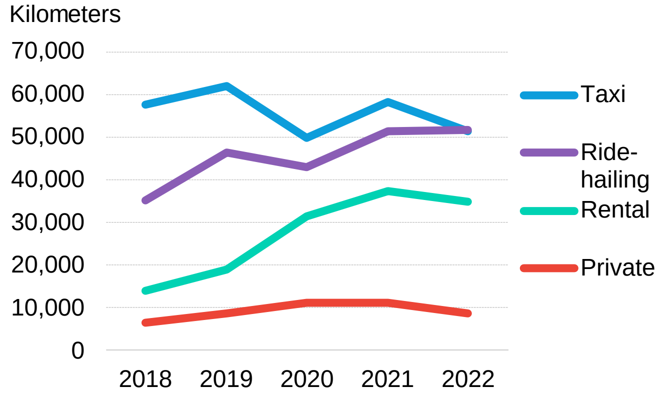
Working drivers

A much higher share of EVs in high-mileage driving – like ride-hailing, taxis, car rental and company cars – has increased the average EV utilization in many markets. High-mileage drivers are more willing to switch to EVs because of better economics, particularly for fleet operators, but also due to policy measures which have necessitated or facilitated the purchase of an EV.

In China, the average annual mileage of BEVs has increased to almost 17,000 kilometers, which is more than 60% higher than that of ICE vehicles, because of a large fleet of high-mileage shared EVs. Battery-electric taxis and ride-hailing vehicles typically drive more than 50,000 kilometers per year, around five times that of private EVs (Figure 139). The EV share of passenger cars sold to taxi and ride-hailing drivers has also been increasing rapidly, reaching 87% in 2023 from just 33% in 2018 (Figure 140). Such high EV penetration in shared cars means that more than 3.5 million EVs, or 16% of the passenger EV fleet in China, have registered on the country's leading shared mobility platform Didi, the world's largest ride-hailing platform by number of users. These vehicles accounted for 57% of kilometers traveled on the Didi platform in 2023.

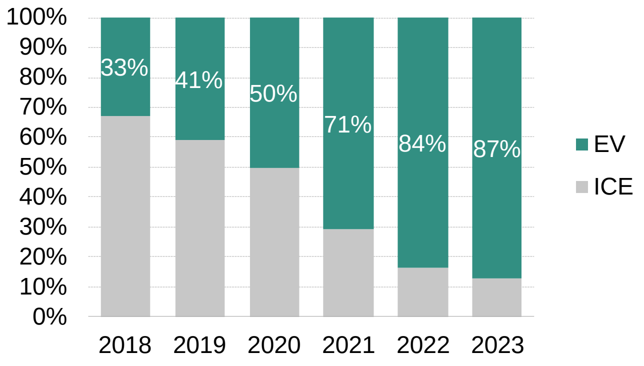
Even in markets with a lower degree of EV adoption, like in the US, high-mileage vehicles have shown to be some of the first to switch over to EVs. Uber reported that in 1Q 2024, 8.2% of all on-trip miles booked via its app in the US and Canada were completed in zero-emission vehicles. This is around five times the average of both markets.

Figure 139: Vehicle kilometers traveled of EVs by type of ownership in China



Source: BloombergNEF, National Big Data Alliance of New Energy Vehicles of China. Note: Includes battery-electric vehicles and plug-in hybrid electric vehicles.

Figure 140: Split of passenger cars sold into taxi and ride-hailing markets in China by drivetrain



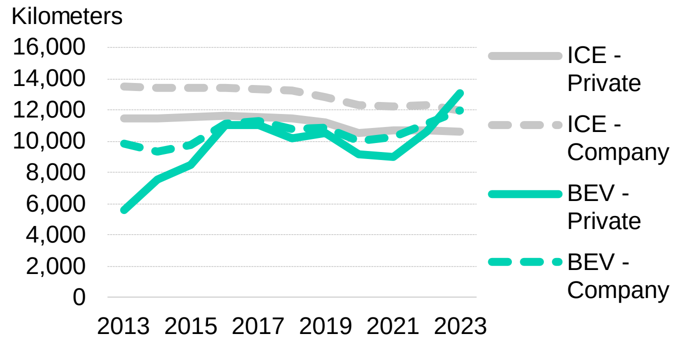
Source: BloombergNEF, China Passenger Car Association Secretary General Cui Dongshu via WeChat.

In Europe, the high utilization is in part due to the large share of EVs sold into corporate fleets and businesses. Corporate fleets and other company cars accounted for 87% of passenger EVs sold in the Netherlands in 2022, 81% in the UK and Belgium, and 67% in France in 2023. These vehicles include rental cars, which are usually driven about 2-5 times as much as privately-owned vehicles each year. While company cars are intended to be provided to employees for business use, there are many cases where these vehicles are a perk or employment benefit, rather than to fulfil work needs. In such cases vehicles would be driven in a similar manner to privately owned vehicles. The average driving distance of company cars, as a result, can vary by market. In Sweden, for instance, the average driving distance of electric company cars was only slightly higher than that of private EVs (Figure 142).

Figure 141: Share of EVs sold to corporate fleets and businesses in European countries

Source: BloombergNEF, Vias Institute, UK Department for Transport, Statistics Belgium (Statbel), news reports. Note: latest data available.

Figure 142: Vehicle-kilometers traveled by drivetrain and type of ownership in Sweden



Source: BloombergNEF, Statistics Sweden. Note: BEV = battery-electric vehicle. ICE = internal combustion engine vehicle.

Relationship between EV usage and driving factors

A multivariate regression model using more than 1,300 observations of energy delivered monthly across the UK, the US, Germany and the Netherlands from 2020 to 2023 found that EV owners drove 1,815 kilometers per month on average. EV range, model features, brand and drivetrain, all had an impact on the use of EVs:

- **EV range:** Results indicate that every additional kilometer of range an EV is capable of may lead to an additional 0.35 kilometers driven per month, meaning that an owner driving an EV with a range of 200 kilometers may travel 35 more kilometers each month than the owner of a 100-kilometer range EV.
- **Brand:** The model suggests that owners of a Tesla or similar vehicle – who also tend to be pursuers of new technology – may drive their cars 803 kilometers more each month than users of other brands.
- **Drivetrain:** BEV owners may drive vehicles 564 kilometers less than PHEV owners per month, likely due to the additional range offered by PHEVs.
- **EV operating economics:** A 100% increase in the cost of traditional road fuel relative to the local residential electricity price may lead to an additional 31 kilometers driven per month, however, results show that such impact is not statistically significant.
- **Region-specific factors:** Average driving distance, demographic features and charging infrastructure density for each market also have an impact on vehicle driving distances. For instance, US EV owners may drive 351 kilometers less per month than the global EV average, likely due to a less dense charging network and the use of EVs as the non-primary vehicle in a household. This is despite US drivers typically travelling further annually compared to other markets. Meanwhile, Dutch EV owners drive their cars 491 kilometers more each month, which may be due to a large share of high-mileage company cars in the market and one of the densest charging networks in the world.

Alternative scenarios and impacts

The EV market is still at an early stage of development and there are many uncertainties about how vehicles will be utilized in future. To help analyze the range of possibilities and the implications, we have modeled four additional scenarios.

Scenarios and assumptions

In the Economic Transition Scenario, we assume that annual vehicle kilometers traveled do not differ between drivetrains. While the available data shows that EVs are mostly driven further on an annual basis than ICE vehicles, there is a high degree of variation across regions. Even in the most mature markets, EVs remain the minority of the passenger vehicle fleet and the behavior of EV drivers could change as the market scales. To test the sensitivity of EV usage over time, BNEF offers alternative scenarios to the Economic Transition Scenario to assess the impact of EV driving distance on charging infrastructure, electricity demand, road fuel demand and emissions (Figure 143):

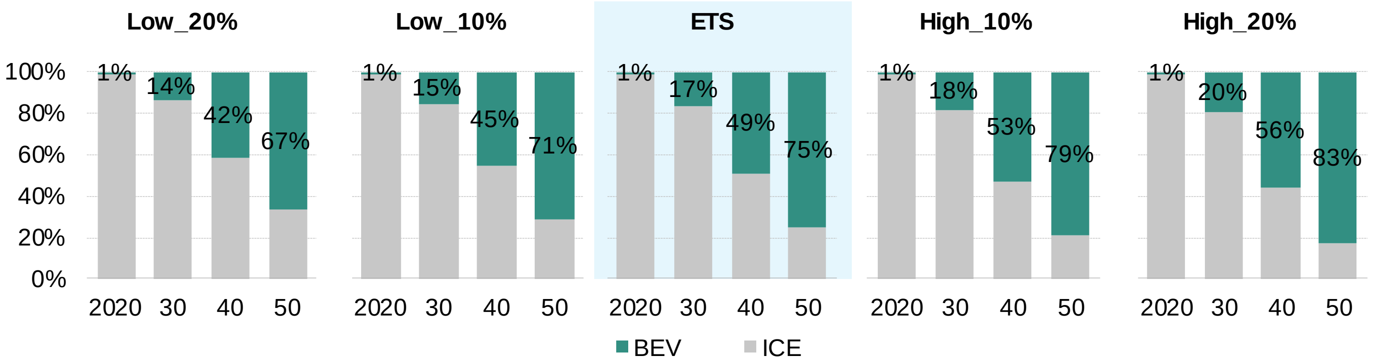
These include two scenarios where **EVs are used more than ICE cars**, driven by faster EV adoption among high-mileage drivers, or higher EV penetration in high-mileage fleets such as ride-hailing and taxis:

- **High_10%**: Private EVs are driven on average 10% more than ICE vehicles, beginning from 2024. Electric-powered kilometers reach 79% of all kilometers driven by 2050.
- **High_20%**: Private EVs are driven on average 20% more than ICE vehicles, beginning from 2024. EV share of kilometers reach 83% by 2050 in this scenario.

And two scenarios where **EVs are used less than ICE vehicles**, where EV penetration among high-mileage drivers remains limited:

- **Low_20%**: Private EVs are driven on average 20% less than ICE vehicles, beginning from 2024. EV share of kilometers will reduce to 67% by 2050 in this scenario.
- **Low_10%**: Private EVs are driven on average 10% less than ICE vehicles, beginning from 2024. EV share of kilometers will fall to 71% by 2050 in this scenario.

Figure 143: EV share of total kilometers driven by scenario



Source: BloombergNEF. Note: The Economic Transition Scenario highlighted in light blue is the main scenario of this report. EV includes battery-electric vehicles and plug-in hybrid electric vehicles. ICE includes hybrid electric vehicles.

All alternative scenarios make the following assumptions:

- **Total vehicle kilometers traveled across all drivetrains do not change.** Demand to drive is highly correlated with GDP per capita. We assume a switch in drivetrain does not lead to a change in total kilometers traveled. Evidence of higher EV kilometers in leading markets reflects a faster adoption of EVs among high-mileage drivers, as opposed to a change in overall driving behavior. Our scenarios where EVs are driven more than ICE vehicles (High_20% and High_10%) result in quicker EV adoption among high-mileage drivers, and the other scenarios (Low_10% and Low_20%) assume EVs have not appealed to high-mileage drivers.

- **Automated driving features do not lead to an increase in driving distances.** Studies have shown that passengers may travel more if vehicles are equipped with partially automated driving systems, however that research has only been conducted on small samples. More data on EV driving distance with automated driving systems engaged is needed to assess the impact of automated driving features on vehicle usage.

Impacts on charging infrastructure, electricity demand, road fuel demand and emissions

Charging connectors

In the High_20% scenario 138 million connectors more would be required than in the Low_20% scenario by 2050. Around 95% of additional charging connectors required are slow 11 kilowatt (kW) chargers to meet the demand for home charging. Around 1 million public chargers with power greater than 150kW are needed for markets where not every home can install a slow home charger, such as China.

Table 10: Demand for charging infrastructure by scenario in 2050

Scenario	3kW (million)	11kW (million)	50kW (million)	150kW (million)	350kW (million)	Total (million)	Impact (million)
Low_20%	12.3	334.7	0.8	3.6	1.5	352.9	-74.1
Low_10%	13.9	369.8	0.9	3.8	1.6	389.9	-37.0
ETS	15.4	404.9	0.9	4.0	1.7	427.0	-
High_10%	17.0	440.0	1.0	4.3	1.8	464.0	37.0
High_20%	18.1	465.7	1.0	4.4	1.8	491.1	64.2

Source: BloombergNEF. Note: ETS = Economic Transition Scenario, which is the main scenario of this report. Assumes charger power trends in the ETS remain consistent in other scenarios.

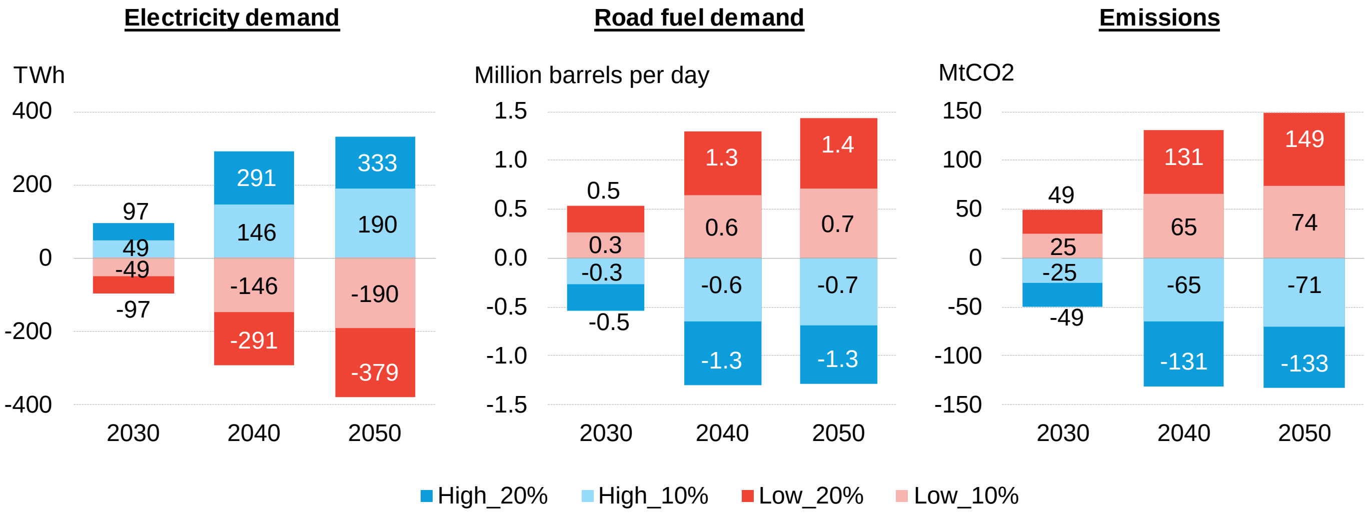
Electricity

The higher average EV driving distance in the High_20% scenario can require as much as 291 terawatt hours (TWh) more power consumption than in our ETS by 2040, and 333TWh by 2050 (Figure 144). Such additional demand is more than the 2023 electricity generation of Italy or the UK, respectively. Less usage of EVs, however, can lead to electricity demand that is around 379TWh lower by 2050.

Road fuel and emissions

Depending on the scenario, demand for road fuel including gasoline and diesel can be 1.4 million barrels per day more by 2050 than in the Economic Transition Scenario, or 1.3 million barrels per day less (Figure 144). If EVs are driven in the manner of the High_20% scenario, reduced vehicle emissions would eliminate up to 204 megatons of CO2 per year by 2050, roughly equivalent to half the annual the emissions of Australia or Brazil.

Figure 144: Impact of BNEF's EV driving distance scenarios on electricity demand, road-fuel demand and emissions compared to the Economic Transition Scenario



Source: BloombergNEF

Implications and opportunities

The way vehicles are driven should continue to be studied and monitored in order to maximize the decarbonization potential and business opportunities of EVs.

- Policymakers may need to reassess the decarbonization capabilities of electric vehicles based on user behavior in different markets. If the trend of higher EV usage continues as EVs increase in market share, the vehicle fleet will decarbonize quicker. If EV utilization lags that of ICE vehicles, as it currently does in the US, governments may need to consider additional policy measures to align usage rates.
- If EVs continue to attract high-mileage drivers, fuel usage could drop quicker. This would have major implications for the oil industry. Sinopec has stated that in its view gasoline demand in China peaked in 2023, a full two years earlier than previous outlooks, due in part to a surge in battery-powered ride-hailing. Governments may also take a revenue hit and will likely contemplate a switch away from fuel taxes to road-use taxes or tolls, like in Norway.
- Automakers have an opportunity to shape their product portfolio to appeal to high-mileage drivers. High usage of EVs among working drivers is a strong signal that these vehicles are in demand. In some instances, automakers may need to tailor their vehicles to specific use cases. For example, Roewe vehicles, which are popular with ride-hailing drivers in China, have a lower range than many other EVs but are offered at upfront price points that are attractive to ride-hailing drivers.
- High-mileage drivers will need a mix of home and public charging. If these drivers continue to electrify quicker than the general population, public charging may provide a higher share of the power supplied to EVs in the near to mid-term. This presents an opportunity for those that can position charging stations appropriately.

Further reading

- *Driving the Next Phase of Electric Mobility in Europe* (web | terminal)
- *The Lifecycle Emissions of Electric Vehicles* (web | terminal)

Commercial vehicles

Section 5. Commercial vehicle outlook

Road freight demand follows economic growth and increases 30% between 2023 and 2040. In our Economic Transition Scenario, electric and natural gas powertrains are increasingly being used, but adoption patterns differ between segments and countries.

For light-duty commercial vehicles, such as delivery vans and smaller trucks, the economics of electrification drive strong growth in many markets. By 2030, about a third of all new sales globally are electric, while in China, the UK, Germany and elsewhere the sales share is between 45% and 50%.

In heavier trucks, alternative powertrains are slower to displace diesel and adoption rates vary widely. Vehicles operating in and around cities are gradually powered by batteries, as their total costs start to drop closer to those of diesel trucks. For regional and long-haul duty cycles, natural gas technology is making inroads. The economics of battery-powered trucks improve toward 2030, with the supporting charging infrastructure developing. By that time, almost 18% of new sales of medium- and heavy-duty trucks are electric and fuel cell, with about 8% being natural gas. By 2040, these shares grow to 43% and 23%, respectively.

The difficulties in achieving a commercial-vehicle fleet with zero tailpipe emissions are large and reflect that diverse adoption of alternative powertrains in different segments. The net-zero sales trajectory of electric light vans and trucks should accelerate starting early in the 2030s. This is still challenging, but within the realm of a relatively smooth transition in the sector.

In heavier truck segments, the Net Zero Scenario requires switching the industry's technology and industrial assets to batteries and hydrogen starting almost immediately. The gap to the net-zero sales trajectory grows rapidly, especially from 2030 as heavier vehicles and longer routes prove more difficult to turn to zero-emission powertrains. By 2050, the industry is just over halfway on the trajectory to the NZS.

The global bus fleet consists of about 86% electric and fuel-cell buses by 2050 in the ETS. While this is closer to a net-zero trajectory than other sectors, sales of electric buses in many countries are very low throughout the 2020s and 2030s. Reaching a net-zero fleet by 2050 requires firmer policy targets, especially in emerging economies.

5.1. Freight demand and the market for commercial vehicles

Global demand for goods movement increased 1.7% in 2023, with activity levels on their pre-2019 long-term trajectory. By 2040, freight demand is set to expand by 38% driven by growth in smaller and emerging economies. Economic growth in India, China and some countries categorized as 'rest of world' in this report results in shifting demand centers for commercial vehicle growth. Notably, road freight in India grows at such rate that the country becomes the third-largest commercial vehicle market globally, after the US and China by 2040 (Figure 145 and Figure 146).

Truck sales increased in most major markets for all vehicle types, with a 14% rise globally in 2023

Global commercial-vehicle sales expanded 14% in 2023 with most markets and segments experiencing rising sales. Heavier truck sales grew faster than those for light-duty commercial vehicles (LCVs), 19% versus 13%, as fleet replacements and reasonable levels of economic activity in several countries supported demand for goods transport.

By 2040, the global market for commercial vehicles grows 90% in our ETS from 2023, mostly as sales of vans and lighter trucks rise 125%. Sales of heavier vehicles increase by about a quarter, consistent with the expansion of freight demand. As a result, more than three out of four commercial vehicles sold in 2040 are LCVs, from about two-thirds of the total in 2023 (Figure 145). While sales of vans and light delivery trucks expand rapidly across markets, sales of heavier trucks grow faster in countries such as India and some in the 'rest of world' category.

The global fleet of commercial vehicles approaches 340 million by 2040, about a third higher than in 2023 (Figure 146). Beyond the expansion of the LCV fleet, the number of heavy-duty trucks on the road increases faster than that of medium-duty trucks. The continued improvements in logistics infrastructure in some large markets with high economic growth, such as China and India, result in a shift to bigger trucks for heavy-duty and long-haul transport.

Such growth patterns are affecting the adoption of cleaner propulsion technologies for commercial vehicles. In countries with more modest growth in sales and fleet, such as in the US and some in Europe, new powertrains enter the mix by substituting existing vehicles. In these markets, the economics of electric and fuel-cell trucks are improving and can become competitive in the 2020s in several use cases. In contrast, many countries that are set to experience the strongest demand, especially for heavier vehicles, tend to have lower levels of wealth, delaying the economic competitiveness of new technologies to the 2030s. An exception is China, which is set to see rapid expansion of some segments of its commercial vehicle market and where electric and fuel-cell vans and trucks are already being adopted in large numbers.

Figure 145: Commercial van and truck sales outlook by class – Economic Transition Scenario

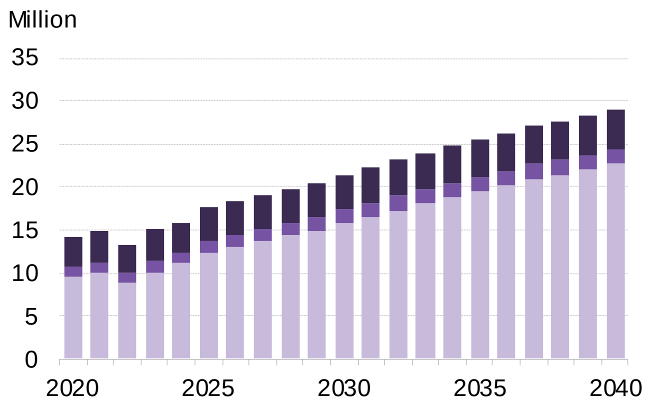
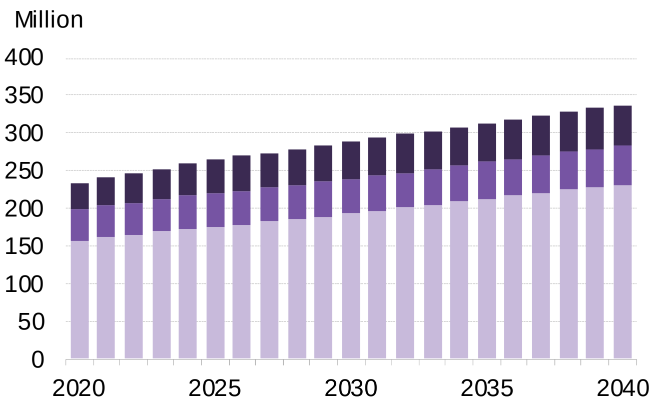


Figure 146: Commercial van and truck fleet outlook by class – Economic Transition Scenario



Source: BloombergNEF

5.2. Near-term outlook for low- and zero-emission commercial vehicles and buses

Vans and trucks

5.3% of global sales of vans and lighter trucks were electric in 2023, concentrated in China and European countries

The market for electric and fuel-cell vans and trucks grew two-thirds in 2023 to over 580,000 units. More than half of those vehicles were sold in China, which also accounted for more than 70% of the global volume for electric trucks in the heavier segments.

Most low- and zero-tailpipe emission vans and trucks are LCVs, used in urban deliveries, utility services, construction support and similar applications. In this segment, EV sales in Europe exceeded 137,000 units in 2023, with adoption accelerating in countries such as Germany, the UK and Norway. The sector is also providing an opportunity for manufacturers to increase their market share; for example, PSA’s share of electric van sales exceeds its share of the total van market in the region.

In 2023, Europe electric van sales grew by more than 50% year-on-year, while they exceeded 60% in China. Those two regions accounted for 80% of global electric LCV sales in 2023. Elsewhere, the market for electric vans in South Korea remained the strongest globally, with a share of about 30%. While we expect adoption to grow, the withdrawal of some subsidies, and rules targeting Chinese-made batteries mean that the growth rate may not continue to rise as quickly in the near term.

The US market for light commercial vehicles is far smaller. Despite increasingly favorable electrification economics, just over 16,000 e-vans were sold in the country in 2023, or about 2.9% of sales. Adoption in China and Europe was 11.7% and 7.4%, respectively. Supply of suitable vehicles is severely restricting growth in the US, as only two model families – Ford’s e-Transit and Rivian’s EDV – accounted for all sales in the segment.

About a third of the global market for light-duty commercial vehicles is electric in 2030

In the next few years, sales of electric vans accelerate and lead growth rates across all commercial vehicles. Growth rates average about 38% by 2030, resulting in 5.2 million such vehicles sold globally. More and more duty cycles, within and outside cities, reach parity on a total cost of ownership (TCO) basis with diesel and gasoline vans, and the share of e-LCVs reaches a third of total volume by 2030. In China, South Korea and some European countries, adoption rates are nearing, and in some cases exceeding, 50% by that time (Figure 147).

The global market for zero-emission medium- and heavy-duty trucks is even more concentrated than for lighter vehicles, with China accounting for more than 70% of sales in 2023. Adoption rates in the country are very high for what was previously viewed as the hardest-to-abate segment of road transport; e-truck sales were 3.4% of the total in 2023 and reached 4.6% in the first quarter of 2024 (Figure 147).

The e-truck market in China was already 4.6% of total sales in the first quarter of 2024, and exceeds a third of annual volume by 2030

China is the only country with a sizeable market for fuel-cell vehicles in the segment, even though these are still outsold at about 10-to-1 by all-battery trucks. The market for e-trucks has developed on the back of government and municipal support as well as a high share of vehicles with swappable batteries (For more, see the section on battery swapping below). Sales of fuel-cell vehicles have also been rising under specific conditions in the country, such as the availability of hydrogen as a by-product from some industrial processes and purchase subsidies. Such conditions, as well as better economics, push the market for e-trucks in China to over a third of sales by 2030, by far the largest globally.

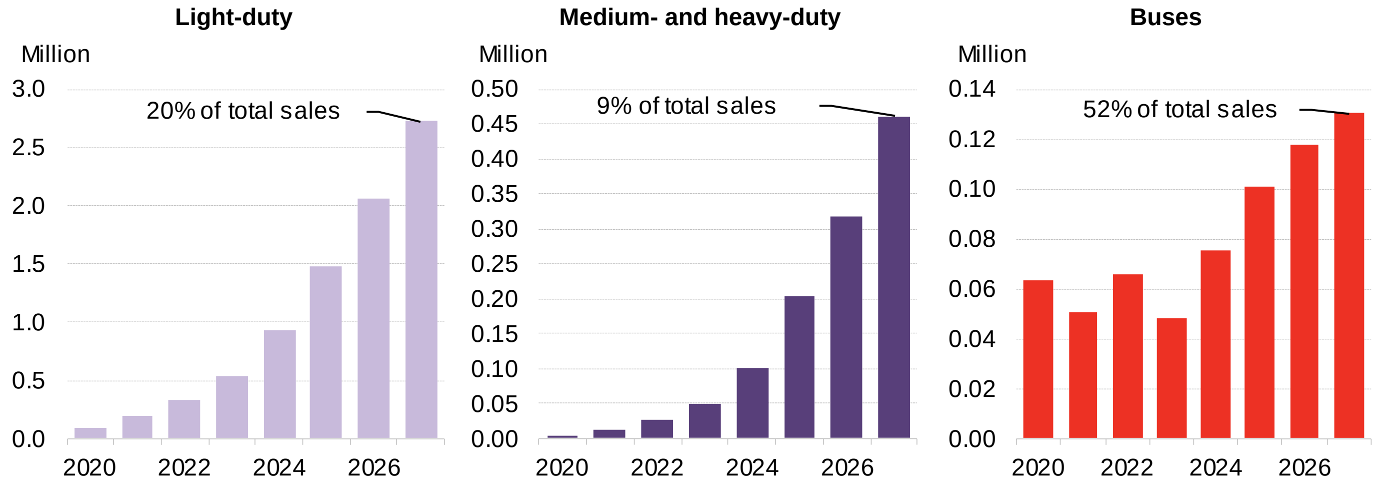
The European and US market for low- and zero-emission trucks grows to around 23% of total volume by 2030 – a massive scale-up in both regions

Outside of China, sales of electric trucks are low. The European market is further ahead of others with just under 8,000 medium- and heavy-duty e-trucks sold in 2023 – about 2% of the total. As the EU's tailpipe CO2 emission targets come into force and become ever more stringent in the region, e-truck sales reach just over 40,000 in 2026 and exceed 100,000 units by 2030. That is less than a quarter of annual volume and lower than the level needed to comply with CO2 targets (see section on the EU's CO2 targets below) (Figure 148).

The US market sees similar growth in adoption, primarily driven by demand in California and other states following its sales and fleet purchase mandates. Large manufacturers sound committed to expanding the supply of suitable, mostly all-battery, trucks in the next few years. Still, sales of such trucks in 2023 were miniscule and the embryonic supply chain for these vehicles only demonstrates the scale of the challenge ahead (For more, see the section on manufacturers below).

By 2030, the global market for battery- and hydrogen-powered trucks grows to 1 million units, with China, Europe and the US accounting for 80% of those sales, while the global share of sales is just under 18%.

Figure 147: Global electric and fuel-cell commercial van, truck and bus near-term sales outlook



Source: BloombergNEF, China Automotive Technology and Research Center, European Alternative Fuels Observatory, South Korean Ministry of Trade, Industry and Energy (MOTIE), EV-volumes, Ministry of Road Transport and Highways of India, Australia Bureau of Infrastructure and Transport Research Economics (BITRE), Ministry of Transport (Brazil), Brazilian Association of Automotive Vehicle Manufacturers (ANFAVEA), Japan Automobile Dealers Association (JADA), EV-Volumes. Note: Electric vehicles include battery-electric and plug-in hybrid vehicles.

Buses

Globally, battery-electric and fuel-cell bus sales fell 27% in 2023, primarily due to a decline in China sales. Some 48,519 zero-emission buses were sold and 69% of those were in China. The rest of the volume was concentrated in Europe, and other Asian countries such as India and South Korea (Figure 147).

China's electric medium- and large-bus sales dipped due to the phase-out of purchase subsidies and a lack of funding for municipal governments to acquire new fleets. Most of the country's sales growth was concentrated in the light e-bus segment, accounted for in the passenger EV and ride sharing vehicle segments of this report. By 2027, e-bus sales grow to 94,797 units annually, as the Chinese government's project to electrify public fleets is also under way. The program aims for 80% of new municipal buses to be new energy vehicles in 15 pilot cities by 2025, with incentives likely to stimulate e-bus purchases in the medium term (Figure 148).

In the US, battery-electric and fuel-cell transit bus sales grow to 2,652 units by 2027. Federal money will likely stimulate e-bus adoption across the nation, even though states with stricter targets will see higher adoption in the long term. While Proterra's bankruptcy in 2023 set off a chain of exits and high costs persist in the country, more purchase incentives may lift e-bus demand in the next few years. The $932 million Clean Heavy-Duty Vehicles Grant Program sets the tone nationally, with several states having ambitious targets for sales of zero-emission buses (Table 11).

Table 11: Select US state and municipal clean bus programs and targets

State/municipality	Program	Targets
California	Innovative Clean Transit (ICT)	100% zero-emission bus purchases by 2029
New York	Metropolitan Transportation Authority (MTA) Zero-Emission Bus Transition Plan	100% zero-emission bus purchases by 2029
Seattle	King County Metro Transit Zero Emission Fleet Transition Plan	100% zero-emission bus purchases from 2024

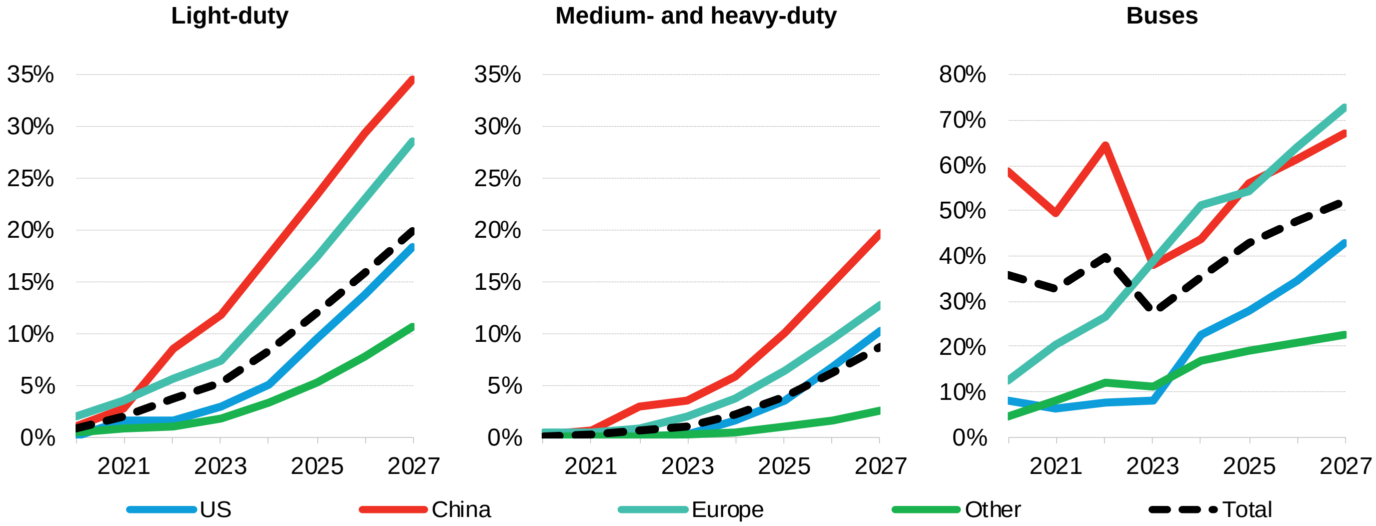
Source: BloombergNEF, California Air Resources Board (CARB), Metropolitan Transportation Authority (MTA), King County Metro.

In Europe, the European Commission has adopted new rules for all new urban buses to be zero emissions by 2035, with an intermediate goal of 90% by 2030. This is set to spur further growth of e-bus sales in the EU to reach over 14,000 units in 2027.

Some emerging markets also have ambitions to deploy more electric city buses, despite funding and infrastructure delays. In August 2023, the Indian government introduced the PM-eBus Sewa scheme, offering $2.4 billion in subsidies to deploy 10,000 e-buses across 169 cities by 2026. However, the poor financial and operational health of State Road Transport Undertakings, which own municipal fleets, has reportedly led to payment delays to e-bus operators over the past year. While high upfront costs of e-buses may slow short-term uptake, more favorable TCO may stimulate adoption in the long run. In India, the TCO for e-buses driving 169 kilometers a day is 11% lower than a diesel equivalent. In Brazil, where e-bus adoption is just starting, various hurdles are limiting current vehicle deployments. Sao Paulo had a target to acquire 2,600 battery-electric city buses by the end of 2024, but that may be delayed due to lack of funding and the need to upgrade the grid.

Despite short-term setbacks, e-bus adoption gradually ramps up to more than 130,000 units annually in 2027 (Figure 147). Globally, electric and fuel-cell buses capture a share of sales larger than 60% for medium and large transit buses by 2030 under the ETS. Notably, e-bus shares top 80% of new transit bus sales in Europe, constituting half of the public bus market by 2030 under upcoming emissions reduction rules (Figure 148).

Figure 148: Historical and short-term forecast of combined electric and fuel-cell commercial van, truck, and bus sales share by market



Source: BloombergNEF, China Automotive Technology and Research Center, European Alternative Fuels Observatory, South Korean Ministry of Trade, Industry and Energy (MOTIE), EV-volumes, Ministry of Road Transport and Highways of India, Australia Bureau of Infrastructure and Transport Research Economics (BITRE), Ministry of Transport (Brazil), Brazilian Association of Automotive Vehicle Manufacturers (ANFAVEA), Japan Automobile Dealers Association (JADA), EV-Volumes. Note: Electric vehicles include battery-electric and plug-in hybrid vehicles. Other includes Japan, India, South Korea, Australia, and countries in the 'rest of world' group.

5.3. Highlights of the switch to clean trucking

While electrification is gaining traction as one of the main pathways to clean up trucking, manufacturers are pursuing a wider list of low and zero tailpipe-emission technologies (Table 12). As truckmakers attempt to balance the different costs, maturity and market potential of those technologies with evolving policy developments, the following sections dive into some of these aspects in more detail.

Table 12: Low and zero tailpipe-emission technologies for commercial vehicles

Technology	Strengths	Weaknesses	Development status
Battery electric	Performance, efficiency, declining vehicle cost	Range, refueling network	Series production
Battery electric with swappable batteries	Efficiency, vehicle cost	Standardization requirements, swapping station cost	Series production in China; non-existent elsewhere
Plug-in hybrid	Range, efficiency	Vehicle cost, complexity	Small volume production
Hydrogen fuel cell	Range	Vehicle and fuel cost, refueling network	In development and small volume production
Hydrogen combustion	Range, vehicle cost, technology maturity	Fuel cost, refueling network, residual tailpipe emissions	In development

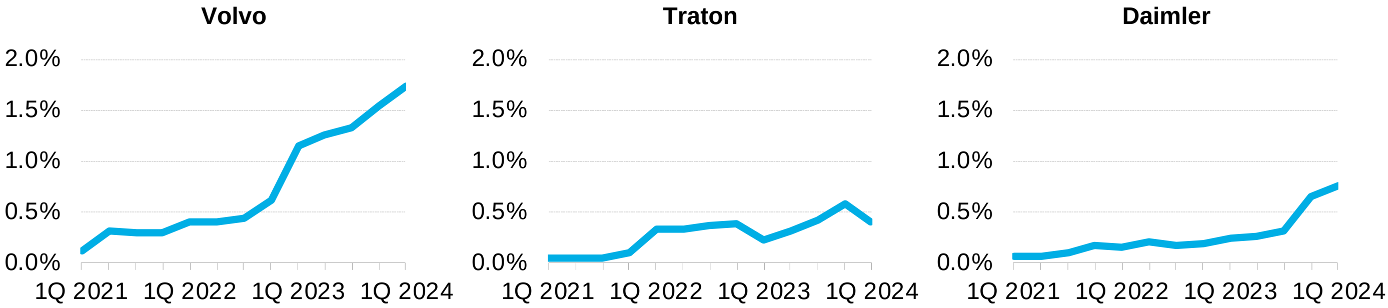
Source: BloombergNEF. Note: "Development status" reflects an overall industry view, as individual manufacturers may be at different stages.

Truckmakers slowly prepare for the long road to clean vehicles

Major manufacturers in Europe and North America have been developing the technology and assets necessary to transition to cleaner vehicles. Those headquartered in Europe – Daimler, Volvo and Traton – accounted for 55% of both the US and European markets for medium- and heavy-duty trucks.[3] They will rely mostly on all-battery trucks to help them meet stringent tailpipe CO2 limits on the continent (see the section on policy below) as well as their own ambitious targets of at least 50% zero-emission sales share by 2030.

All three are far from such goals (Figure 149). Still, having established some strategic supply relationships for battery cells and modules, they are now planning the next phase of integrating the technology deeper in their operations. By 2025, they will be producing battery packs, and in some cases the modules as well, in their own plants with cells will come from few suppliers such as CATL, Samsung SDI and Northvolt. The chemistry choice is settling on lithium-iron phosphate (LFP), matching the technology's maturity and lower cost with the 150-300-mile (241-482-kilometer) range requirements of the initial wave of e-truck buyers.

Figure 149: Truckmakers' quarterly electric and fuel-cell vehicle share of sales



Source: Bloomberg Terminal, BloombergNEF, company annual and quarterly reports. Note: Shows year-to-date share of electric and fuel-cell vehicle sales; for example, 3Q 2023 shows sales between January and September 2023. Includes trucks and buses. Traton values exclude sales of MAN TGE vans.

Most of battery assembly capacity used by these truckmakers is in Europe. The development of the supply chain is slower in North America, despite pressing needs in the US on the back of California's sales and purchase mandates. For example, Volvo, which already sells several electric models in the country, will rely on the now-bankrupt Proterra's battery assets to support its business in the country.

Only around 2030 do Daimler and Volvo plan to integrate the whole battery value chain in-house

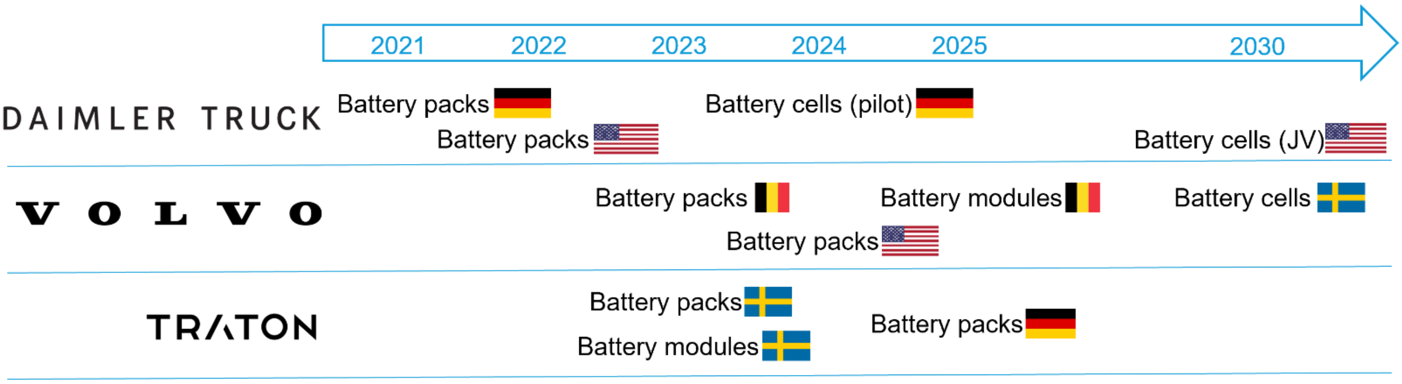
Daimler and Volvo plan in the longer term to take further ownership of the whole battery value chain (Figure 150). Daimler will produce LFP cells in the US, doubling down on its partnerships-heavy strategy. It formed a joint venture with rival Paccar and supplier Cummins, which aims to begin production toward 2030. Still, the industry's heavyweights acknowledged the enormity of that effort and tapped Chinese company EVE Energy to supply LFP technology expertise. Volvo is working toward a similar timescale, but going alone in building a cell manufacturing plant in Sweden, while Traton looks set to continue its cooperation with Northvolt.

Beyond heavy-duty electric trucks, manufactures are also starting to focus on medium-duty vehicles. For example, Daimler setup a separate brand in the US, Rizon, to focus on the sector as part of its global partnership with Fuso. This segment, which includes trucks performing diverse

[3] In the US, the share includes sales in Classes 4 to 8.

tasks including delivering produce and providing sanitation services, is also the target of several startups, such as XoS, REE and Tevva Motors.

Figure 150: Daimler, Volvo and Traton timeline of battery manufacturing in Europe and the US



Source: BloombergNEF, MarkLines, company announcements. Note: VW Group, which owns about 90% of Traton, has invested in battery cell manufacturer Northvolt and Traton's brands procure cells from them.

The e-truck market is set to grow, but scaling up vehicle manufacturing operations remains particularly challenging for both newcomers and incumbents. Startup Volta filed for bankruptcy following that of its single supplier Proterra, XoS recalled most of its vehicles to repair a brake malfunction, while Volvo recalled practically all its cumulative e-truck sales in the US due to battery failures.

China is already far ahead of every other country in all segments

China's electric truck market grew steadily in 2023 despite the phase-out of purchase subsidies. In the first quarter of 2024, China's electric medium- and heavy-duty truck sales reached record levels, with policy incentives and economic recovery being the prime drivers.

Sales in 2024 are off to a strong start and are likely to rise further this year. The Chinese government in early 2024 introduced an action plan to encourage scrappage of old consumer goods, including vehicles, to stimulate consumption. In response, some local governments and companies have been offering subsidies to purchase low- and zero-emission trucks. In addition, China's pilot project to electrify public fleets from 2023-2025 also includes incentives to adopt a higher share of new energy municipal buses and trucks in 15 cities and scale relevant charging infrastructure.

These policies in place will likely lead to growth in e-truck sales from now to 2025. BNEF expects that China's electric light-, medium- and heavy-duty commercial vehicles will reach nearly 20% of total sales in 2025 (Figure 151 and Figure 152).

Plug-in hybrids are becoming part of the sales mix for low-emission trucks in China

Chinese manufacturers are also enhancing their electric product line-up to drive wider adoption. Over the past year, truckmakers have introduced more plug-in hybrid commercial vehicles, particularly in the light-duty segment, leading to a near 10-fold sales growth for plug-in vans and light trucks. This growth in PHEV sales is likely to continue in the next two years, as e-van and truck manufacturers seek to reach markets such as regional delivery where drivers may be more concerned about range. On the other hand, while there was very high growth in fuel-cell medium- and heavy-duty truck sales in China over the past two years, the gradual phase-out of local subsidies may lead to a sales slowdown, as FCVs are still more expensive to purchase and refuel compared to battery-electric models.

Figure 151: Electric and fuel-cell van and light-duty truck sales in China

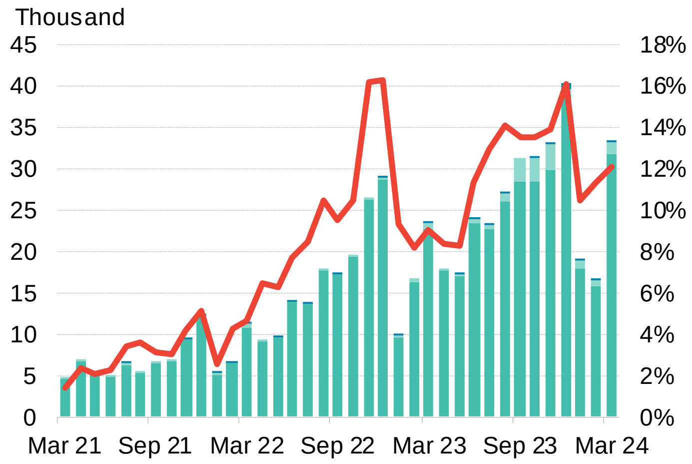
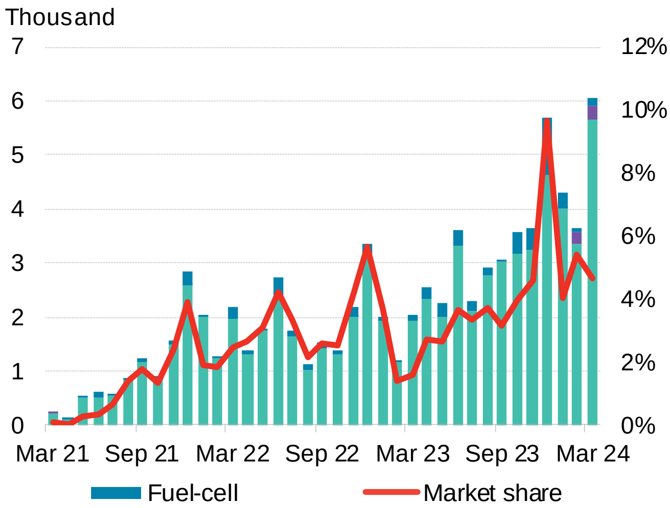


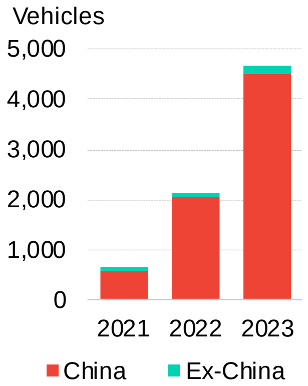
Figure 152: Electric and fuel-cell medium- and heavy-duty truck sales in China



Source: BloombergNEF, Bloomberg, China Automotive Technology and Research Center.

Hydrogen in trucking shows signs of life and may not be about fuel cells alone

Figure 153: Fuel-cell commercial vehicle sales



Source: China Automotive Technology and Research Center, EU Commission, South Korean Ministry of Trade, Industry and Energy (MOTIE), EV-Volumes. Note: Includes light-, medium- and heavy-duty trucks.

Outside of China, the market for hydrogen-fueled trucks remains small with less than 200 units sold in 2023 (Figure 153). Hyundai and Nikola accounted for all the around 90 trucks delivered in the US. Despite the low numbers, pockets of activity are emerging in the country. Nikola is set to surpass last year's performance, as it has already sold about 75 fuel-cell trucks by May. The sales and fleet mandates in California are set to underpin demand for such vehicles, while voucher programs (a form of subsidy) there and elsewhere, such as in New York, also attract fleet owners to hydrogen trucks.

As the supply chain develops and volumes grow, costs should also drop. Still, it will take substantial declines to make those trucks competitive with diesel powertrains. Nikola has revealed that it costs more than $800,000 to produce each of its fuel-cell trucks, with another $460,000 in indirect costs, such as depreciation and amortization. Equivalent diesel trucks cost between $100,000 and $150,000, while battery electrics can be between $250,000 and $350,000 depending on the use case, according to BNEF estimates.

A critical point is whether policy support will be strong for long enough to allow manufacturers to follow any declining cost curve, and whether future costs can drop to levels where policy is no longer required. Our calculations show that fuel-cell stack system costs need to be as low as $100-150 per kilowatt for heavy-duty long-haul FCVs to become competitive with diesel and battery electric equivalents on a TCO basis. At current low production volumes, fuel-cell stack system costs could be $250-350 per kilowatt, according to estimates by the US Environmental Protection Agency.

Hydrogen combustion engines have a potential sweet spot in the medium term – but even that is highly uncertain

Hydrogen use in trucking is not about fuel cells alone, as several manufacturers are also developing hydrogen combustion engines (Table 13). The technology is well understood, even though not as mature as diesel, and has some cost advantages compared to batteries and fuel cells. But these may not persist for long, especially versus all-electric vehicles.

Trucks equipped with hydrogen combustion engines come with relative regulatory benefits compared to diesel and natural gas vehicles. They emit very little CO2 from the engine lubricant and can help manufacturers meet ever stricter targets (see the section on policy below), while they produce small amounts of nitric oxides. Still, those pollutant emissions may require re-engineering exhaust gas aftertreatment components used with diesel engines, as their allowable levels also decline fast under truck emissions regulations.

Hydrogen combustion technology offers manufacturers two advantages: it can be a relatively low-cost route to very low tailpipe CO2 emissions in the short-term, and suitable trucks could hit the road relatively soon.

Table 13: Select industry activities in hydrogen combustion engines and trucks

Companies	Country/region	Launch year	Product	Stage of development
Weichai, Sinotruk	China	2022	Combustion engine, truck	Pilot production
Bosch	Europe, US	2024	Combustion engine	Development
FAW	China	2024	Heavy-duty truck	Pilot production
Tata, Cummins	India	2024	Combustion engine, truck	Production
Reliance, Ashok Leyland	India	2024	Truck	Prototype
Deutz, Mahle	N/A	2024	Combustion engine	Prototype
Liebherr	Europe	2025	Combustion engine	Development
MAN	Europe	2025	Combustion engine, on- and off-road vehicles	Development
Cummins	US, globally	N/A	Combustion engine	Development
JCB	N/A	N/A	Hydrogen combustion engine, machinery	Prototype
Daimler	N/A	N/A	Heavy-duty utility truck	Prototype
Westport	Europe	N/A	Fuel injection system	Development
DAF, Peterbilt	Europe, US	N/A	Heavy-duty truck	Prototype

Source: BloombergNEF, company announcements. Note: The list is not comprehensive. Launch year refers to the start of production or planned delivery in the latest available statements from the companies. N/A indicates that information is not available. Some of these products may also be developed for off-road vehicles and machinery, and stationary applications, rather than on-highway commercial vehicles alone. The 'Development' stage precedes 'Prototype', which comes before 'Pilot production' and, finally, series 'Production'.

Manufacturers can transfer part of the know-how and other resources from diesel and gasoline to hydrogen engine development. Some components are common or similar, even though new designs are developed for items such as injectors, fuel pumps and combustion chambers.

Hydrogen combustion technology scores acceptably on capital cost and potential product supply, but poorly on refueling network availability, operating cost and medium-term prospects

Any overlap in knowledge and equipment will allow truckmakers to partially repurpose existing industrial assets and rely on their long expertise and deep supply chains for combustion engine vehicles. That could help reduce the time and cost it takes to bring those hydrogen trucks to the market.

Refueling those vehicles, however, is the first serious hurdle for any wider adoption. The limited availability and high cost of pump hydrogen works similarly as for fuel cells. In addition, the combustion engine's lower efficiency – which can be as low as half of the fuel cell and a third of the battery truck – means that operating costs will be far higher than either of those two zero-emission technologies.

We also expect that any current cost advantage of hydrogen combustion trucks versus battery ones to diminish like that with diesel powertrains. Battery prices continue to drop sharply as the supply chain expands globally, while cost declines of the more mature combustion engine-related components would be smaller.

For manufacturers, the technology poses a further dilemma. It resembles existing products but has zero overlap with battery and little with fuel-cell trucks, which in turn share some components. Keeping all the options open implies that truckmakers would need to develop and fund a broad, and far larger than in the past, technology portfolio. While sales and income have been strong in recent years, the industry's cyclicality may challenge their ability to continuously invest on all the options. With battery truck sales growing, that would leave an even smaller part of the market accessible to other zero-tailpipe emission technologies.

Hydrogen combustion technology may have a window of opportunity in trucking in the next few years

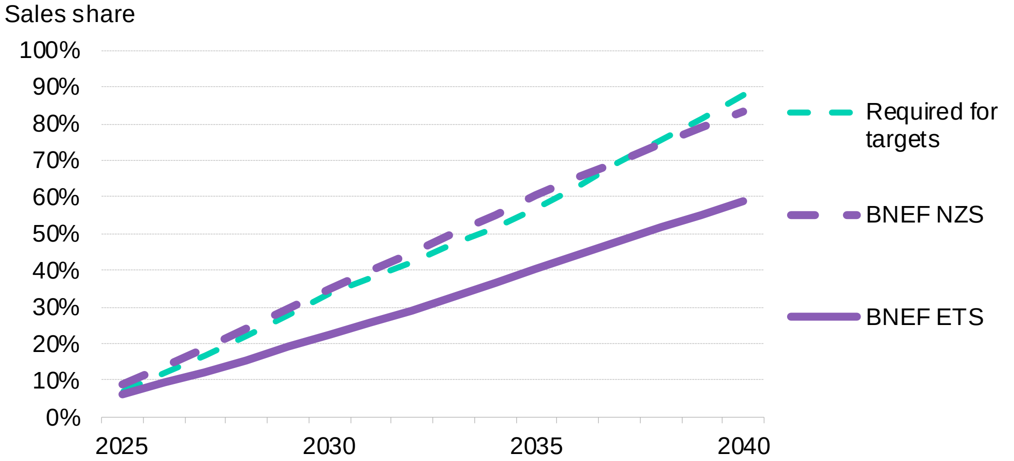
On balance, a window of opportunity for trucks with hydrogen combustion engines could open in the next few years. Still, the near-term refueling hurdles and the dominance of diesel products, and the medium- to long-term cost and refueling advantages of battery trucks make their widespread use highly uncertain.

Tightening CO2 emissions regulations in US and EU to catalyze zero-emission truck uptake

EU

The European Commission's new CO2 emission reduction targets for trucks, if achieved, will set the industry on track for net zero by 2050. Even though there is no zero-emission sales mandate for trucks, manufacturers would struggle to meet tightening CO2 targets with existing combustion engine technologies alone. The zero-emission truck share needed to meet such targets reaches 34% in 2030 and 88% in 2040 (Figure 154). The EU's targets require 45% CO2 emissions reductions by 2030, compared to 2019 levels, rising to 90% lower CO2 output by 2040.

Figure 154: Electric and fuel-cell medium- and heavy-duty truck adoption requirement to meet CO2 targets in the European Union and comparison with adoption outlook



Source: BloombergNEF. Note: ETS is Economic Transition Scenario. NZS is Net Zero Scenario. 'Required for targets' shows the sales share within the regulated vehicle segments.

Stricter emissions targets are set to incentivize higher adoption of zero-emission trucks in Europe

The required zero-emission truck adoption curve under EU targets roughly resembles BNEF's NZS sales share. However, the EU regulation only covers certain vehicle segments, accounting for just over 60% of the medium- and heavy-duty truck market in the region. Even so, the zero-emission share levels would require a big jump from current adoption trajectories under BNEF's ETS. Manufacturers failing to meet the new targets may face hefty penalties reaching tens of billions of euros in 2040. This will likely incentivize higher adoption of zero-emission models.

In contrast, the zero-emission mandate for new urban buses starting from 2035 under the new EU regulation is within reach. In 2023, BNEF estimates that 39% of new city bus sales were already battery-electric or fuel-cell models in Europe. Since the regulation enables municipalities to apply for an exemption in some use cases, it is unlikely that all new urban buses would need to be electric by 2035.

US

New greenhouse gas emissions standards for trucks and buses in the US will likely also encourage higher adoption of zero-emission technologies in light and medium-duty segments. Finalized by the Environmental Protection Agency in March 2024, the new standards will apply to vocational vehicles[4] and tractor models introduced starting from 2027.

Varying by vehicle segment, the new targets will require a 25-60% decrease in CO2 emissions in 2032, compared to 2024 levels (Table 14). The reduction targets are more stringent for light and medium-duty vehicles, especially those for urban uses, compared to heavy-duty segments. As battery-electric trucks are already cost-competitive in some urban duty cycles, stricter greenhouse gas standards should encourage higher uptake of zero-emission urban light and medium trucks.

4 Vocational vehicles are a broad category encompassing delivery trucks, utility trucks, transit buses, and school buses.

Table 14: US Environmental Protection Agency Phase 3 tailpipe CO2 emission reduction targets for commercial vehicles

Model	2027	2028	2029	2030	2031	2032
Light-heavy vocational	17%	22%	27%	32%	46%	60%
Medium-heavy vocational	13%	16%	19%	22%	31%	40%
Heavy-heavy vocational	-	-	13%	15%	23%	30%
Day cab tractors	-	8%	12%	16%	28%	40%
Sleeper cab tractor	-	-	-	6%	12%	25%

Source: BloombergNEF, US Environmental Protection Agency. Note: Reference Phase 2 standards apply from 2024-2026. Light heavy-duty refers to Classes 2b-5. Medium heavy-duty refers to Classes 6-7. Heavy heavy-duty refers to Class 8.

However, the standards make little explicit distinction between buses and trucks, where the technology readiness of zero-emission powertrains varies greatly. Sales shares of battery-electric transit buses and school buses in 2024 are much higher than electric trucks. This means that there is room for federal emissions standards to be more stringent for public buses to push for higher zero-emission adoption.

China

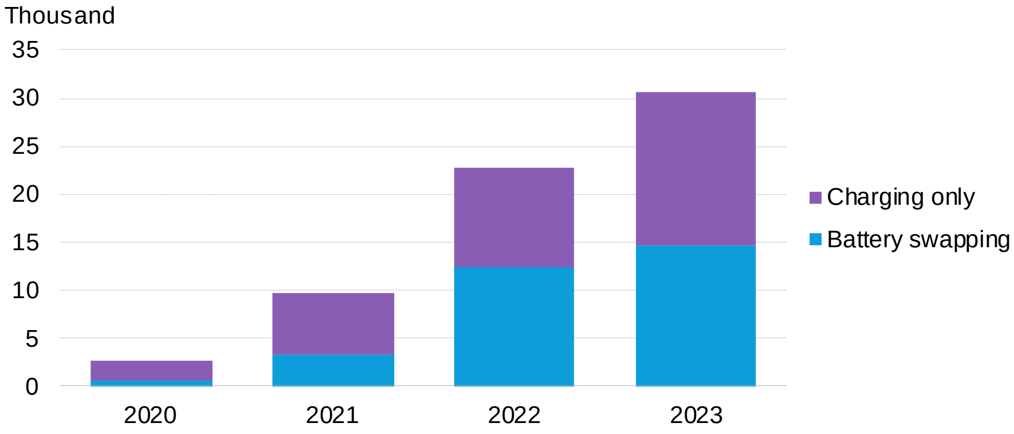
China is behind on fuel economy regulation compared to the US and Europe, as upcoming standards are likely to be less stringent than EU and US equivalents. The country introduced the third phase of “Fuel Consumption Limits for Heavy-duty Commercial Vehicles” were in 2018 and this has been in force since mid-2019. The government is still in the process of revising the standards, with the fourth-phase limits expected to be 12-16% tighter than the third phase according to the policy draft. The fourth-phase limits are supposed to come in force at the beginning of 2025, but this will likely be delayed since the legislation awaits finalization.

Battery swapping has long-term potential to electrify truck fleets

Battery swapping has been part of China’s electric truck growth story and in 2023 around half of the more than 30,000 heavy-duty e-trucks sold in the country were battery swappable models (Figure 155).

The technology’s advantages are the short refueling time, the lower upfront cost for the vehicle and the potential to optimize the timing and cost of charging. All these can improve an e-truck’s utilization and lower its TCO. While battery swapping is unlikely to take off in Europe and the US anytime soon, it can become part of the technology mix to clean up trucking.

Figure 155: Sales of heavy-duty commercial battery-electric vehicles in China by refueling type



Source: BloombergNEF, EVPartner. Note: Numbers vary slightly from Bloomberg's 2023 heavy-duty e-truck sales due to segmentation differences. Might include offroad vehicle sales.

Beyond the current short-haul urban and closed-loop applications, the approach also has the potential to expand the usage of e-trucks to regional and long-haul duty cycles for which battery swapping can complement high-power charging. In China, pilot projects have shifted focus to connecting regional networks, rather than supporting operations within individual cities. For example, the State Power Investment Corporation's pilot project announced in 2024 aims to expand truck battery swap network coverage to a corridor spanning Gansu, Inner Mongolia, Shanxi, and Hebei provinces in northern China by 2026.

Battery swapping can also help separate the cost of the truck from that of the battery, and lower the electrification requirements for smaller fleets by as much as two-thirds of the cost of an e-truck in China. Still, that requires standardized battery systems and recycling networks, where third-party operators – so-called battery banks – can provide rental services and take on battery residual value risk. While in China CATL batteries for trucks are generally accepted by battery banks, other customized designs in the country and abroad may not be as transferrable.

Standardization of technology components and stations is key for battery swapping to work

Government backing is crucial in deploying and scaling up the technology, due to the high initial capital costs for the swap stations and the need for standardization. Battery-swapping hardware, including connectors, cooling connectors, and battery sizes, and software such as battery management system signaling need to be interoperable between truck models of different manufacturers. China is currently in the process of finalizing national standards. The country's state-owned utilities and concentration of large battery manufacturers provides advantages to standardize battery swapping practices.

While it is not too late to standardize electric truck models outside of China for battery swapping since these vehicles are still in the early stages of adoption, it will be difficult in practice. In Europe and the US, government support has focused on high-power charging, while truckmakers in these markets have shown little interest in the technology. Also, utility involvement is trickier in Europe and the US, where the grid is mostly owned by separate private operators.

Despite these roadblocks, battery swapping can serve as another solution alongside other forms of charging to facilitate the transition to zero-emission fleets in the long-term, even outside of China. Establishing battery swapping infrastructure may provide time and cost advantages over setting up high-power charging stations, especially those requiring megawatt-scale power. Not all sites have the grid capacity to support such demand, and grid upgrades could be expensive and time consuming. In contrast, battery-swapping station operators have more flexibility to recharge truck batteries at different times to avoid grid overload. They could then potentially offer more competitive refueling rates as charging at off-peak hours could be cheaper.

Battery swapping could also make demand-response charging feasible for commercial fleets, as off-peak charging times can overlap with peak truck operating hours in some use cases. Battery swap providers in Tangshan, China are already experimenting with demand-response truck battery charging to balance the grid. Offering battery swapping as an alternative option at truck charging stations could help meet rising demand without the need for significant grid upgrades that could delay the rollout of charging infrastructure.

5.4. Electric commercial vehicle and bus adoption outlook – Economic Transition Scenario

Total cost of ownership

Total cost of ownership (TCO) is the main factor driving the share of alternative powertrain technologies in commercial vehicles. TCO quantifies the present value of all relevant costs in owning and running a vehicle. It includes capital, fuel, maintenance and tires, and is normalized over the total distance traveled throughout the vehicle's usage period. Our calculations exclude driver wages and some other costs, such as road taxes or tolls.

We calculate the TCOs of up to six drivetrains[5] for every duty cycle in each weight class and for every outlook year, including a weight penalty of all-battery and fuel-cell medium- and heavy-duty trucks in regional and long-haul operations.

Battery cost and efficiency improvements support our main conclusions that show the economic competitiveness of battery electric vans and trucks. Fuel-cell truck economics also improve, but their trajectory is far less certain (see section on costs and efficiencies below).

- Battery-electric vans and trucks, whether light-, medium- or heavy-duty, that operate in urban duty cycles already become the cheapest option in the 2020s.
- By 2030, the TCOs of battery-electric heavier trucks approach those of diesel. This happens earlier for medium-duty vehicles, which have smaller batteries, and in countries with lower electricity costs.
- Batteries become a contender technology for trucks in long-haul duty cycles around 2030. The variability in these duty cycles is larger than in other use cases, so the conditions for TCO parity – such as battery capacity and charging infrastructure optimized for these operations – are more stringent.
- Fuel-cell trucks can also become a competitive technology for long-haul operations around 2030 under some ambitious technology cost declines. However, the visibility on such costs and the development of the necessary refueling infrastructure make these estimates markedly less certain than for battery trucks.

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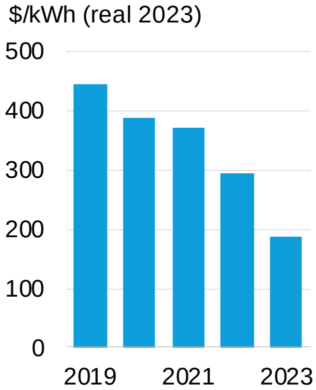
[5] Diesel or gasoline, compressed and liquefied natural gas internal combustion engines, plug-in hybrids, full battery-electric and fuel-cell vans and trucks.

Input costs and efficiencies for battery and fuel-cell trucks

Battery costs and electric truck efficiency

Figure 156: Commercial vehicle and bus battery pack price outside of China



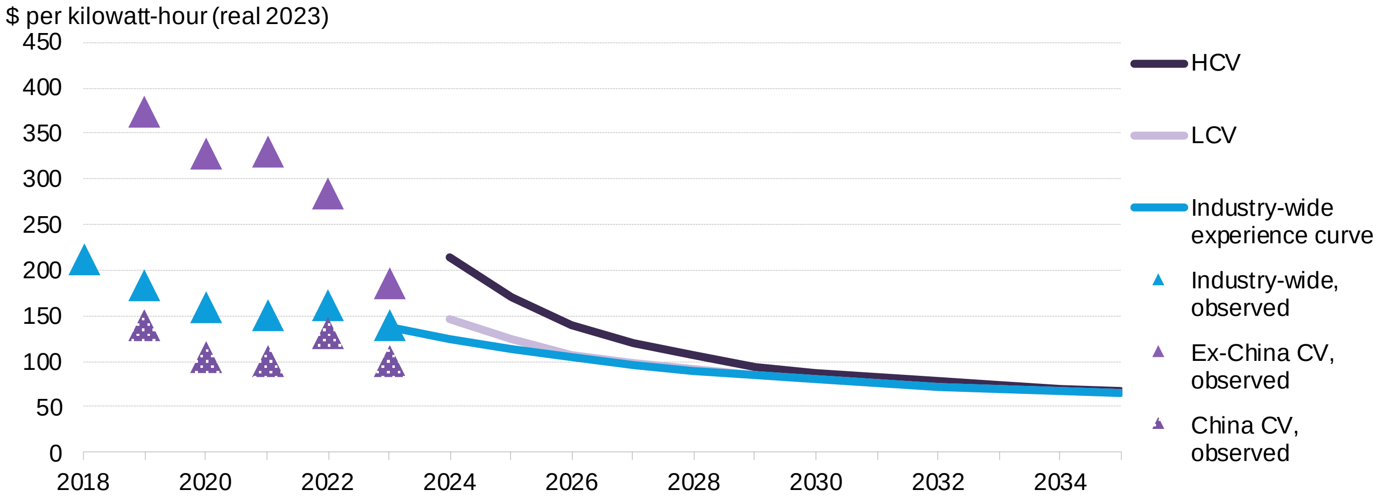
Source: BloombergNEF. Note: kWh is kilowatt-hour.

We have updated the battery cost curves using the latest price survey, which showed that truck battery prices continued to decline especially outside of China. Battery pack prices for electric trucks and buses vehicles declined by around 37% on average (Figure 156). Volumes have started to rise, primarily for delivery vans and some heavier trucks, and manufacturers are using more of the lower-priced lithium-ion phosphate chemistry. In China, such prices reached $100 per kilowatt-hour in 2023, as the electric commercial vehicle market continues to expand.

We continue to expect that truckmakers will pay more for their batteries than the industry-average price, due to lower volumes and additional effort needed to adapt them for specific duty cycles. In the lighter segments, any premium should not persist due to the larger market and milder operating characteristics compared to heavier trucks. For these applications, however, we assume that battery prices will still be about 10% more expensive in 2030 than the industry-average experience curve (Figure 157).

With more electric trucks on the road, some real-world data become available for the actual efficiency of those vehicles. Heavy-duty electric trucks operating in distribution and delivery in urban and regional duty cycles can consume[6] between 105 and 140 kilowatt-hours per 100 kilometers (0.44 to 0.59 miles per kilowatt-hour). Energy consumption can grow as high as 230 kilowatt-hours per 100 kilometers for specialized use cases, such as electric concrete mixers. In our TCO calculations, we use estimates that range between 110 and 122 kilowatt-hours per 100 kilometers (0.52 and 0.57 miles per kilowatt-hour) (Table 15).

Figure 157: Historical and forecast battery prices for electric commercial vehicles



Source: BloombergNEF. Note: CV is commercial vehicle; LCV and HCV are light- and heavy-duty commercial vehicles, respectively.

[6] These are estimated efficiencies based on data released by manufacturer Designwerk and the 'Run on Less' fleet trials in the US. The sample size across both is small to derive reliable statistics across vehicles and use cases, and we use them here as a first indication of real-world efficiencies.

Table 15: Assumed heavy-duty truck efficiency

	2025	2030
Battery-electric vehicle (kilowatt-hour per 100 kilometers)	118	112
Fuel-cell vehicle (kilograms/100 km)	8.3	7.7

Source: BloombergNEF. Note: Corresponds to Class 8 in a long-haul duty cycle.

Fuel-cell costs and efficiencies

The costs for fuel-cell stacks and hydrogen storage tanks also drop by 2030 to about $130 per kilowatt and over $760 per kilogram, respectively. We also assume that compressed hydrogen will be available at around $5.5 per kilogram at that time. Fuel-cell truck technology is also set to improve by 2030 with vehicles becoming about 10% more efficient by 2030 (Table 15).

Both the costs and the efficiencies of hydrogen-based trucks are more uncertain than those of all-battery vehicles, as the market is at a far earlier stage. Nikola recently revealed that its Class 8 heavy-duty fuel-cell trucks consume about 8.6 kilogram of hydrogen per 100 kilometers.

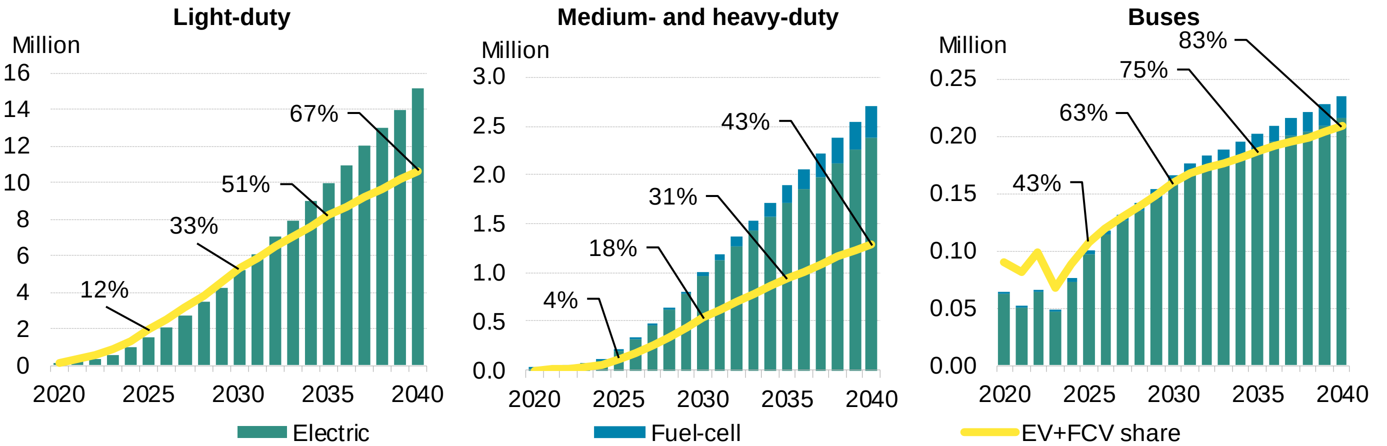
Drivetrain adoption outlook for commercial vehicles and buses

Global electric light-duty commercial vehicle sales continue to grow rapidly and in 2030 about a third of total new sales are electric. Most are battery-only vans, but plug-in hybrids also have a share. The economics of these vehicles continue to improve and their share doubles by 2040, when about two-thirds of sales are electric (Figure 158).

Sales in South Korea lead as a share of the total market in the country on the back of sales already hitting 30% share in 2023. China and countries in Europe also show strong adoption, reaching 45-50% of sales in 2030 and more than 80% by 2040.

Sales of electric and fuel-cell trucks grow slowly and it takes another 15 years to account for a third of the market. Adoption rates for such vehicles globally reveal four groups. China, alone out of the large trucking markets around the world, remains far ahead of other countries by 2030 and beyond. E-truck sales exceed a third of the total by 2030 and climb to almost 80% by 2040. Then, some large European countries, such as Germany and the UK, as well as California land between 28% and 33% by 2030 and over 60% by 2040. Behind that, sales of low- and zero-emission trucks in other European countries and Japan remain at around 15% by 2030 and 50% by 2040. Finally, the market in India, Australia and in the 'rest of world' category end up at around 20-30% of sales by 2040.

Figure 158: Electric and fuel-cell commercial van, truck, and bus sales global outlook



Source: BloombergNEF, China Automotive Technology and Research Center, European Alternative Fuels Observatory, South Korean Ministry of Trade, Industry and Energy (MOTIE), EV-volumes, Ministry of Road Transport and Highways of India, Australia Bureau of Infrastructure and Transport Research Economics (BITRE), Ministry of Transport (Brazil), Brazilian Association of Automotive Vehicle Manufacturers (ANFAVEA), Japan Automobile Dealers Association (JADA), EV-Volumes. Note: 'Electric' includes battery-electric and plug-in hybrid vehicles.

By 2040, the global fleet of light-duty commercial vehicles is practically split in half between battery-driven vans, at about 49% of the fleet, and diesel and gasoline vehicles (Figure 159). The number of e-vans and trucks on the road grows rapidly in the 2030s following strong sales throughout the previous years and the corresponding decline of combustion engine powertrains in the mix.

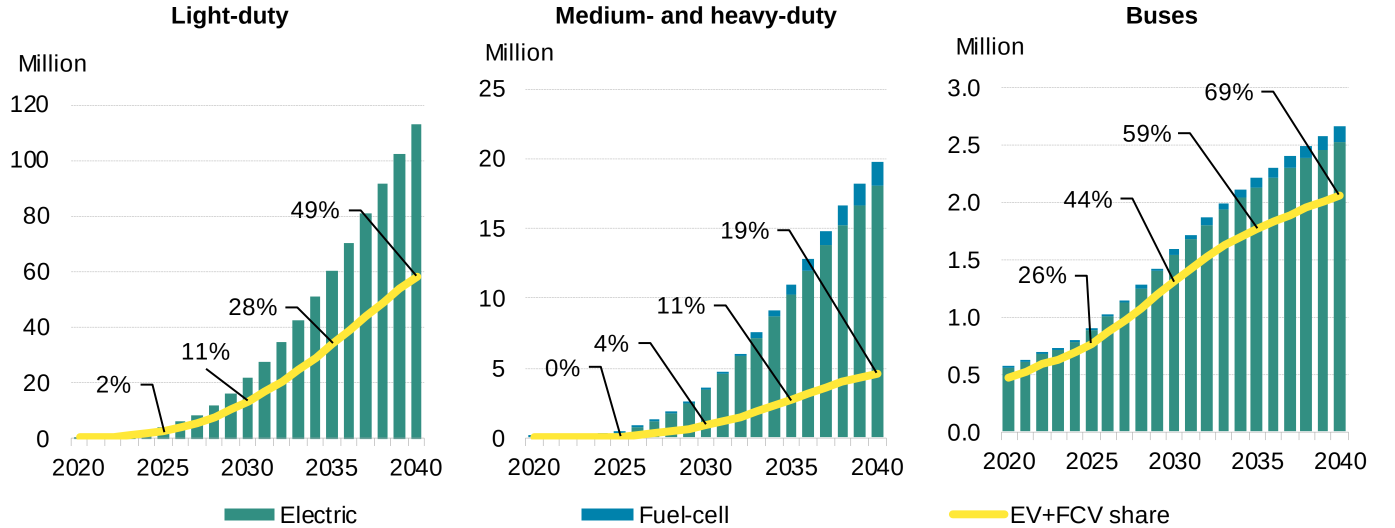
The global fleet of heavier electric and fuel-cell trucks is very small outside of China by 2030 and gets to 17% of all trucks on the road by 2040. In the group of countries behind China in terms of e-truck adoption, the fleet is between 8% and 10% by 2030 and grows to around 40% or more by 2040. Beyond China, Germany, the UK, France and California, e-trucks account for less than 2% of the fleet by 2030 and just exceed 11% by 2040.

E-bus adoption gradually ramps up toward 2030, despite short-term setbacks in some countries. Globally, electric and fuel-cell buses make up over 60% of total sales by 2030. Notably, e-bus shares top 80% of new transit bus sales in Europe and exceed 96% by 2035, when the EU's 100% CO2 emissions reduction targets come into force. The share of e-bus sales does not reach 100% in that year, as some exemptions may continue to apply for use cases that zero-emission buses cannot fulfill.

As the fleet of passenger vehicles continues to grow until 2040, and as advanced self-driving technologies and ridesharing systems make urban transportation more efficient, the demand for public transportation buses is muted, leading to only a 13% increase in the total global bus fleet, from around 3.5 million vehicles in 2023 to 4 million vehicles in 2040.

The e-bus fleet share reaches 69% in 2040. As adoption takes place in more countries, the global e-bus fleet increases 267% from 2023 levels to over 2.6 million vehicles in 2040 (Figure 159).

Figure 159: Electric and fuel-cell commercial van, truck, and bus fleet global outlook



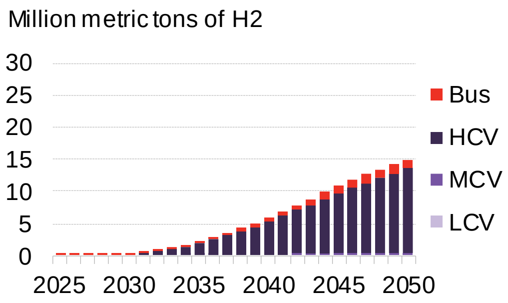
Source: BloombergNEF, China Automotive Technology and Research Center, European Alternative Fuels Observatory, South Korean Ministry of Trade, Industry and Energy (MOTIE), EV-volumes, Ministry of Road Transport and Highways of India, Australia Bureau of Infrastructure and Transport Research Economics (BITRE), Ministry of Transport (Brazil), Brazilian Association of Automotive Vehicle Manufacturers (ANFAVEA), Japan Automobile Dealers Association (JADA), EV-Volumes. Note: 'Electric' includes battery-electric and plug-in hybrid vehicles.

Fuel-cell trucks and hydrogen demand in trucking

Hydrogen truck sales grow to about 5% of the global market by 2040 and they are exclusively medium- and heavy-duty trucks. China, Japan, South Korea and Europe lead in the share of sales, ranging between 10% and just over 18% by that time. As such sales happen mostly in the 2030s, the FCV fleet remains at about 1.6% by 2040. Most hydrogen trucks are used in regional and long-haul duty cycles.

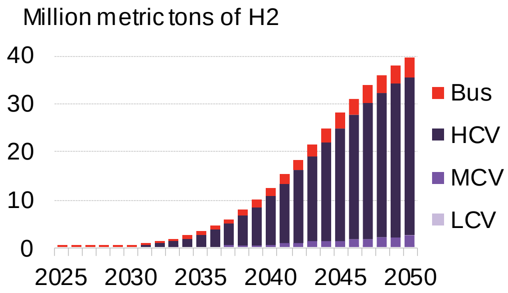
Demand for hydrogen in road transport is 6 million tons by 2040 and more than doubles to 15 million tons by 2050 in the ETS. In the NZS, the fleet of fuel-cell trucks reaches about 10% of the global commercial vehicle fleet by 2050, or about 11.7 million vehicles. Hydrogen demand is 12.5 million tons in 2040 and almost 40 million tons by 2050 (Figure 160 and Figure 161).

Figure 160: Hydrogen demand – Economic Transition Scenario



Source: BloombergNEF. Note: LCVs, MCVs and HCVs are light-, medium- and heavy-duty commercial vehicles.

Figure 161: Hydrogen demand – Net Zero Scenario



Source: BloombergNEF. Note: LCVs, MCVs and HCVs are light-, medium- and heavy-duty commercial vehicles.

5.5. Commercial EV adoption outlook – Net Zero Scenario

Vans and trucks

The NZS for commercial vehicles develops based on vehicle segment, use and location. For light-duty vans and trucks, the net-zero trajectory requires a manageable acceleration of zero-emission vehicle adoption compared to the ETS (Figure 162 and Figure 164). That may be more difficult for some countries in the 'rest of world' group.

Heavier trucks remain far from reaching fleet-wide net-zero tailpipe emissions by 2050. This is the case even in China, where sales of battery and hydrogen trucks are already higher than elsewhere and we expect them to keep rising fast. In other countries and regions, like in Europe and California, the increase of such sales is steeper (Figure 163 and Figure 165).

The LCV fleet includes about 23% fossil-fueled vans by 2050 in the ETS. The net-zero sales trajectory for electric LCVs gradually diverges from that in the next few years. The sales adoption gap remains about 10-20% between the ETS and NZS throughout the period to 2050. Diesel and gasoline vans and lighter trucks continue to be sold in the early 2040s at very low numbers. These may be used in some of the highest utilization duty cycles at the time.

While the NZS is achievable for LCVs, it is still a challenge. The remaining gap can be difficult to close depending on economics in different locations, grid availability to support the necessary charging infrastructure and incentives for fleets to switch to zero-tailpipe-emission vehicles.

Reaching a net-zero capable fleet by 2050 in the medium- and heavy-duty truck segments is far more difficult. Only under a third of such trucks on the road are either electric or fuel cell in the ETS by that time. For these segments, a net-zero sales trajectory that follows typical industry timescales of vehicle utilization and retirement should deviate from that of the ETS starting about now. However, the necessary supply chain and refueling infrastructure are currently not in place to support that scale-up.

Figure 162: Light commercial van and truck fleet share outlooks by drivetrain – Economic Transition and Net Zero Scenario

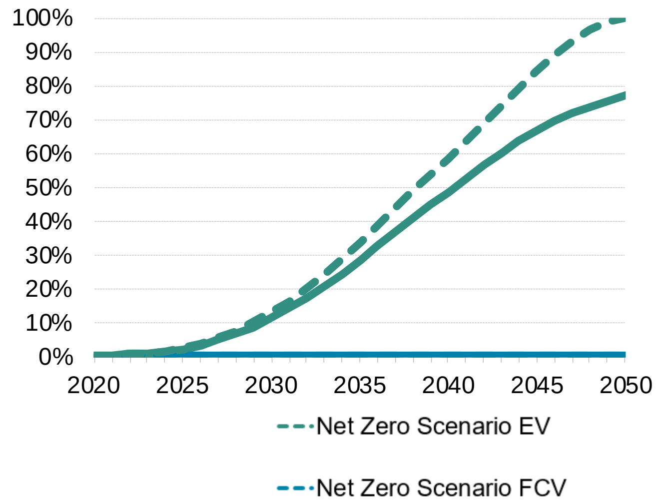
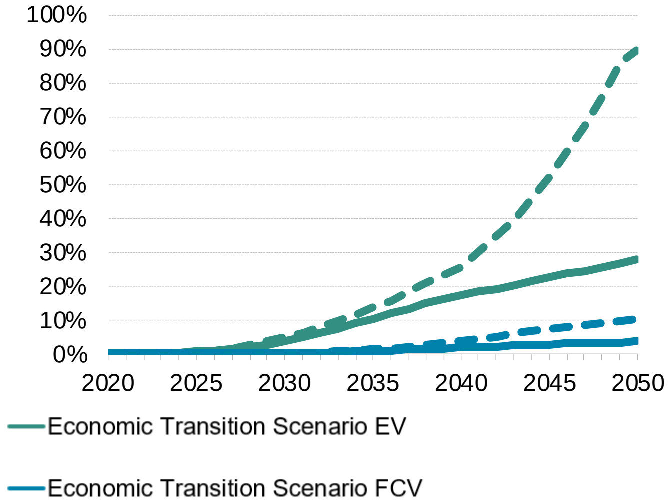


Figure 163: Medium/heavy commercial van and truck fleet share outlooks by drivetrain – Economic Transition and Net Zero Scenario



Source: BloombergNEF. Note: ETS is Economic Transition Scenario. NZS is Net Zero Scenario. EV is electric vehicle. FCV is fuel-cell vehicle.

Our NZS for medium- and heavy-duty trucks reflects accelerated retirements late in the 2030s and even more so throughout the 2040s (Figure 163). While this looks more realistic, preparations for the transition would need to start now to guarantee the availability of batteries and refueling infrastructure. Also, manufacturers, fleet owners and financiers should come up with strategies to hedge any ensuing value destruction from the quicker depreciation of vehicle and other assets. Governments need to devise policies addressing this specific aspect of the net-zero transition in trucking.

Electric trucks account for most of the net-zero-emission medium- and heavy-truck fleet, as most vehicles operate in urban and suburban duty cycles. The economics of zero-emission technologies for such applications are continuously becoming more competitive, while model availability also improves. Fuel-cell vehicles are around 10% of the M/HCV fleet in 2050 in the NZS and these are primarily used in long-haul operations, which are more challenging to convert to zero-emission options (Figure 163). In the NZS, the M/HCV heavy-duty long-haul fleet consists of both electric and fuel-cell trucks at a roughly equal split globally.

Figure 164: Light commercial van and truck sales share outlooks by drivetrain – Economic Transition and Net Zero Scenario

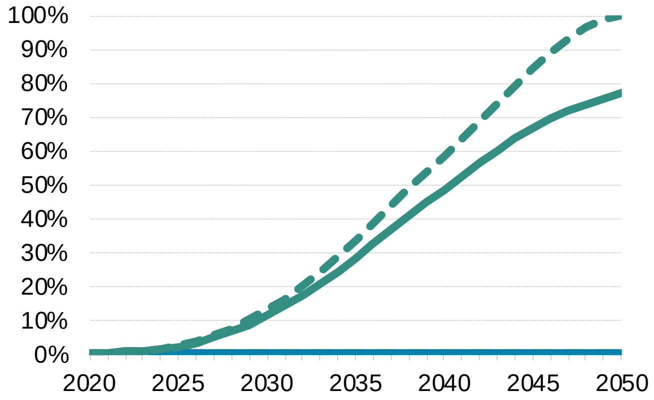
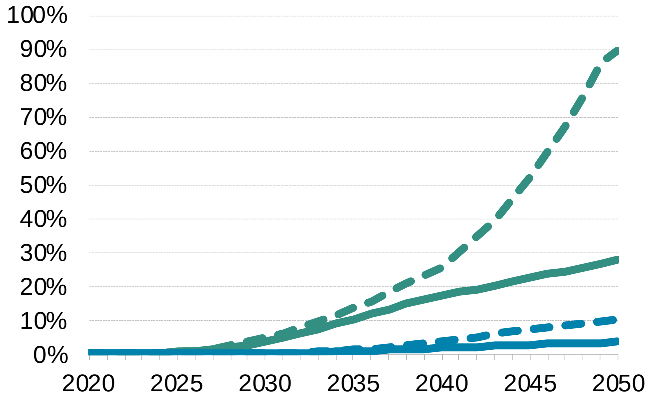


Figure 165: Medium/heavy commercial van and truck sales share outlooks by drivetrain – Economic Transition and Net Zero Scenario



Net Zero Scenario EV
Economic Transition Scenario EV
Net Zero Scenario FCV
Economic Transition Scenario FCV

Source: BloombergNEF. Note: ETS is Economic Transition Scenario. NZS is Net Zero Scenario. EV is electric vehicle. FCV is fuel-cell vehicle.

Buses

Zero-emission bus adoption needs to scale at a faster rate to achieve net-zero transport emissions by 2050. Under the NZS, battery-electric and fuel-cell medium and large municipal bus sales shares globally would need to reach over 90% in 10 years' time, compared to less than 30% in 2023. Similarly, the global zero-emission bus fleet share would need to reach 76% in 2040 under the NZS, compared to around 20% last year. Internal combustion engine bus sales would reach a peak in 2024 but continuously decline afterwards, in order to be completely phased out by 2050 (Figure 166 and Figure 167).

While the total global bus fleet will increase steadily under the NZS, most growth would come from battery-electric buses, with fuel-cell models only comprising less than 10% of the public bus fleet by 2040 and less than 20% by 2050. As this model primarily takes into account urban buses, which typically do not require extended range, fuel-cell buses have limited use case for the segment.

Manufacturers and policymakers would need a further push to increase zero-emission bus adoption levels to meet NZS requirements. Busmakers would need to address the higher upfront costs of electric models, by optimizing the supply chain and turning to cheaper battery suppliers. While supply chain localization may bring long-term economic gain, policymakers also need to be mindful that scaling e-bus and battery manufacturing facilities will take time, and globalization still has cost-saving benefits.

While governments worldwide have introduced an increasing amount of funding and purchasing plans for zero-emission city buses, funding mechanisms should be improved to ensure that money can reach end recipients more efficiently and provide funds for charging infrastructure in addition to vehicle purchases. The infrastructure challenge to support a fully zero-emission bus fleet would be particularly acute for emerging economies without a mature grid network.

Figure 166: Zero-emission bus share of total bus sales – Net Zero Scenario and Economic Transition Scenario

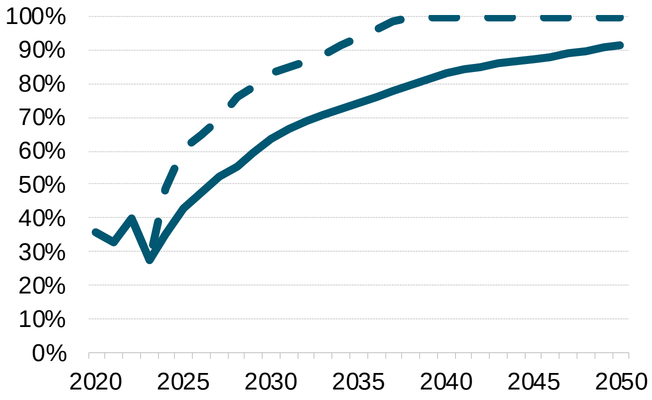
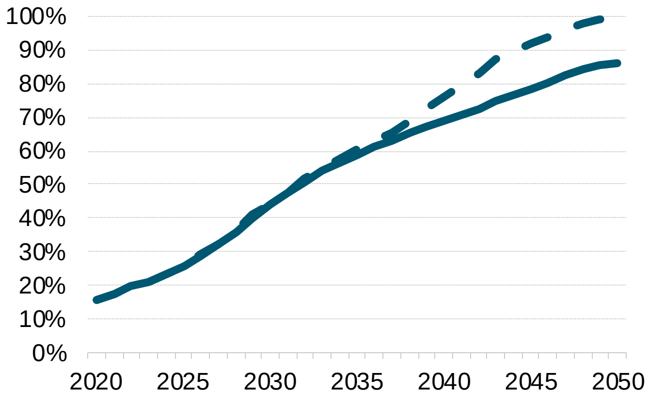


Figure 167: Zero-emission bus share of total bus fleet – Net Zero Scenario and Economic Transition Scenario



Source: BloombergNEF. Note: ETS is Economic Transition Scenario. NZS is Net Zero Scenario. Zero-emission vehicles (ZEVs) include both electric and fuel-cell buses.

Further reading

- *Electric Trucks Need Incentives Boost to Grow* (web | terminal)
- *Bankrupt E-Bus Firm Proterra Went Too Far, Too Soon* (web | terminal)
- *Truckmakers Need Zero-Emission Push to Avoid Big EU Fines* (web | terminal)
- *Zero-Emission Commercial Vehicle Models Dataset Update* (web | terminal)
- *Vehicle Total Cost of Ownership Model (TCOM 1.1.0)* (web | terminal)
- *Scaling EV Battery Swapping Needs All Hands on Deck* (web | terminal)

Two-wheeled vehicles

Section 6. Two-wheeler outlook

Two-wheeler vehicles – including mopeds, scooters and motorcycles – provide critical means for personal and commercial transportation, especially in China, South Asia and Southeast Asia. In 2023, 92 million two-wheelers were sold globally, with 41% being electric. Led by China, where 74% of two-wheeler sales were electric, the segment is moving faster on electrification than passenger or commercial vehicles.

Growing policy support, model availability and improved economics are set to kick-start electric two-wheeler demand in other markets. In the Economic Transition Scenario, global electric two-wheeler sales reach 90 million in 2040. EVs' share of sales rises to 90% in the same year, from 41% in 2023. By 2040, 47% of the global two-wheeler fleet is electric, increasing to 74% in 2050.

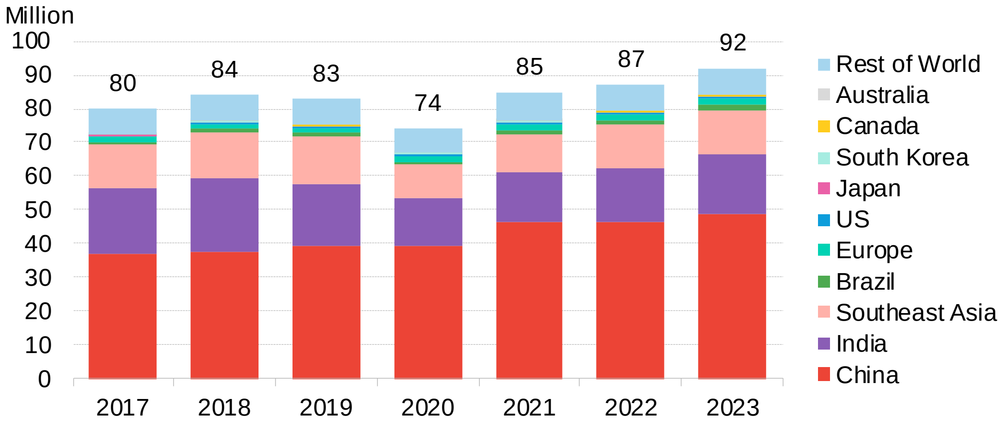
Rapid electrification has already transformed the two-wheeler segment, which is closer to becoming a zero-emission fleet by 2050 than other vehicle segments. Still, slower uptake in some countries and the long use life of internal combustion engine vehicles reduces the electric fleet share compared to our previous outlook. A faster growth in electric two-wheeler sales is needed to ensure the market stays on track for BNEF's Net Zero Scenario, in which all new sales are electric by 2040.

6.1. Two-wheeler market today

Global two-wheeler sales in 2023 grew 5.5% from 2022, to 92 million, with China, India and Southeast Asia representing 87% of the total market (Figure 168). Sales in India and Indonesia increased 13% year-on-year, while sales in China and Thailand rose 4-5%. In Brazil, two-wheeler sales reached a record 1.58 million in 2023, up 16% from the previous year.

In contrast, a sluggish economy, high interest rates and surging vehicle prices have damped demand for two-wheelers in Vietnam, Pakistan, Malaysia and Bangladesh, where sales dropped by 9-27% in 2023. Sales in most emerging markets were still below pre-pandemic levels.

Figure 168: Global two-wheeler sales by market



Source: BloombergNEF, national governments, industry associations, news reports. Note: 'Southeast Asia' refers to Indonesia, Malaysia, the Philippines, Thailand and Vietnam. 'Europe' refers to the EU, the UK and European Free Trade Association (EFTA) countries.

Growth across the high-income countries varies. Two-wheeler sales in Europe edged up 3% to 1.55 million in 2023, led by Italy and Spain. However, France and the UK lost momentum and experienced modest sales declines due to consumers cutting spending. Two-wheeler sales in Germany, the US, Japan and Australia were relatively flat, largely aided by the demand for ICE models. South Korean market fell sharply by 17%, back to 2018-19 levels. The growth between 2020-22 there was largely driven by the demand from food and last-mile delivery services.

6.2. Total sales and fleet outlook

Global two-wheeler market continues to expand in next decade, driven by demand from China, India and Southeast Asia

Global sales of two-wheelers increase from 96 million in 2024 to 105 million in 2030 as rising urban population and growing income levels boost new demand (Figure 169). The market peaks around 2034-35 at 107 million, then drops to 101 million in 2040. Saturation in some established two-wheeler markets and consumers switching to other modes for personal transportation are the main reasons behind the fall. The global two-wheeler fleet keeps rising over the next two decades, hitting 1.4 billion in 2040 from 1.06 billion in 2023 (Figure 170).

The bulk of new two-wheeler demand comes from China, India and Southeast Asia. Sales in China hover around 50 million in 2024-25 before dropping to 45 million in 2030 and 34 million in 2040. India and Southeast Asia see sales increase steadily to 26 million and 17 million in 2030, respectively. Those markets reach a peak in the late 2030s.

Among all emerging economies, Brazil also fares quite well, with two-wheeler sales approaching 2 million in the early 2030s. A booming young population, inadequate public transportation infrastructure and expanding economy create new demand for personal two-wheelers. The Brazilian government has taken various initiatives to support its domestic motorcycle industry, with a focus on flex-fuel models that can run on both gasoline and ethanol. Meanwhile, most countries in South Asia, Africa and Latin America do not see sales peak in the next two decades. Their combined sales jump from 8.5 million in 2024 to 16 million in 2040.

Figure 169: Global two-wheeler sales outlook by market

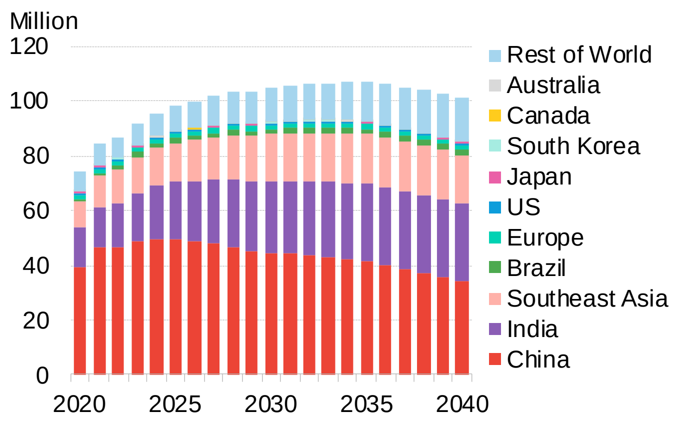
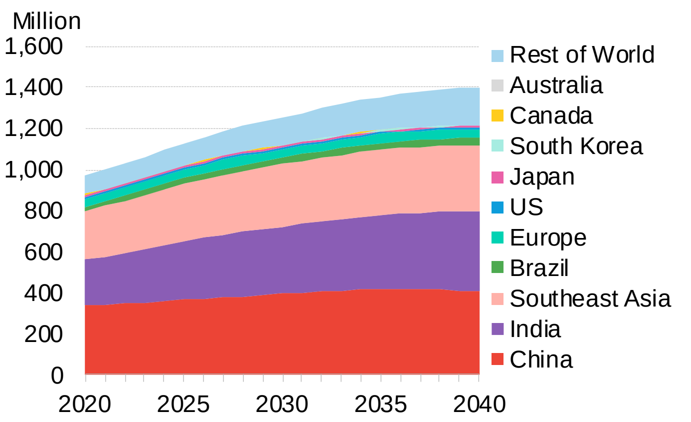


Figure 170: Global two-wheeler fleet outlook by market



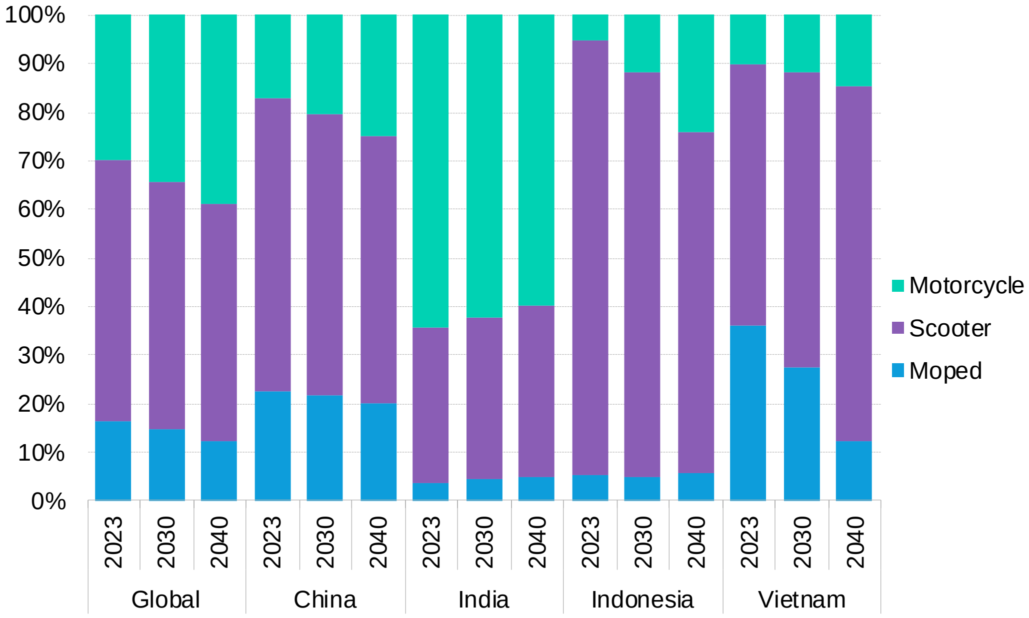
Source: BloombergNEF. Note: 'Southeast Asia' refers to Indonesia, Malaysia, Philippines, Thailand and Vietnam. 'Europe' refers to the EU, the UK and European Free Trade Association (EFTA) countries.

High-income countries continue to make up only a small portion of the total two-wheeler sales between now and 2040. Most two-wheeler buyers use their vehicles for recreational purposes, rather than daily commutes and personal transit. Such recreational products are often affected the most as economic slowdown alters consumer spending habits, curtailing discretionary spending.

Still, changes in consumer preferences and the launch of new electric models could spur some new demand. Annual sales in Europe and Canada increase marginally, while demand in the US, Japan and Australia shrinks in late 2020s. The outlook for South Korea is bleaker compared to our previous forecast. Two-wheeler sales in the country remain flat at pre-pandemic levels, while the government push for electrification adds momentum.

Globally, motorcycles see their market share increase steadily as buyers opt for larger, more powerful vehicles. They account for 39% of total two-wheeler sales in 2040, up from 30% in 2023 (Figure 171). Scooters remain dominant over the next two decades in major two-wheeler markets, such as China, Indonesia and Vietnam. The mopeds market is already on a downward trajectory and declines to 12% from 16% of total two-wheeler sales between now and 2040.

Figure 171: Two-wheeler sales outlook by segment in China, Indonesia, Vietnam and India



Source: BloombergNEF

6.3. Electric two-wheeler adoption outlook – Economic Transition Scenario

Near-term outlook for electric two-wheelers: 2024-27

Global electric two-wheeler sales in 2023 grew 6% from 2022, to 38 million units, which represented 41% of total two-wheeler sales (Figure 172). China leads the global market by a wide margin, accounting for 95% of electric two-wheeler sales. The enactment of new e-bike standards across Chinese cities, combined with intense price competition, continues to drive up demand for electric models in 2024-25. EV penetration in the Chinese two-wheeler market is already high and rises from 74% in 2023 to 81% in 2027 (Figure 173).

Figure 172: Electric two-wheeler sales outlook by market

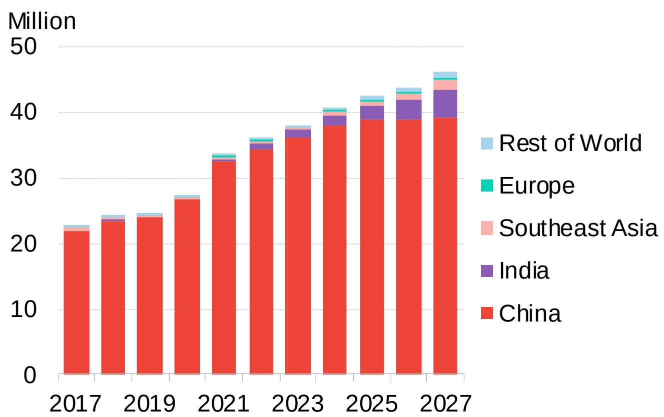
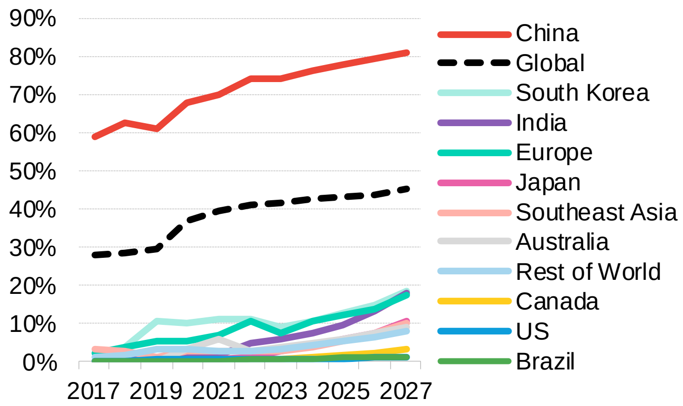


Figure 173: Electric share of two-wheeler sales outlook by market



Source: BloombergNEF. Note: 'Southeast Asia' includes Indonesia, Malaysia, Philippines, Thailand and Vietnam. 'Europe' refers to the EU, the UK and European Free Trade Association (EFTA) countries.

India's electric two-wheeler sales hit 1 million in 2023, up 37% from the same period last year. New models from Ola, Ather and TVS, high gasoline price and purchase subsidies are key drivers of this uptake. A cut to subsidies in 2024 may hurt demand from price-sensitive private buyers. Still, as electric models approach cost parity with ICE counterparts on a total-cost-of-ownership basis, EV adoption is set to rise quickly, especially for fleet operators (Figure 174). About 18% of two-wheeler sales are electric in India in 2027, compared with 6% in 2023.

Figure 174: Total cost of ownership outlook for lithium-ion electric two-wheelers versus gasoline vehicles in India

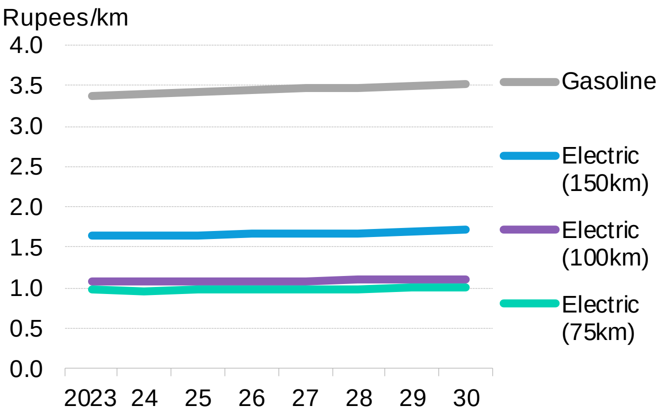
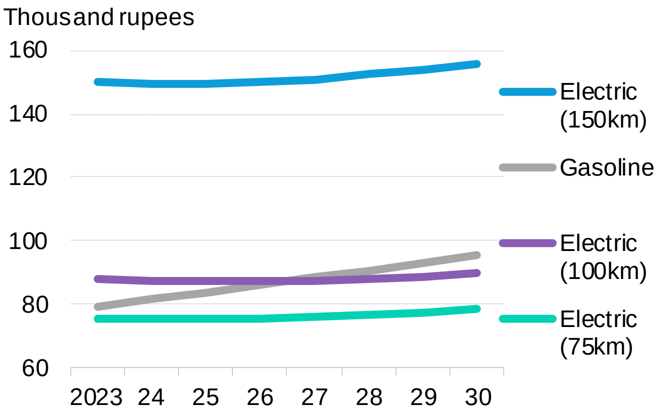


Figure 175: Upfront price outlook for lithium-ion electric two-wheelers versus gasoline vehicles in India



Source: BloombergNEF. Notes: Cost of gasoline assumed at 102.8 rupees per liter. Electric two-wheelers are modeled using different range assumptions shown in the brackets. Assumed distance travelled is 14,600 kilometers per year.

Vietnam is the third-largest electric two-wheeler market, after China and India. Sales in 2023 dropped by 4% to 304,000 units, or roughly 11% of the total two-wheeler market. A struggling economy has led consumers to tighten spending, putting a dent on both electric and combustion vehicle sales. Still, new electric models from the likes of Vinfast, Pega and Yadea, combined with increasing cost-competitiveness compared to ICEs, pushes Vietnam's electric two-wheeler share to 27% in 2027.

Emerging markets in Asia are chasing China's lead in electric two-wheelers, thanks to government support, new model launches and improved economics

Electric two-wheeler sales in Indonesia and Thailand exceeded 71,000 in 2023, rising from about 45,000 in 2022. Both countries have introduced subsidies for selected electric models based on vehicle type, battery capacity and local content requirements. Governments in Indonesia, Thailand, Malaysia and the Philippines have also set long-term targets for EV production and sales. While the supportive policies can help kickstart local markets, lack of competitive EV models, limited charging infrastructure and a slow ramp-up of local manufacturing capacity suggests those goals can be challenging to reach. Together, Southeast Asia's electric two-wheeler sales increase from 379,000 in 2023 to 1.5 million in 2027. The share of EVs jumps from 3% to 10% in the same period.

Electric two-wheelers make up 9% of sales in South Korea in 2023, falling from 11% in 2022. This is largely a result of the slowing demand from delivery services and concerns over the short driving range of existing models. To revive the local market, the South Korean government has raised purchase subsidies for electric two-wheelers for food delivery by 10% and offered incentives directed at building new battery swapping infrastructure. South Korea sees two-wheelers hit 19% of total sales in 2027.

In Japan, higher subsidies budget for EVs and new modes, like Honda EM1 e, pushed electric share of two-wheeler sales to 3% in 2023. The outlook for the Japanese market is more optimistic than in 2023 outlook, with 10% of sales being electric in 2027.

Europe's electric two-wheeler sales fell 26% to 120,000 units in 2023, with the UK, Germany, France and Italy experiencing 10% to 38% decreases. Despite growing commitment from manufacturers, the market still lacks affordable, electric two-wheeler models. We therefore revise down our outlook for Europe. The share of electric two-wheelers grows from 8% in 2023 to 18% in 2027, compared to 28% in our previous outlook.

Electric two-wheeler sales remain muted in the US, Canada and Brazil. These countries see electric two-wheeler demand expand slowly from 2024 to 2027, reaching 1% to 3% of total sales. Dwindling consumer interest in low-performance vehicles and limited model availability are some key headwinds in those markets.

Long-term outlook for electric two-wheelers: 2028-2040

Sustainable policy support, improving economics and investment in refueling infrastructure play an important role in electrifying the two-wheeler sector in the long term. In the ETS, global sales of electric two-wheelers rise from 48 million in 2028 to 90 million in 2040 (Figure 176). The number of electric two-wheelers on the road more than triples to 724 million by 2040 from 218 million in 2023 (Figure 177).

Similar to passenger vehicles, sales of ICE two-wheelers have most likely already peaked in 2018. Although the ICE two-wheeler market continues to expand until 2026 in the ETS, we do not expect annual sales to rebound to pre-pandemic levels of nearly 60 million.

Figure 176: Long-term electric two-wheeler sales outlook by market – Economic Transition Scenario

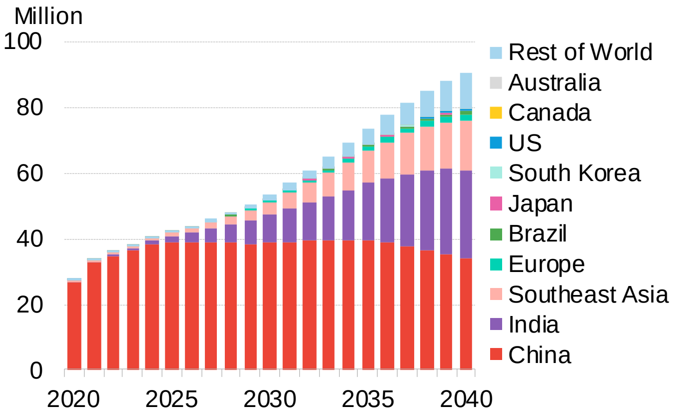
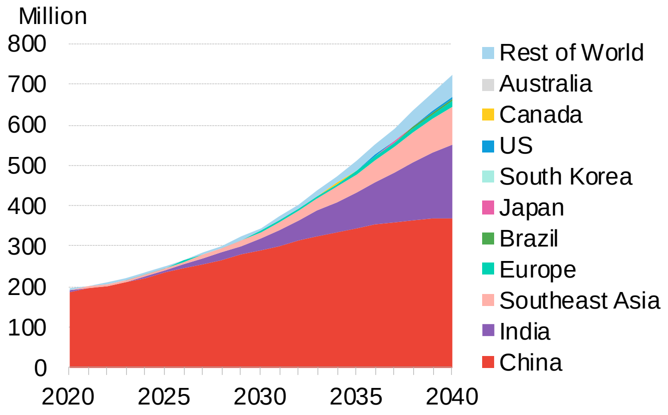


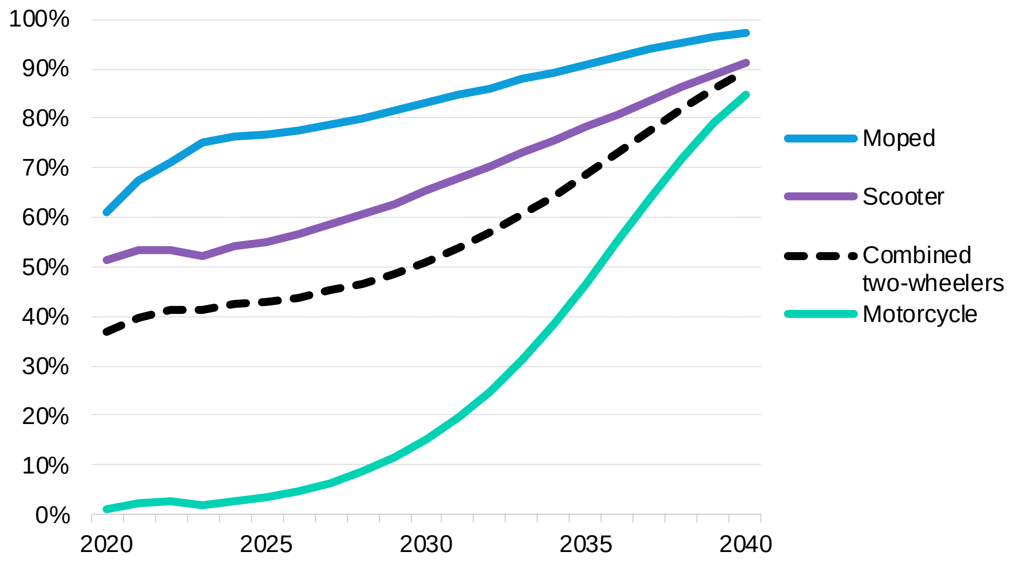
Figure 177: Long-term electric two-wheeler fleet outlook by market – Economic Transition Scenario



Source: BloombergNEF. Note: 'Southeast Asia' includes refers to Indonesia, Malaysia, Philippines, Thailand and Vietnam. 'Europe' refers to the EU, the UK and European Free Trade Association (EFTA) countries.

Falling battery prices continue to drive down the cost of electric two-wheelers, making them competitive with their ICE counterparts in markets outside of China around 2026-27 on an upfront price basis, and even earlier based on the total cost of ownership. Government incentives and investment from a multitude of industry majors can speed up the expansion of charging and battery swapping infrastructure, which also helps to accelerate electric two-wheeler adoption. Within the electric two-wheeler market, lower-performance vehicles like mopeds and scooters are easier to electrify than motorcycles. We expect mopeds and scooters to achieve higher electric share of sales of 97% and 91% in 2040, respectively (Figure 178). The motorcycle segment hits an electric adoption rate of 85%.

Figure 178: Global electric share of two-wheeler sales outlook by segment – Economic Transition Scenario



Source: BloombergNEF

Compelling economics and manufacturers' interests make mopeds and scooters easier to electrify than motorcycles, while a slow uptake of electric motorcycles could hinder the progress of two-wheeler decarbonization

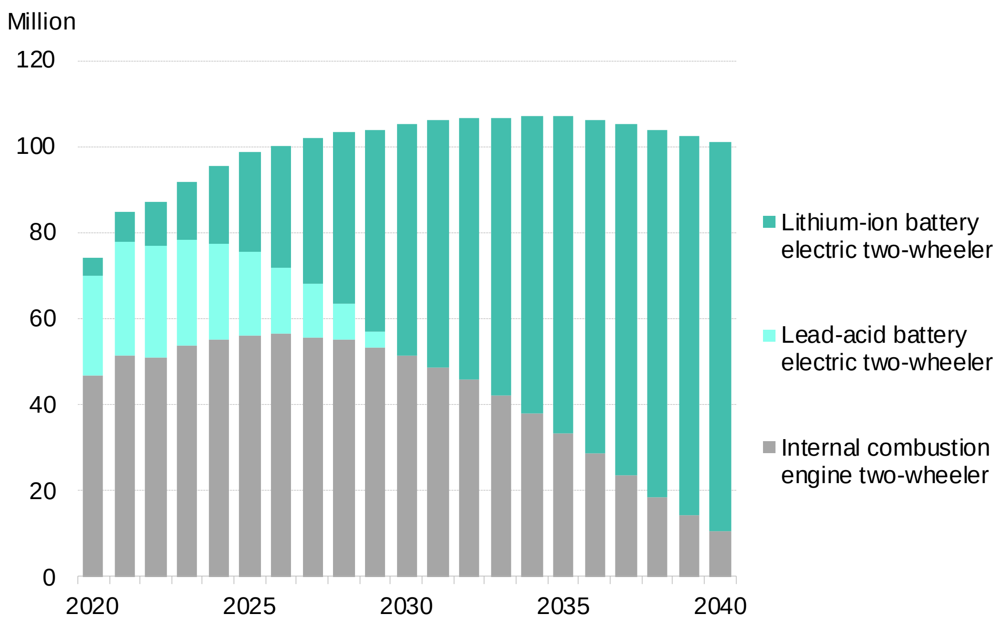
China remains the largest electric two-wheeler market in the ETS, but its share of global sales drops to 38% in 2040 from 80% in 2028. Nearly all two-wheelers sold in 2040 in China are electric.

India and Southeast Asia are the main markets driving the growth of electric two-wheeler sales. Vietnam, India and Indonesia achieve EV adoption of 96%, 94% and 90% in 2040, respectively, while some 71-82% of sales in Malaysia, the Philippines and Thailand are electric in the same year.

Europe moves ahead of other high-income markets in terms of electrification. The region also reaches very high levels of EV penetration in the two-wheeler segment, with 98% of sales being electric in 2040. South Korea and Japan see EV adoption of 94% in 2040, while the US lags at 75%.

In all major markets, policy pressures and declining lithium-ion battery pack prices drive lead-acid electric two-wheelers out of the market around 2030 (Figure 179). The emergence of sodium-ion batteries could accelerate the phase-out of lead-acid two-wheelers, especially in segments where lithium-ion powered two-wheelers still have higher upfront costs.

Figure 179: Global long-term two-wheeler sales outlook by drivetrain – Economic Transition Scenario



Source: BloombergNEF

In the ETS, EVs represent 52% and 90% of two-wheeler sales globally in 2030 and 2040, respectively (Figure 180). By 2040, 47% of the global two-wheeler fleet is electric, down from our previous forecast due to slow retirement of some ICE vehicles (Figure 181). In China, 91% of two-wheelers running on the road are electric by then. However, in other countries, EVs only make up 20% to 50% of the local two-wheeler fleet by 2040, and these markets need a stronger push to stay on track for the NZS.

Figure 180: Global share of two-wheeler sales by drivetrain – Economic Transition Scenario

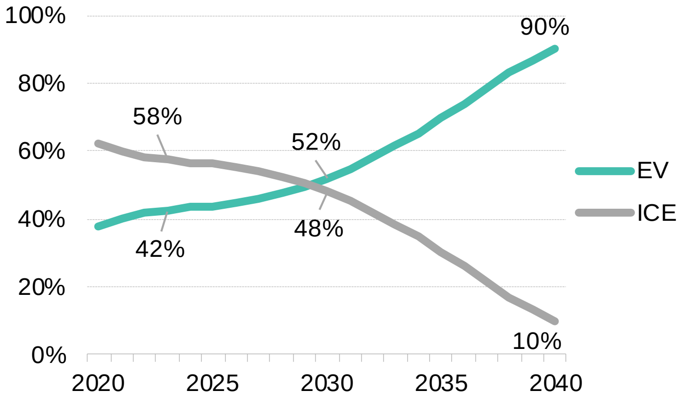
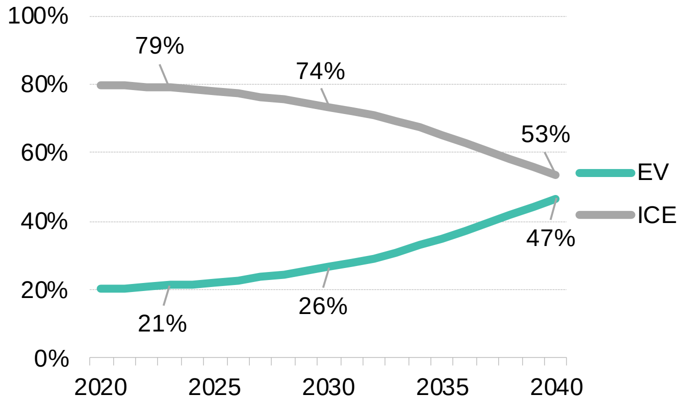


Figure 181: Global share of two-wheeler fleet by drivetrain – Economic Transition Scenario

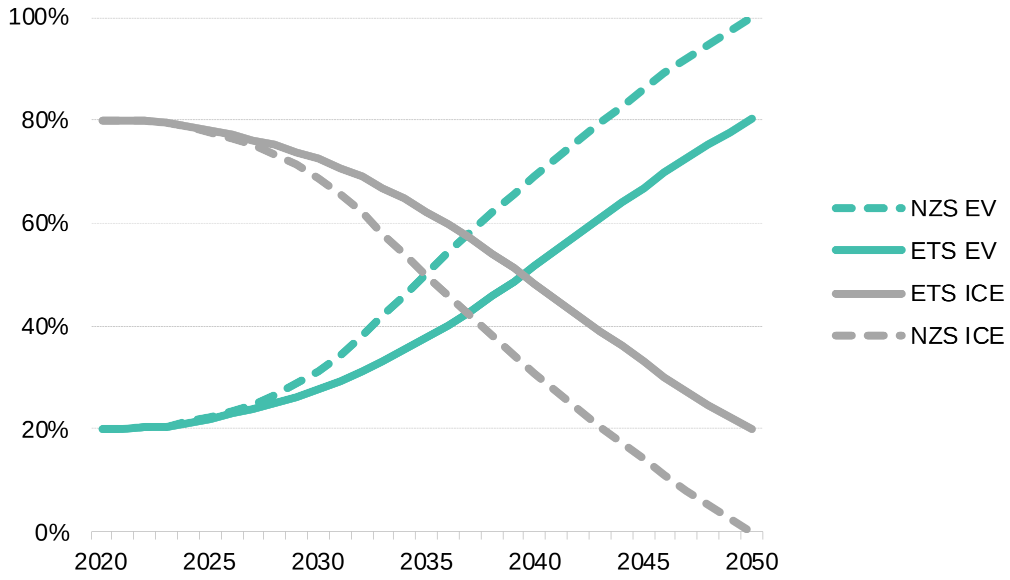


Source: BloombergNEF

6.4. Electric two-wheeler adoption outlook – Net Zero Scenario

Electrification is already proven as a cost-competitive pathway for reducing carbon emissions from two-wheelers. Competing technologies like hydrogen fuel cells are not projected to be economically competitive in this segment. In our NZS, all two-wheelers on the road are battery-electric vehicles by 2050.

Figure 182: Two-wheeler fleet split by drivetrain – Economic Transition Scenario and Net Zero Scenario



Source: BloombergNEF. Note: ETS is Economic Transition Scenario and NZS is Net Zero Scenario.

The two-wheeler segment is closer to achieving a 100% zero-emission fleet by 2050 than other vehicle segments. Accelerated EV adoption is pushing the electric share of fleet to 52% in 2040 and 80% in 2050 under the ETS, similar to the results in our previous outlook. Still, policymakers and manufacturers should not ease their efforts at this point, as any delay in electric sales can still derail two-wheelers from the net-zero trajectory. Under the NZS, the share of EVs rises to 69% in 2040 and 100% in 2050 (Figure 182). Sales of combustion two-wheelers end around 2040 and the ICE fleet peaks around 2027, at 892 million units (Figure 183).

All new sales of two-wheelers are electric by 2040 in the NZS. China is nearly on track, but other countries need to move faster

In China, almost all two-wheelers on the road are electric by 2050 under the ETS. However, most countries need to speed up EV adoption in the two-wheeler segment to achieve a 100% ZEV fleet by 2050. In India, under the NZS, 64% of the two-wheeler fleet is zero-emission in 2040, while it reaches only 47% under the ETS. Southeast Asia requires 60% of the fleet to be ZEV in the same year under the NZS, up from just 29% under the ETS (Figure 184).

Stringent emission targets, ICE phase-out plans and more investment in charging and battery swapping infrastructure can drive up sales of electric two-wheelers and accelerate the retirements of ICE equivalents.

Figure 183: Two-wheeler fleet outlook by drivetrain – Net Zero Scenario

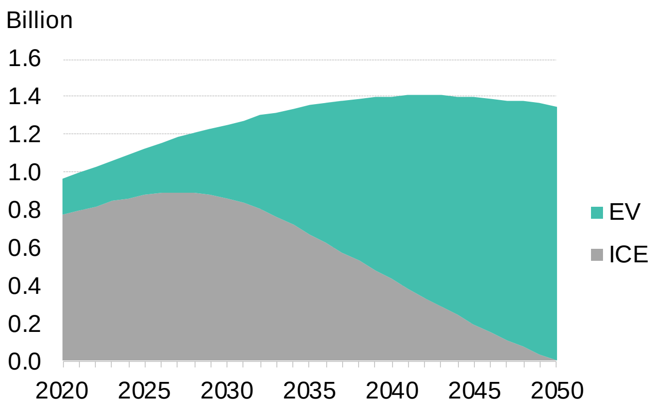
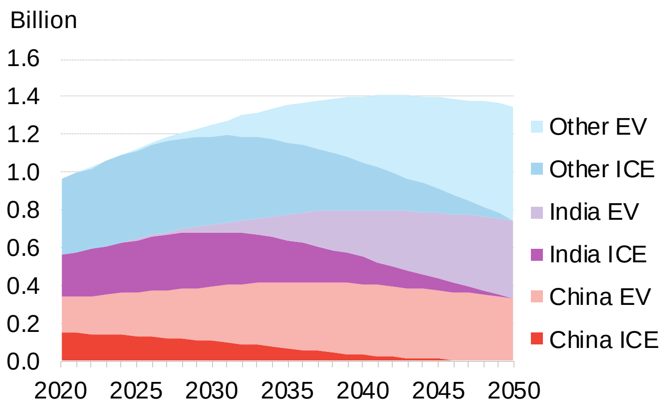


Figure 184: Two-wheeler fleet outlook by drivetrain and market – Net Zero Scenario



Source: BloombergNEF

Further reading

- *India EVs Cost Less Over Lifetime But Face Uptake Hurdles* (web | terminal)
- *Low Running Costs, Policy Support Boost EV Uptake in India* (web | terminal)
- *Southeast Asia Road Transport Electrification Outlook* (web | terminal)

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EVO 23

Three-wheeled vehicles

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Section 7. Three-wheeler outlook

Three-wheeled vehicles are a much smaller market than two-wheelers but are electrifying faster. Global sales of electric three-wheelers reached 13 million in 2023, accounting for 80% of the total three-wheeler market. There were about 120 million three-wheelers on the road by 2023 with 69% already electric. Policy and attractive economics are driving up EV adoption in this segment and the bulk of demand is concentrated in China and India. Electric three-wheelers make up 96% of sales globally and 89% of the fleet in 2040 in the Economic Transition Scenario.

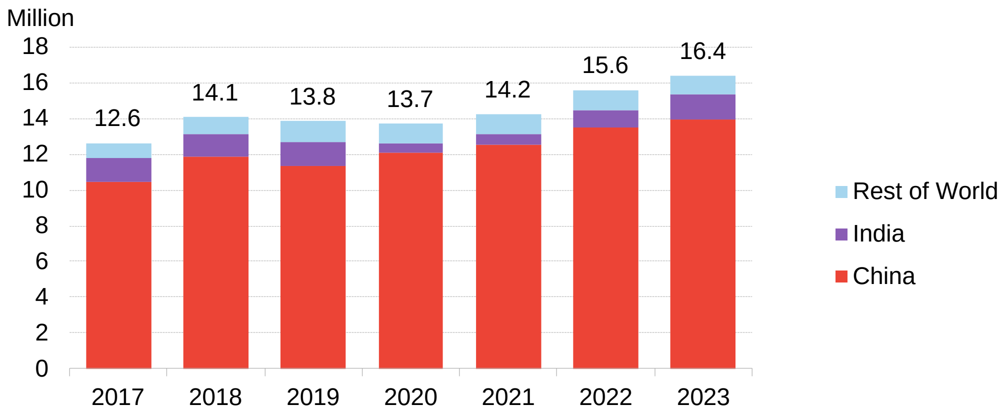
Three-wheelers are mostly on track to achieve a zero-emission fleet by 2050. Under the ETS, 95% of three-wheelers running on the road globally are electric by 2050. While China and India have an almost fully electric fleet by then, additional measures are needed in other emerging markets to ensure this segment reaches the Net Zero Scenario.

7.1. Three-wheeler market today

Three-wheelers are commonly used for commercial purposes, transporting passengers and goods over short trips. Global sales of three-wheelers exceeded 16 million in 2023, up 5% from the same period last year (Figure 185). China dominates the global three-wheeler market, followed by India. The two countries accounted for 94% of total sales. In China, an economic slowdown, cities' crackdown on illegal three-wheelers and a lack of attractive new models limited the annual sales increase to a modest 5%. By contrast, India's three-wheeler sales grew 54% to a whopping 1.4 million in 2023, largely driven by surging demand for electric rickshaws. These e-rickshaws can provide consumers with a cheap alternative for last-mile transportation.

Demand for three-wheelers outside of China and India dropped 16% in 2023, BNEF estimates. Countries like Vietnam and Pakistan face tough economic conditions and rising fuel prices, which dented local three-wheeler markets. Sales in high-income countries remain limited.

Figure 185: Global three-wheeler sales by market



Source: BloombergNEF, national governments, industry associations, news reports. Note: Sales for the 'rest of world' group is estimated based on three-wheeler exports from China and India. Data covers more than 95% of the global market and include both internal combustion engine and electric vehicles. Historical data is updated to reflect new data sources.

7.2. Total sales and fleet outlook

Global sales of three-wheelers grow from 17 million in 2024 to a peak of 22.4 million in 2035, then drop to 21.6 million in 2040 (Figure 186). China continues to dominate the global market, but its share of total sales fell to 73% in 2040, from 85% in 2024. Tightened restrictions around three-wheeler manufacturing and usage hurt demand growth in the country. In India, three-wheeler sales rise from 1.6 million in 2024 to 3.4 million in 2040 as demand from both goods and passenger transport keeps booming. In the 'rest of world' category, three-wheeler sales increase from 1 million to 2.3 million in the same period.

The global fleet of three-wheelers reaches 178 million by 2040, up from 124 million in 2024. Nearly 89% of the three-wheelers on the road are concentrated in China and India in 2040 (Figure 187). Outside of these two markets, the three-wheeler fleet totals 20.4 million in 2040, with growth in Asia and Africa.

The three-wheeler segment faces some major risks and uncertainties. Policymakers in India and China are taking note of the rapid proliferation of this segment and are evaluating regulations to manage the growing fleet. Many governments are regulating slow-speed electric three-wheelers under motor vehicle rules, which means they are subject to licensing and registration requirements that they previously avoided. The three-wheeler segment is also increasingly competing with low-speed four-wheelers and quadricycles, and even small electric cars.

Figure 186: Global three-wheeler sales outlook by market

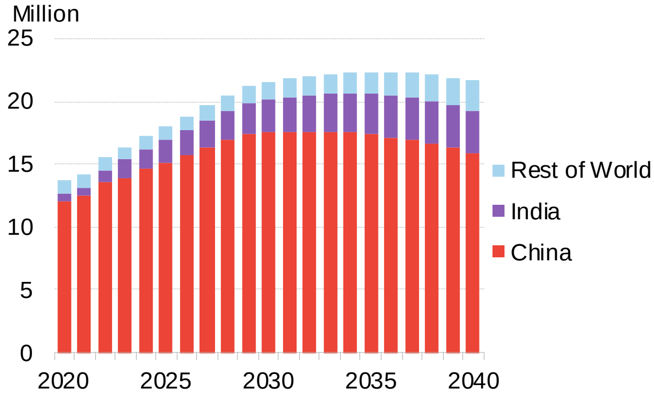
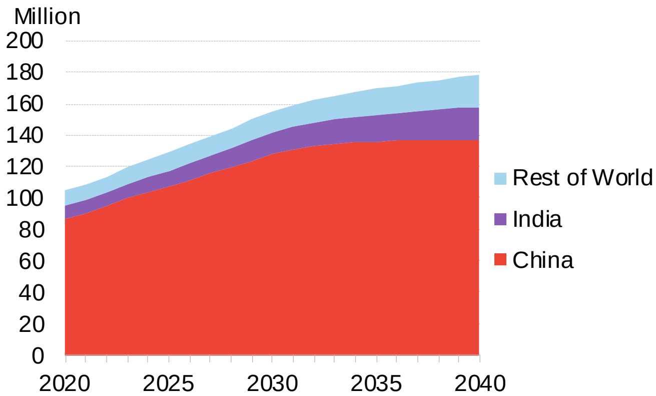


Figure 187: Global three-wheeler fleet outlook by market



Source: BloombergNEF. Note: Includes both internal combustion engine and electric three-wheelers.

7.3. Electric three-wheeler adoption outlook – Economic Transition Scenario

Three-wheelers have already achieved high electrification rates. Electric three-wheeler sales surpassed 13 million in 2023, up 6.6% from the previous year. Three-wheelers have electrified much faster than two-wheelers because their primary owners are commercial entities, such as delivery businesses and shared mobility service providers. These companies respond quickly to the attractive total cost of ownership savings, faster than private buyers. The adoption of electric three-wheelers also helps fleet operators to achieve their own decarbonization goals.

In the ETS, sales of electric three-wheelers hit 20.8 million globally in 2040, up from 14.3 million in 2024 (Figure 188). EV sales rise to 96% from 83% in the same period.

There are 158 million electric three-wheelers on the road globally by 2040, compared to 89 million in 2024 (). Over 89% of the fleet in 2040 is electric, rising from 71% in 2024. China and India are moving even faster – 97% of the fleet is electric in China by then and 90% in India.

Figure 188: Long-term electric three-wheeler sales outlook by market – Economic Transition Scenario

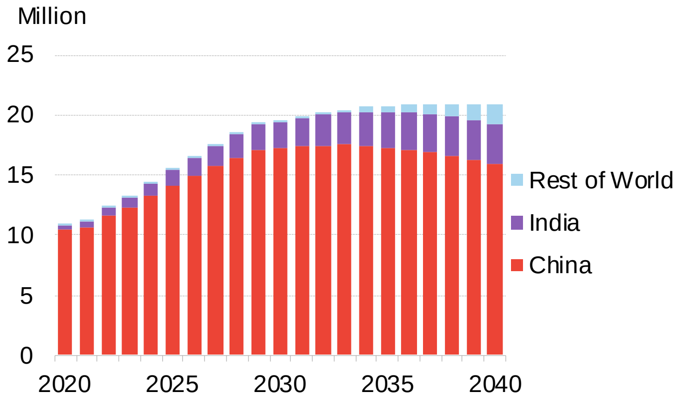
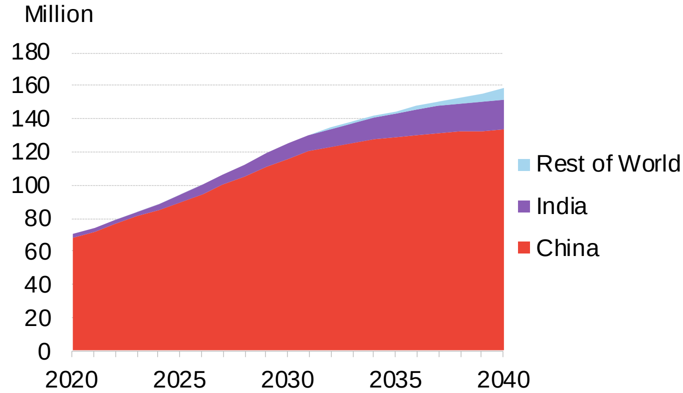


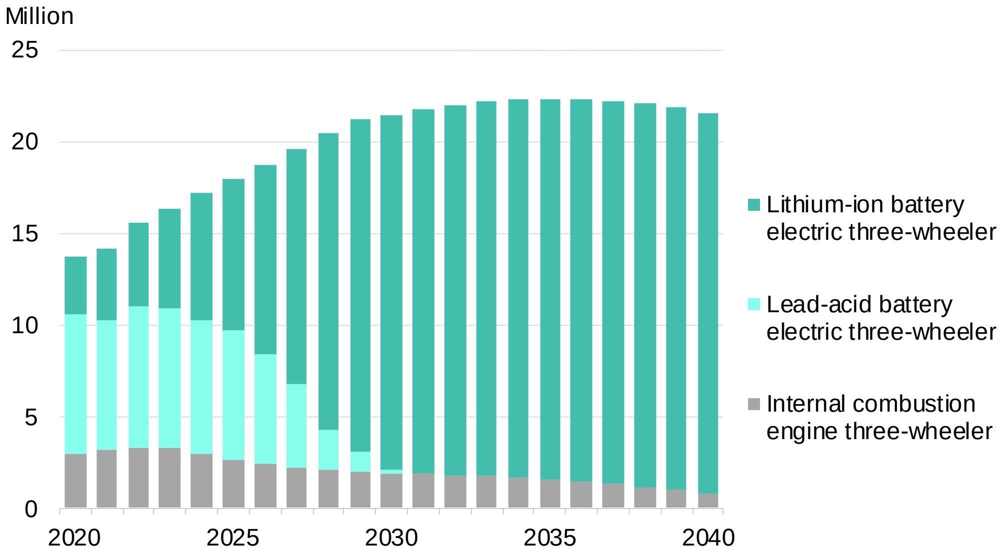
Figure 189: Long-term electric three-wheeler fleet outlook by market – Economic Transition Scenario



Source: BloombergNEF

In the three-wheeler segment, lithium-ion batteries are quickly replacing lead-acid batteries. Consumers' need for longer range models pushes up demand for more energy-dense lithium-ion batteries. Falling battery material prices and increasing investment in the technology can drive down costs, making them more competitive with ICE and lead acid equivalents. Meanwhile, automakers are introducing battery swapping and leasing model on electric three-wheelers equipped with lithium-ion batteries to lower upfront price. In our ETS, the market share of lead-acid batteries drops quickly in the next decade, and they are fully displaced by lithium batteries around 2030 globally (Figure 190).

Figure 190: Global three-wheeler sales outlook by drivetrain – Economic Transition Scenario



Source: BloombergNEF

The rise of sodium-ion batteries can accelerate the phase-out of lead-acid batteries. Zhongna Energy (CNAE) signed a $3.75 million deal in April 2024 with PT Huai Hai Indonesia to supply sodium-ion battery packs for the latter's electric three-wheelers. It also locked in a purchase agreement with Wuling for battery modules that are used in electric motorcycles and three-wheelers, with a total value of $1.45 million. A Chinese startup Qingna Technology (QNAS) secured a partnership with Lima, a Zhejiang-based electric two- and three-wheeler manufacturer, to provide sodium-ion batteries for its products, with an annual deployment target of 0.5 gigawatt-hours.

However, some headwinds could derail the penetration of lithium-ion batteries in this vehicle segment. In China, the vehicle weight and battery specifications of electric three-wheelers are not strictly regulated like electric two-wheelers, which may discourage suppliers from switching to lithium-ion batteries. While India's incentives are clearly directed at lithium-ion battery-electric three-wheelers, the vast low-income population, who are the typical buyers of three-wheelers, may still opt for cheaper lead-acid models.

Figure 191: Global share of three-wheeler sales by drivetrain

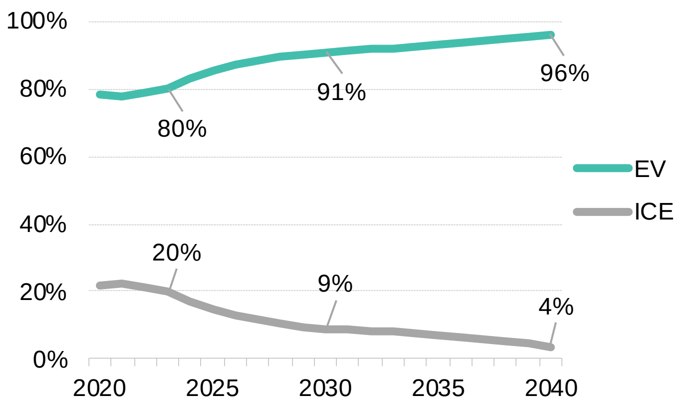
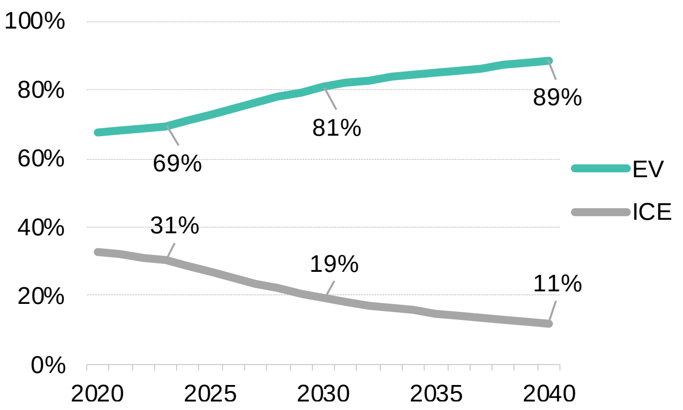


Figure 192: Global share of three-wheeler fleet by drivetrain



Source: BloombergNEF

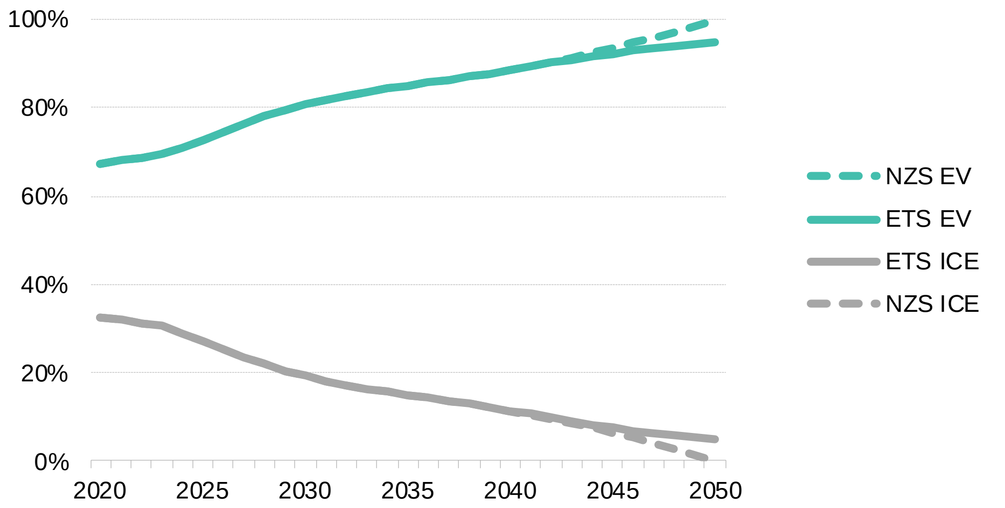
7.4. Electric three-wheeler adoption outlook – Net Zero Scenario

The three-wheeler segment is the closest to reaching a zero-emission fleet by 2050, with 69% of the vehicles on the road being electric in 2023

Three-wheelers are almost on track to reach fully zero-emission fleet by 2050. In the ETS, EVs make up 89% of the global three-wheeler fleet by 2040 and 95% by 2050, similar to our previous outlook (Figure 192). A steep rise in electric three-wheeler adoption in China and India is the main driver – 99% of the three-wheeler fleet in China and 97% of the fleet in India are electric by 2050 under ETS.

To reach a fully zero-emission fleet by 2050, countries need to ramp up three-wheelers sales in the 2040s (Figure 193). In our NZS, sales of combustion three-wheelers must end in 2045 for the sector to reach net-zero fleet by 2050. Global ICE three-wheeler vehicle sales likely already peaked in 2013 at 3.7 million (Figure 194).

Figure 193: Three-wheeler fleet split by drivetrain – Economic Transition Scenario and Net Zero Scenario



Source: BloombergNEF. Note: ETS is Economic Transition Scenario and NZS is Net Zero Scenario.

Fleets in China and India are already mostly electric in the ETS. Both countries could reach the net-zero target ahead of 2050 if the respective governments put further pressure on commercial entities to electrify their fleets. This suggests efforts to accelerate the phase out of ICE three-wheelers must come from other markets. Under the NZS, the electric three-wheeler fleet outside of China and India rises to 29 million in 2050, from 766,000 in 2023 (Figure 195).

This segment is a minor contributor to overall road transport emissions but could have great symbolic importance if it hits net zero much earlier than 2050 should policymakers in countries other than India and China prioritize this.

Figure 194: Three-wheeler fleet outlook by drivetrain – Net Zero Scenario

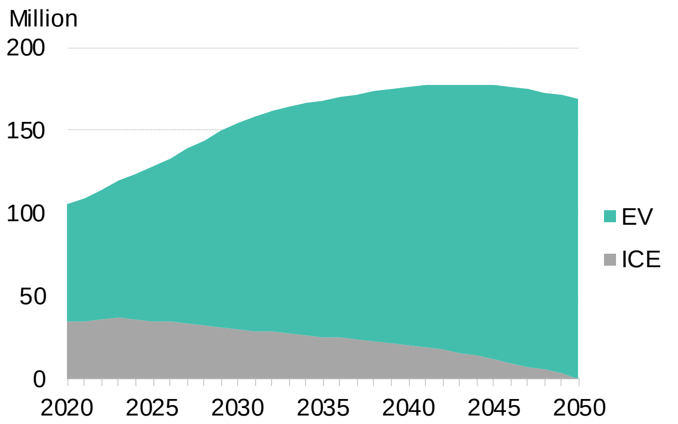
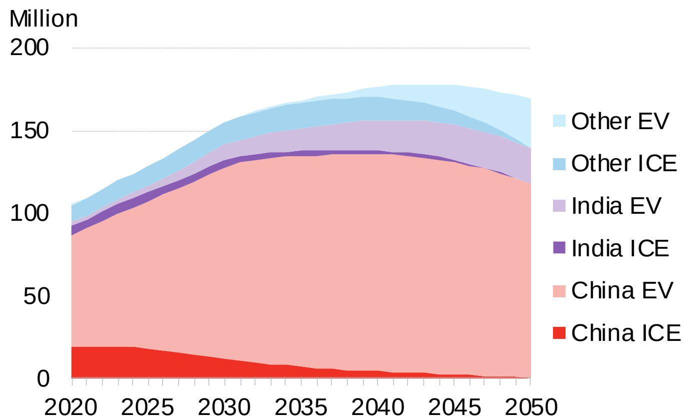


Figure 195: Three-wheeler fleet outlook by drivetrain and market – Net Zero Scenario



Source: BloombergNEF

Impacts

Section 8. Impacts on batteries and materials

Annual lithium-ion battery demand grows rapidly in our Economic Transition Scenario (ETS), approaching 3.6 terawatt-hours (TWh) across road transport and stationary storage by the end of the decade, almost quadruple today's levels. The ETS requires at least $242 billion be invested in battery cell and component plants between now and 2030 to meet this level of demand. But more than four times that amount has been announced by companies, totaling $1.1 trillion, signaling overcapacity and sustained low prices that will challenge suppliers, despite the upside for electric vehicle demand.

Annual lithium-ion battery demand for road transport and stationary storage almost quadruples from today to reach 3.6TWh in 2030 in the ETS

The planned investment even exceeds the $448 billion needed across the rest of this decade to be on track for net-zero by mid-century. Under BNEF's Net Zero Scenario (NZS) annual demand for batteries for road transport and energy storage nears 6TWh by 2030, before almost doubling to a peak of 11.9TWh in 2045 amid the surge in EV adoption required to switch the vehicle fleet from combustion engines to electric drivetrains ahead of 2050.

The current overcapacity of battery manufacturing capacity is one factor driving record-low prices in the Chinese domestic market. Recent energy density and charging advances relating to lithium iron phosphate (LFP) batteries have also led BNEF to update its view for low-cost chemistries, which could now account for over half the market across all EV segments as soon as 2026, growing to 65% through to 2035. This has a substantial impact on upstream demand for battery metals and materials, and our outlook for nickel and manganese consumption has been revised to align with the automakers' changing chemistry preferences.

There is a supply glut for raw materials too, with prices of all major battery metals having fallen over the last 18 months. This comes as the expectation of demand growth has led to a tremendous amount of capital investment in some commodities, including lithium, nickel and cobalt. BNEF's outlook sees metals demand going into lithium-ion batteries growing ninefold between 2023 and 2035.

China remains dominant across the battery landscape, controlling over 70% of the current supply chain. As other regions look to bring production closer to home, they will have to invest in new capacity and operate at competitive costs to succeed.

8.1. Battery demand: Economic Transition Scenario

Total annual demand for lithium-ion batteries – which encompasses consumer electronics, road transport and stationary storage – passes 3.7TWh by 2030 in the ETS, more than tripling from current levels (Figure 196).

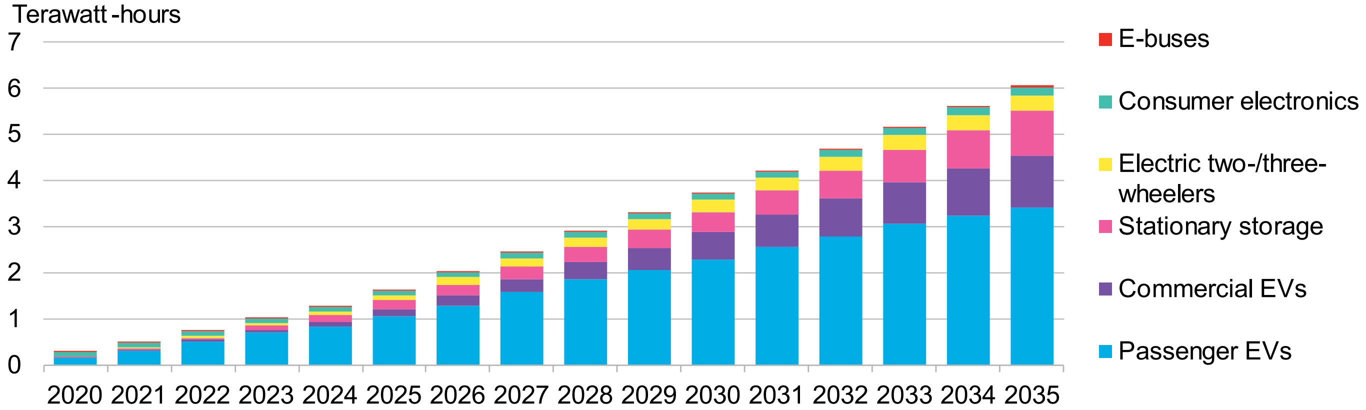
Passenger EVs are the largest driver of battery demand for road transport, accounting for 72% of the total in 2030 in the ETS

Demand for road transport alone comes to just under 3.2TWh by the end of the decade, almost four times 2023 levels. Passenger EVs are the largest driver with a 72% share of the road transport total in 2030, far ahead of the next-biggest segment, commercial EVs, on just 19%.

This edition of the *Electric Vehicle Outlook* envisages total annual battery demand across all sectors being 2% higher in 2030 versus last year's outlook. This reflects increased demand from stationary storage offsetting a 3% reduction from vehicle segments.

Still, as the electrification of road transport continues, battery demand for vehicles climbs by more than 50% from 2030 to reach 4.9TWh in 2035.

Figure 196: Lithium-ion battery demand outlook in the Economic Transition Scenario, by sector



Source: BloombergNEF, Avicenne. Note: The demand outlook for consumer electronics comes from Avicenne. Under the Economic Transition Scenario, EV adoption is primarily driven by techno-economic trends and market forces.

8.2. Battery pricing and manufacturing outlook

Lithium-ion battery prices resumed their downward trend in 2023, after briefly going up in 2022

This year's outlook uses battery price data from our *2023 Lithium-Ion Battery Price Survey* (web | terminal). Battery prices resumed their decline in 2023, following an unprecedented increase in 2022 – the first rise since BNEF started tracking this data back in 2010. The volume-weighted average price for lithium-ion battery packs across all sectors dropped by 14% to $139 per kilowatt-hour (kWh) last year (Figure 197). This came as significant growth in production capacity for all parts of the battery value chain led to decreasing raw material and component prices, which are still driving pack prices down. Meanwhile, demand growth may have fallen short of industry expectations last year.

As well as supply and demand dynamics, growing uptake of lower-cost LFP (lithium iron phosphate) batteries, pushed prices down. Battery prices are expected to keep declining in the long term as the industry continues to grow and pivot to cheaper technology, and as many automakers and battery manufacturers adopt more aggressive raw material hedging strategies to improve their ability to offer batteries at lower prices. These strategies range from forming partnerships with raw material providers to investing directly in mining and refining projects.

We have split our analysis into a near-term outlook based on the impact of raw material prices out to 2026, and a long-term outlook that uses an experience curve approach. In the *Thematic Highlight* that accompanies this section, we explore a specific scenario for China, where extremely low prices are being driven by intense competition in an oversupplied market, leading to lower EV prices there.

Globally, the observed learning rate for lithium-ion batteries remained at 17% in 2023.[7] Assuming this holds true in the future, implied average battery pack prices could fall below $100/kWh in 2027 (in real 2023 dollars) (Figure 197). This is the threshold often referenced as the point where EVs reach price parity with internal combustion engine vehicles (although price parity varies

[7] The learning rate is the rate at which prices fall every time cumulative demand doubles. It dictates that technologies generally follow a long-term experience curve, where economies of scale and technology improvements lead to growing scale and maturity of the industry, leading to lower prices. As scale increases, doubling demand takes longer, hence the price curve asymptotes.

significantly by vehicle segment and region, and due to inflation, pack prices may never cross the $100/kWh mark in nominal terms). Pack prices could drop further to $80/kWh in 2030 (in real 2023 dollars).

Figure 197: Lithium-ion battery pack price outlook

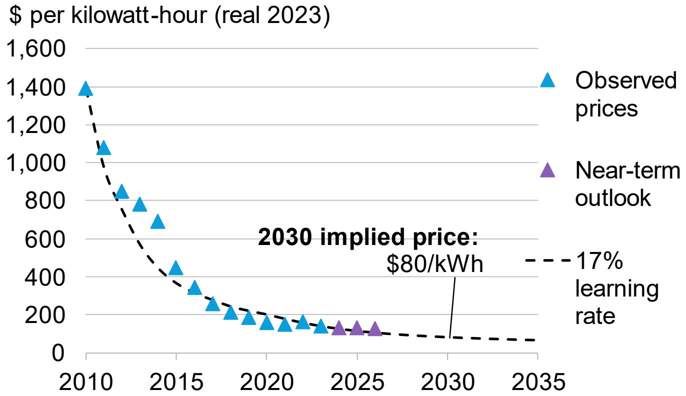
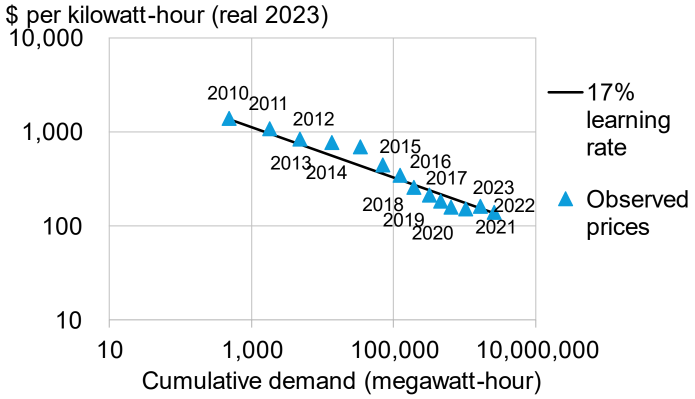


Figure 198: Log-log lithium-ion battery pack experience curve

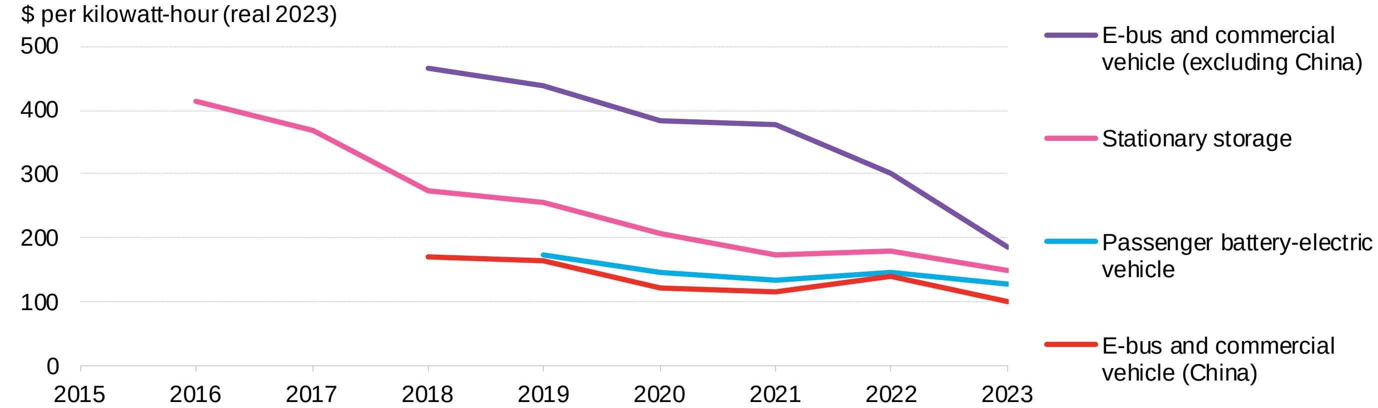


Source: BloombergNEF. Note: The data in these charts has been adjusted to be in real 2023 dollars. BNEF will be updating its battery price outlook at the end of 2024. The log-log chart uses a logarithmic scale on both the horizontal and vertical axis.

Pricing across sectors

The requirements for pack and cell design, and power output, vary by sector, which in turn affects pricing. In China, electric buses and commercial EVs had the lowest volume-weighted average pack price in 2023 at $100/kWh, followed by battery-electric vehicles (BEVs) at $150/kWh (Figure 199). E-bus and commercial EV pack prices in China are much lower than elsewhere, though the gap has narrowed dramatically in the past three years. Outside China, pack prices for e-buses and commercial vehicles have dropped significantly and are now closer than ever to the $139/kWh industry average, at $186/kWh.

Figure 199: Volume-weighted average lithium-ion battery prices, by sector



Source: BloombergNEF

Chinese firms favor LFP batteries since they have a local established supply chain and are perceived to be safer than nickel manganese cobalt oxide (NMC) or nickel cobalt aluminum oxide (NCA) chemistries. The higher safety of LFP allows for larger cells and simpler pack designs.

Order volumes are also higher in China than other parts of the world. Segments outside China are shifting towards LFP and growing in volume, so the price difference between countries will likely shrink as the market matures.

EV battery pack pricing varies by drivetrain too. A battery-electric vehicle, for instance, has very different pack design, size and power requirements than a plug-in hybrid. BEV packs are much larger than their plug-in hybrid counterparts, which means the inactive pack material costs are spread over more kilowatt-hours. In addition, BEV packs use ‘energy-oriented’ cells, which pack in more kilowatt-hours and are cheaper to manufacture than the ‘power-oriented’ cells needed for plug-in hybrids.

Getting to $100/kWh and below

The $100/kWh battery pack price point is often referenced as the threshold when EVs reach price parity with ICE vehicle. The price parity point will look different by region and vehicle segment (Section 12). However, $100/kWh nonetheless remains a useful metric to understand the trajectory of battery prices.

Lithium-ion battery pack prices in China have experienced a particularly dramatic drop since the beginning of 2023 through to April 2024. They have been consistently below $100/kWh since September 2023 for both LFP and (non-high-nickel) NMC packs, which we explore further in the *Thematic Highlight:* at the end of this chapter. Reaching $100/kWh globally is still an achievable goal with the emerging generation of battery chemistries and cell designs, amid lower commodity prices.

Reaching a battery pack price of $100/kWh globally – the threshold often seen as when EVs reach price parity with ICE vehicles – is still an achievable goal

In our *2023 Lithium-Ion Battery Price Survey*, LFP packs had the lowest global volume-weighted average price at $95/kWh. The introduction of new high-nickel, high energy density cathode material, like NMC (955), alongside new manufacturing processes and techniques, should make pack prices under $100/kWh possible for performance-based battery packs in the next few years. Last year saw raw material prices for batteries fall significantly from the peaks in 2022, alleviating the pressure on battery pack prices. However, should raw material prices start to climb again, global average prices could take longer to reach $100/kWh.

While not all automakers are open about their forward pricing expectations, many have discussed their targets. Raw material and component price fluctuations will likely change some of these expectations.

- **Toyota:** The Japanese auto giant unveiled a technology roadmap for next-generation batteries in 2023, which included:
  - ‘Performance’ lithium-ion technology, aiming to reduce costs by 20% (compared to the bZ4X model) by 2026.
  - ’Popularization’ lithium-iron-phosphate (LFP), aiming to reduce costs by 40% (compared to the bZ4X model) by 2026-27.
  - ’High performance’ lithium-ion technology with high-nickel cathodes, aiming to reduce costs by 10% (compared to the Performance technology) by 2027-28.
- **Renault-Nissan-Mitsubishi Alliance**: The group announced a common battery strategy in 2022, which aims to reduce battery costs by 50% by 2026 and 65% by 2028. It plans to achieve this through economies of scale. Targets for solid-state batteries are even more aggressive, with the group targeting pack costs of $75/kWh by 2028, with potential to further decrease to $65/kWh in the future.

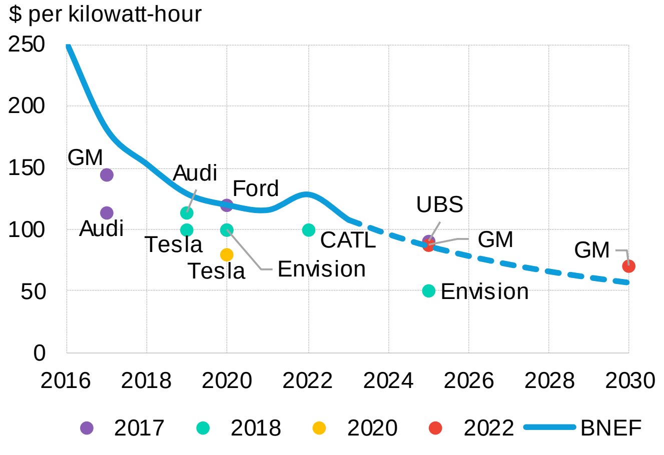
Publicly disclosed battery cell and pack price targets are consistent with BNEF's volume-weighted average prices out to 2030

- **Hyundai:** The company announced in 2023 a commitment to spend $28 billion in its electrification strategy over the next 10 years, of which $7.4 billion will go into next-generation batteries, including introducing LFP to lower battery costs in its EVs, starting in 2025. According to Hyundai's 2022 strategic plan, its integrated modular architecture based on the cell-to-pack approach can reduce costs by 35% between 2021 and 2030.
- **Volkswagen**: VW re-affirmed its expectation in 2023 of lowering the costs of its battery packs by 50% (a cost target originally announced in 2021), through its unified battery cell strategy and newly formed battery manufacturing spin-off PowerCo. The unified battery uses one prismatic cell format for all chemistries, aiming to make mass production highly optimized. In addition to commitment through PowerCo, VW partnered with Gotion in 2023 to supply LFP unified cells to VW outside China. Based on the timelines the company disclosed, BNEF expects the earliest VW could realize these savings is 2025.[8]
- **Tesla**: As of the first quarter of 2024, Tesla has started ramping up production of its 4680 cells at its Texas plant, at an output level of around 7 gigawatt-hours (GWh) per year, out of the 100GWh planned. These cells are central to the EV maker's battery price reduction strategy unveiled at its Battery Day in 2020, where the company announced planned pack price reductions of 56%. Though it was not originally clear when Tesla would be able to achieve the price target, BNEF believes 2025 is likely the earliest point commercial packs could be produced with such a discount.
- **GM**: The US automaker announced plans in 2022 to reduce its Ultium cell costs to $87/kWh in 2025 and below $70/kWh by later in the decade. This followed the April 2021 remarks of GM President Mark Reuss, when he said he expected battery costs to fall at least 60% in the next decade.
- **Stellantis**: The company signed an LFP supply agreement with CATL in 2023 to provide batteries to its European EV models. The deal is part of a strategy to lower battery costs to support the aggressive electrification targets outlined in its "Dare Forward 2030" strategic plan announced in 2022. Stellantis has not announced new cost targets since its "EV Day" in 2021, where it outlined a route to reduce its cell and pack costs by 40% by 2024 and pack costs a further 20% by 2026.

Automaker and battery manufacturers' publicly disclosed cell and pack price targets are consistent with BNEF's volume-weighted average prices out to 2030 (Figure 200 and Figure 201). Pack price goals from 2020 are lower than the revised BNEF outlook, which was updated in 2022 as a result of the higher observed prices. In 2020, prior to the commodity price increases, companies were also more optimistic and transparent regarding their price targets in the decade.

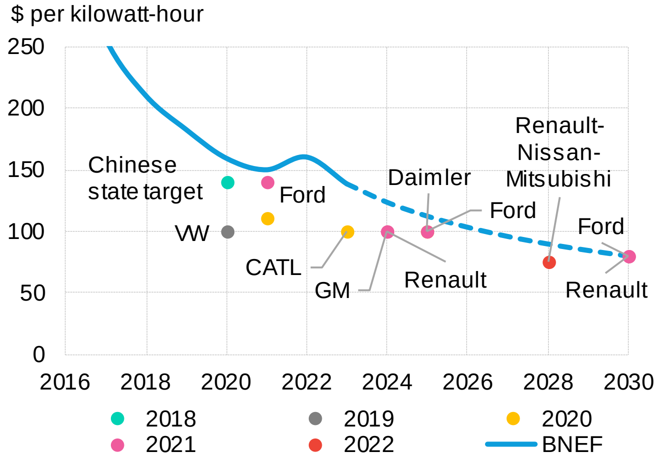
[8] For more, see *Volkswagen's PowerCo to Become Top European Battery Maker* (web | terminal).

Figure 200: Publicly announced lithium-ion cell prices



Source: BloombergNEF, public statements. Note: BNEF prices are in real 2023 dollars per kilowatt-hour, while company statements are nominal. BNEF solid line reflects historical prices and dotted line reflects long-term outlook based on experience curve approach and 22% learning rate.

Figure 201: Publicly announced lithium-ion pack prices



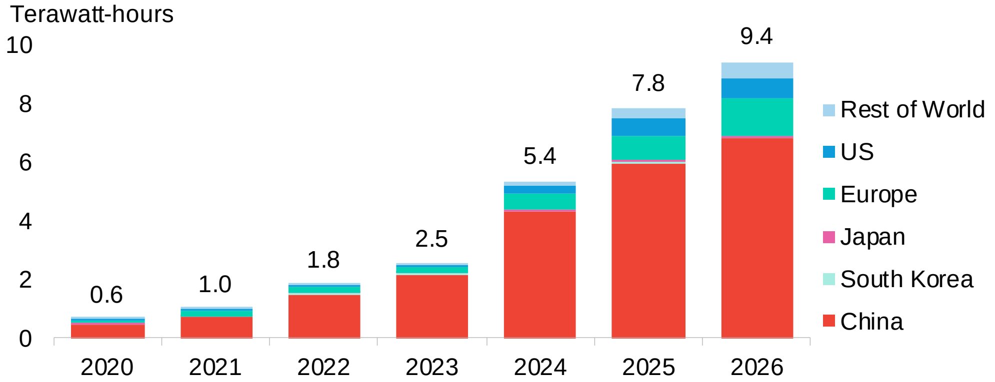
Source: BloombergNEF, public statements. Note: BNEF prices are in real 2023 dollars per kilowatt-hour, while company statements are nominal. BNEF solid line reflects historical prices and dotted line reflects long-term outlook based on experience curve approach and 17% learning rate. Renault-Nissan-Mitsubishi target refers to solid-state batteries.

Battery manufacturing and supply chains

China's share of global cell manufacturing capacity could fall from 86% today to 76% by 2026, if company announcements are delivered on time

By the end of 2023, there was 2.5TWh of commissioned annual lithium-ion battery manufacturing capacity globally. This will almost quadruple to 9.4TWh per year by 2026, if company announcements are delivered on time (Figure 202). China will continue to be the largest manufacturer over this time horizon, but new cell-making capacity is also being planned closer to demand centers in the US and Europe. This could see China's share of global cell manufacturing capacity drop to 72% by 2026, from 86% at the end of 2023.

Figure 202: Commissioned and announced annual lithium-ion battery cell manufacturing capacity, by region



Source: BloombergNEF. Note: Data up to 2023 includes fully commissioned capacity. Data from 2024 onwards includes announced, under-construction and fully commissioned capacity, not de-risked. Data as of May 9, 2024.

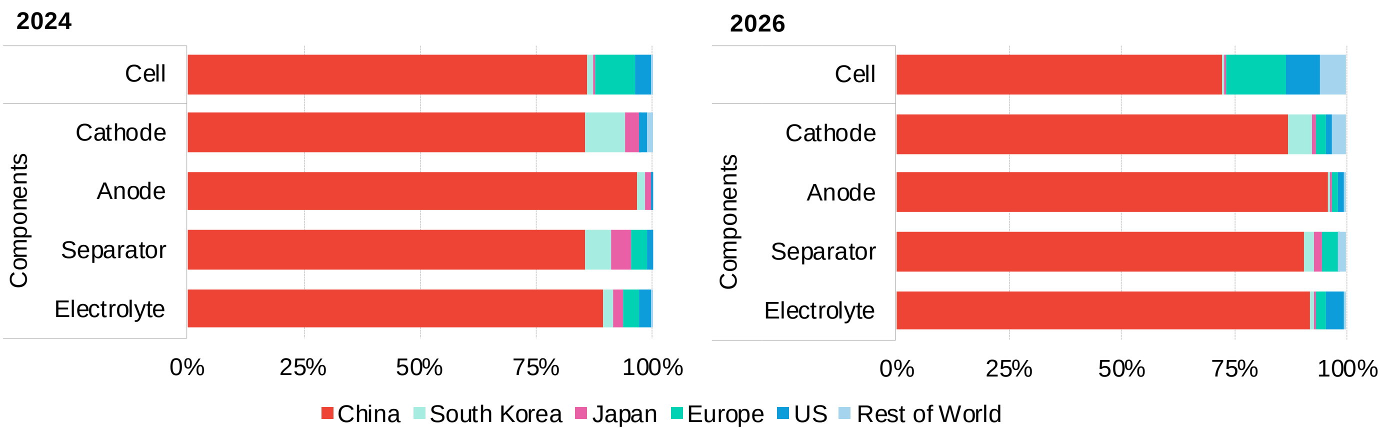
The upstream battery value chain, specifically the production of key battery components – cathodes, anodes, separators and electrolytes – is concentrated in China

The key challenge for the new announced capacity is ensuring it gets commissioned on time, if at all, and ultimately operates at high utilization rates – a scenario that has become increasingly difficult in the near term given the significant overcapacity. Overcapacity has been a major driver of the very low battery prices seen more recently in China, which is further explored in Section 8.6.

BNEF tracks nameplate battery manufacturing capacity, which reflects a plant's theoretical maximum output but is not equal to the real output. For example, while China had 2.2TWh of commissioned cell manufacturing capacity in 2023, utilization rates only averaged around 43%. At a plant and company level, utilization depends on the ramp-up schedule, actual demand, maintenance requirements and other unforeseen factors that may impact a plant's operation. For newer battery manufacturing facilities in regions with less mature battery supply chains, the utilization rates could be even lower. Experienced battery manufacturers usually operate at much higher utilization rates, though the run rate will also be dictated by customer demand.

The upstream battery value chain, specifically the production of key battery components – cathodes, anodes, separators and electrolytes – is also concentrated in China (Figure 203). Some 86% of the world's total cathode processing capacity is located in China and it is an even higher 97% for anodes. While more companies like BASF, Umicore, LG Chem, Panasonic and even Chinese firms like Gotion and Huayou Cobalt are making announcements for component plants in the US and Europe, China is poised to remain the leader in component production capacity.

Figure 203: Geographic distribution of lithium-ion cell and component manufacturing capacity, by region of plant location



Source: BloombergNEF. Note: 2024 includes facilities commissioned up to May 9, 2024. Announced capacity is not de-risked.

In the past three years, Europe and the US have focused on increasing their control and localizing production of batteries and components, as well as the mining and refining of key battery metals. This will come at a cost and lead to higher prices as energy, equipment and labor are more expensive in these regions than China.

The European Union aims to supports localization through policies such as the proposed Net Zero Industry Act, which sets a target of 550GWh of battery manufacturing capacity in the region by 2030. The US is also supporting localization through the Inflation Reduction Act, which includes lucrative production tax credits for facilities located in the US and requires batteries and materials be sourced from North America and/or countries with which the US has a free trade agreement to qualify for the EV credits.

Batteries and industrial policy

Batteries are becoming central to major industrial policies across Europe and the US. Governments can play a critical role in onshoring the battery supply chain through support such as tax credits for cell production or EVs and lowering costs for interested buyers. These policies highlight that localization of the battery industry is not only tied to reducing the risk of relying on certain countries for batteries, but also taking advantage of the economic opportunities associated with the industry.

China: Chinese battery manufacturing owes its rise to support from local institutions and the national government. Access to cheaper labor, power and capital, in combination with a large domestic market, has sharpened local manufacturers' competitive edge. Early on, these advantages were significant, but building on them required subsidies. Before 2010, incentives provided to companies in the battery value chain ran as high as 75% of total costs. The sector was far smaller than it is today, but the sums involved were likely in the tens of billions of dollars. While the low cost of labor is not China's main competitive edge today, the country is seeing the benefits of decades worth of support in the battery industry. More recent policies, as recent as earlier in 2024, have been aimed at factory equipment replacement, regulating over-investment in capacity expansion to assess factory utilization, and reducing reliance on an export-only strategy.

US and Canada: In the US, the Inflation Reduction Act was signed into law by President Biden on August 16, 2022 and represents the largest effort yet to strengthen the battery supply chain in the country. It introduced a variety of credits to support the battery supply chain, from raw materials to battery cells, modules, EVs and energy storage. Two of the key credits for batteries include production tax credits for cells and modules at $35/kWh and $10/kWh, respectively, and a $7,500 credit for EVs. These credits will put downward pressure on prices for batteries manufactured in the US. Meanwhile, Canada's 2023 budget also offers support to the battery industry and the region is already attracting investment related to battery metals, components and manufacturing.

Europe: Following the passage of the Inflation Reduction Act in the US, the EU responded with its own Net Zero Industry Act. The proposed legislation includes the objective of having local manufacturers establish 550GWh of battery manufacturing capacity by 2030. Meeting this target seems easy, as cumulative announced battery manufacturing capacity exceeds it. However, these capacity numbers should be treated with caution: the Net Zero Industry Act provides little in the way of incentives to ensure this capacity gets built.

The main areas of investment in the EU are 'Important Projects of Common European Interest' (IPCEI), where large groups of industry participants across multiple member states contribute funds. IPCEIs are not financed by public money alone, and beneficiaries need to co-invest. The end goal is to establish domestic value chains or so-called strategic autonomy in priority sectors, including batteries.

The push to localize battery supply chains grew amid the disruptions brought about by Covid-19 lockdowns, Russia's invasion of Ukraine, and tensions between the US and China. These policies, especially the Inflation Reduction Act, put significant emphasis on the economic opportunities tied to localization, such as job creation. Canada, Japan, South Korea, India and Indonesia are some of the other countries looking to attract investment in domestic battery manufacturing and support their homegrown battery industries.

Further reading

- *2023 Lithium-Ion Battery Price Survey* (web | terminal)
- *New US Rules on Foreign EV Batteries Set High Bar to Clear* (web | terminal)
- *China's Clean-Tech Overcapacity Threatens Onshoring Dreams* (web | terminal)
- *Global Lithium-Ion Battery Supply Chain Ranking 2024* (web | terminal)
- *Company Profiles: 2023 Global Battery Manufacturers* (web | terminal)
- *Sizing Up the US Clean-Tech Manufacturing Boom One Year In* (web | terminal)
- *Europe's Bid to Reshore Clean Tech Pulls Its Punches* (web | terminal)
- *EU's Critical Minerals Act Lacks Incentive and Funding* (web | terminal)

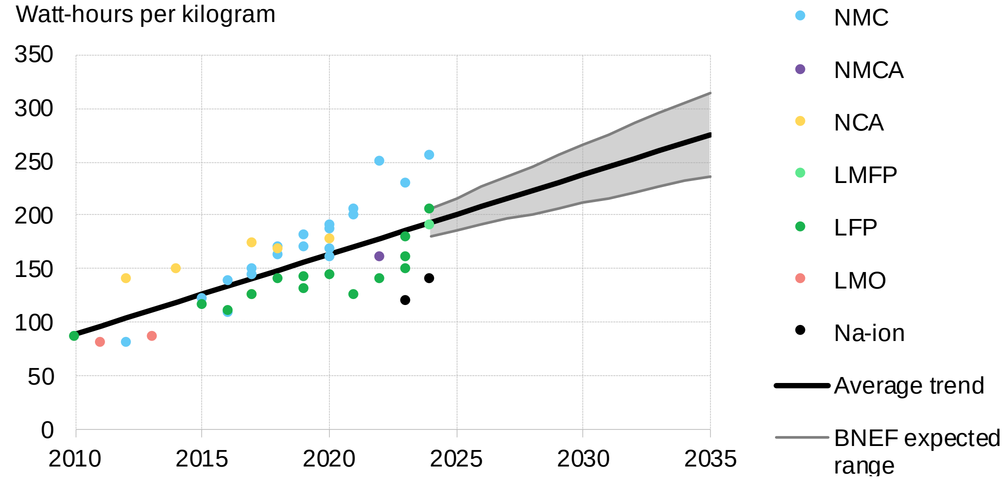
8.3. Battery technology outlook

Energy density

Average battery pack energy density has increased by 117% since 2010

The average battery pack energy density in battery-electric vehicles has more than doubled since 2010, rising 117% to 194 watt-hours per kilogram (Figure 204). Increasing energy density reduces the associated material and manufacturing costs, and improves a vehicle's efficiency and driving range. High energy density cells pack in more kilowatt-hours per unit of weight.

Figure 204: Historical and estimated changes to battery-pack energy density



Source: BloombergNEF. Note: NMC refers to nickel manganese cobalt oxide; NMCA is nickel manganese cobalt aluminum oxide; NCA is nickel cobalt aluminum oxide; LMFP is lithium manganese iron phosphate; LFP is lithium iron phosphate; LMO is lithium manganese oxide; Na-ion is sodium ion.

NMC is the highest-performing group for energy density, with some packs having achieved 250 watt-hours per kilogram in 2022

We expect benchmark pack-level energy density in BEVs to keep improving. There are currently three major cathode chemistry groups: NMC (nickel manganese cobalt oxide), NCA (nickel cobalt aluminum oxide) and LFP (lithium iron phosphate), with varying density trends. NMC is the highest-performing group, with some packs having achieved 250Wh/kg in 2022, and CATL's Qilin battery entering the market in 2023 at 255Wh/kg. LFP energy density has also improved significantly, increasing 107% since 2010, and this has been pivotal to this chemistry taking a larger market share.

LFP technology continues to break new limits. CATL launched the Shenxing Plus in April 2024. These battery cells use an LFP cathode and will be able to deliver superfast charging, offering a range of 1,000 kilometers on a full charge and 600 kilometers with 10 minutes of charge.[9] BYD also launched the next generation of it Blade EV battery in April, which will have an energy density of 190Wh/kg.

9 Shenxing Plus is an improvement on CATL's Shenxing Superfast Charging Battery launched in August 2023, which offered 700 kilometers in a single charge, 400 kilometers with a 10-minute charge, plus improved performance in cold temperatures. See *CATL Pushes Limits Again With New Fast-Charging Battery* (web | terminal).

Continued innovation and development of LFP batteries is leading to increased market share, particularly in China, where many of the companies making LFP cells are based. For passenger EVs, for example, LFP's share grew to 41% in 2023, up from just 5% in 2019.

The shaded area in Figure 204 represents BNEF's expected range of the trendline for battery pack energy density. We anticipate the upper limit of this area will align with state-of-the-art battery packs, and the lower limit approximately follow more affordable, mass-market battery packs. We estimate average pack energy densities will continue to increase in the long run.

Leading battery cell energy densities could reach 500Wh/kg in 2025

By 2025, large cell producers are aiming to produce cells with energy densities of 350-500Wh/kg. For example, CATL unveiled a 500Wh/kg "condensed battery" that was expected to start mass production in 2023, although there has not been an announcement to confirm this. The battery is initially targeted for aviation applications and further details of the automotive version are unclear. Still, the breakthrough helps contextualize what is possible.

A cell energy density of 500Wh/kg correlates to pack-level energy densities of 280-300Wh/kg. To reach these high energy densities, manufacturers will need to use silicon or lithium metal anodes, solid electrolytes and high-voltage cathodes.[10] These cells are likely to cost more than the average so will be confined to high-end vehicles initially, and average pack energy densities (including other chemistries) will be closer to 200Wh/kg.

Sodium-ion batteries are an emerging technology in the EV sector, although the trendline is based on lithium-ion batteries. Sodium-ion battery energy density is currently lower than that of lithium-based batteries, but BNEF expects sodium-ion's energy density to improve and by 2025 to be comparable with that of LFP in the early 2020s, when LFP took a significant share of global battery demand.

Cathode chemistries

A number of different cathode chemistries are currently in use or development. High commodity prices in 2022 led automakers to accelerate their shift to lower-cost cathodes and this trend has continued, despite metals prices dropping in 2023, due to slower-than-expected EV demand. Fiercely competitive pricing strategies are maintaining the pressure on technology improvement.

Even South Korean companies that have historically specialized in NMC chemistries have begun to embrace LFP production

Tesla, Rivian, Ford and VW are still pursuing adoption of low-cost chemistries like LFP. Even South Korean companies that have historically specialized in NMC chemistries have begun to embrace LFP production, as has government policy, aligning with market demand. Due to continued commitment and improvement in LFP technology, the share of LFP has grown across all segments, and is expected to keep squeezing other nickel-based chemistries out to 2035.

In parallel, in early 2023, a number of Chinese battery manufacturers and automakers announced their next generation of low-cost batteries: sodium-ion. HiNa Battery's partnership with Chinese automaker JAC to use its batteries in a production car for the first time came to fruition last year, as the first sodium-ion powered cars – JAC's Hua Xianzi – rolled off the production line in the final days of 2023. The agreement paves the way for continued price reductions in the already highly competitive Chinese market for small electric vehicles. CATL has subsequently announced that its sodium-ion cells will be used to power Chery EV models in China.

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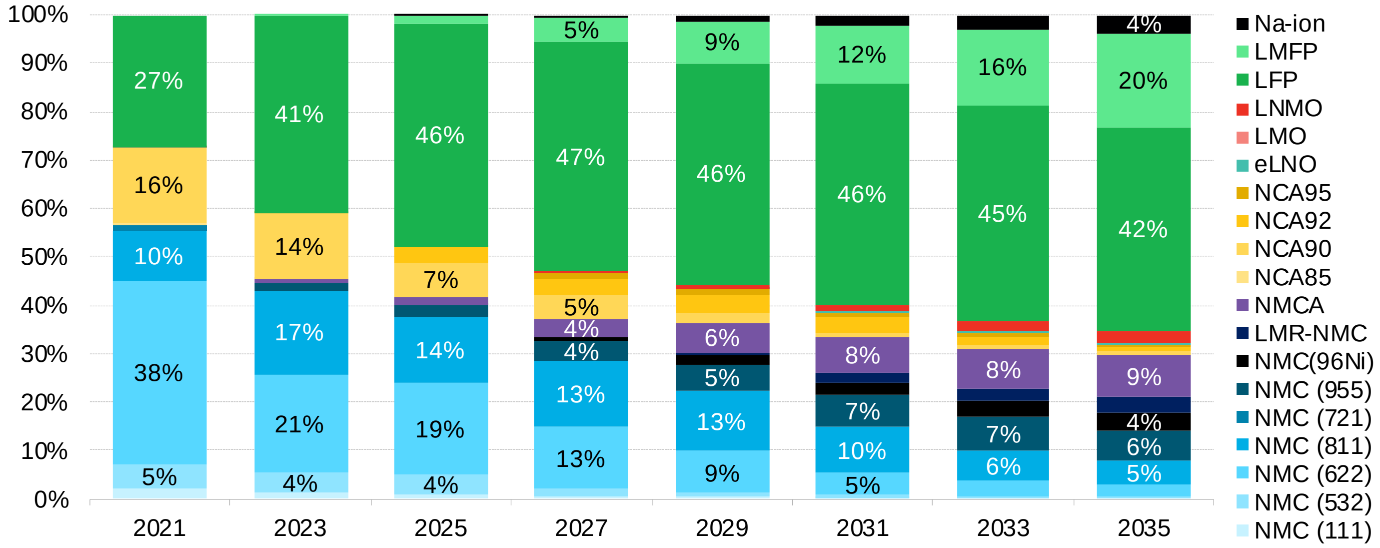
10 The cathode is the positive electrode in a battery, where electrons flow from during charging and flow to during discharging. The anode is the negative electrode, on the opposite side of the cathode. The electrolyte is the chemical solution, often liquid, that allows ions to flow from the anode to cathode (and vice versa) between charging and discharging.

Passenger EVs

The starting point for BNEF's cathode chemistry outlook is the current breakdown of chemistries used in different EVs and the number of vehicles sold. We combine this with our knowledge of new and existing chemistries, future vehicle release dates and other company announcements to estimate how the chemistry mix could change between now and 2035 (Figure 205).

Figure 205: Evolution of cathode chemistry mix across all passenger electric vehicle segments



Source: BloombergNEF. Note: Na-ion refers to sodium ion; LMFP is lithium manganese iron phosphate; LFP is lithium iron phosphate; LNMO is lithium nickel manganese oxide; LMO is lithium manganese oxide; LNO is lithium nickel oxide; NCA is nickel cobalt aluminum oxide; NMCA is nickel manganese cobalt aluminum oxide; LMR is lithium- and manganese-rich; NMC is nickel manganese cobalt oxide. See Appendix A for glossary of battery chemistries.

There could be 15 distinct cathode chemistries in 2035, although this would be down from a peak of 17 envisaged in 2029

The outlook for chemistry demand in the near term is more certain as we base this on the announcements from leading automakers, cell manufacturers and cathode material producers. Towards the end of this decade, the outlook is less clear. We expect new chemistries to be announced as 2030 approaches that will play a role in the EV market, and chemistries such as nickel manganese cobalt aluminum oxide (NMCA) can also have variable compositions, as seen with NMC and NCA today. By 2035, there are 15 distinct chemistries in BNEF's mix, although this is down from a peak of 17 in 2029.

Current technologies can be separated into three categories: performance, mid-market and low-cost. BNEF expects these three classifications to continue to define the market in the future.

Performance chemistries

Performance chemistries will primarily be focused on high energy densities and fast charging, with the aim of providing long driving ranges or light packs to improve performance and handling. These chemistries tend to have high nickel content and, as a result, high raw material prices. BNEF classifies lithium nickel oxide (LNO), nickel cobalt aluminum oxide 95 (NCA95), NMCA, NMC (955) and NMC (96Ni) as performance chemistries, and they are seen as being more prevalent in 2035.

These chemistries will not necessarily be confined to the most expensive car brands but will likely be used in vehicles with the top specifications for each model. LG Energy Solutions is supplying NMCA batteries to Tesla and is also working with GM to manufacture NMCA through its joint venture Ultium Cells.

Performance chemistries are expected to drop to 26% of the passenger EV cathode market in 2035, from 33% in 2023

BNEF expects performance chemistries to account for a third of the market in 2030, staying flat relative to 2023, before subsequently dropping to 26% in 2035 – although year-on-year gigawatt-hour growth continues in the 2030s. The decline in market share is a result of cheaper alternatives becoming more prominent, especially as EV makers target more price-sensitive and larger portions of the car market. BNEF has reduced the 2035 share of these chemistries by 5 percentage points compared to last year's outlook, as we have seen more traction around mid-market and lower-cost chemistries in new markets and segments. As the nickel content increases, particularly to 90% or more, the lines between NCA, NMC and NMCA become harder to define and the differences between these chemistries become more nuanced.

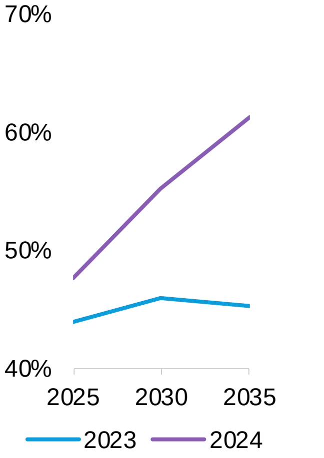
Mid-market chemistries

Mid-market chemistries will balance performance with cost by substituting some of the contained nickel for cheaper manganese (Figure 207). In the near term, this will include mid-nickel NMC chemistries such as NMC (532) and NMC (622). In the future, BNEF expects two chemistries to join this group: lithium nickel manganese oxide (LNMO) and lithium- and manganese-rich NMC (LMR-NMC). We anticipate these four chemistries will have a combined 24% market share in 2025, down from 26% in 2023, before steadily dropping to 9% by 2035.

As these technologies develop, the EV market will mature towards a more diverse range of vehicles available. Morrow Batteries, a Norway-based battery maker, is looking to produce LNMO in its second-generation cell after LFP, and PowerCo, which was spun out of VW, also plans to manufacture a high-manganese cell for what it calls "volume" EV models.

The mid-market chemistry segment is losing market share compared to our last outlook due to the announcements and progress around LFP – market leading LFP battery packs, such as BYD's Blade and CATL's Shenxing Plus, are starting to bridge the gap from low-cost to performance chemistries.

Figure 206: LFP/LMFP share of passenger electricity vehicle chemistry mix – BNEF's 2023 and 2024 outlooks



Source: BloombergNEF. Note: LFP refers to lithium iron phosphate; LMFP is lithium manganese iron phosphate.

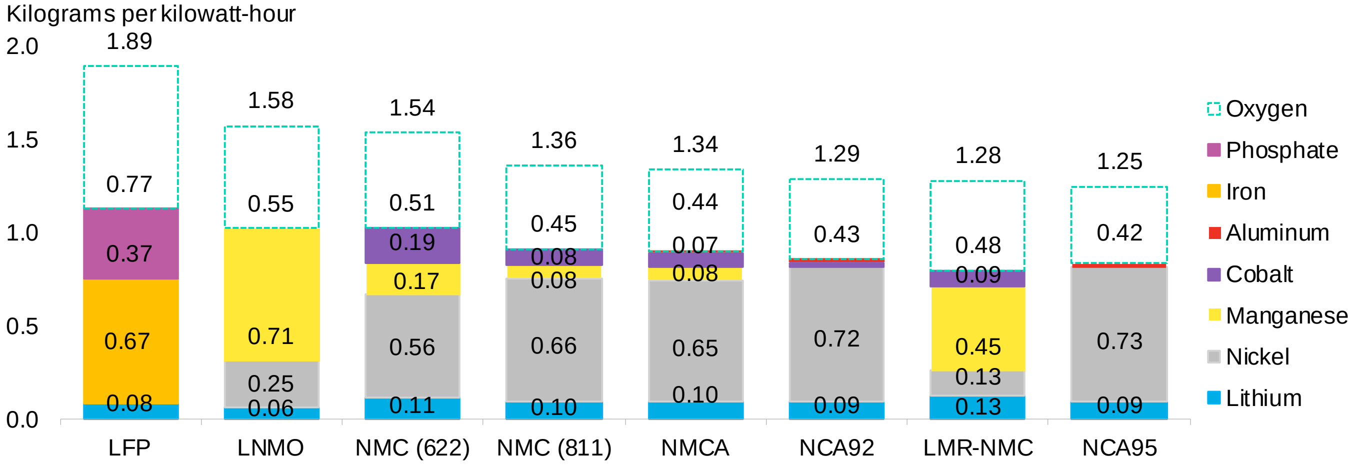
Low-cost chemistries

In the low-cost segment, LFP-based chemistries are expected to be dominant. This includes variations such as lithium iron manganese phosphate (LMFP), which, with the addition of manganese, will have many of the same properties as LFP (like safety and cost advantages), with a higher energy density. Lithium is the only expensive material in these chemistries, so they are cheap and do not face the same potential material constraints that nickel-based chemistries could encounter in the future. Sodium-ion is also included in this segment, which is also a low-cost chemistry. Sodium-ion batteries are the most viable alternative to lithium-ion batteries, using sodium in place of lithium.

Low cost does come with performance limitations. LFP-based chemistries have lower energy densities than the other chemistries covered in this outlook. This means that for a given pack size and design, EVs using LFP will have shorter driving ranges than those using nickel-based chemistries. However, recent advances relating to LFP, particularly at the pack level, have gone some way to bridging this gap (Figure 204). BNEF expects these chemistries to account for over half the market as soon as 2026, a share that is anticipated to grow through 2035 to reach 65% (61% for LFP-based chemistries and 4% for sodium-ion), while absolute gigawatt-hour demand also continues to expand. This is an increase of 16 percentage points compared to our 2023 outlook, since we now expect these chemistries to be more versatile and used in mid-sized cars and SUVs, such as the Ford F-150 Lightning being sold in the US, which started using LFP in 2024 (Figure 206).

As supply constraints around lithium-ion batteries intensify and the development of sodium-ion technologies takes off, BNEF expects sodium-ion to break into the EV market at commercial scale in small vehicles first, and then medium-sized vehicles in China.[11]

Figure 207: Metal content of selected lithium-ion battery cathode materials



Source: BloombergNEF. Note: LFP refers to lithium iron phosphate; LNMO is lithium nickel manganese oxide; NMC is nickel manganese cobalt oxide; NMCA is nickel manganese cobalt aluminum oxide; NCA is nickel cobalt aluminum oxide; LMR is lithium- and manganese-rich. See Appendix A for glossary of battery chemistries.

Other high-performance chemistries with low material costs are being developed, including lithium-sulfur and lithium-air, but these are so far still at the laboratory stage. If they prove successful, they could be used across all segments.

Low-cost chemistries will make EVs more accessible to consumers and could allow automakers to make better margins on vehicles. In the long run, however, they could result in lower returns for battery recyclers, reducing the financial incentive to recycle. Regulation may be necessary to ensure higher recycling rates, even with tailwinds from recycling technology innovation and sustainability targets.

Commercial EVs

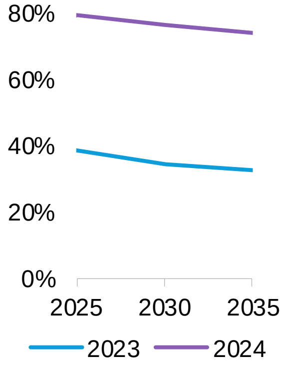
LFP is expected to dominate the cathode chemistry mix in the commercial electric vehicle segment

BNEF foresees LFP dominating the chemistry mix in the commercial electric vehicle segment, similar to the passenger EV market. We have significantly increased the share of LFP compared to last year's outlook, due to the growth of LFP in current truck models in all regions (Figure 208 and Figure 209). This is because fleet owners are focused on the total cost of ownership of these vehicles, and although size, range and performance vary significantly, depending on the weight and duty cycle of the vehicle, LFP has become more widespread with improved performance, while also outcompeting NMC on price.

LFP has a higher cycle life compared to nickel-based alternatives, meaning it can be charged and discharged more times. Additionally, the first commercial segments being electrified are for uses

[11] BNEF expects a more rapid uptake of sodium-ion batteries for stationary energy storage – for more information, see our *1H 2024 Energy Storage Market Outlook* (web | terminal).

Figure 208: LFP/LMFP share of commercial electric vehicle chemistry mix – BNEF's 2023 and 2024 outlooks



Source: BloombergNEF. Note: LFP refers to lithium iron phosphate; LMFP is lithium manganese iron phosphate.

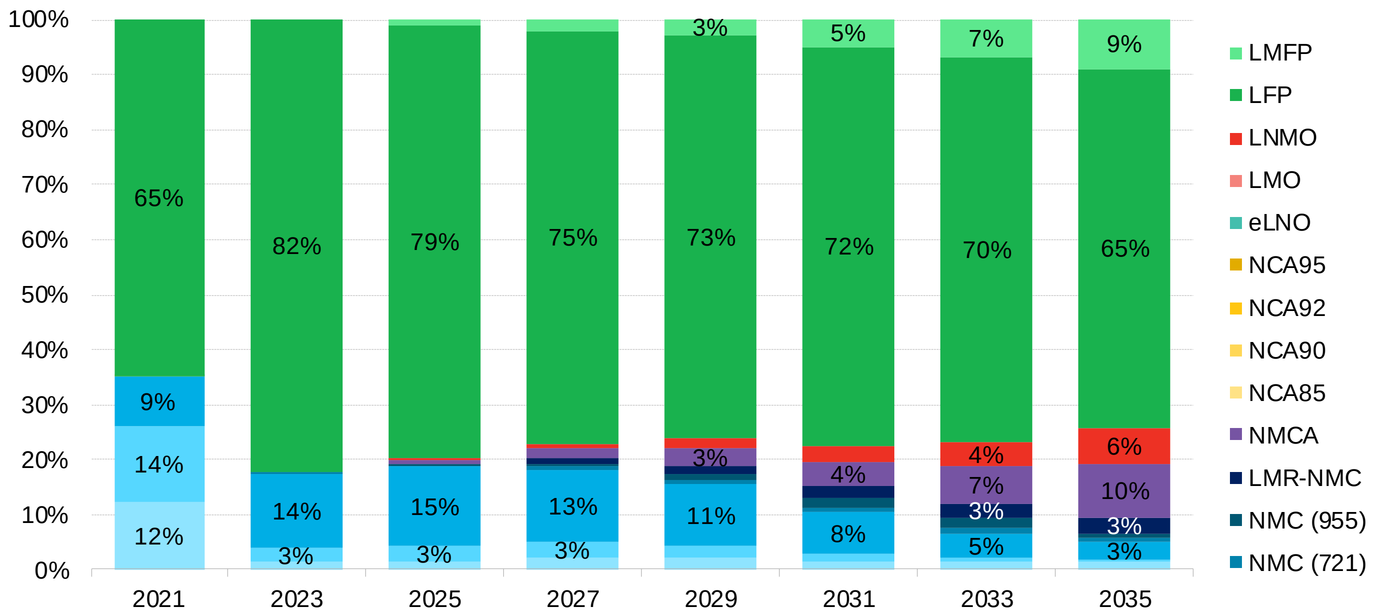
cases of less than 300 kilometers, so the energy density requirements are less strict than for longer-haul trucks. LFP remains the technology of choice in China for commercial vehicles, used by companies such as Beiqi Foton Motor, SAIC Motor and Zhejiang Geely Holding Group. Geely also uses nickel-based materials (NMC and NCA) for some longer-range vehicles. Outside of China, firms are working with a range of chemistries, although this is increasingly trending towards using LFP. Daimler uses LFP supplied by CATL, as well as NMC from LG Chem and SK Group, and AB Volvo is using LFP supplied by SAFT.

Globally, we expect LFP to be a significant part of the market. From 2030 onwards, LFP's share drops as uptake of electric commercial vehicles in Europe and the US grows, where LFP is less prevalent compared to the more mature market in China. The emergence of new technologies like lithium manganese nickel oxide (LMNO) will also impact the growth of LFP in commercial vehicles as they offer a balance of cost and performance, benefitting large and heavy vehicles, a segment that will electrify later than short-haul and lighter-duty applications.

BNEF anticipates battery-electric light-duty commercial vehicles outside of China will largely use a mix of chemistries, based on the range they are traveling, although LFP will also be popular across most segments. Heavy- and medium-duty commercial vehicles that cover shorter routes will, in some cases, use LFP-based batteries. Those traveling longer routes will generally require more energy-dense systems to help reduce the weight of the battery pack. The chemistry mix, especially for heavy-duty vehicles, will also depend on fleet operators' preference for longer-cycling chemistries, such as LFP, over energy-dense materials. There are numerous tradeoffs here around cycle life and charge time.

We do not expect sodium-ion to break into the commercial EV sector due to its lower energy density paired with the greater weight of the vehicles, although technological advancements may lead to progress in this segment further in the future.

Figure 209: Evolution of cathode chemistry mix across all commercial electric vehicle segments



Source: BloombergNEF. Note: LMFP refers to lithium manganese iron phosphate; LFP is lithium iron phosphate; LNMO is lithium nickel manganese oxide; LMO is lithium manganese oxide; LNO is lithium nickel oxide; NCA is nickel cobalt aluminum oxide; NMCA is nickel manganese cobalt aluminum oxide; LMR is lithium- and manganese-rich; NMC is nickel manganese cobalt oxide. See Appendix A for glossary of battery chemistries.

E-buses

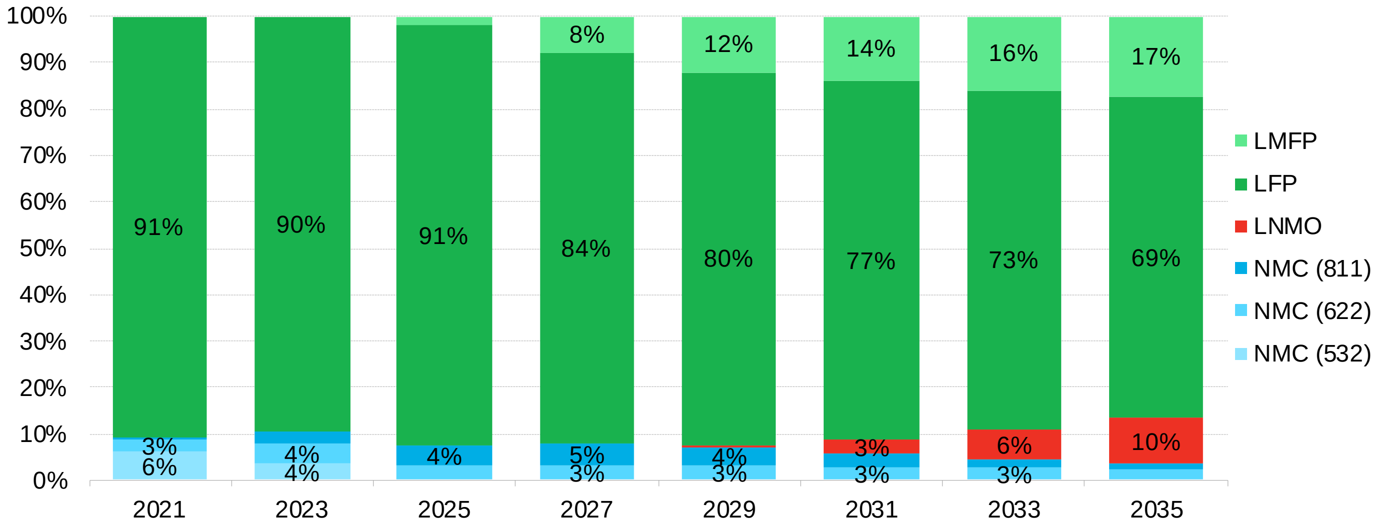
E-bus owners often prioritize total cost of ownership, rather than upfront price, encouraging the use of chemistries with a high cycle life, such as LFP

LFP remains the chemistry of choice for electric buses (Figure 210), as energy density is not as much of an issue in this segment. There is a preference in the e-bus sector for LFP given the improved safety, which is a more significant concern for the larger packs required in this market. The e-bus market is dominated by China, which accounted for 58% of e-bus battery demand in 2023 – another reason LFP is so prevalent.

Our outlook has remained largely the same for this segment compared to last year, though we have decreased the share of LNMO due its slower-than-expected progress and the continued improvement of LFP technologies. There has also been an increase in Chinese manufacturers selling e-buses into other markets as they look to expand on their domestic success.

As with commercial vehicle fleet owners, e-bus owners often prioritize the total cost of ownership, rather than the upfront price of the vehicle. This encourages the use of chemistries with a high cycle life, such as LFP. It also explains why 10% of the market uses cells with a lithium titanate oxide (LTO) anode, which is often expensive and has lower energy density but better cycle life. BNEF expects LMNO to break into the market toward the end of the decade and likely be paired with LTO anodes, with the combination offering both improved energy density and high cycle life.

Figure 210: Evolution of cathode chemistry mix for electric buses



Source: BloombergNEF. Note: LMFP refers to lithium manganese iron phosphate; LFP is lithium iron phosphate; LNMO is lithium nickel manganese oxide; NMC is nickel manganese cobalt oxide. See Appendix A for glossary of battery chemistries.

LFP's share in the e-bus market is expected to drop as more electric buses are sold outside China

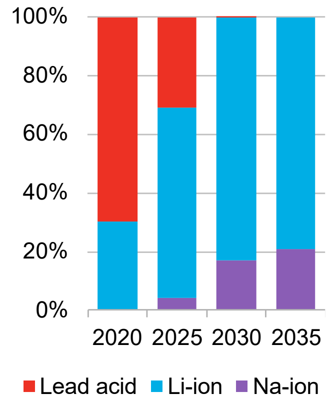
A number of e-bus manufacturers outside of China have opted for chemistries other than LFP. US-based Proterra had used NMC (811) cells from LG Chem for a number of years, although it went bankrupt in 2023 and its battery business was subsequently acquired by Volvo. In contrast, Chinese manufacturers, such as BYD and Yutong, already sell their vehicles at scale in many other markets around the world. The reduced adoption of LFP we anticipate in the 2030s reflects a growing share of e-bus sales outside of China.

The electrification of long-distance buses for intercity transport is not included in our outlook but would change the evolution of e-bus cathode chemistries. If a vehicle needed to travel over 300 miles, a more energy-dense cathode material could offer an advantage. BYD and CATL's new LFP pack designs, with a higher energy density, may also be enough to satisfy these needs.

Electric two- and three-wheelers

So far, the electric two-wheeler market is largely driven by the sale of scooters in China. The market will continue to grow as electric mopeds that currently use lead-acid cells switch to lithium-ion. China has implemented a policy to restrict the weight of e-bikes to below 55 kilograms, forcing manufacturers to shift from lead acid to more energy-dense technologies such as lithium- and sodium-ion batteries (Figure 211).

Figure 211: Evolution of electric two-wheeler battery mix



Source: BloombergNEF. Note: Li-ion refers to lithium ion; Na-ion is sodium-ion.

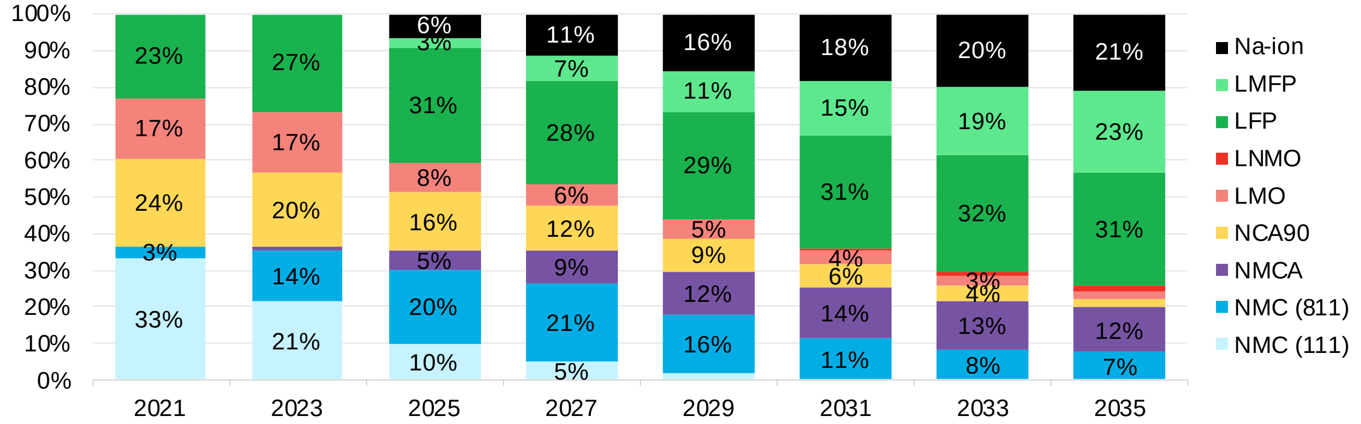
In Europe and the US, sales are driven by the adoption of electric motorcycles and scooters. For performance-oriented two-wheelers, such as motorcycles and high-end scooters, energy density is just as important as price, since this determines range. The wide variety of use cases in the two-wheeler segment results in an eclectic battery chemistry mix (Figure 212).

There is a relatively high proportion of lithium manganese oxide (LMO) in the two- and three-wheeler segment compared to passenger EVs, especially in the 2020s. Chinese manufacturer Phylion is one company leading the deployment of LMO-based cells in electric two-wheelers. Two-wheelers can use LMO more readily than passenger EVs because smaller packs do not face the same internal heating issues as larger ones. This mitigates some degradation processes associated with LMO.

BNEF expects the share of LMO to fall in the future as sodium-ion cells penetrate the market. Sodium-ion uptake may happen quickly, scaling up to 6% of the market in 2025 and 21% by 2035, from zero at present (Figure 211). This ramp-up for is less significant than expected in our last outlook, where BNEF expected sodium-ion to reach a 30% share by 2035, due to fewer-than-anticipated announcements from manufactures about this chemistry. However, the scale-up is still faster and higher than in any other EV segment due to the lower cost and reduced energy-density requirements for scooters and short-range three-wheeled vehicles.

The share of the market taken by LMNO is also much lower than in last year's outlook, reaching just 2% in 2035 versus the 10% previously envisaged, as LFP takes that market share instead. Energy density is more important for larger and more performance-oriented two-wheelers, such as motorcycles. High energy density cells are required to allow vehicles to travel a suitable distance without significantly increasing the vehicle weight.

Figure 212: Evolution of cathode chemistry for two- and three-wheeled electric vehicles



Source: BloombergNEF. Note: Na-ion refers to sodium-ion; LMFP is lithium manganese iron phosphate; LFP is lithium iron phosphate; LNMO is lithium nickel manganese oxide; LMO is lithium manganese oxide; NCA is nickel cobalt aluminum oxide; NMCA is nickel manganese cobalt aluminum oxide; NMC is nickel manganese cobalt oxide. See Appendix A for glossary of battery chemistries.

Anode chemistries

Our anode outlook is based on a bottom-up approach, with different anode technology adoption rates used for different vehicle segments. Next-generation technologies such as silicon-carbon composites are adopted at higher rates for vehicles with high performance requirements, such as large battery-electric vehicles and SUVs. Silicon and lithium are two materials with a higher 'specific capacity' than graphite and can offer battery cells higher energy density.

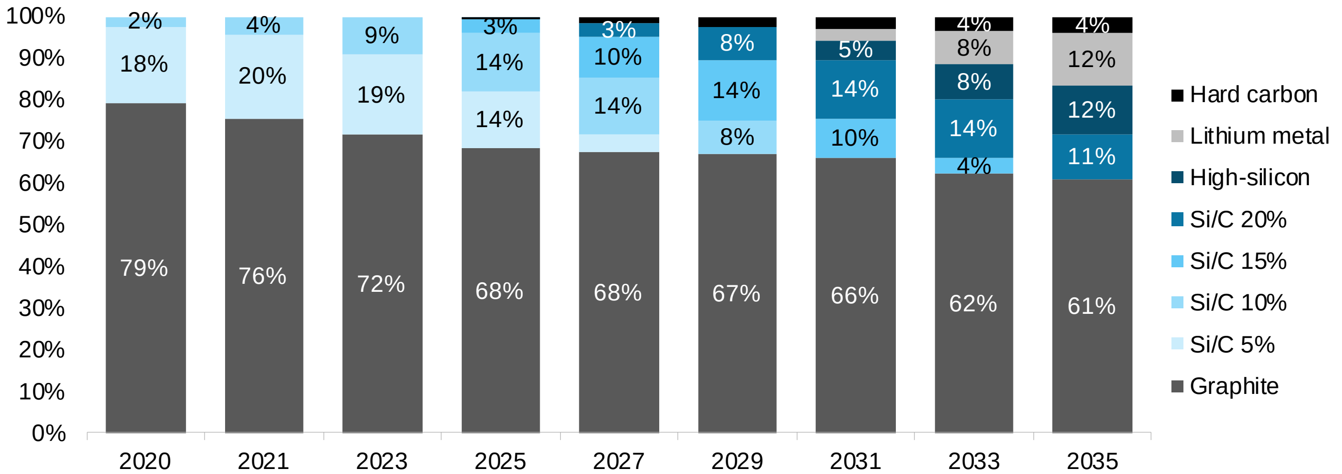
But silicon and lithium-based anode materials come at a higher cost, at least initially, due to raw material input costs, the sophisticated engineering required to incorporate them into cells, and the cost of scaling up their production with specialized equipment. Next-generation anode materials are more likely to be seen in higher-performing vehicles first, which particularly value energy density and are less sensitive to cost.

Silicon and lithium-based anodes can offer increased energy density but come at a higher cost

BNEF's latest anode chemistry mix is based on the announcements from the market and our expectation of when new anode materials like silicon or lithium metal could be introduced. Compared to last year's outlook, we have reduced the share of silicon-graphite composite anodes (Si/C) with 15% silicon composition from 2024, pushing its introduction to 2025 onwards given a lack of announcements about its adoption. We have also adjusted our expectation for lithium metal downwards, with it now only introduced from 2030 onwards, based on a more conservative view of the pace of manufacturing scale-up. Lastly, hard carbon has a smaller share in the near term as adoption of sodium-ion may take longer to scale.

BNEF expects **graphite** anodes to remain an important part of the battery industry into the 2030s (Figure 213). Their performance is well understood and they are particularly suited for applications where cycle life is important. Graphite is also a material with relatively low cost compared to silicon or lithium, with a well-established supply chain. The introduction of techniques like 'pre-lithiation' – which introduces extra lithium in the battery anode to compensate for the lithium loss seen during the first charge cycle – will also help cells using this material have improved energy densities.

Figure 213: Lithium- and sodium-ion electric vehicle battery anode chemistry outlook



Source: BloombergNEF. Note: Si/C refers to silicon-graphite composite anodes, with the silicon percentage expressed alongside. High-silicon refers to anodes using more than 50% silicon.

Silicon will play an important role in high-performance cells in the coming years, particularly where optimizing for high energy density is a priority. Companies like Tesla and Audi already use 5-10% silicon doping in their graphite anodes. Chinese companies like BTR New Material Group and Gotion High-Tech are also introducing anodes with silicon doping. **High-content silicon** anodes are likely to be introduced late this decade and would likely require optimized cell design. Companies like US-based Solid Power are planning on launching solid-state cells using this anode material.

Silicon will play an important role in high-performing vehicle segments, where optimizing for energy density is a priority

In the long run, BNEF expects **lithium metal anodes'** share of the market to grow and compete with high-content silicon anodes, due to the high energy density they provide, although speed of adoption may also be influenced by their technology readiness and future constraints on lithium supply. Lithium metal anodes are typically paired with solid-state electrolytes or advanced liquid electrolytes that do not have side reactions with lithium anodes, similar to those being developed by US-based SES. We include anode-less cells, like those being developed by QuantumScape, under our lithium anode section. This is because although no lithium foil is used during cell production, an excess of lithium is included in the cathode, which is then deposited onto the anode side during cycling.

Hard carbon emerges with the introduction of sodium-ion chemistry the technology mix. The two main anode technologies for sodium-ion batteries are hard carbon and sodium metal. Sodium metal is used in molten-salt batteries, which are unlikely to be used in vehicles, and hard carbon is used in most other sodium-ion technologies. BNEF's anode outlook assumes hard carbon is the anode technology of choice for the sodium-ion batteries seen in EVs.

Further reading

- *Technology Radar: Next-Generation Anodes* (web | terminal)
- *The Next-Generation Battery Tech Vying to Supercharge EVs* (web | terminal)
- *CATL Pushes Limits Again With New Fast-Charging Battery* (web | terminal)
- *Battery Startups 2022: Key Trends* (web | terminal)
- *Company Profiles: 2022 Battery Startups* (web | terminal)
- *Technology Radar: Sodium-Ion Batteries* (web | terminal)

8.4. Impact on battery metals supply

Lithium

Overall lithium demand from batteries is expected to reach 1.2 million metric tons of lithium carbonate equivalent (LCE) in 2024. China represents half of this demand, while 27% comes from Europe and 15% from the US.

There are two types of refined lithium products: carbonates and hydroxide. The carbonate product is mostly suitable for iron-based lithium-ion batteries, while the hydroxide product is often used in the manufacturing of high nickel chemistry batteries. Lithium carbonate demand is forecast to reach 2.6 million tons LCE in 2035, up 81% from 2023 (Figure 214). Meanwhile, lithium hydroxide demand is set to more than triple over the same period to 863,000 metric tons LCE (Figure 215). This brings overall lithium demand from batteries to just under 3.5 million tons LCE in 2035, nearly three times 2024 levels.

Prices of battery-grade lithium hydroxide dropped by more than 80% between January 2023 and May 2024, from around $80,000 to $14,000 per ton in the US and Europe. This crash reflects a sharp shift in fundamentals in the lithium market as supply has quickly started to outpace demand, in part due to slower-than-expected EV demand but also due to an uptick in supply of the metal. The astronomical rise in prices in 2022 meant that historically unviable sources of lithium, such as lepidolites, became commercially viable, and this was coupled with the expansion of existing projects in countries like Australia and Zimbabwe. The current lower price environment means that not all these new and expansion projects will be built, but their steady rise could extend the surplus in the market.

Figure 214: Lithium carbonate demand outlook

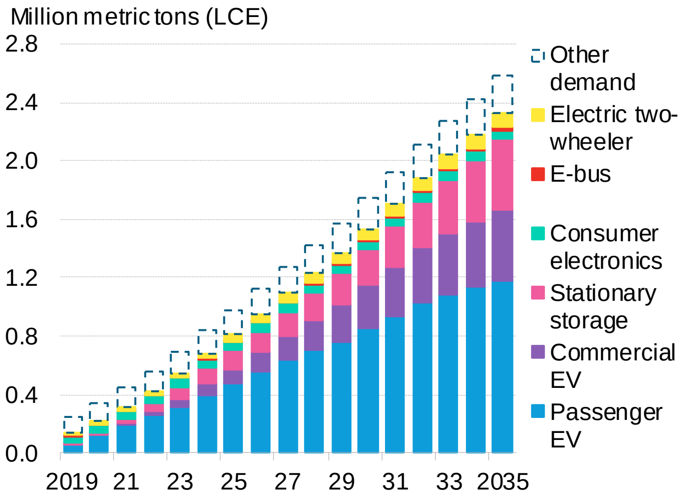
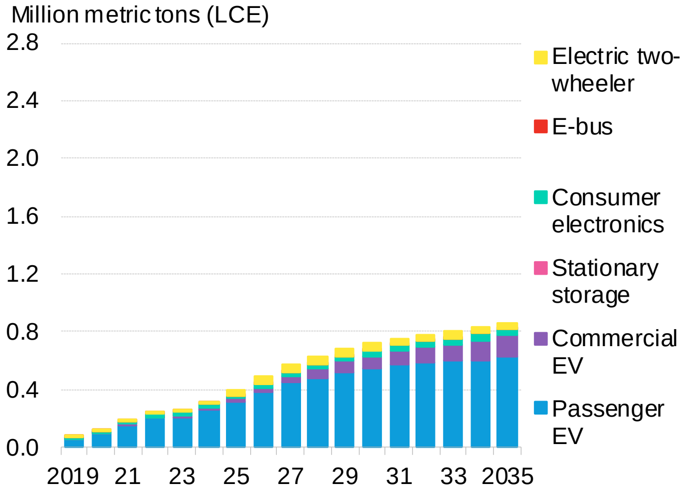


Figure 215: Lithium hydroxide demand outlook



Source: BloombergNEF. Note: Demand expressed in year of metal demand, which occurs about one year before battery demand. Demand also includes lithium used in the production of electrolytes. Battery demand for lithium has built-in material scrappage, and waste assumptions include an additional 5% waste material, 5% inactive material and 15% material loss during formation cycle. 'Other demand' (dotted box) includes technical grade used in industrial, pharmaceuticals, and other applications.

Lithium can be extracted from a range of resources, including hard rocks (spodumene and lepidolite) and brines. Extraction from spodumene deposits has been increasing at a faster rate than brine because the industrialized processes of hard rock extraction are easier to scale. There was also a surge of investment in extraction from the lower-grade hard rock lepidolite amid the high price environment between 2021 and 2022.

If direct lithium extraction (DLE) is successfully commercialized, the supply of lithium from evaporation and DLE technology will be comparable by 2030

Though extraction from brine requires lower capital investment, since it primarily needs large open-air ponds for evaporation, expansion is stunted by the limited availability of high-quality brines and the sometimes uncontrollable production conditions related to, for example, the weather or brine impurities.

Recently, there has been increased investment in direct lithium extraction (DLE) technologies for use on brines with lower quality. The lithium industry is eager to develop and deploy technologies that can rapidly ramp up lithium supply in a low-cost and sustainable way. DLE technologies aim to extract lithium from lower-quality brines at recovery rates greater than existing evaporation processes. The technology also provides scope for reducing production timelines from years to weeks and minimizing the environmental impact of extraction from brines primarily through lowering the use of freshwater and land. If DLE is successfully commercialized, the supply of lithium from evaporation and DLE technology will be comparable by 2030. However, this is dependent on the successful deployment of existing and emerging DLE technologies at scale.

Cobalt

Cobalt demand from batteries is expected to grow to 185,000 tons in 2035, from 158,000 tons in 2024 (Figure 216). Despite the decreasing cobalt intensity recorded in the last two years in the battery industry, as cobalt-free LFP battery penetration has risen, the long-term outlook for the metal remains strong. Over 60% of cobalt demand in 2024 is forecast to come from the lithium-ion battery industry.

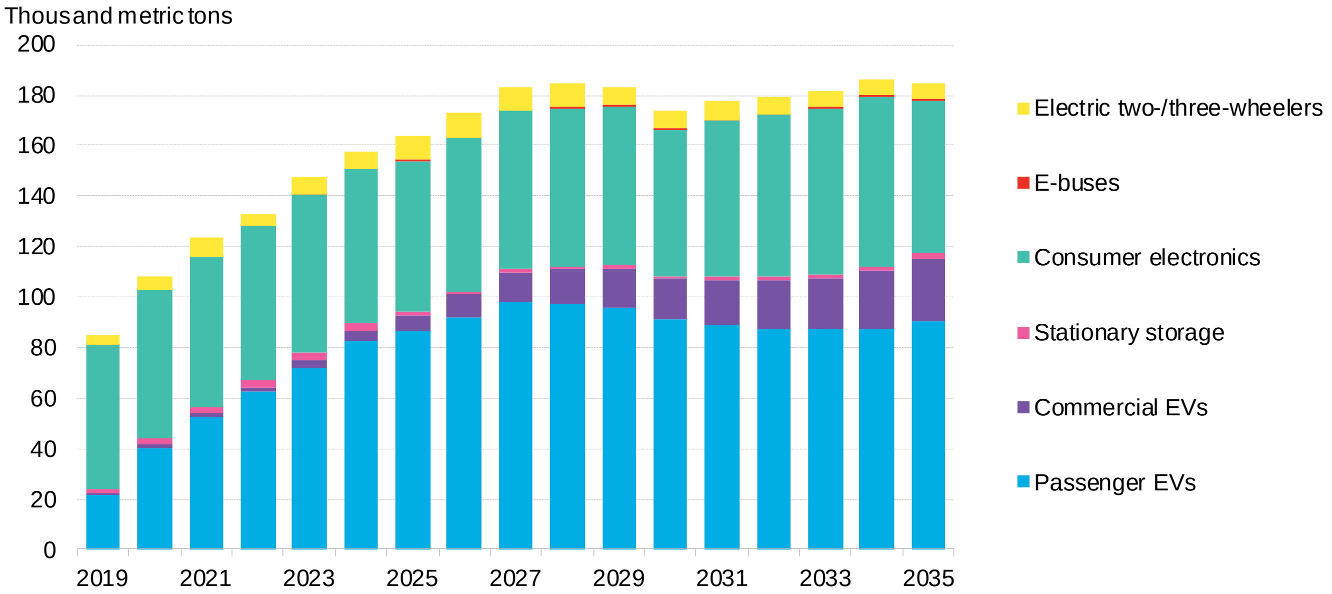
The Democratic Republic of Congo remains the largest cobalt producer at the mine level. Despite the slowdown in the country's artisanal production due to the slump in prices, new large-scale producers recorded high growth. CMOC Group (previously known as China Molybdenum) completed the Kisanfu project, which produced about 33,000 tons of cobalt in 2023, equivalent to 16% of global production.

Over 60% of cobalt demand in 2024 is expected to come from the lithium-ion battery industry.

Cobalt supply has significantly outstripped demand, which has led to prices falling from a peak of $80,000 per ton in 2022 to $26,000 per ton in May 2024. The downward trend is likely to continue this year as Indonesia ramps up supply from its high-pressure acid leaching plants. The country produced about 8,000 tons in 2023 and its output is expected to keep growing significantly this decade.

Domestic policies such as the US Inflation Reduction Act, coupled with other industry tailwinds, had pushed the US closer to developing its first domestic large-scale cobalt facility in decades. But Jervois Mining halted the construction of its Idaho Cobalt Operations mine in 2023, citing low cobalt prices and inflationary impacts on construction costs. Other countries outside Indonesia and the DRC looking to build new capacity might also struggle in this low-price environment.

Figure 216: Cobalt sulfate demand outlook



Source: BloombergNEF. Note: Demand is expressed at mine mouth, approximately one year before battery end-use demand.

Nickel

The global nickel market is dealing with supply shocks in an environment where prices are likely to remain low. Nickel used in lithium-ion batteries is expected to grow to about 1.1 million tons by 2035, from around 517,000 metric tons in 2024 (Figure 217). Despite the year-on-year decline in BNEF's projections for nickel-based battery chemistries (given higher LFP penetration), the long-term prospects of the metal's demand remain significantly high. China currently consumes about a third of the high-purity nickel used in batteries.

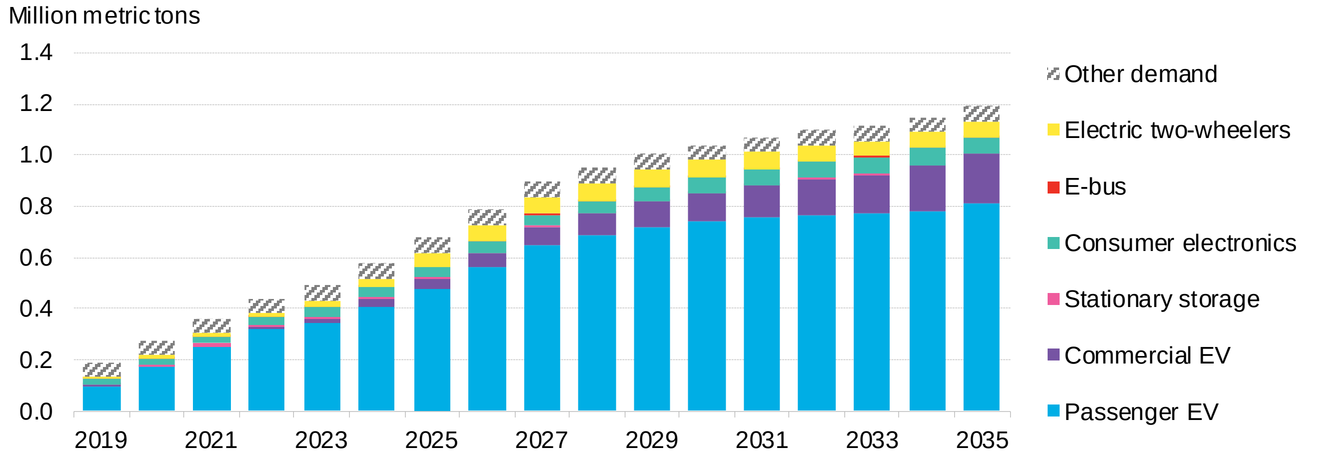
China is expected to maintain its lead in nickel sulfate refining capacity, with a more than 50% share of the global total by 2030

China is expected to retain its lead in nickel sulfate refining capacity globally, with a more than 50% share by 2030. Indonesia rises to take the second spot as its capacity grows from zero in 2022 to 255,000 tons annually by the end of the decade. China-based battery materials supplier CNGR invested heavily in nickel matte smelters in Indonesia to secure feed material for its nickel sulfate refineries. CNGR is estimated to remain the largest nickel sulfate producer by 2030.

China-based companies take up the next three spots – Tsingshan, GEM Co. and Huayou Cobalt – while Indonesia-based Trimegah Bangun Persada, the subsidiary of which is Harita Nickel, rounds out the top five. Four of these top five producers had no nickel sulfate capacity in 2018. The massive scale-up in investment activity has given rise to new major producers globally, as well as leading to a decline in prices recently.

The nickel market has been hit by a slew mine suspensions and closures so far in 2024. These have been driven by the decline in prices, with 2023 being the worst year on record since 2008. Nickel prices have dropped to $19,000 per ton on the London Metal Exchange, from $30,000 per ton at the beginning of last year. This has primarily been driven by Indonesia's rapid capacity additions from 2021. BNEF sees additional nickel assets being at risk of supply curbs this year, although the potential operational suspensions will not have an immediate impact on the market. Supply from Indonesia will likely keep growing, exerting downward pressure on prices despite the recent shocks to supply.

Figure 217: Refined battery-grade nickel demand outlook



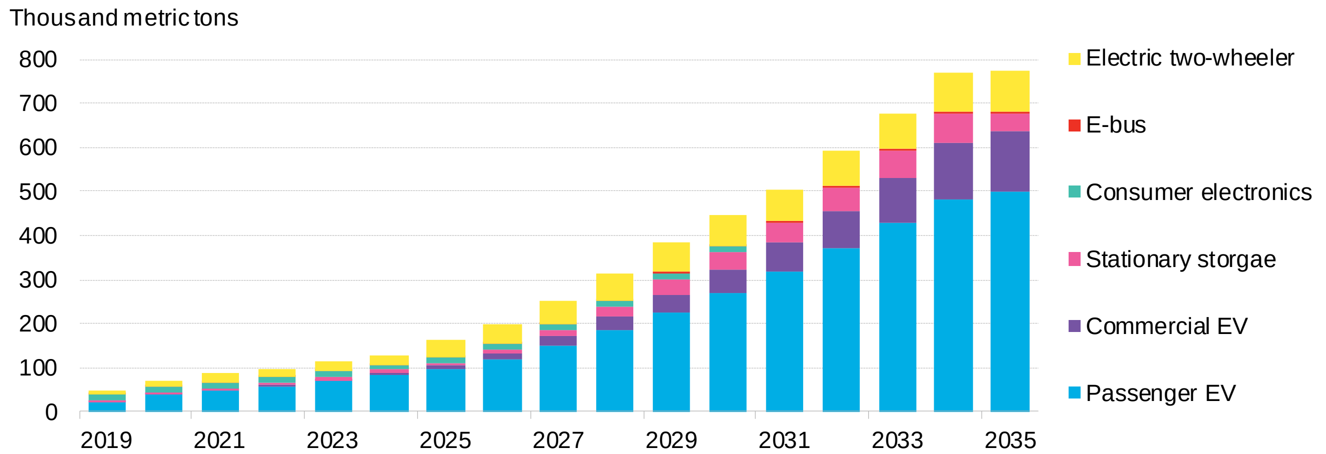
Source: BloombergNEF. Note: Demand is expressed at mine mouth, approximately one year before battery end-use demand.

Manganese

Manganese sulfate demand is expected to grow to 787,000 tons in 2035, from just 131,000 tons in 2024 (Figure 218). This is lower than our outlook from last year due to BNEF's upward revision of LFP battery adoption, which does not use manganese.

A lack of new manganese sulfate plants continues to pose a risk to the industry. Top manganese producer South Africa is working on building its downstream capacity. Canada-headquartered Giyani Metals Corp. secured a funding package of $26 million to develop Africa's first low-carbon, battery-grade manganese sulfate project. Some $16 million is from South Africa's Industrial Development Corporation and the remainder from private equity player ARCH Sustainable Resources Fund. The capital will feed into the process of Giyani taking a final investment decision on its flagship K.Hill project in Botswana and the commissioning of the demonstration plant in South Africa to produce 'high-purity manganese sulfate monohydrate'– a precursor material used by lithium-ion battery manufacturers.

Figure 218: Manganese sulfate demand outlook



Source: BloombergNEF. Note: Demand is expressed at mine mouth, approximately one year before battery end-use demand.

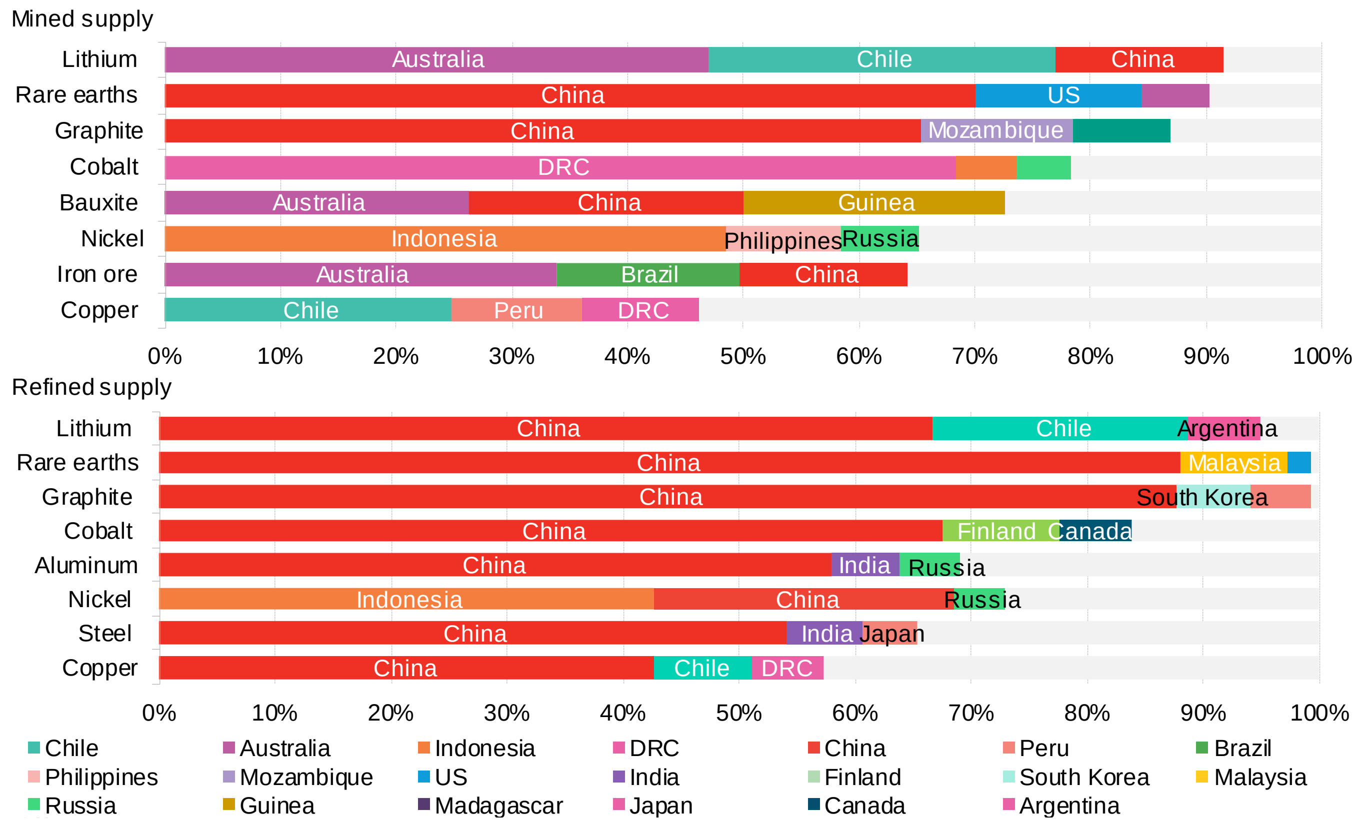
Supply chain diversification

Onshoring efforts in the US, EU and India have yet to bear fruit as China dominates new battery factory capacity

China currently controls a significant portion of the downstream processing of battery raw materials (Figure 219). The US, EU and India are among those most eager to onshore production and each is employing a range of policy instruments, including trade barriers, local content targets and manufacturing subsidies. But their approaches have yet to bear fruit: an overwhelming majority of the world's new factories are still starting up in China.

For metals, there has been an increased push by countries through incentives and national policies to refine and process ores into finished products domestically. This is likely to marginally improve the diversification of existing supply chains. However, in the medium term, China's dominance is likely to remain strong due to the country's cheap cost of manufacturing.

Figure 219: Market share of top three suppliers of transition metals in 2022 – mined and refined supply



Source: BloombergNEF, US Geological Survey, Bloomberg Intelligence, World Steel Association, Iluka Resources, Adamas Intelligence, Lynas Rare Earths.

Further reading

- *Direct Lithium Extraction on the Cusp of Commercialization* (web | terminal)
- *Global Class 1 Nickel Outlook 2023-2030* (web | terminal)
- *1H 2023 Battery Metals Outlook: Shift In Demand Dynamics* (web | terminal)
- *Data Hub: Metals Mine Assets Map* (tool)
- *Data Hub: Metal Refinery Supply Forecast* (tool)
- *Battery Price Sensitivity Tool* (web | terminal)

8.5. Comparison with Net Zero Scenario

Battery demand

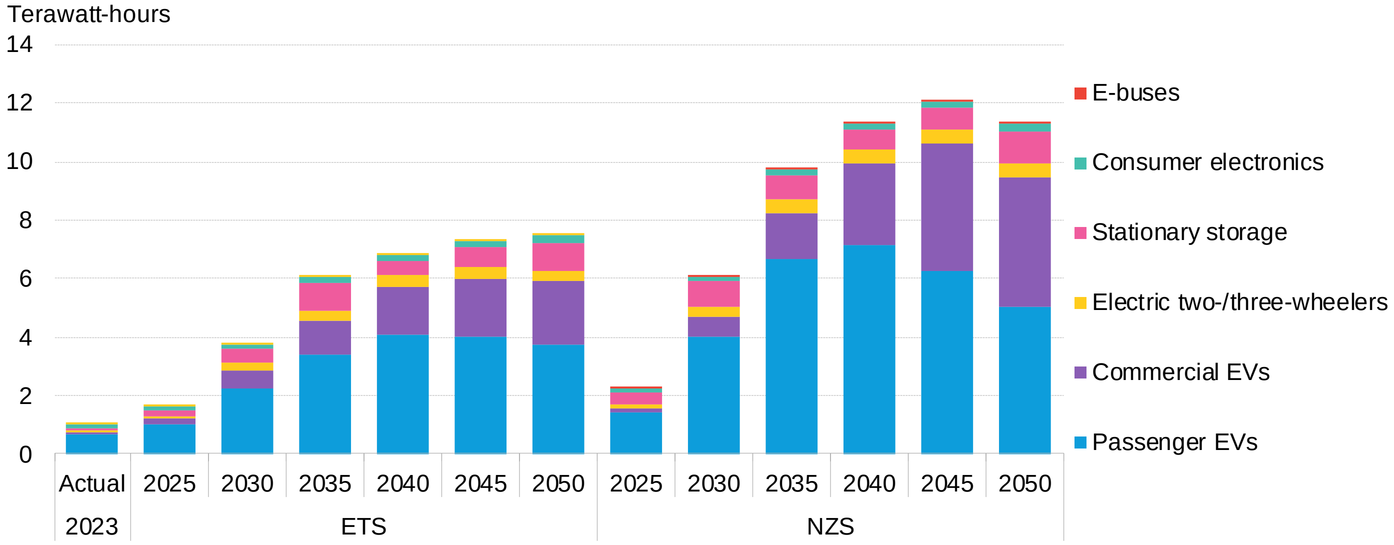
Annual battery demand for road transport peaks at 11.1TWh in 2045 in the Net Zero Scenario

In our Net Zero Scenario (NZS), cumulative demand for lithium-ion batteries from road transport is 1.6 times that of our Economic Transition Scenario, reaching 215TWh by 2050 (Figure 220). Annual demand peaks around 2045 at 11.1TWh and then settles at 10TWh by mid-century. This peak is due to the sales surge needed to be able to switch the fleet from combustion engines to electric drivetrains ahead of 2050, followed by a slowdown as the market approaches saturation. Overall vehicle sales also start to slow noticeably over this period due to urbanization, shared mobility, autonomous vehicles and demographic changes.

Battery prices in the Net Zero Scenario

We have used the same battery prices in both our base-case Economic Transition Scenario and Net Zero Scenario. The additional volume of battery demand in the NZS could, in theory, push lithium-ion battery prices further down the experience curve and lead to lower prices. We have opted to keep prices the same as in the base case due to the extreme increase in battery material demand outlined above, which will likely cause prices to rise in the near term, though manufacturers will adjust their battery chemistry mix and may change battery pack sizes accordingly, which could cancel out some of the price gains that would otherwise be seen.

Figure 220: Annual battery demand outlook under BNEF's Economic Transition Scenario and Net Zero Scenario



Source: BloombergNEF. Note: Consumer electronics and stationary storage demand are assumed to be the same under both scenarios. ETS is the Economic Transition Scenario; NZS is the Net Zero Scenario. Stationary storage battery demand in the NZS is from BNEF's New Energy Outlook 2024 (web | terminal), which shows accelerated buildout in the 2020s to accompany the ramp-up in solar and wind, followed by an uneven buildout in the following decades.

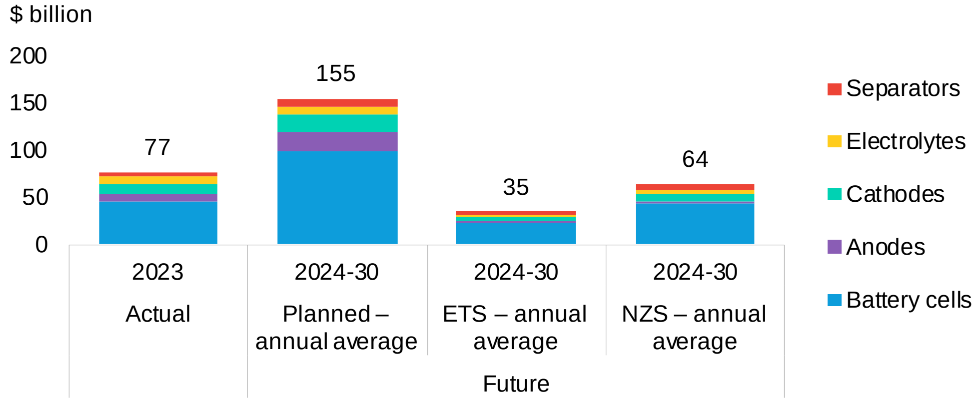
Battery manufacturing investment

The rapid anticipated increase in demand for lithium-ion batteries requires significant investment in battery manufacturing and related supply chains. Between today and 2030, the ETS sees at least $242 billion needing to be invested across the battery manufacturing value chain to support battery demand, equivalent to $35 billion annually. This jumps to $448 billion in the NZS, or $64 billion annually (Figure 221). Based on planned investment across this period, more than enough capital has been committed, totaling $1.1 trillion (averaging $155 billion annually), equivalent to 2.4 times what is needed under NZS.

Announced investment across the battery manufacturing value chain to 2030 exceeds $1 trillion, more than double what is needed in the Net Zero Scenario

Investment over the last few years has been very high. BNEF estimates $77 billion was invested in battery factories last year, more than the annual investment needed looking ahead in both the ETS and NZS. This indicates battery manufacturers have been rapidly investing in new capacity ahead of new demand. Battery cell and component manufacturing capacity is not currently the bottleneck in the industry today and if the rate of investment in this part of the value chain continues, we may see instances of cell and component overcapacity constrained by raw materials supply or by battery demand.

Figure 221: Annual battery factory investment, by scenario



Source: BloombergNEF. Note: ETS is Economic Transition Scenario; NZS is Net Zero Scenario. Battery factory requirements include investment needed to meet electric vehicle demand and stationary energy storage. Planned investment based on companies' factory announcements benchmarked by respective regional capital expenditure. ETS and NZS are based on China capex estimates.

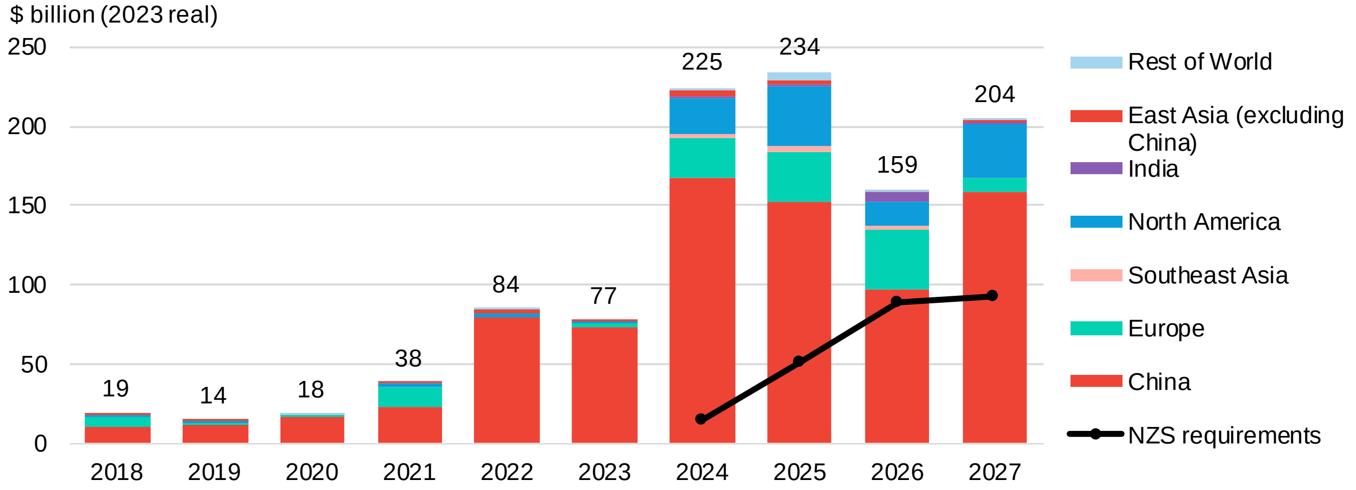
For this analysis, we considered companies' factory announcements for the planned investment across 2024 to 2030 and applied a regional capital expenditure assumption, stacking global investment from regional announcements (Figure 222). Capex assumptions are higher for the US and European markets, and lower in markets like India and Thailand.

Comparatively, for the ETS and NZS future annual estimates, we applied a weighted global capex benchmark for ETS and NZS investments, thereby avoiding taking a view on *where* factories will be brought online. These benchmarks are held constant over the measured periods. For batteries, because so much of the value chain has historically been built in China, where capex is generally lower, it means these values should be interpreted as a lower bound of what investment will actually look like in any of these scenarios. Even if we equalized capex in the regional planned investment analysis, there would still be outsized investment planned relative to what is still needed this decade in the ETS and NZS scenarios.

More generally, however, as noted in the section above on *Battery manufacturing and supply chains*, a significant push by nations to onshore supply chains will likely lead investment to be higher than the ETS and NZS analysis above.

This year, BNEF has updated its battery manufacturing investment analysis for the ETS and NZS to add utilization assumptions for future manufacturing capacity, ranging from 40% to 80% depending on the year and component, since plants do not typically run at 100% of their nameplate capacity. This inflated required capacity compared to last year's analysis. We also included planned investment and adjusted future investment to real 2023 dollars.

Figure 222: New and planned lithium-ion battery factory investment, by region



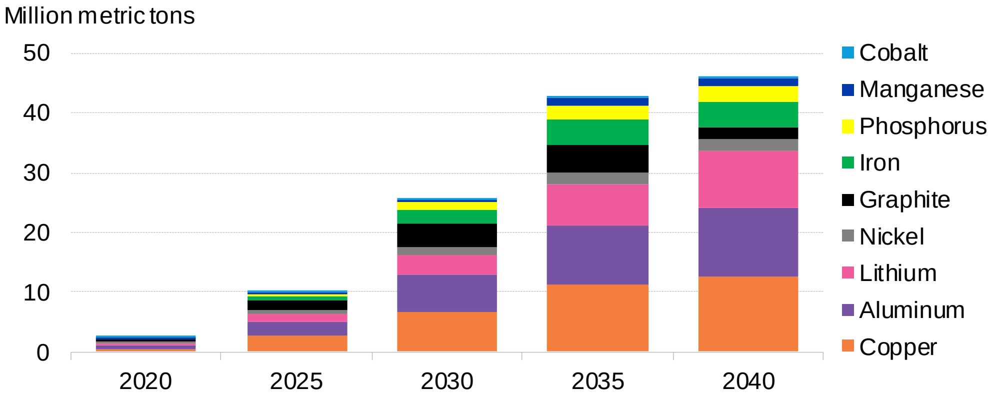
Source: BloombergNEF. Note: Includes battery cell, anode, cathode, electrolyte and separator plants. Net Zero Scenario here refers to BNEF's pathway to net-zero emissions by 2050 from the New Energy Outlook 2024 (web | terminal).

The mass of metals going into lithium-ion batteries rises to 46 million tons by 2040 in the Net Zero Scenario, from 9 million tons in 2024

Battery metals demand

Battery metals demand increases significantly under the NZS. The mass of metals going into lithium-ion batteries rises to 46 million tons by 2040, from 9 million tons in 2024. Copper, aluminum and lithium form the largest part of this total by weight, with 12.8 million tons of copper required in 2040, 9.4 million tons of lithium and 11.4 million tons of aluminum (Figure 223).

Figure 223: Annual metals demand from lithium-ion batteries under the Net Zero Scenario

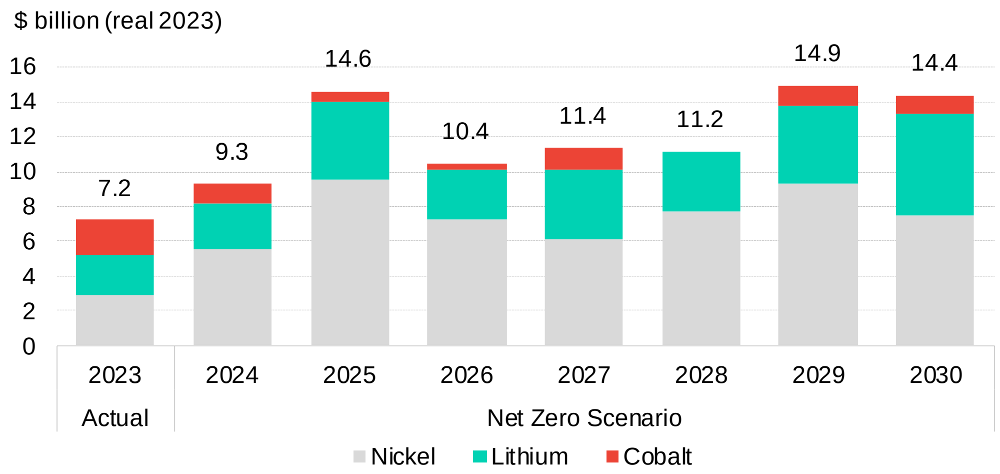


Source: BloombergNEF. Note: Lithium is expressed in million metric tons lithium carbonate equivalent (LCE). Note: Demand occurs at the mine mouth, one year before battery demand.

This rapid growth in demand needs a corresponding increase in supply. If this fails to materialize, prices could rise quickly, driving up battery costs and slowing the transition to EVs. Recycling could help alleviate the need for new mines to meet this exponential increase in demand.

Mining and metals companies are ramping up investment in supply to ensure there is adequate capacity to meet growing demand from the energy transition. Under the NZS, investment in new capacity has two waves, with a peak in 2025 and another in 2029. The scale-up in investment to 2025 leads to overcapacity for some metals such as nickel and cobalt. The upstream (mining) attracts majority of the investments this decade. This is likely to expose the midstream (refined products) to potential deficits. There is already adequate investment planned to meet the additional raw materials demand required for net zero for most of the decade until 2028. Investment in new capacity will be needed to ensure supply meets demand beyond 2030.

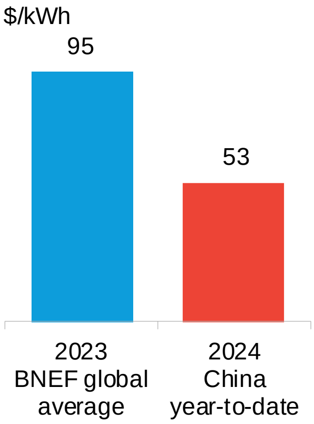
Figure 224: Battery metal mining and refinery investment – actual and required under Net Zero Scenario



Source: BloombergNEF. Note: Includes mines and processing facilities. Nickel is battery-grade.

Thematic Highlight
China's Low-Cost Battery Push

Figure 225: Lithium iron phosphate (LFP) battery cell prices



Source: BloombergNEF, ICC Battery. Note: 2023 price from BNEF's Lithium-ion Battery Price Survey. 2024 price from Jan-Apr from ICC Battery.

BNEF tracks global lithium-ion battery prices on an annual basis and found that pack prices dropped 14% in 2023 on a volume-weighted average basis, to $139/kWh, across electric vehicle and stationary storage segments (reviewed in Section 8.2). While already a significant drop, monthly battery price data for China reveals a more striking decline over the course of the year, one that is reverberating in the electric vehicle market there. China LFP cell prices for electric vehicles are now barely half the global average price in 2023 (Figure 225). Battery cell prices dropped between 41% to 50% across different battery chemistries, and by 37% to 44% for packs within 2023 (Figure 226, Figure 227). So far in 2024, prices have continued to fall, albeit at a slower rate.

Pack prices have been consistently below $100 a kilowatt-hour in China since September 2023, for both LFP and (non-high-nickel) NMC packs, a major milestone for the industry. China has the cheapest batteries in the world due to the maturity of its battery manufacturing sector, prevalence of lower-cost chemistries (LFP) and fierce competition. North American and European battery packs averaged 11% and 20% higher than China in 2023, at $140 and $151 per kilowatt-hour, respectively.

This thematic highlight explores factors driving the drastically low battery prices in China, what conditions will enable prices to remain low, overall impact on EV uptake in China and broader implications for the EV industry. Economies of scale, low metal prices, overcapacity and slower-than-expected EV demand are major factors driving low prices in China. These low prices should provide some upside for EV demand, but not to the extent that it solves the growing overcapacity in the sector. Additionally, low prices impose a challenging outlook for domestic battery makers in China who are facing declining margins and an increasingly complex global political environment.

Figure 226: Observed China EV battery cell prices

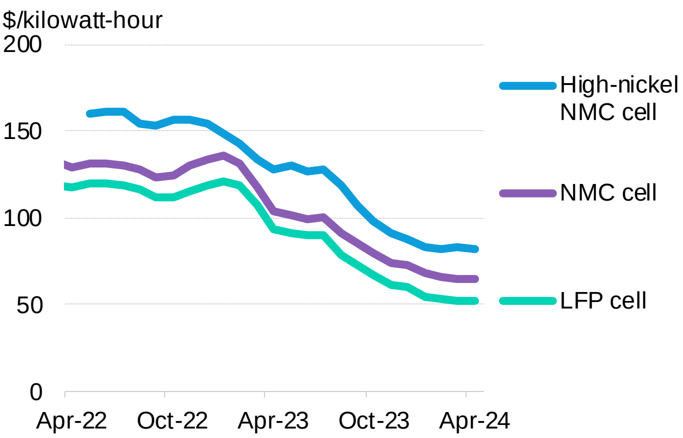
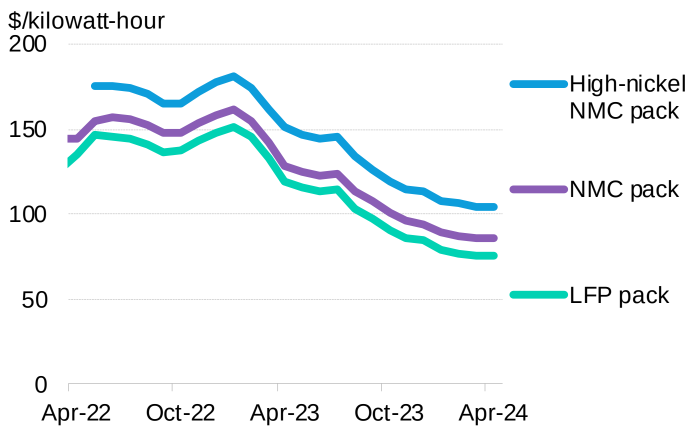


Figure 227: Observed China EV battery pack prices



Source: ICC Battery, BloombergNEF. Note: All cells mentioned here are in prismatic format and exclude taxes. NMC includes NMC111, NMC532, NMC 622. High-nickel NMC includes NMC811, NMC955, and NCA.

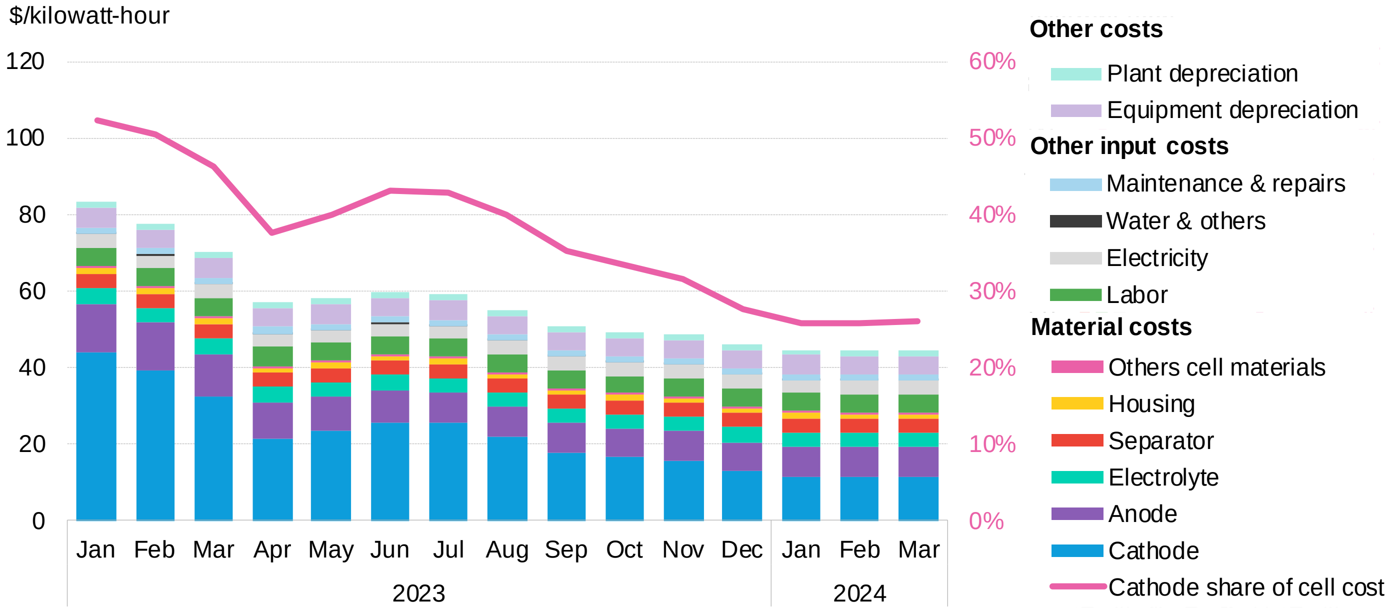
Low battery metal prices

Metals prices have fallen due to supply and demand dynamics covered in Section 0. As metal prices drop, their contribution to overall battery costs decreases, along with cathode prices, since the cathode prices are highly dependent on metal prices. In January 2023, lithium iron phosphate (LFP) cathodes accounted for more than 50% of the cost of manufacturing a $83/kWh cell. That has steadily dropped to less than 30% in 2024 (Figure 228).

We have focused on LFP because it is the chemistry whose prices dropped the most from January 2023 to March 2024, and due to our more bullish outlook for the chemistry together with the role it will play in driving mass EV adoption. Unlike NMC and high-Ni NMC, LFP's manufacturing cost benefits from simpler raw material combinations, in which lithium carbonate plays the most significant role. Therefore, the LFP price is more closely tied to fluctuations in the lithium prices. Aside from raw material price, manufacturing scale is another key factor in reducing the production cost. Therefore, BNEF attributes LFP cell price declines in China to both cheaper lithium, as well as a huge amount of commissioned capacity coming online last year.

Given lower material prices, other non-material input costs and depreciation have become a bigger portion of battery cell manufacturing costs. Battery makers capable of lowering those costs are at an advantage and can therefore offer lower prices. This means improving manufacturing efficiency to reduce labor costs, use less electricity and water and require less maintenance overall. This is true even if they don't have high purchasing power to bargain for lower material costs, since these are now a lower share of cell costs. Bidding for high-volume orders has therefore become more important than in the past, since manufacturing efficiency gains are best achieved through optimizing equipment to achieve higher utilization rates and lower scrap rates. This ends up feeding into a cycle of lower prices, because offering low cell prices is an effective strategy when bidding for a large deal in a very competitive market.

Figure 228: Lithium iron phosphate (LFP) battery cell manufacturing costs by component and cathode share of cell cost



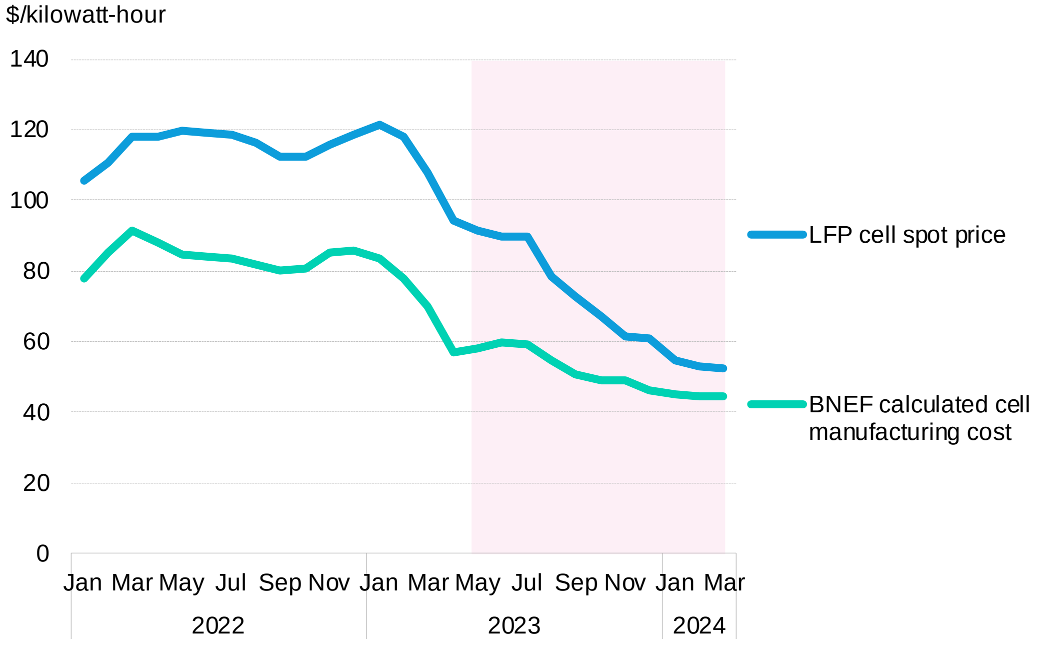
Source: BloombergNEF, ICC Battery. Note: The cost breakdown uses BNEF's BattMan Cost Model to calculate the production cost of a 120Ah LFP and artificial graphite prismatic cell produced in a 10GWh LFP battery cell plant located in China. Cathode costs are adjusted using the cathode spot price from ICC Battery.

Battery prices are usually linked to metal prices, but delinking occurs when the supply-demand relationship drastically changes. The pink area in Figure 229, between April 2023 and February 2024, is a period in which cell spot prices dropped faster than the decline of battery cell manufacturing costs. The cell prices even dropped when raw material increased in April to June 2023. That squeeze indicates the market's willingness to offer lower prices at lower margins.

Looking forward, we have reached a point where the difference should stabilize at this level for a while. Currently, battery metal prices are stable and cell prices have been low enough to push out small players. This year, 2024, is quite important for manufacturers to stand out from their peers and survive, so low cell prices will likely remain until unqualified and less well-established players quit. This will lead to a rebalancing of demand and supply, probably more than a year out into the future.

There are a number of external factors which can destabilize the price and cost relationship. Geopolitical risk, natural disasters and interest rates impact all companies, while foreign-exchange rates can have a high impact on any companies looking to operate across multiple countries.

Figure 229: China LFP cell spot price and BNEF LFP cell calculated manufacturing cost



Source: ICC Battery, BloombergNEF. Note: The cell mentioned here is in prismatic format and excludes taxes. LFP spot price comes from the ICC Battery price database, where spot price is based on reported quotes from companies, battery cell prices could be even lower if batteries are purchased in high volume. Estimated cell manufacturing cost uses the BNEF BattMan Cost Model, adjusting LFP cathode prices with ICC cathode spot prices. The cost here refers to manufacturing cost which is different from price and does not include company expense, delivery cost, subsidy, and margin.

Overcapacity as demand slows and factories come online

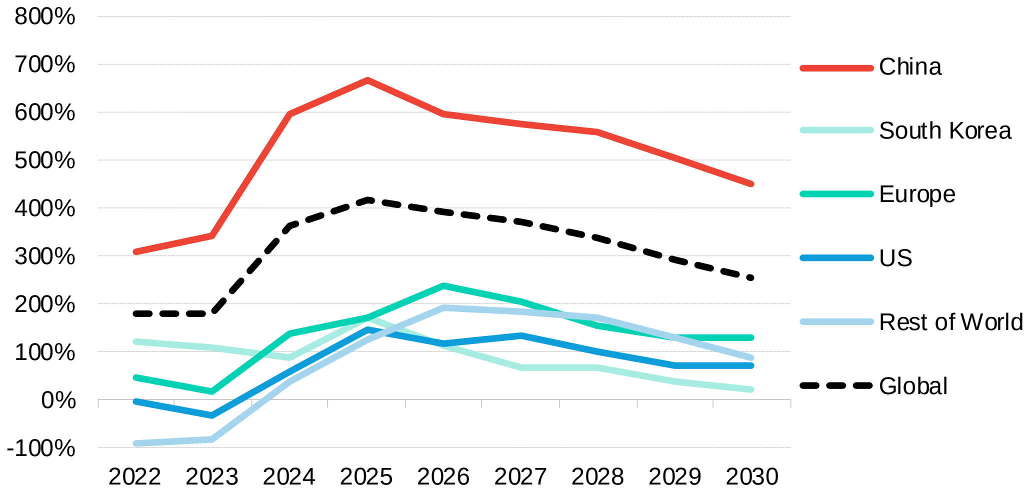
Battery manufacturers are facing price pressure in large part due to the competitive dynamics caused by the massive overcapacity in the market today and in coming years. Planned lithium-ion cell manufacturing capacity by the end of 2025 is 7.9TWh – over five times the 1.5TWh global battery demand expected that year. Overcapacity is a big issue for battery makers, especially as many manufacturers are still announcing ambitious plans to expand. Smaller manufacturers are being challenged by their peers, and even battery giants like CATL and Eve Energy are announcing ever-lower cell prices to fight for market share.

Capacity within China was already more than three times domestic demand in 2023, which would rise to more than six times in 2025 if all factories planned were to come online

Most overcapacity is in China. China had 2.2TWh of global cell manufacturing capacity in 2023, representing 86% of global capacity, and has 6.0TWh planned by the end of 2026. Capacity within China was already more than three times domestic demand in 2023, and that would rise to more than six times in 2025 if all factories planned were to come online (Figure 230). These overcapacity values may be overstated, as not all capacity will come online as announced. On the other hand, the further out we look in this period, from 2027 onwards for example, the higher the possibility of new announcements which are not yet accounted for in our data.

With falling battery prices and declining margins in 2022 and 2023, battery manufacturers supplying to electric vehicles sought ways to enter new markets, including energy storage, while also eyeing overseas markets willing to pay more for batteries, including the US, Germany, Italy, and South Africa.

Figure 230: Lithium-ion battery cell manufacturing overcapacity ratio from 2022 to 2030



Source: BloombergNEF. Note: Overcapacity ratio based on the manufacturing capacity over the same year's demand. Demand is based on BNEF's EVO 2024. Nameplate manufacturing capacity as of May 9, 2024. Includes plants that are fully owned by battery makers, as well as joint ventures with automakers, however, pack assembly plants are excluded. 2023 manufacturing capacity includes only fully commissioned capacity. Future capacity is based on non-de-risked capacity tracked by BNEF's battery manufacturing database based on commissioning date before December 31 of respective years.

Table 16: Surplus (deficit) Chinese lithium-ion battery cell production relative to global demand

	EV	ESS
2018	(-40%)	(-34%)
2019	(-37%)	(-15%)
2020	(-55%)	(-33%)
2021	(-40%)	42%
2022	(-11%)	181%
2023	(-17%)	93%

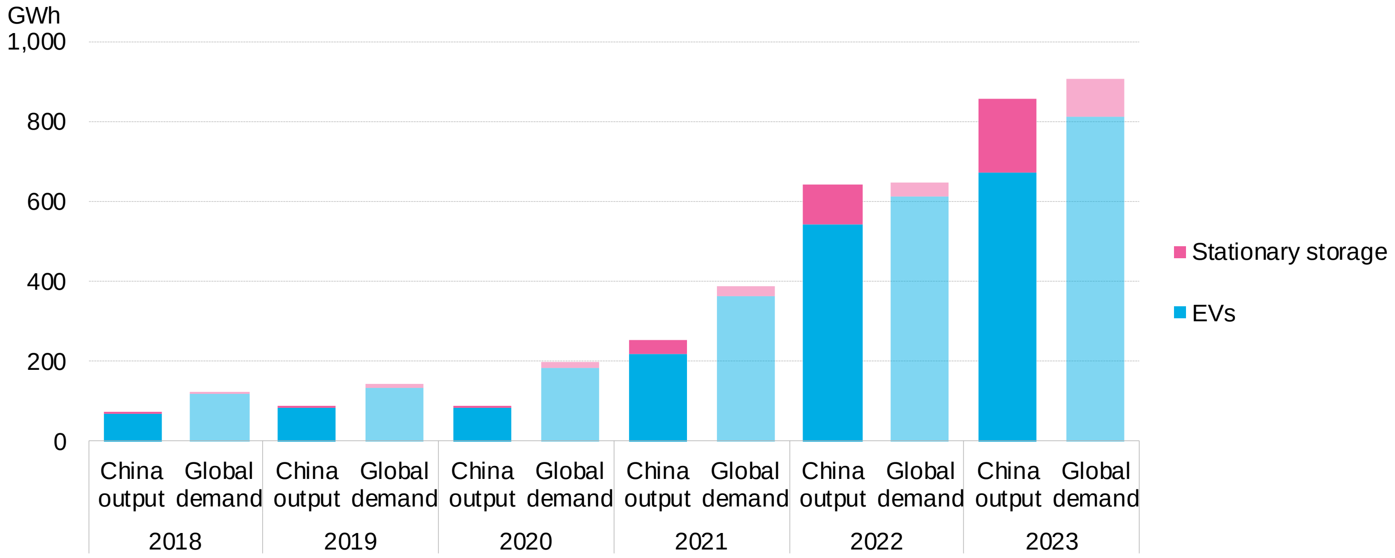
Source: BloombergNEF

Despite these overcapacity dynamics, not every segment has seen over-production. China's overall cell production has been enough to meet at least 90% of global battery demand for the last two years (Figure 231), but while it produced a surplus of batteries for stationary storage in recent years, China has not produced surplus EV batteries relative to global EV demand (Table 16). EV manufacturers in markets like Europe and the US are still sourcing cells from within their markets or from outside of China.

For EV batteries, oversupply is not likely to become systemic. Usually, EV batteries are co-developed by EV and battery manufacturers, since EV cells are more specialized and can be custom designed for specific models or EV platforms. This means that shipments of an EV cell are dependent on sales volumes of the models that cell powers, which are a function of the OEM's success in selling to consumers. Close collaboration with OEMs means that a battery maker is unlikely to manufacture a surplus of EV cells, and the low utilization of specific production lines may be less the function of cell manufacturers' ability to sell low-cost batteries and could be more due to poor sales by EV manufacturers.

For stationary storage cells, China has produced more than enough batteries each year to meet annual global demand since 2021. Stationary storage projects have longer deployment timeframes than EVs, meaning cells produced one year may be installed in the following year. Therefore, to consider if the storage market is oversupplied, future demand growth and a multi-year view must be taken. Also, compared to EV cells, ESS cells are more commoditized because of product similarities. Oversupply became a risk for stationary storage from 2021, as the majority of these battery cells are prismatic LFP cells. For EV batteries, there are several cell formats and chemistries.

Figure 231: China lithium-ion battery cell production and global lithium-ion battery demand



Source: BloombergNEF, Ministry of Industry and Information Technology, China automobile battery innovation alliance. Note: Solid is China production and shaded is global demand

The ease of entering the stationary storage market for Chinese manufacturers has also led to falling utilization rates for smaller cell manufacturers (Figure 233). The utilization rate is calculated based on the ratio of China's actual production to overall commissioned capacity. Of the past three years, China's average utilization rate was highest in 2022 at 51%, but dropped in 2023 to around 43%.

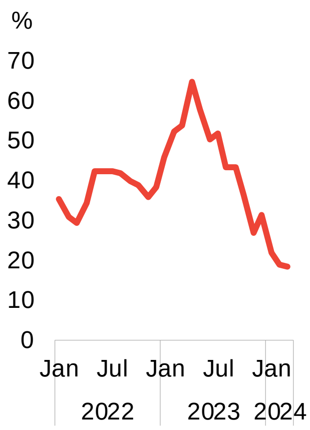
China average utilization rate was highest in 2022 at 51%, but dropped in 2023 to around 43%

Top-tier manufacturers followed the same trend, running at around 61% in 2023, dropping from around 69% in 2022, respectively. The analysis includes production from Chinese battery makers overseas (such as CATL's plant in Germany), due to lack of disclosure of more granular data, though production and capacity overseas to date is comparatively small.

An industry is regarded as at overcapacity when the utilization rate is lower than 70%, so even top manufacturers in China are facing overcapacity issues right now, assuming disclosed nameplate capacities of their plants are correct. These conditions are likely to remain until manufacturing capacity expansions slow, which they are not expected to do before 2025 based on company announcements.

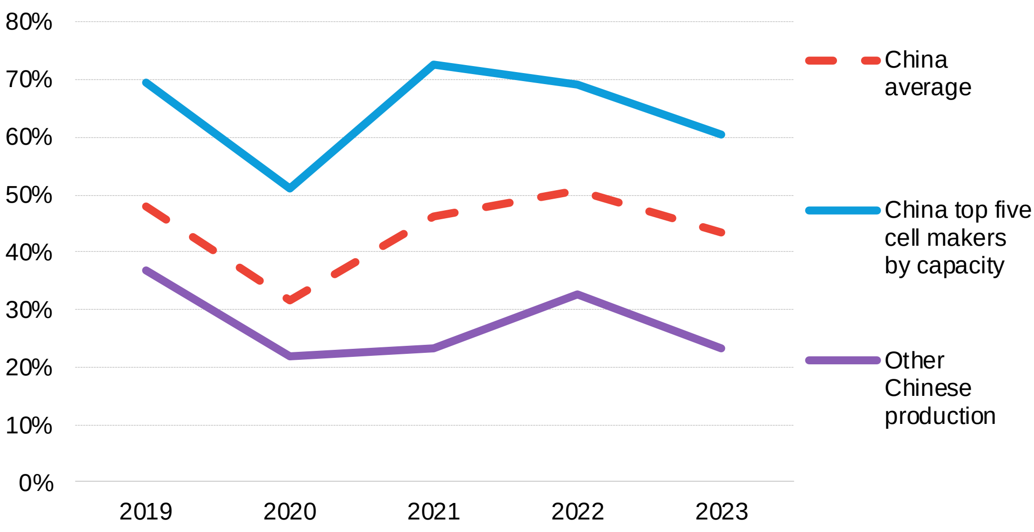
Domestic EV demand growth is slower because the EV adoption rate has reached a point where accelerating demand growth is much harder than before (further explored below). Meanwhile, geopolitical tensions and localization policies overseas are making it harder for Chinese manufacturers to export to markets like the US.

Figure 232: BNEF-estimated margin for EV LFP cells in China



Source: BloombergNEF, ICC Battery. Note: BNEF calculated LFP cell manufacturing cost relative to ICC Battery LFP cell spot prices.

Figure 233: Utilization rates of Chinese battery manufacturers



Source: BloombergNEF. Note: The top five manufacturers selected based on their manufacturing capacity in BNEF database include CATL, BYD, CALB, Eve Energy and Gotion. The chart does not exclude top manufacturers' production facilities and production output outside China.

BNEF calculated margins indicate that they have been heavily squeezed, from a high of 65% in April 2023 to 18% in March 2024 (Figure 232). Though they are still positive, these margins do not consider costs such as research and development, overheads at the corporate level, shipping and may understate costs at an individual factory level given overcapacity risks mentioned above.

The impact of low battery prices in the US

Low prices in China impact battery prices and EV markets overseas, too. We decided to look at the US specifically, given its growing reliance on Chinese batteries over past years and because it is yet to have substantial LFP production capacity domestically.

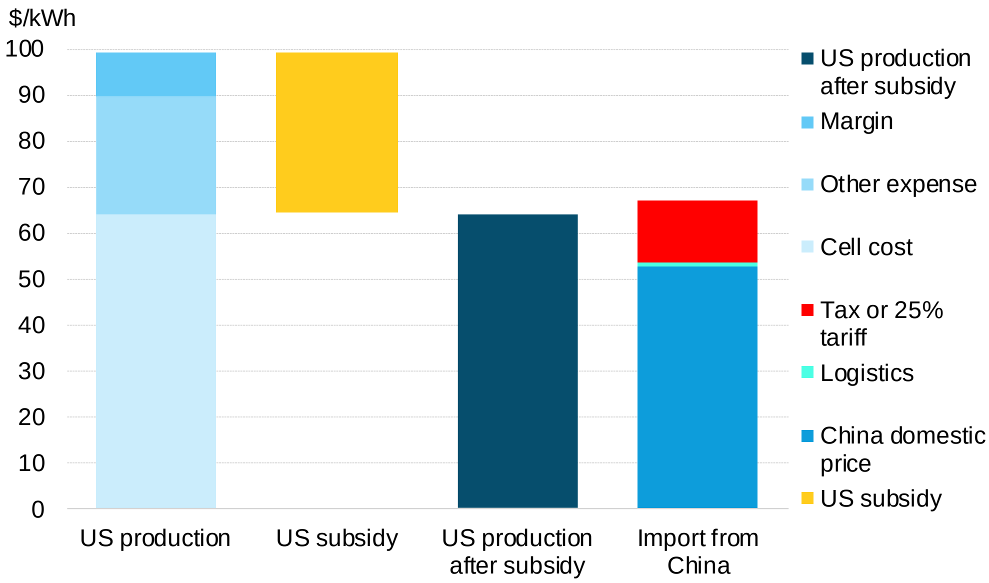
The US offers a $35/kWh manufacturing tax credit for battery cells produced within the US (approved through the Inflation Reduction Act[12]) and is increasing import tariffs to 25% for EV lithium-ion batteries, up from 7.5% previously (see *Biden's China Tariffs Big on Posturing, Small on Impact* (web | terminal)).

BNEF believes the increased tariff is not large enough to stop the import of batteries from China

We calculate that a hypothetical US plant could produce LFP cells at a post-subsidy cost of $64.3/kWh, which is just $2.9/kWh less than the cost of importing from China, including the new tariffs (Figure 234). BNEF believes the $2.9/kWh gap is not large enough to stop the import of batteries from China, since it only requires a 5.5% decrease in China domestic LFP cell prices relative to March 2024. This decline is achievable within 2024 if manufacturers in China are willing to lower margins or improve production efficiency. That said, EV credits also play a role in automaker battery purchasing decisions (see box further below).

Generally, automakers' plans have skewed towards EV models using LFP batteries over the past few years. This means lower cell prices in China can eventually translate to impact overseas. But the availability of low-priced batteries may be limited because China does not seem to be producing excess EV batteries. Therefore, overseas cell prices will likely drop slower than in China itself, but still faster than before 2023.

Figure 234: Comparison of LFP cell prices produced in the US and imported from China



Source: BloombergNEF, ICC Battery. Note: other expenses include marketing & sales, management, financial, logistics, and inventory. Taxes include 25% import tariff US applies to China electric vehicle lithium-ion battery imports.

[12] The US Inflation Reduction Act also awards an additional $10/kWh for battery modules manufactured in the US, taking pack level incentives to $45/kWh. For more context, see *The 45X Factor: US Tax Credits Boost Industry on Home Turf* (web | terminal).

US Inflation Reduction Act: EV credits further encourage non-Chinese batteries

Aside from the manufacturing credits, the US IRA also provides up to $7,500 in tax credits to consumers buying EV models which meet strict critical material and battery component requirements. EVs cannot qualify for EV credits under IRA if batteries or critical minerals are sourced from Foreign Entities of Concern (FEOC), a clause targeting mainly China. Automakers could still choose to forego the full $7,500 EV credit and offer EVs with Chinese batteries, potentially still at competitive prices to comparable models without Chinese batteries.

The $7,500 per vehicle is similar to the total cost of a battery pack, for example, a 60kWh electric vehicle pack with the average 2023 price of $139/kWh would cost $8,340. Hence, this is a strong driver for EV makers to opt for a battery not manufactured in China.

For more, see *New US Rules on Foreign EV Batteries Set High Bar to Clear* (web | terminal) and *Final US EV Sourcing Rules Throw Battery Makers a Lifeline* (web | terminal)

How do low battery prices impact uptake of EVs?

To estimate how these low prices could impact EV uptake, we have constructed a **low-price** scenario and modeled how that may impact China passenger EV sales. Our **base-case scenario** refers to our ETS scenario, which uses our global lithium-ion battery prices and outlook as input. Our **low-price scenario** applies a more aggressive battery price decline to model the resulting additional uptake.

For the **low-price scenario,** we use the observed average battery prices in China from January to April 2024 as a starting point for battery prices in 2024[13], and then apply the same yearly percentage price declines as the base-case scenario. We then model the impact on passenger EV sales in China, as well as fleet size and battery demand. Results are summarized in Table 17 and expanded in following sections.

Table 17: China's low-cost battery thematic highlight scenarios main findings

Scenario	Description	Variable: **Battery price**	Highlights
Economic Transition Scenario	Base case in EVO 2024	Global lithium-ion battery pack prices used in EV uptake analysis taken from BNEF's *2023 Lithium-Ion Battery Price Survey* (web | terminal), applied to all markets	In our ETS scenario there is steady growth of EV sales in China, from 9.9 million sales in 2024 to 23.5 million in 2035.
Low-price scenario	Lower battery prices than base-case applied to China	Adjusted lithium-ion battery pack prices used in EV uptake analysis for China starting 2024. Used observed China average battery pack prices from January to April 2024. Battery prices in 2024 are significantly lower, future prices are also adjusted to account for China discount relative to global prices.	From 2024 to 2035, lower battery prices enable an additional 11% of EV sales in China. In absolute terms this is an extra 24 million EVs, equating to 1.2 terawatt-hours of additional battery demand.

Source: BloombergNEF

13 Historical global prices refer to *BNEF's Lithium-ion Battery Price Survey* (web | terminal). 2024 prices taken from ICC Battery data, which is for prismatic LFP battery pack prices were CNY 545/kWh ($75/kWh), NMC packs were higher, at CNY 620/kWh ($85/kWh). We applied China passenger EV chemistry mix for 2024 calculate a weighted average price.

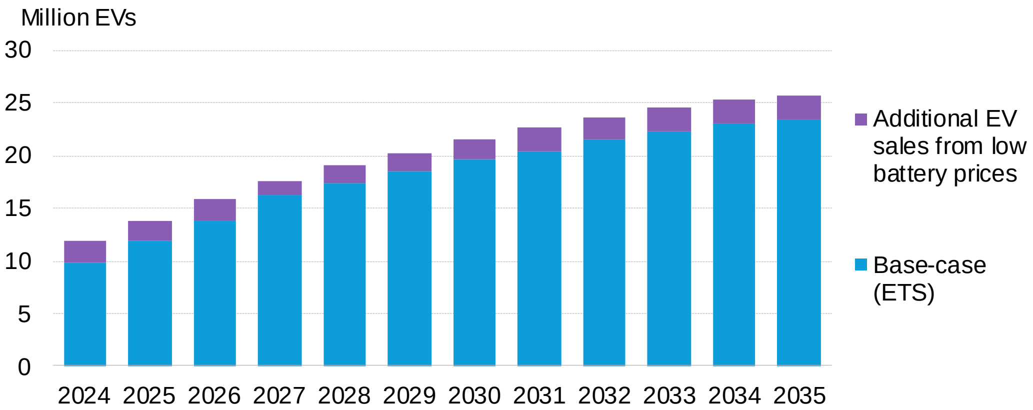
An additional 23.9 million EVs are sold in China in our low-price scenario between 2024 and 2035

Electric vehicle sales and fleet

An additional 23.9 million EVs are sold in China in our **low-price scenario** between 2024 and 2035, 11% more than our **base-case** scenario. That uptick averages 2 million additional BEVs and PHEVs per year, which is fairly evenly distributed throughout the next decade (Figure 235). The lower prices encourage additional adoption from 2024 to 2026, hurrying uptake along the consumer adoption S-curve. However, the share this incremental sale represents of new EV sales each year slows from 17% to 9% between 2024 and 2035, which indicates a limit to how much faster consumers are willing to adopt EVs even with a cheaper sticker price. At lower prices, the cost of the battery relative to the rest of the EV also compresses, so a further reduction in battery prices has a diminishing impact on the total vehicle cost.

China is also further along the EV adoption curve compared to other markets like Europe and the US, so lower battery prices may have less of an impact compared to if they were applied to a less saturated market. Additional factors that could limit faster EV adoption, even at lower prices, include the availability of charging infrastructure, the cost of electricity and petrol, whether the battery price declines are passed on to consumers, and other factors.

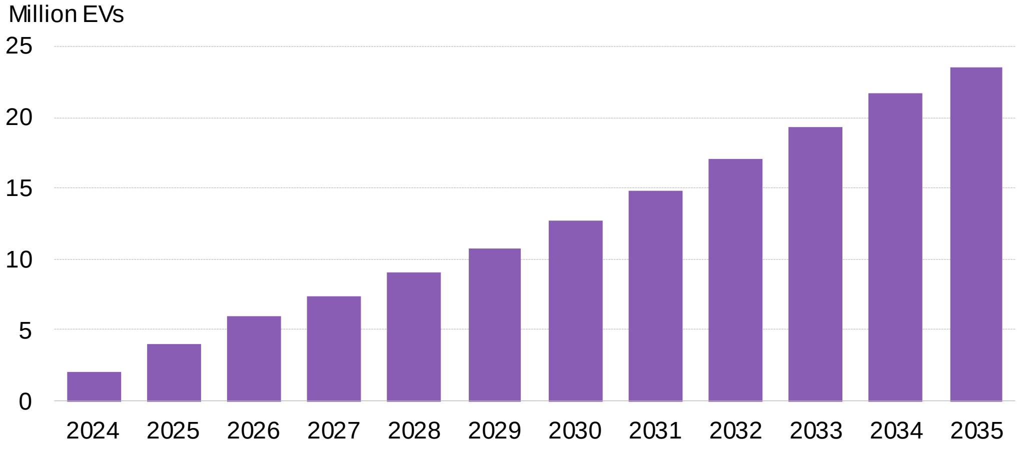
Figure 235: China base case and additional passenger EV sales from low battery price scenario in China



Source: BloombergNEF. Note: The base-case uses BloombergNEF's ETS scenario with battery prices from the 2023 Lithium-Ion Battery Price Survey, the low-price scenario uses the same proprietary modeling with battery price data from ICC Battery averaged over January to April 2024 for the 2024 price and then the same year on year decreases expected in the price survey's long-term outlook.

The passenger EV fleet grows by slightly less than the sum of the additional sales due to EV retirements during the same period, though there are still 23.6 million additional EVs on the road in 2035 in the **low-price scenario** compared to the **base-case**, representing 10% of EV fleet**.**

Figure 236: Additional vehicles in China passenger EV in fleet if low battery prices hold



Source: BloombergNEF

Battery demand

Additional battery demand in the **low-price scenario** requires the equivalent of three large gigafactories, averaging 100GWh per year over the next 12 years. This additional demand is front-loaded with 442GWh produced between 2024 and 2026, peaking at 152GWh in 2025 (Figure 237). This amount of additional demand can be easily accommodated at the cell manufacturing level. Chinese battery manufacturing overcapacity is expected to be 5.2TWh in 2025, meaning this additional demand in the low-price scenario reduces the overcapacity ratio from 666% to 541% (Figure 238). This additional demand will not solve China's overcapacity issue.

Figure 237: Cumulative additional China passenger EV battery demand in low-price scenario

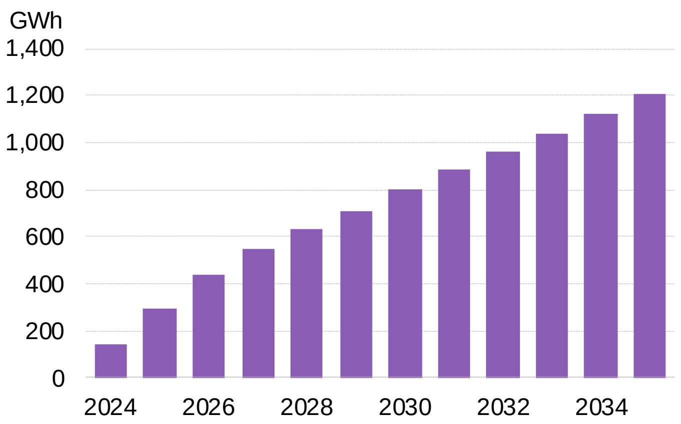
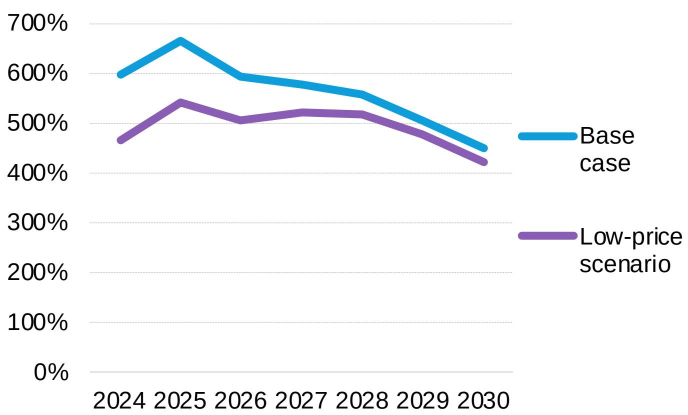


Figure 238: China lithium-ion battery cell overcapacity ratio



Source: BloombergNEF. Note: Overcapacity ratio based on the manufacturing capacity over the same year's demand. Nameplate manufacturing capacity as of May 9, 2024. Includes plants that are fully owned by battery makers, as well as joint ventures with automakers, however, pack assembly plants are excluded.

Given the persistence of overcapacity in China even in the **low-price scenario**, BNEF expects these battery prices to continue, at least in the Chinese market, unless other factors drive up demand significantly. The analysis re-affirms that small battery manufacturers will struggle to keep afloat given factory utilization rates are unlikely to improve for everyone. A consolidation in the market, with some players going out of business, would reduce supply and cause some upward pressure on prices.

BNEF expects these low battery prices to persist

It is still not clear how accessible these prices are to automakers in other parts of the world. Low prices would improve EV demand outside of China, but the raft of protectionist and localization policies the US and Europe are implementing will mean low prices will not be fully accessible in some major markets overseas. If that changes, and these prices start being accessible to automakers in the rest of the world, the impact could be even more significant than in this scenario.

Further reading

- *2023 Lithium-Ion Battery Price Survey* (web | terminal)
- *Price Wars Spur Energy Storage Equipment Leaps in China* (web | terminal)
- *China's Clean-Tech Overcapacity Threatens Onshoring Dreams* (web | terminal)
- *Global Lithium-Ion Battery Supply Chain Ranking 2024* (web | terminal)
- *Company Profiles: 2023 Global Battery Manufacturers* (web | terminal)

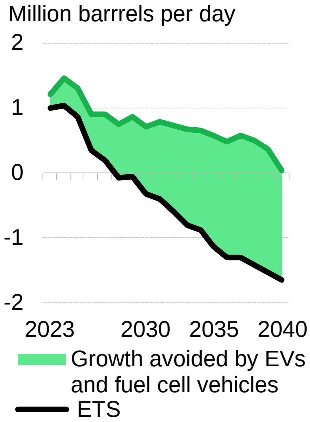
Section 9. Impacts on oil and electricity demand

Oil demand avoided by EVs and fuel cell vehicles is set to double by 2027, and triple by 2029

In this section, we highlight how our vehicle outlooks impact oil and electricity demand. The changes we have described so far in this report represent a seismic shift in energy demand from liquid fuels to the power sector, impacting the fuel mix of the future and in turn the investment decisions and strategic positioning of automakers, oil companies, fuel retailers and utilities.

9.1. Oil demand

Figure 239: Road fuel demand growth year-on-year



Source: BloombergNEF.
Note: Includes biofuels.

EVs of all types are already displacing nearly 1.8 million b/d of oil. That is set to double by 2027, and triple by 2029, compared to last year's volumes. The pivot toward low-emission miles causes oil demand from road transport to peak by 2027 in our Economic Transition Scenario, some 2.5 million b/d higher than in 2023. Without the growth of EVs and fuel cell vehicles, road fuel demand would rise until 2040 (Figure 239).

The rapid uptake of passenger EVs in markets like China, Europe and California propels the jump in avoided oil consumption over the coming years as disruption to the status quo spreads beyond the bus, and two- and three- wheeler segments. In the ETS, oil demand from road transport declines by over 21% by 2040 compared to 2023 levels. The drop is much sharper in the Net Zero Scenario, with demand falling an additional 8.7 million b/d by 2040, leading to a full phaseout by 2050.

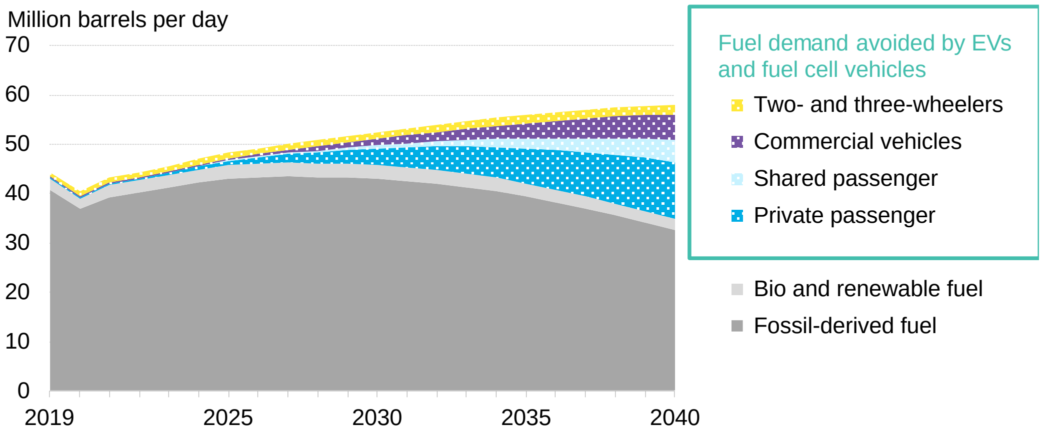
Oil – Economic Transition Scenario

In our ETS, the proliferation of alternative drivetrains has a profound effect on future oil[14] demand. By 2030, consumption would have been over 6.6 million b/d higher, rising to 23 million b/d in 2040, had every kilometer driven by EVs and fuel cell drivetrains been oil powered (Figure 240).

Bio and renewable fuels, like ethanol, biodiesel and renewable diesel, further impact demand for fossil-derived fuels. Despite taking a growing fuel share and reducing emissions relative to fossil-derived fuels, bio and renewable fuel demand peaks in 2030 as blend limits cap the upside. In 2040, demand reaches 2.2 million b/d for bio and renewable fuels.

[14] We define oil to include gasoline, diesel and liquefied petroleum gas (LPG), both fossil and bio-derived.

Figure 240: Road demand and fuel displaced by electric and fuel cell vehicles – Economic Transition Scenario

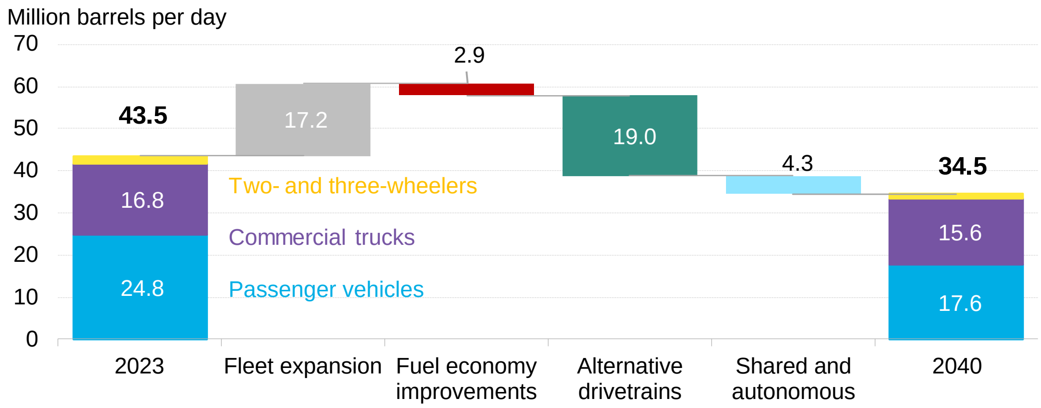


Source: BloombergNEF. Note: Commercial vehicle fuel avoided includes metropolitan buses. Fossil, bio and renewable fuel total does not include volumes consumed by ICE buses and coaches.

Drivers of oil demand growth

In a business-as-usual case – where no technological advancements are made and growth in mobility and freight demand is met with a fleet as it was in 2023 – oil demand would reach roughly 61 million b/d by 2040, over 40% higher than 2023 levels (Figure 241).

Figure 241: Evolution of oil demand from road transport – Economic Transition Scenario

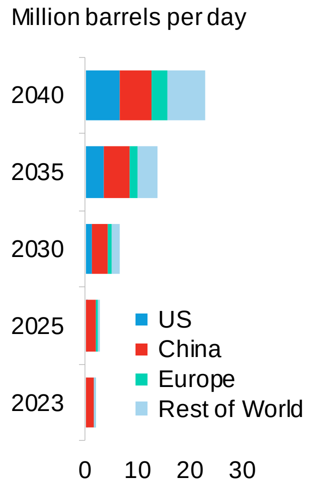


Source: BloombergNEF. Note: Excludes buses. Alternative drivetrains include EVs, fuel cell and natural gas. Demand avoided is relative to 2023 levels and includes natural gas, meaning numbers will differ from Figure 240. Biofuels are included in total oil demand.

Three drivers offset this potential growth in oil demand:

- Improvements in fuel-economy across segments, supported by legislation in major markets.
- Penetration of plug-in hybrid, battery electric, natural gas and fuel-cell vehicles.
- Increased use of shared and autonomous mobility solutions to meet transportation demand in the passenger vehicle and two- and three-wheeler markets.

Figure 242: Oil demand avoided by electric and fuel cell drivetrains across segments – Economic Transition Scenario



Source: BloombergNEF. Note: Excludes natural gas.

Europe, the US and China accounted for over half of all road fuel consumed in 2023. All three have reached or are about to reach peak road fuel demand

Passenger vehicles

Passenger vehicles consumed just under 25 million b/d of oil in 2023. In our Economic Transition Scenario, demand peaks at roughly 25.3 million b/d in 2025. This is due to a structural decline in mature markets like Europe and the US, and growth in alternative drivetrains in fast-growing markets like China. Had every kilometer driven by private passenger EVs and fuel cell drivetrains been covered by oil-powered ICE vehicles, oil demand would have been just over 0.37 million b/d higher in 2023. Alternative drivetrains in the shared passenger fleet displaced an additional 0.05 million b/d. This brought the total amount of oil use avoided in passenger cars to some 0.42 million b/d – similar to the amount of oil consumed in Nigeria each day.

Although the global passenger vehicle fleet grows to 2040, the ICE fleet peaks by 2027. Fuel-economy improvements in the ICE fleet along with shared mobility services and EVs lead to oil use declining by 7.2 million b/d in 2040 in the passenger vehicle segment, compared to 2023. The peak in road fuel demand lags that of the ICE fleet. That's because even as older, less fuel-efficient cars are taken off roads, a shift away from diesel passenger vehicles sees regions like Europe become less efficient on a miles per gallon basis.

Commercial trucks

Commercial trucks consumed just over 16.8 million b/d of oil in 2023. Electric and fuel cell drivetrains have had a negligible impact on oil use to date in this segment, at some 0.05 million b/d.

Growing demand for the transport of goods leads to an increase in the global commercial truck fleet to over 338 million by 2040, compared to 253 million in 2023. Despite this, oil demand growth slows in our ETS as ICE fuel economy improves and the penetration of EVs increases, particularly in lighter trucks and heavier models operating in urban environments. Long-haul heavy-duty trucks drive oil demand growth, but natural gas, fuel cells and, increasingly, EVs, threaten diesel's dominance in the segment. Oil use in commercial vehicles declines to 15.6 million b/d in 2040 in our ETS.

Electric and hydrogen-powered buses[15] displaced just under 0.22 million b/d of oil demand in 2023. Thanks to their operational concentration in metropolitan areas, along with favorable economics, electric and fuel cell buses initially led in terms of oil displaced from alternative drivetrains. However, as the global bus fleet is far smaller than the three other main road fuel-consuming segments, its oil use is limited.

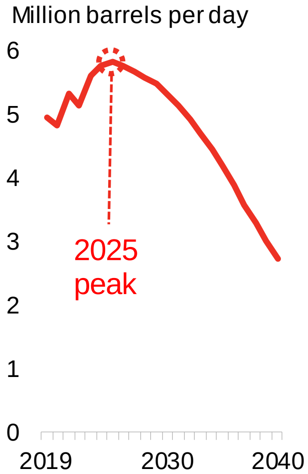
Two- and three-wheelers

Two- and three-wheelers consumed almost 2 million b/d of oil in 2023, even after early electrification in the segment led to roughly 1.1 million b/d of oil demand avoided last year. Two- and three-wheelers are often the entry point for motorized transport in developing markets and the fleet grows by almost 33% by 2040. If there were no fuel economy improvements and all kilometers traveled were ICE-powered, this growth in motorization would result in over 2.5 million b/d more oil demand by 2040 than in our ETS. Mobility demand growth in future is predominantly met by EVs. This, coupled with improving ICE fuel economy, means oil use in this segment has already peaked and declines by just over 0.85 million b/d, or 38%, in 2040 compared to 2023 levels.

[15] BNEF includes the electrification of municipal buses in this research and does not model oil consumed in other buses and coaches.

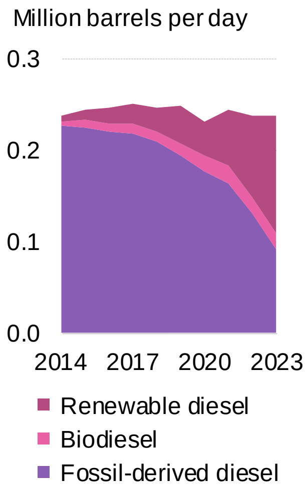
Combined impact on oil

Figure 243: China road fuel demand – Economic Transition Scenario



Source: BloombergNEF. Note: Includes biofuels. Excludes buses.

Figure 244: California diesel demand by type



Source: BloombergNEF, California Air Resources Board.

The use of oil by passenger vehicles, commercial trucks and two- and three-wheelers peaks globally in 2027 in our ETS (Figure 245). Bio-derived fuels like renewable diesel grow until 2030, accelerating the decline of more carbon-intense fuels (Figure 246). Total oil demand – including biofuels – from these three segments declines to 34.8 million b/d in 2040 from 43.8 million in 2023, a dip of almost 9 million b/d. The combined figure masks a divergence between fuel types and across markets.

Demand for gasoline, predominantly used in passenger vehicles and light commercial trucks, peaks in 2027, declining by some 5.1 million b/d by 2040 compared to 2023. This is propelled by the prolific electrification of passenger cars and light commercial vehicles. Heavier commercial vehicles are slower to decarbonize. However, the sharp drop in diesel-powered passenger vehicle sales in Europe means that diesel demand is also set to peak in 2027. In 2040, diesel use is some 3.1 million b/d lower than 2023 levels.

Europe, the US and China accounted for over half of all road fuel consumed globally in 2023. That is set to change in our Economic Transition Scenario as all three have reached, or are about to reach, peak road fuel demand.

Road fuel use in Europe is already in structural decline and strict fuel-economy mandates across all vehicle segments drive fuel use down to 4.1 million b/d in 2040, from 6.7 million b/d in 2023. Still, a faster-than-expected decline in diesel passenger car sales leads to a higher gasoline fleet for the remainder of the 2020s. As gasoline vehicles are less efficient than diesel vehicles on a miles per gallon basis, and typically diesel cars are utilized more, gasoline use grows until 2032 in Europe as diesel declines. Our ETS does not assume the EU meets its target of phasing out new combustion vehicle sales in the passenger segment by 2035.

California: Is it all electric?

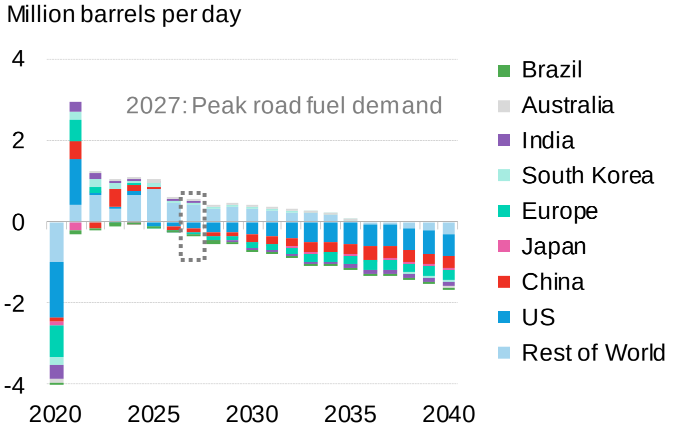
While electric passenger car sales hit 22% of all sales in California in 2023, the commercial fleet continues to rely on ICE engines. However, the introduction of the Low Carbon Fuel Standard in 2007 has led to the proliferation of renewable diesel in the California diesel pool. In 2023, over 61% of all diesel consumed in California was bio-based (Figure 244).

The fuel-neutral, market-based program encourages the use of alternative fuels to reduce greenhouse gas emissions in transport by rewarding low-carbon fuels. The success to date of the rule is notable given commercial vehicles in California consume roughly the same amount of diesel as the commercial fleet of Italy or the UK.

Road fuel demand in China is set to peak in 2025 in our ETS (Figure 245). Two- and three-wheelers in China consume almost 0.5 million b/d of fuel – similar to the total oil consumption of Norway and Greece combined. But some 70% of kilometers driven by two- and three-wheelers in 2023 were electric-powered, and electric model sales neared 80%. In the same year, over 7% of passenger cars and over 3% of light commercial vehicles on China's roads were electric, while 6.4% of the medium and heavy commercial truck fleet was electric or natural gas-powered. Overall, this mix of alternative drivetrains means road fuel demand plummets to just over 2.7 million b/d by 2040, from 5.6 million b/d in 2023.

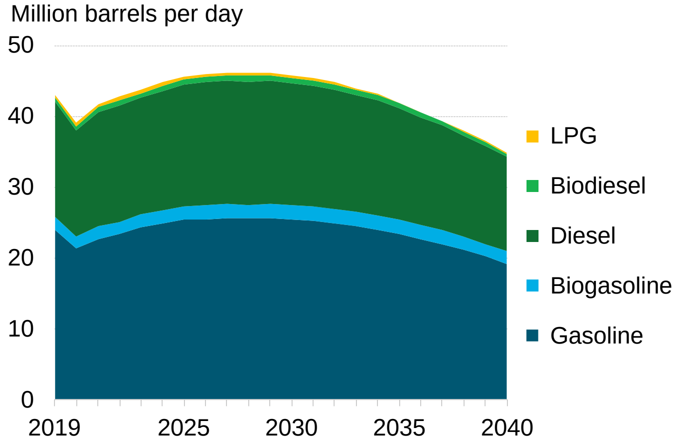
In the US, the Inflation Reduction Act has accelerated the penetration of alternative drivetrains and lowered demand for road fuel – which does not return to pre-pandemic levels in our scenario. California accounted for roughly 9% of all US road fuel use in 2023, and leads the shift away from fossil-fuel mobility with some 6.3% of passenger cars and nearly 4% of commercial vehicle kilometers driven in 2023 powered by non-oil-based drivetrains, including electric and natural gas. Across the US, road fuel declines by almost 56% by 2040, compared to 2023 levels, in the ETS.

Figure 245: Oil demand growth by region – Economic Transition Scenario



Source: BloombergNEF. Note: Includes biofuels. Excludes buses.

Figure 246: Oil demand by fuel – Economic Transition Scenario

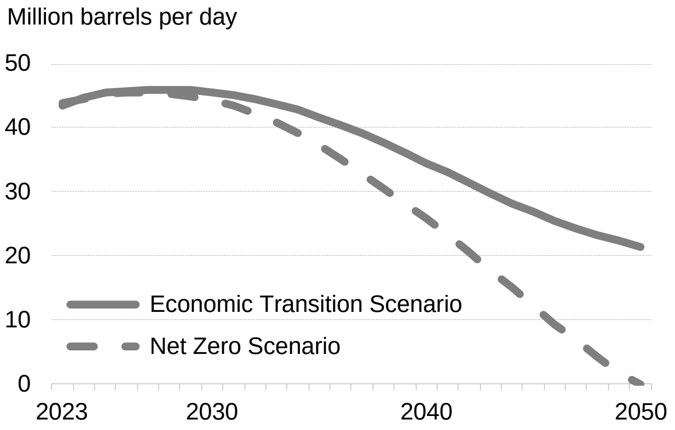


Source: BloombergNEF. Note: Includes biofuels. Excludes buses.

Oil – comparison with Net Zero Scenario

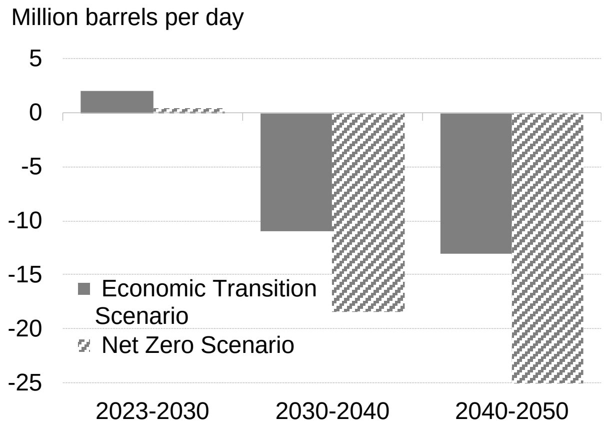
In our Net Zero Scenario, road transport oil demand trends to zero by 2050 with mobility powered exclusively by alternative drivetrains like EVs and fuel cell vehicles. Biofuels continue to play a role in the fuel mix until ICE vehicles are phased out, with blend rates kept in line with our Economic Transition Scenario.

Figure 247: Oil demand from road transport by scenario



Source: BloombergNEF. Note: Includes biofuels.

Figure 248: Oil demand growth from road transport by scenario



Source: BloombergNEF. Note: Includes biofuels.

While oil demand disappears by 2050 (Figure 247), the pathway to net zero varies over time by segment, and as a result impacts the decline of each oil product differently. Overall, the trajectory for oil use in road transport remains broadly similar in both scenarios until 2030, with a slight decline in demand in the NZS, compared to small growth in the ETS (Figure 248). The two scenarios do not diverge earlier because it takes a long time for changes in new vehicle sales to begin to impact the fleet.

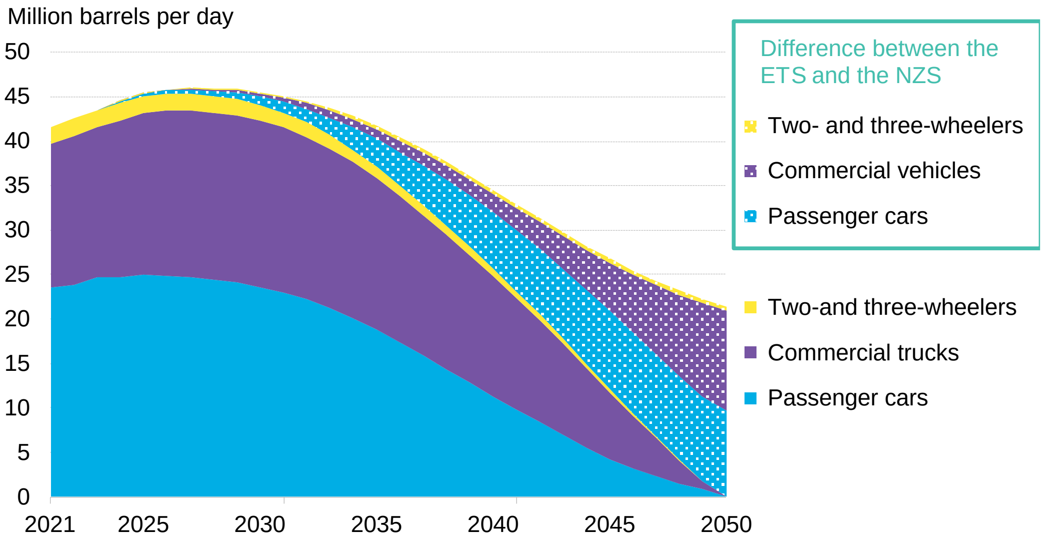
However, from 2030 in the NZS, the rate of decline in oil demand accelerates. In 2030, oil demand in road transport is some 1.4 million b/d lower in the NZS compared to the ETS. By 2040, this gap increases to more than 8.8 million b/d, and over 21.5 million b/d by 2050.

The rapid electrification of buses and two-and three-wheelers in the NZS has a limited impact on the overall oil demand (Figure 247) as oil use in both segments is an order of magnitude lower than for passenger vehicles or commercial trucks. In order for net zero to materialize, commercial trucks have the most work to do to decarbonize quicker.

Trucks need to catch up for BNEF's Net Zero Scenario to materialize

Passenger cars decarbonize faster than commercial trucks in the NZS, as long-haul, heavy trucks remain one of the last segments to phase out ICE vehicles. In this scenario, passenger cars begin to decarbonize quicker in the 2020s, before the rapid acceleration of alternative drivetrain adoption leads to a large drop in oil use in the 2030s.

Figure 249: Oil demand from road transport by scenario and segment



Source: BloombergNEF. Note: Includes biofuels.

Oil consumption by commercial trucks continues to rise in the 2020s in the Net Zero Scenario, driving growth in demand for diesel (Figure 249). From 2030, the adoption of alternative drivetrains – first in light and urban-operating vehicles – leads to a decline in consumption in commercial trucks. LNG plays a role in decarbonizing heavier trucks that operate on long-haul routes in the 2030s. However, as LNG trucks emit carbon, the longer-term role of these vehicles is limited. The growth of alternative drivetrains in the heavy and long-haul segments in the 2040s leads to a rapid decline in oil demand in the commercial truck segment, with diesel leading the descent.

- *Series: Road Fuel Outlook (web | terminal)*
- *US Biofuels Policy Outlook 2024: Credits at Risk (web | terminal)*
- *Global Renewable Fuel Projects Tracker (web | terminal)*

9.2. Electricity demand

Global electricity demand for passenger and commercial EVs, e-buses and electric two- and three-wheelers increases nearly four times to 976TWh in 2030, from 253TWh in 2023, in the Economic Transition Scenario, similar to the electricity consumption of Japan last year. It further triples to 3,140TWh in 2040 (Figure 250). By 2030, electricity demand for EVs in the Net Zero Scenario is 14% larger than in the ETS, before growing to more than 38% larger by 2040 and 57% by 2050. By 2050 in the NZS, 8,313TWh of electricity is needed to power an all-electric vehicle fleet, double the amount of electricity consumed in the US in 2023.

Figure 250: Global electric vehicle electricity demand by scenario to 2050

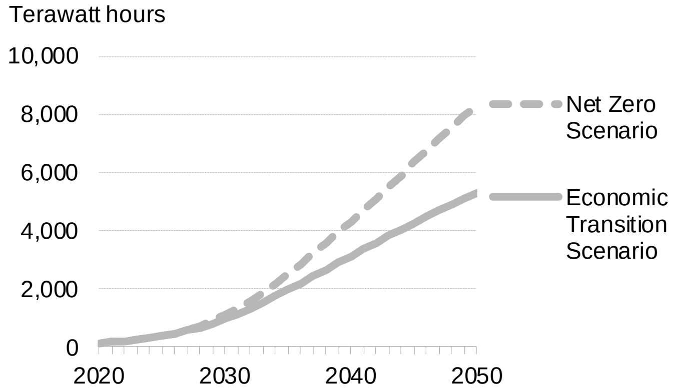
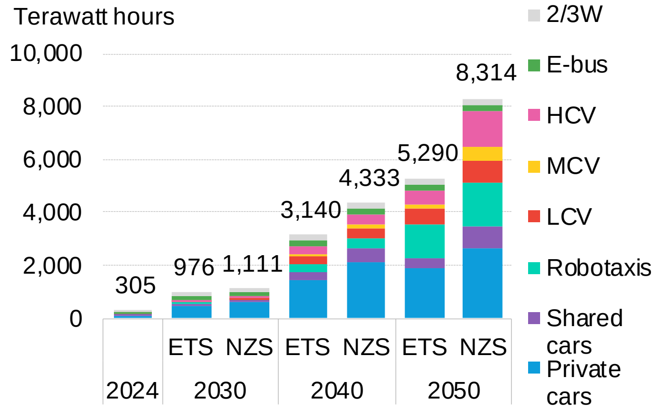


Figure 251: Global electric vehicle electricity demand split by vehicle segment



Source: BloombergNEF. Note: ETS is Economic Transition Scenario, NZS is Net Zero Scenario. 'LCVs, MCVs and HCVs' are light, medium and heavy-duty commercial vehicles.

Today, e-buses and electric two- and three-wheelers combined account for 54% of electricity demand, with passenger vehicles consuming another 42%. This is driven by strong adoption of e-buses in China and of electric two- and three-wheelers in China, India and Southeast Asia.

An almost fully electric fleet in 2050 would require 8.3 petawatt hours of electricity annually

Over time, the passenger and commercial vehicle fleet grows to take a larger share of EV electricity demand. The commercial fleet share grows strongly after 2030 and accounts for as much as 33% of all EV electricity demand by 2050 in the Net Zero Scenario (Figure 251). Electric heavy-duty trucks have the highest demand of any commercial vehicle classification by 2050 in the NZS, alone accounting for 16% of EV electricity demand, or 1,349TWh. Electrifying commercial vehicles will require dense deployments of high-power charging infrastructure. This will challenge grid operators to deploy the necessary infrastructure in a timely manner.

The fleet of autonomous vehicles (robotaxis) begins to eat into kilometers travelled by ordinary private and shared electric vehicles in the 2030s. The electricity demand from these vehicle groups grows to 10% of demand in 2040 from less than 1% in 2030. This will have knock on effects for the required charging infrastructure and is likely to lead to more wireless and robotic charging. An autonomous fleet could also utilize charging infrastructure more efficiently, meaning fewer chargers may be required. For a more detailed view, see the electricity demand by country and vehicle classification in our online tool (web).

Electric vehicle electricity demand as part of global consumption

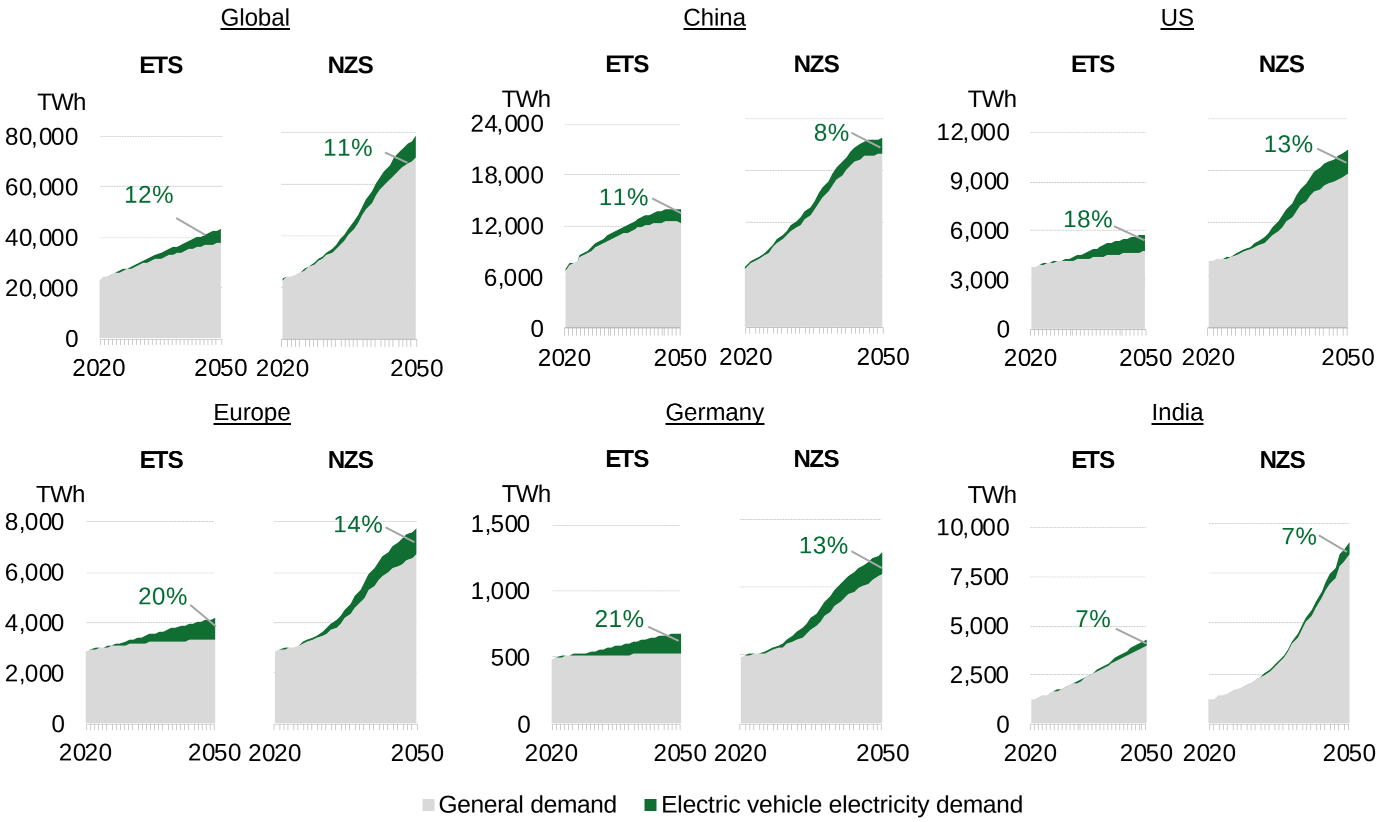
Electric vehicles grow to between 11% and 12% of global electricity demand by 2050

The total electricity demand from electric vehicles becomes a significant portion of electricity consumption over the next two decades. Globally electric vehicles account for between 11% and 12% of all electricity demand by 2050, depending on the scenario (Figure 252).

It is important to note that there are significant increases in electricity demand from other areas, especially in the NZS. This includes the electrification of heating, industry and electrolyzers for making hydrogen at scale. Grid operators are also planning for challenges such as ageing grids, extreme weather conditions and the incorporation of more renewable energy generation.

While electric vehicle electricity demand is significant, it is part of a bigger picture for grid operators and will have to be considered within a wide range of plans.

Figure 252: Electricity demand outlook for select regions by scenario



Source: BloombergNEF. Note: Uses general electricity demand projections from BNEF's New Energy Outlook 2024. This is the final energy consumption and excludes any losses in transmission. EV electricity demand includes demand from passenger EVs, commercial EVs, e-buses and electric two- and three-wheelers. Percentages refer to percentage of EV electricity demand of total in 2050.

In China and India, even in the ETS, electricity demand excluding electric vehicles is growing fast, so incorporating electric vehicles must be considered alongside other projects that expand the size of the overall power system. In Europe and the US, electric vehicles are the main driver of electricity demand growth in the ETS. Without them electricity demand is relatively flat due to increasing energy efficiency and, in some cases, falling populations. Growth in demand in Europe is otherwise driven by the electrification of heating and rail transport, but incorporating electric vehicles becomes a focus for grid operators in this scenario.

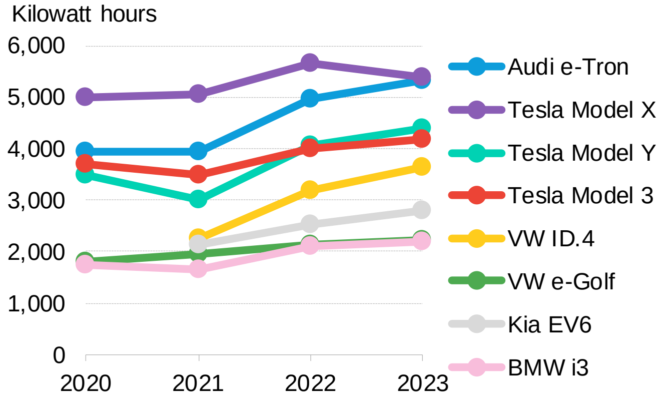
These differences are exposed by a look at EVs' total share of electricity demand by region. In China and India, EVs account for between 7% and 11% of electricity by 2050 in the ETS, and 18% to 20% in the US and Europe.

Electric vehicle usage on the rise

Data on the average electricity consumption of various EV models suggests that individual vehicles are being used more often. In the UK, Tesla Model Y drivers on the ev.energy platform consumed 26% more electricity on average in 2023 compared to 2020, while the electricity consumed by an Audi e-Tron increased by 35%. Even vehicles with smaller batteries, including the BMW i3 and VW e-Golf, have followed this upward trend in electricity consumption, with the vehicles on average using at least 20% more electricity in 2023 than in 2020 (Figure 253).

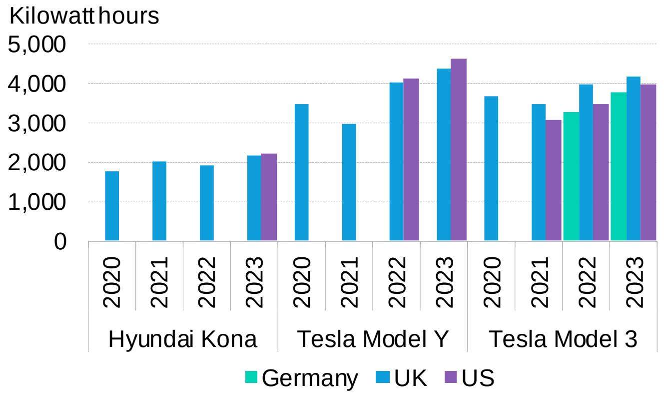
Similar trends can be seen in the US and Germany. An Audi e-Tron in Germany, for example, consumed 14% more electricity in 2023 than the previous year; and in the US, both the Tesla Model 3 and Model Y consumed more electricity year-on-year, on average (Figure 254).

Figure 253: Annual electricity consumption in the UK by electric vehicle model on ev.energy's platform



Source: BloombergNEF, ev.energy.

Figure 254: Annual electricity consumption by vehicle model and region on ev.energy's platform



Source: BloombergNEF, ev.energy.

The range of EVs is improving as the technology matures, contributing to this upward trend in electricity consumption. But it also suggests that how people drive EVs is evolving as familiarity with the technology and the availability of charging infrastructure improves.

The average driving distance, regardless of drivetrain, is higher in the US than in the UK, but the average electricity consumption of an EV in the US is lower or very similar to that in the UK. This suggests that drivers in the US are using their EVs as a second vehicle and may be reverting to an ICE model for longer journeys. EV power consumption could rise in the US as public charging infrastructure becomes more readily available.

Smart charging provides up to 67% of demand-side flexibility by 2050 in our Economic Transition Scenario

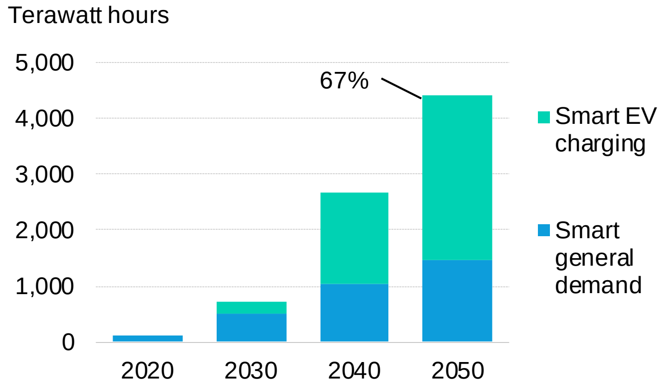
EVs will be an increasingly important source of grid flexibility

Smart charging helps reduce peak demand and provides flexibility to balance the power system. It works by moving charging to a time that is more suitable, based on factors such as cost, grid load and emissions.

In our modeling, we assume an increasing share of EV connectors will have smart-charging capability to address system constraints. By 2050, 50% of workplace and public slow chargers will be capable of smart charging, as will 70% of home chargers and 20% of fast chargers. This enables smart charging of electric vehicles to become one of the largest sources of demand-side flexibility in the future energy system, providing 67% of demand-side flexibility by 2050 in the ETS in BNEF's New Energy Outlook (Figure 255). It should be noted that this model does not account for smart heating, which may play a larger role in flexibility than is depicted in our scenarios. Electrolysers are also not modeled in the ETS.

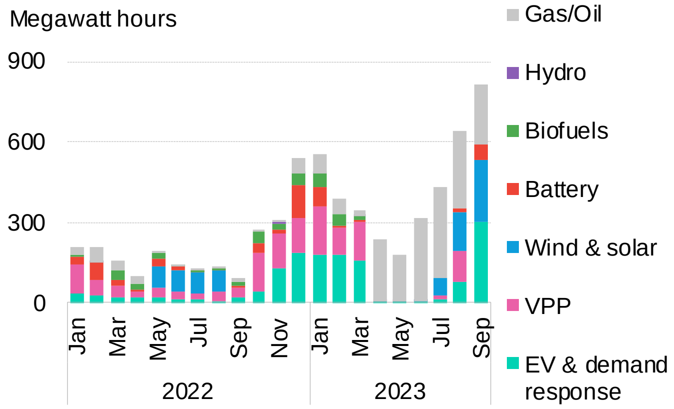
Scaling up to this level will take time, however, and usage of EV charging flexibility has been relatively slow to date. Challenges predicting EV charging behavior and a lack of suitable charging stations have limited use of the technology. But EVs are starting to compete with small gas and oil plants to provide flexibility in the UK in 2023 (Figure 256).

Figure 255: Global demand-side flexibility by source in the ETS in BNEF's New Energy Outlook



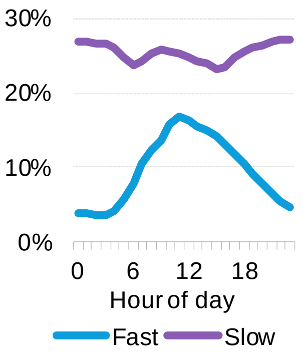
Source: BloombergNEF. Note: Smart general demand includes flexibility provided by consumers via smart appliances and other demand-side response. Does not include space heating.

Figure 256: Dispatched local flexibility capacity in UK by resource



Source: BloombergNEF, UKPN, NGED, SSEN. Note: EVs includes EV charging and demand response. VPPs is virtual power plants and may include EV charging.

Figure 257: Utilization of chargers in the Netherlands



Source: Eco-Movement, BloombergNEF. Note: Data averaged for weekdays in 2022.

The availability of smart charging is growing constantly, and regulations are in place to boost the number of compatible public chargers. The new Alternative Fuels Infrastructure Regulation (AFIR) in Europe and the National Electric Vehicle Infrastructure (NEVI) funding program in the US both require that new chargers be capable of providing smart charging and communication with the grid. Predicting driver behavior may prove more challenging to address but a growing fleet and new shorter-term markets for the procurement of flexibility could help to ease the issue.

Most home chargers on the market today already have some degree of 'smartness', and the availability of smart charging electricity tariffs, from providers including UK-based Octopus Energy, that can offer up to $750 of savings per year make it an appealing option for drivers. One requirement is the installation of a smart meter, something that varies significantly by market. Germany is on the back-foot because of its delayed rollout of smart electricity meters, but installations are accelerating.

The Netherlands by contrast is already in need of flexible smart charging. The rapid electrification of heating and transport in addition to substantial adoption of renewables has led to very high levels of grid congestion. One regional grid operator, Stedin, has suggested that turning down EV demand during peak hours is now insufficient, and is considering switching off all EV charging between 4pm and 9pm to free up capacity for homes.

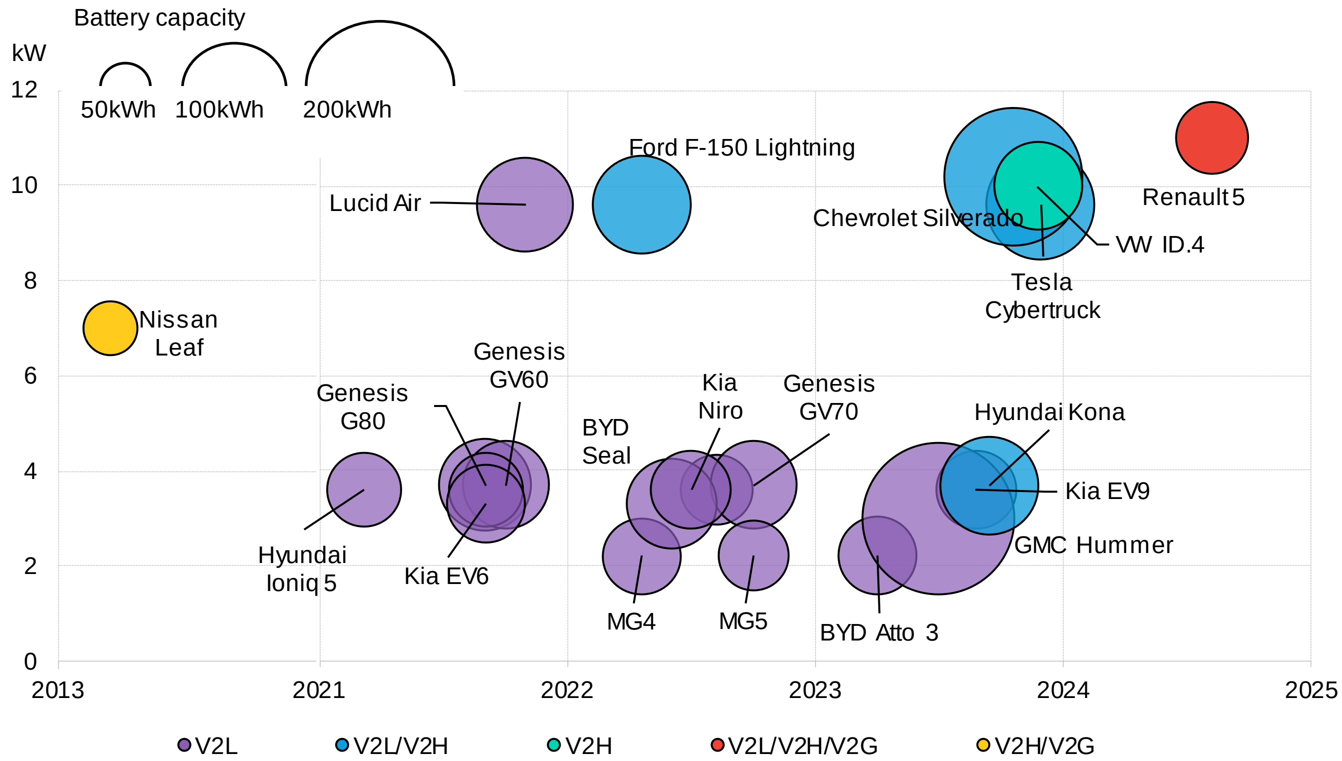
The average utilization of slow chargers in the Netherlands reaches 27% during this four-hour window, with drivers plugging in as they come home, but remains high overnight with vehicles predominantly left connected (Figure 30). This creates the opportunity to push the demand from EVs back by a few hours, easing strain on the grid with minimal inconvenience to drivers, but it relies on the availability of smart charging tech.

While smart charging could also be used to better align EV demand with solar generation during the day, more workplace and destination chargers would be required to achieve this, something the industry is largely moving away from. The utilization of fast chargers by comparison is already a better match to solar generation and variable pricing could further incentivize midday fast charging, lowering the evening peak.

EVs could also provide flexibility through vehicle-to-grid

Bi-directional charging technology could also allow EVs to participate in supply-side flexibility markets by discharging their batteries back to the grid when called upon, similar to a residential battery. While still nascent and awaiting meaningful levels of commercialization, the technology has piqued the interest of more than a dozen automakers and there are 25 EV models with some level of bi-directional functionality on the market (Figure 258).

Figure 258: Bi-directional EV models by discharge functionality

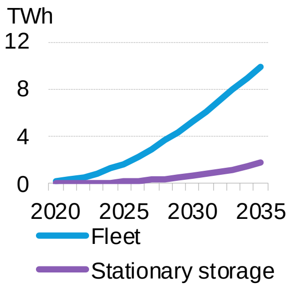


Source: BloombergNEF, company press releases. Note: V2L is vehicle-to-load. V2H is vehicle-to-home. V2G is vehicle-to-grid.

The Renault 5 is set to be the first EV to facilitate full vehicle-to-grid functionality on a commercial scale when it launches later this year, but chargers available with select Tesla, Ford and GM vehicles already allow drivers to power their home from their car in the event of a grid outage.

Managing the energy stored in aggregated EV assets could prove lucrative as the market for behind-the-meter flexibility continues to grow. Our outlook suggests that the storage capacity in EVs will be several times greater than the capacity required for all residential and grid-scale storage, meaning EVs could cannibalize the stationary storage market. In China, for example, the battery capacity in the EV fleet nearly reaches 10TWh in 2035, versus almost 2TWh in our stationary storage outlook (Figure 259). The technology is dependent on vehicle batteries being efficiently and reliably controlled, however, something BMW, Ford and Honda are tackling through a new joint venture called ChargeScape.

Figure 259: Fleet versus stationary storage capacity in China in the ETS



Source: EVCIPA, BloombergNEF. Note: Only passenger BEVs, assumes average pack size of 55kWh.

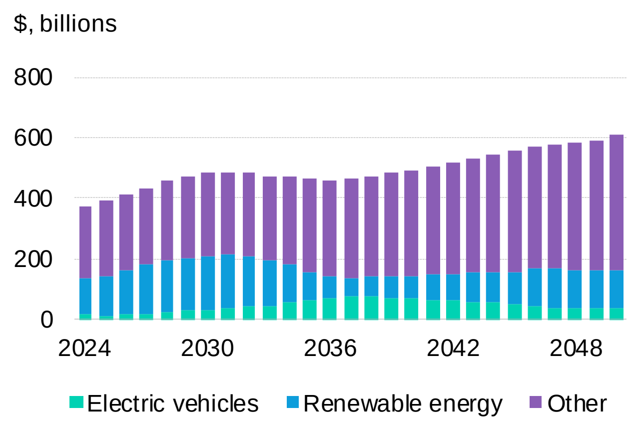
Impact of EVs and smart charging on grid investment

Meeting the maximum power demand from EV charging in our current modeling will require annual grid investment to peak at $75 billion in the ETS in 2038 and $82 billion in 2034 in the NZS. This represents about 16% of grid capex on average globally. Today, only around 5% of annual grid expenditure is connected to EVs, equivalent to $19 billion (Figure 260).

Scaling up to achieve this investment and deploy infrastructure in a timely manner will be challenging and grid upgrades are identified by the charging industry as a barrier to progress. Some networks have announced plans to install onsite storage as an interim solution, providing increased capacity to the site while they await a suitable grid upgrade. The significant costs associated with this approach mean it has not been hugely popular in the industry to date, but it is relevant regionally depending on the make-up of electricity tariffs.

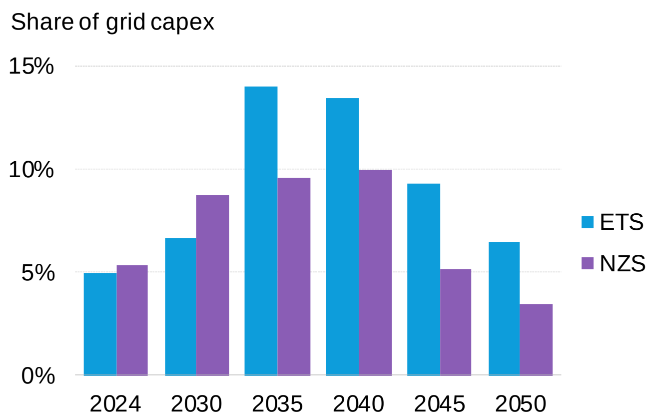
It is worth noting that EVs account for a slightly lower share of annual investment in the NZS. The annual grid capex derived from EVs grows by a smaller proportion than total grid spend in the scenario, in part due to the number of electrolyzers that come online from 2030 in the NZS, which alone raise annual grid capex by up to $70 billion (Figure 261).

Figure 260: Annual grid capex – Economic Transition Scenario



Source: BloombergNEF. Note: 'Other' includes ageing assets, general demand growth, electrolysers and firm generation in the Economic Transition Scenario.

Figure 261: EV share of annual grid capex in ETS and NZS

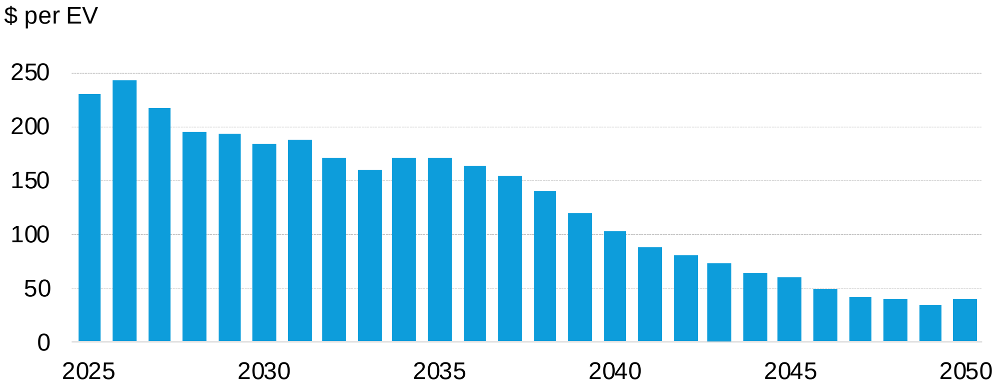


Source: BloombergNEF. Note: The percentages shown indicate the share of annual grid capex derived from demand from electric vehicles in the ETS and NZS scenarios.

While the total grid capex for EVs continues to grow until 2038 in the ETS, the annual spend per EV declines as the charging infrastructure more efficiently serves the growing EV fleet. Today, required grid investment in EVs amounts to $230 per vehicle, assuming that passenger vehicles are the primary driver of demand. This falls to under $100 a year from 2040 (Figure 262).

Grid infrastructure upgrades due to electric vehicles account for about 11% of annual capex required on average between 2030 and 2050

Figure 262: Grid capex per passenger BEV in the ETS



Source: BloombergNEF. Note: Assumes annual grid capex is divided only between passenger battery electric vehicles.

Charging infrastructure outlook

EVO 23

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Section 10. Charging infrastructure outlook

Some $2.5 trillion in cumulative investment in EV charging is required by 2050 for a fully electric fleet

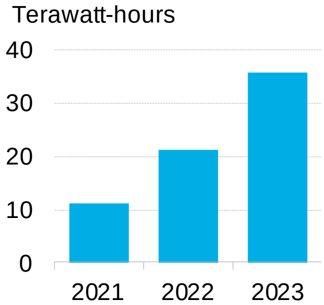
The charging sector requires as much as $1.6 trillion in cumulative investment by 2050 in the Economic Transition Scenario, and $2.5 trillion by 2050 in the Net Zero Scenario to meet the needs of an all-electric vehicle fleet. Sales of alternating-current (AC) chargers rise over the next two decades in both scenarios, while sales of direct-current (DC) chargers drop globally in the 2030s, dragged down by slowing sales in China despite an uptick across the rest of the world.

Public-charging companies' annual revenues reach hundreds of billions of dollars from electricity sales in the early 2030s in both the ETS and NZS, creating a mature and established industry from today's niche market. Yet this growth will require a major mobilization of capital and expertise, and challenges in deployment of charging infrastructure remain. Technological changes, such as charging at greater than 350 kilowatts (kW), wireless charging and the adoption of autonomous vehicles, are all variables that will influence the development of the charging industry.

The evolution of the charging network will not be the same in every country. Relative reliance on home charging, public slow charging or public fast charging will depend on the makeup of the housing stock and government incentives. Home-charger sales are set to grow globally over the next two decades, as around half of new EV drivers adopt the technology. Countries outside China, Europe and North America become increasingly important to charger manufacturers in the 2030s, as the growth in public networks slows in these three major markets. Commercial vehicle charging will also become an increasingly important segment.

10.1. Global overview

Figure 263: Public charging electricity demand in China



Source: BloombergNEF, China Electric Vehicle Charging Promotion Alliance.

Global electricity demand from EVs reached 162 terawatt-hours (TWh) in 2023. That pales in comparison to the 5,050TWh of demand seen by 2050 in the ETS and the 8,070TWh in the NZS, in which the global fleet is entirely made up of electric vehicles by this date. Serving this skyrocketing demand requires 524 million to 750 million chargers and $1.7 trillion to $2.5 trillion of investment, depending on the scenario (Figure 264). The pace of electric and autonomous vehicle adoption, as well as the success of new charging technologies, all add uncertainty to the long-term outlook for charging demand, but over the next five years the niche industry is likely to grow into an established market for hardware manufacturers, software providers, site operators and developers.

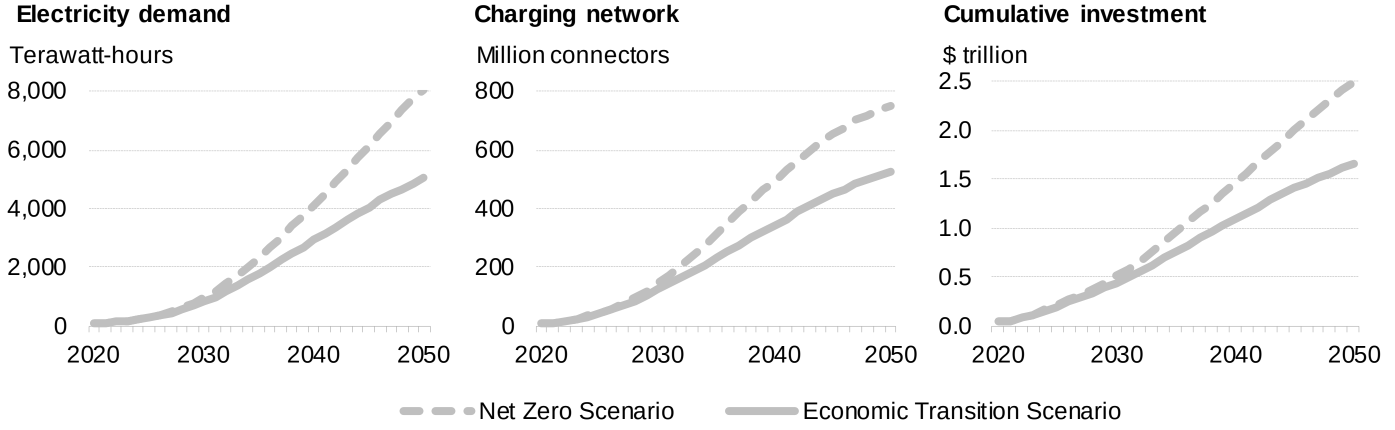
Under our more conservative ETS, in which EV adoption is primarily driven by techno-economic trends and market forces, electricity demand from EVs is 826TWh by the end of this decade – five times demand today. This figure soars to 3,000TWh 10 years later, requiring 342 million chargers and over a trillion dollars in investment, before passing 5,000TWh by 2050. That's an eye-popping figure, but it's only 62% of the demand seen in 2050 in the NZS, highlighting the potential for growth in the industry even in 25 years' time.

China, currently the most established EV charging market in the world, saw almost one million public chargers installed last year. The country's total electricity demand for public charging hit 36TWh – greater than the total electricity demand of Ireland (Figure 263).

This figure, while exceptional, points to a significant global trend: most countries will see EV charging become a large class of electricity demand over the next decade. Charging operators are preparing for this by liaising more closely with utilities for grid connections and signing power purchase agreements to source their own renewable electricity.

Some operators are also co-locating renewables, battery storage and charging. While rare today, co-location can mitigate grid costs, decrease connection timelines and potentially lower electricity costs. One of the largest existing stations with co-located technologies is WattEV's truck charging stop in Bakersfield, California, which includes a 5.7-megawatt (MW) solar array, 2.7 megawatt-hours (MWh) of battery storage,16 dual-cord 360kW grid-connected chargers, 15 single-cord 240kW chargers and three 1,200kW rapid chargers.

Figure 264: Global electricity demand for electric vehicles, charging network size and investment in charging infrastructure, to 2050



Source: BloombergNEF. Note: Excludes two- and three-wheelers. Investment includes hardware, installation and maintenance costs.

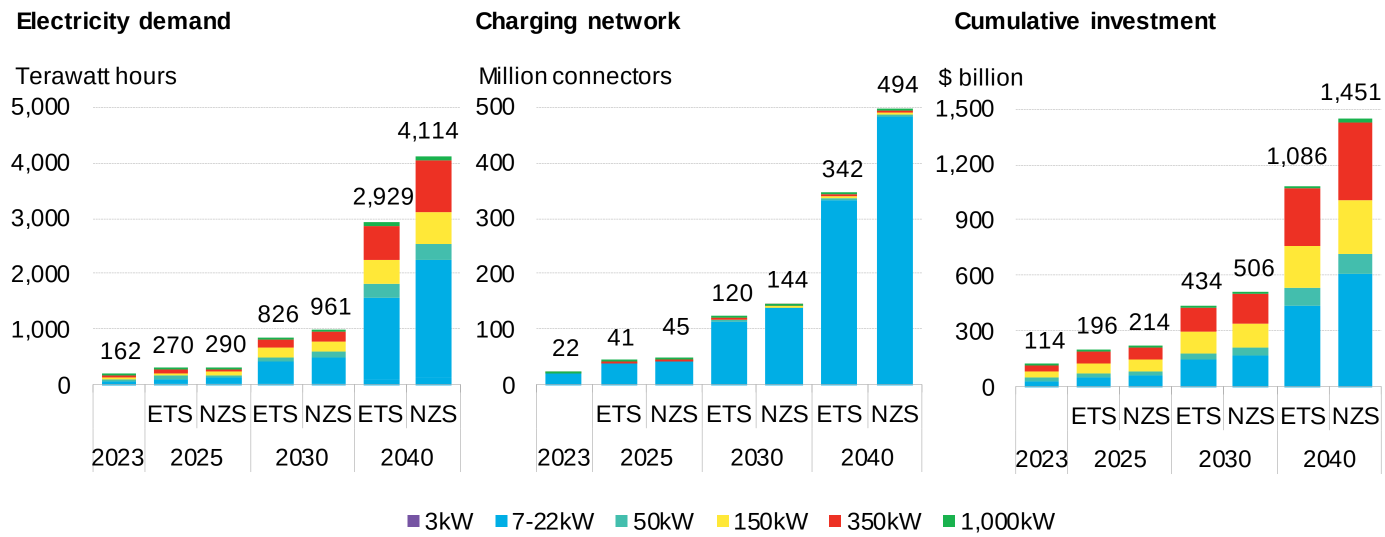
Charger sales

Some 97% of the installed chargers in our outlook in 2040 are slow 7-22kW chargers, installed at homes, in workplaces and in public. Yet while fast 50-1,000kW chargers make up only 3% of deployed infrastructure, they account for around 46% of electricity demand and 59% of investment by 2040 (Figure 264). These fast chargers are needed to serve the increasing number of electric passenger cars that do not have access to private charging and the growing fleet of electric commercial vehicles.

Global charger sales grow from just over 7 million in 2023 to over 40 million by 2040 in our outlook (Figure 266). AC charger sales (which are categorized as 7-22kW in power in our outlook and take several hours to charge an EV) continue to rise across this time in all regions as home charger sales drive demand. Numerous companies are currently entering the AC charging space, which is likely to be commoditized over time.

Sales of DC chargers (greater than 50kW) decline globally in the 2030s, as the expansion of the network slows and replacement chargers – rather than newly installed ones – begin to account for a majority of sales (Figure 267). This shift is largely driven by a decrease in demand in China, which can be partly attributed to the country's public charging network reaching capacity. To keep growing, DC charging manufacturers will have to enter new geographies and segments. They will also need to stay abreast of the latest technology and consumer trends. Charging operators, such as Electrify America and Fastned, have already ripped out and replaced infrastructure that has been in the ground for a limited amount of time, as charging power has increased and some equipment has been unreliable.

Figure 265: Global electricity demand for electric vehicles, charging network size and investment in charging



Source: BloombergNEF. Note: Excludes two- and three-wheelers. Investment includes hardware, installation and maintenance costs. ETS is Economic Transition Scenario, NZS is Net Zero Scenario, kW is kilowatt.

The reduction in DC charger sales in China will affect global manufacturers, as domestically made products are exported on the global stage. Propping up DC charger sales in China would require either a heavily underutilized network or replacement of chargers before they've reached their lifetime, both of which would present challenges for the business models of the companies in the market. The US has partly shielded itself from Chinese exports through the "Build America Buy America Act," which requires a high share of charging components to be manufactured domestically to receive subsidies.

Figure 266: Annual sales of chargers, by power category and region

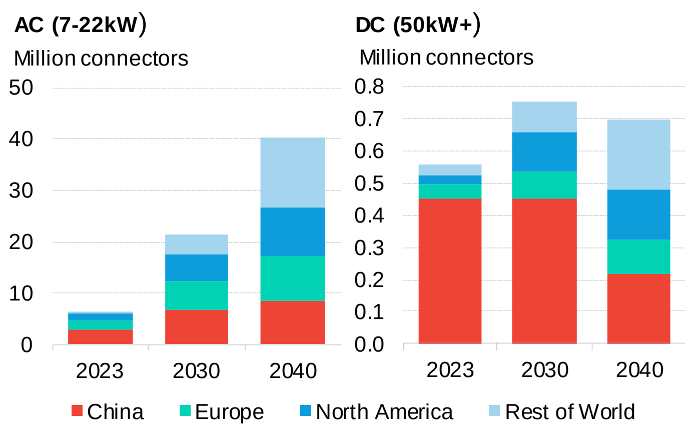
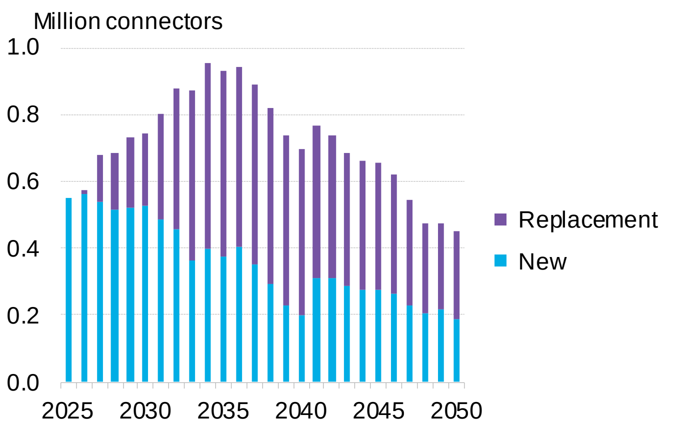


Figure 267: Annual sales of DC chargers globally, new build versus replacements



Source: BloombergNEF. Note: Rest of world here includes India, Brazil and Southeast Asia, as well as all markets categorized as "rest of world" elsewhere in this report. AC is alternating current, DC is direct current, kW is kilowatt.

Investment

As the rollout of chargers picks up steam, annual investment in all types of charging globally increases in the ETS to over $50 billion in 2029, and peaks at $69 billion in 2035. In 2023, we estimate that spending on charging was $36 billion globally. China is the largest market for charger investment until 2035, when the US, Canada and the 'Rest of World' category all overtake it (Figure 268). AC chargers account for close to a quarter of annual investment today, a share that grows to over 50% by 2038, as home charger sales continue to increase and the fast-charging network saturates (Figure 269).

Installation represents the largest share of cumulative investment by 2040, followed by hardware sales. The share of maintenance and operation investment expands over time but is less than 10% of cumulative investment by 2040 (Figure 270). As more electric vehicles join the global fleet the costs for charging per electric vehicle go down, from over $2,500 per electric vehicle today to less than $1,300 per electric vehicle in 2040 (Figure 271). This is because the capital outlay is spread across more vehicles and the network is used more efficiently due to higher charging powers and utilization.

Figure 268: Annual investment in chargers in the Economic Transition Scenario, by region

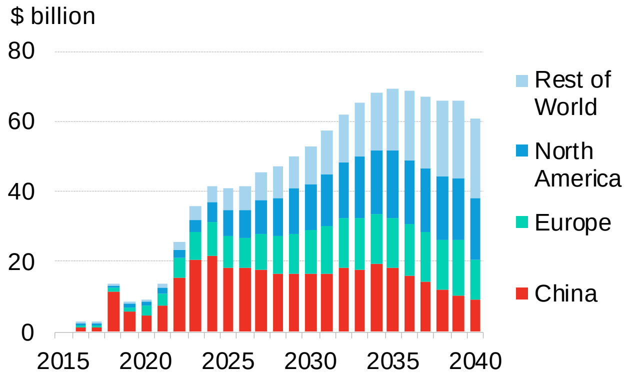
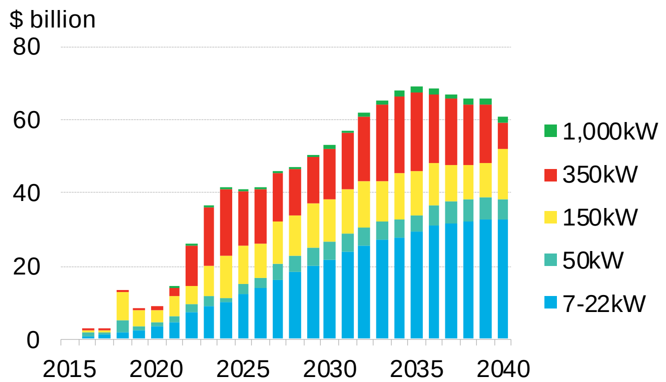
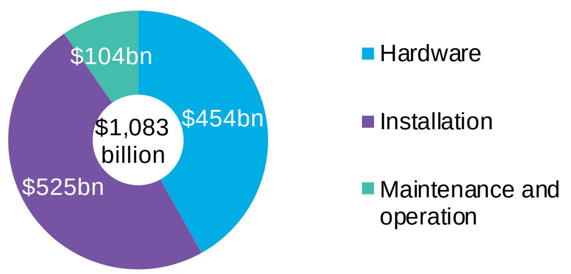


Figure 269: Annual investment in chargers in the Economic Transition Scenario, by power category



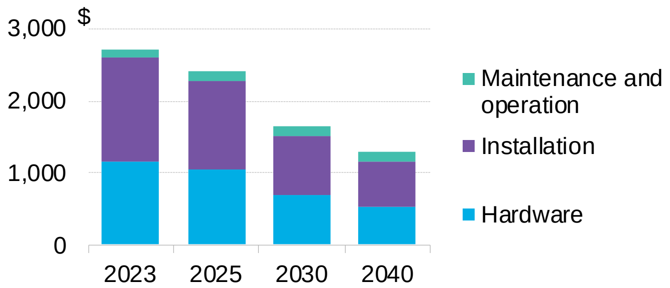
Source: BloombergNEF. Note: Investment includes hardware, installation and maintenance costs. Rest of world here includes India, Brazil and Southeast Asia, as well as all markets categorized as "rest of world" elsewhere in this report.

Figure 270: Global cumulative charging investment in 2040 in the Economic Transition Scenario, by category



Source: BloombergNEF

Figure 271: Cumulative charging investment per EV in the fleet in the Economic Transition Scenario, by category



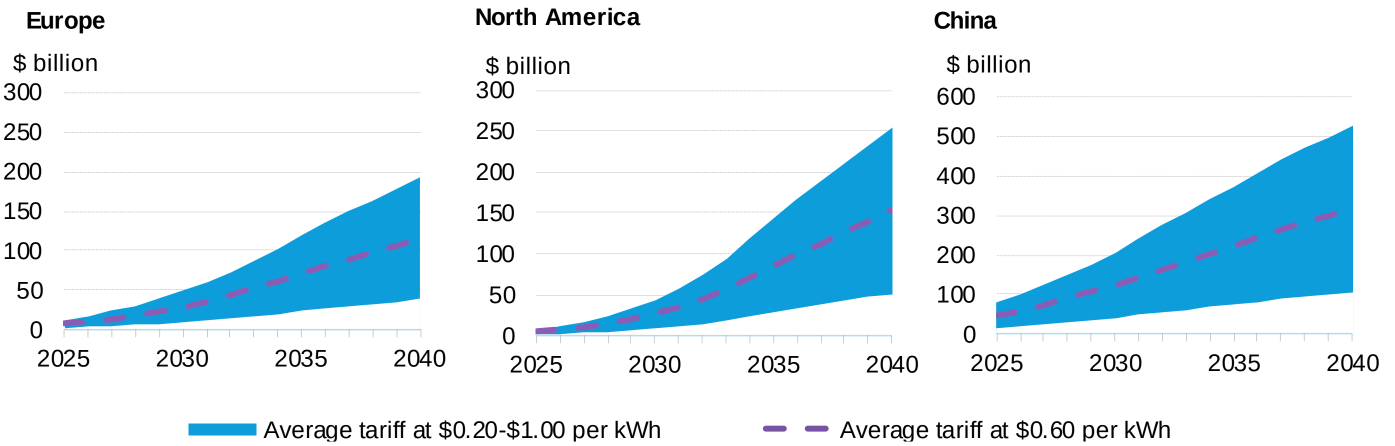
Source: BloombergNEF. Note: Divides the cumulative investment by all passenger and commercial EVs in the fleet.

Public-charging revenues

As the EV fleet grows over the next two decades, annual revenue from public charging soars to hundreds of billions of dollars. The average public charging price in Europe and North America today is around $0.60 per kilowatt-hour (kWh), but the price at many fast-charging networks is higher. Assuming an average price of $0.60/kWh until 2040, charging revenue hits $153 billion by 2040 in North America and $116 billion in Europe (Figure 272). At that price, China would be by far the largest charging market globally, with annual revenue from public charging of $316 billion in 2040. Today, however, many fast-charging networks in China cost around 1.4 CNY/kWh ($0.2/kWh) to use; should prices remain this low, China's public charging revenues would be just $105 billion.

To aid profitability, charging operators will likely look to drive down electricity costs by working with utilities on special tariff structures, signing power purchase agreements and co-locating renewables and batteries at stations. As the demand for charging at workplaces and commercial depots is set to increase as well, several companies have set up all-encompassing packages that include the chargers, maintenance and electricity to serve these locations.

Figure 272: Public-charging revenue, by region and average tariff price



Source: BloombergNEF. Note: Includes public charging for all vehicle types. Real tariffs can vary from those shown; kWh is kilowatt-hour.

10.2. Charging requirements per electric vehicle

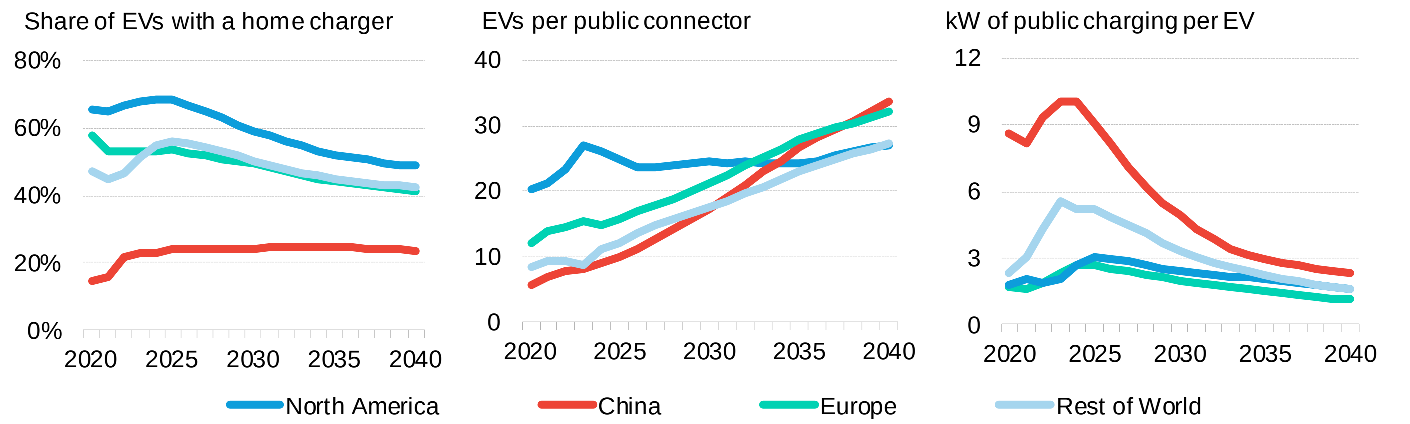
Passenger vehicles and vans

The density of the global public charging network is set to hit 25-35 EVs per public connector in 2040, depending on the region

As the public charging network expands, utilization increases and fewer chargers are needed per electric vehicle. As a result, there are between 25 and 35 EVs per public charger in 2040 across the world. This drop in density occurs despite a decrease in the share of EVs with access to home charging across Europe, the US and the rest of the world, from around 51-68% in 2023, to 40-50% in 2040 (Figure 273). In China, around 24% of vehicles have access to a home charger in 2040 in our scenario.

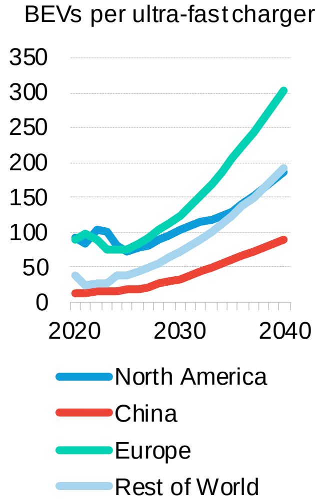
Public charging power per vehicle grows until 2026 as the network is built out quickly and operators install chargers ahead of demand. After this point, power per EV decreases as operators require higher levels of utilization for new chargers to be economically viable.

Figure 273: Regional overview of passenger electric vehicle demand for charging infrastructure in the Economic Transition Scenario



Source: BloombergNEF. Note: Includes light-duty commercial electric vehicles. Note: Rest of world here includes India, Brazil and Southeast Asia, as well as all markets categorized as "rest of world" elsewhere in this report; kW is kilowatt.

Figure 274: BEVs per ultra-fast charger



Source: BloombergNEF. Note: Rest of world here includes India, Brazil and Southeast Asia, as well as all markets categorized as "rest of world" elsewhere in this report.

In 2040, some 1.6kW is needed per vehicle in North America to satisfy demand, while 1.1kW per vehicle is needed in Europe. This is less than the 1.3kW legislated in the European Commission's Alternative Fuels Directive, suggesting the legislation is requiring countries to build too much infrastructure in the long term. In China, 2.3kW of public infrastructure is built per EV in 2040 to account for less private charging.

The prominence of ultra-fast chargers, which deliver over 100kW of power, contributes to the need for fewer chargers per electric vehicle in the coming years. While the number of BEVS per ultra-fast charger has dropped significantly in the last two years, to around 100 per ultra-fast charger in Europe and North America, the ratio of BEVs per ultra-fast charger rises over time, reaching over 300 BEVs per ultra-fast charger in Europe by 2040 and almost 200 in North America. In China, where public charging is more important, the ratio is 90 BEVs per ultra-fast charger in 2040 (Figure 274). The ratio changes over time due to higher utilization of the infrastructure and increasing amounts of charging occurring at 350kW chargers.

Commercial vehicles

Today, many commercial vehicle fleets are installing a charger for every one or two vehicles. This ratio will decrease over time as companies look to reduce costs and become more familiar with their fleets' charging patterns. In our outlook, the number of depot chargers per vehicle is the highest for buses, with around 40-60% of these vehicles having a depot charger by 2040 in the ETS; heavy-duty trucks (17-57%) and medium-duty trucks (15%-25%) follow (Figure 275).

China requires the fewest chargers per vehicle, as on average each vehicle travels less distance than in other regions, thereby requiring less electricity and having more time to charge. Heavy-duty trucks in the US travel the longest distances – around 76,600 kilometers annually, compared with 47,000 km in Germany and 23,000 km in China – and therefore have the highest demand for electricity and greatest need for charging infrastructure.

This variance in demand is reflected by the public infrastructure required for heavy-duty commercial vehicles (Figure 276). In North America by 2040 there is one public connector needed per 12 heavy-duty vehicles, compared with one charger per 24 vehicles in Europe.

Figure 275: Share of commercial electric vehicles with a depot charger in the Economic Transition Scenario

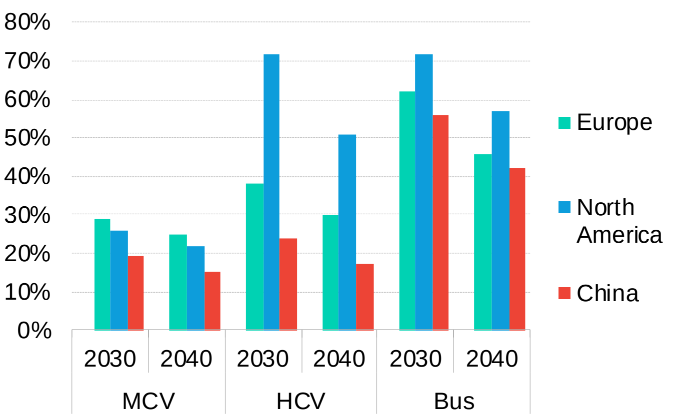
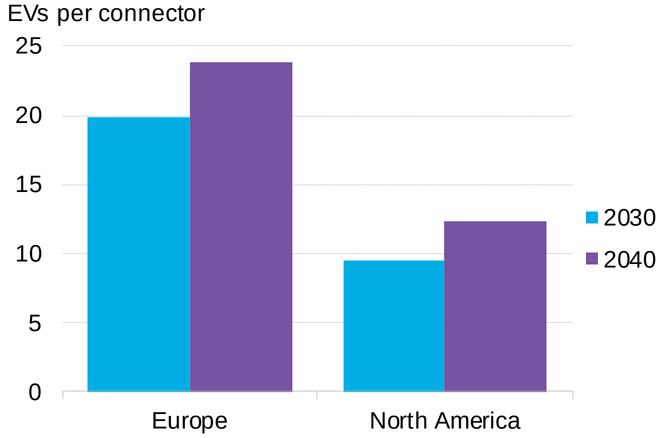


Figure 276: Heavy-duty commercial vehicles per public connector



Source: BloombergNEF. Note: MCV and HCV refer to medium- and heavy-duty commercial vehicles, respectively.

10.3. Considerations for the outlook

The future growth of the global charging network is still uncertain due to many technological, regional and consumer-usage considerations. Changes in how these parameters develop can alter the evolution and size of the required network and therefore the market for companies in the sector. This section reviews some of the variables that affect the outlook.

Location of charging

Building stocks and annual driving distances vary across the world. For example, in Norway nearly 60% of the population lives in a detached house, compared with 13% in Spain. These differences will influence the relative prevalence of home or public charging – and therefore the makeup of the charging network – in the future.

Figure 277: Charging demand for passenger EVs in the Netherlands, by location

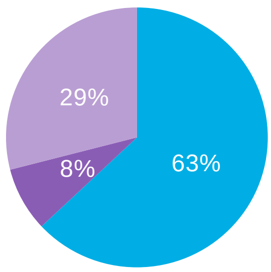
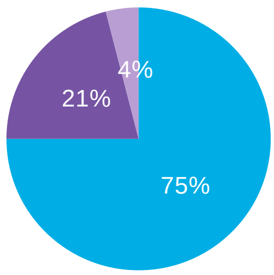


Figure 278: Charging demand for passenger EVs in Norway, by location



Home and work Public fast Public slow

Source: BloombergNEF, Netherlands National Charging Survey, DrivkraftNorge. Note: Assumes the average EV in Norway consumes 2,300 kilowatt-hours of electricity each year and drives 12,800 kilometers. Data for Norwegian public chargers extrapolated from publicly available data. Both data sets from 2022.

The availability of government funding is another key factor influencing the makeup of a country's charging network. For instance, public slow charging accounts for around 29% of charging demand in the Netherlands (Figure 277) but just 4% in Norway (Figure 278), where both home charging and public fast charging are more prevalent. In the Netherlands the prevalence of public slow charging can be partly attributed to the structure of government funding contracts, where municipalities tender out certain areas to operators. These tenders include stipulations on expanding the network when certain utilization or density metrics are hit, and the structure and availability of these contracts have contributed to the success of public slow charging in the country.

Table 18: Country split, by charging location mix category

Category	Countries
(A) Heavy home charging	Australia, Canada, Norway, US
(B) Heavy public fast charging	China, South Korea
(C) Mixed charging with a weight to public fast charging	Austria, Brazil, Bulgaria, Croatia, Cyprus, Czechia, Denmark, Estonia, Finland, France, Germany, Hungary, Iceland, Indonesia, Ireland, Italy, Japan, Luxembourg, Malaysia, Malta, Philippines, Poland, Portugal, Rest of World, Romania, Singapore, Slovakia, Slovenia, Spain, Sweden, Switzerland, Thailand, UK, Vietnam
(D) Mixed charging with a weight to public slow charging	Belgium, Greece, Lithuania, Netherlands

Source: BloombergNEF

Our outlook is split into four country categories based on charging location mix. An overview can be found in Table 18, with more details of specific assumptions in the charging infrastructure outlook methodology in Section 12.5.

Figure 279: Share of electricity demand in 2040 in the Economic Transition Scenario, by location

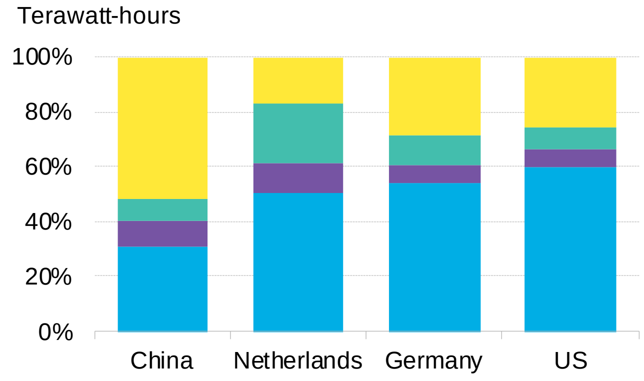
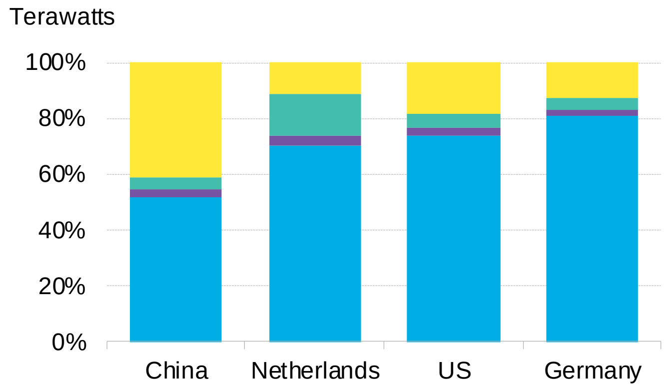


Figure 280: Share of charging network capacity in 2040 in the Economic Transition Scenario, by location



Source: BloombergNEF. Note: Includes only passenger vehicles and vans.

Based on these assumptions, by 2040 over 50% of electricity demand for passenger vehicles and vans in China comes from public fast chargers. By contrast, home charging delivers the most electricity in the Netherlands, Germany and the US (Figure 279). The Netherlands delivers the highest share of charging through public slow charging, assuming that the current success of charging via this method continues.

In all regions, home charging accounts for a higher share of the total network charging power than the share of electricity that the chargers deliver. This is because the chargers are significantly less utilized than chargers at other locations, typically serving only one vehicle's electricity demand. Yet distance driven also impacts this ratio. For instance, the share of installed power capacity attributed to home charging is higher in Germany than in the US, despite home charging delivering a lower share of electricity. This is because, on average, each electric vehicle in the US drives further and consumes more electricity annually than its German counterparts.

The high share of home charging as a proportion of total network power highlights the underutilization and expense of home chargers. Companies are already trying to take advantage of this by producing apps where drivers can share their home chargers with other drivers. If these become popular, they could reduce the demand for public charging.

Network utilization and average power

In our outlook the amount of electricity delivered per charger in the public network rises over time due to increasing utilization and charging power. The amount of electricity delivered per charger rises fast for DC chargers – reaching 680kWh per charger per day in 2040 across Europe and the US, up from 200kWh per charger per day for networks such as Electrify America, Tesla and Fastned today (Figure 282). The energy delivered from AC chargers increases as well, but at a slower rate, reaching 25kWh a day in 2040 (Figure 281). This is because we assume utilization of and average power demand at AC chargers grows more slowly.

Figure 281: Historic and assumed electricity delivered per public AC charger

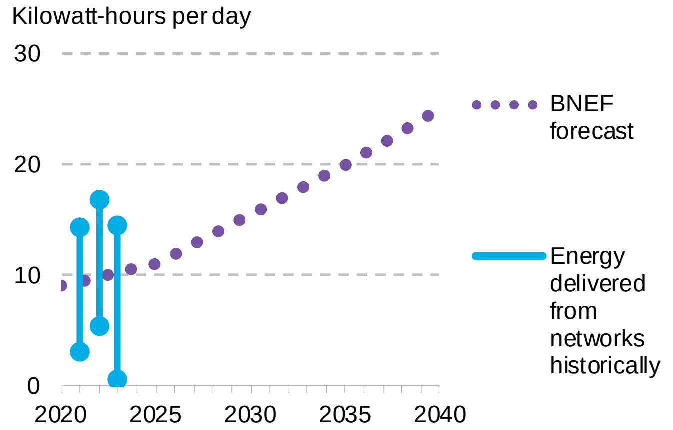
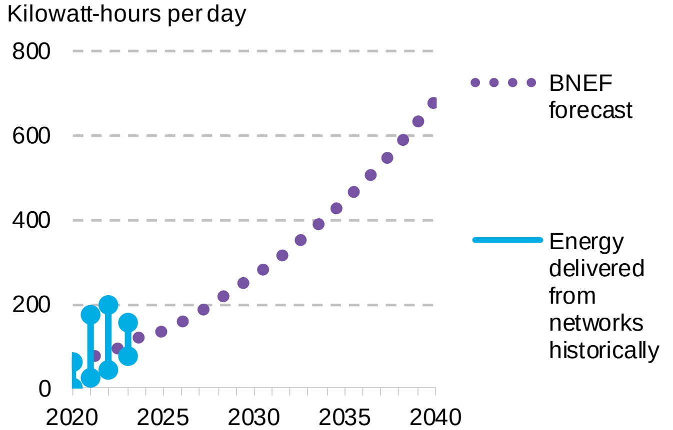


Figure 282: Historic and assumed electricity delivered per public DC charger

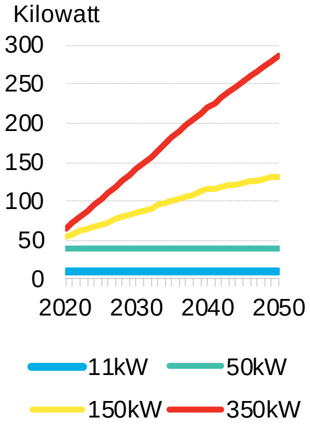


Source: BloombergNEF. Note: assumed values are a weighted average of 50 kilowatt (kW), 150kW and 350kW chargers in the forecast.

The fast-charging network rapidly expands until, as the utilization and power of charging rises, the need for more chargers slows. As the model reaches the 2040s and 2050s, the network size reaches a peak and even decreases in some markets, an effect similar to that observed with gas stations over the last two decades as certain sites become uneconomic.

The peak network size can vary vastly depending on the average power of charging and the utilization of charging. In our model, the assumed average power of fast charging rises over time

Figure 283: Assumed average power delivered by charger type depending on year



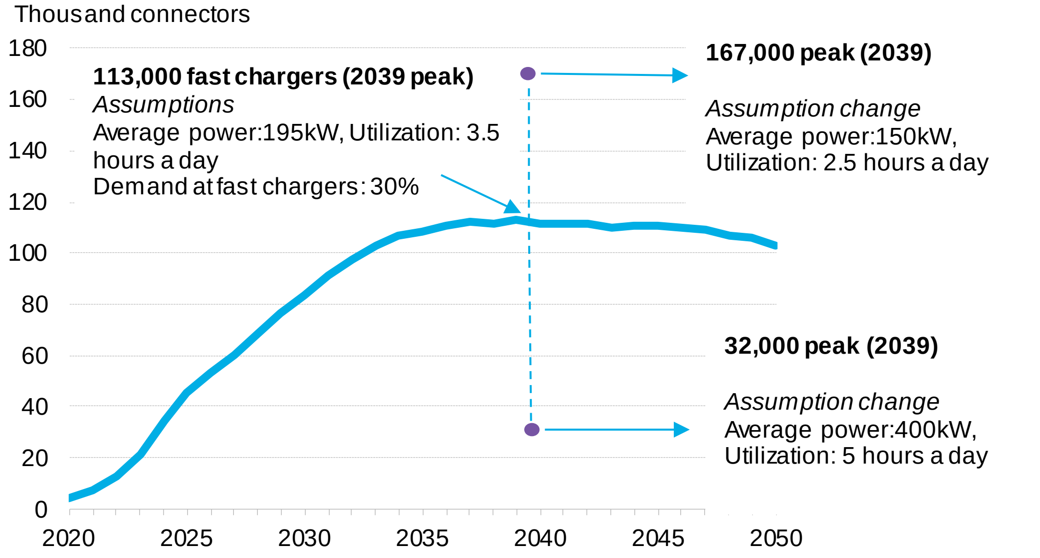
Source: BloombergNEF. Note: kW is kilowatts.

– 350kW chargers deliver 87kW on average in 2023, 220kW in 2040 and 287kW in 2050 (Figure 283). The average power delivered is always lower than the charger's nameplate capacity, as some vehicles will not be able to charge at the maximum power. EVs are also subject to charging curves, where the power of charging varies across a given session.

If we take Germany as an example, the public fast charging network peaks at 113,000 chargers in 2039 in the ETS. This assumes around 30% of charging is completed at public fast chargers that have an average power of 195kW in 2040 and are utilized around 3.5 hours a day.

Flexing the boundaries in two different scenarios, the network size could peak at 32,000 or 167,000 fast chargers, representing very different outcomes for the size of the market for charging manufacturers and the number of viable locations for operators (Figure 284).

Figure 284: German public fast network size, depending on charger power and utilization assumptions



Source: BloombergNEF. Note: Uses the Economic Transition Scenario as a base; kW is kilowatts.

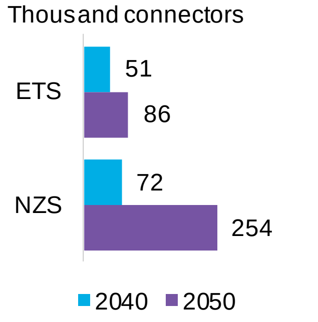
In the first scenario mentioned above, we assume that the average charging power rises higher and breaks the maximum limits today, reaching 400kW on average in 2040, with utilization reaching an average of five hours a day. In the second scenario we assume that the average charging power only rises to 150kW by 2040 and utilization reaches only 2.5 hours a day on average.

Both parameters are subjective. Some in the EV sector believe that charging will get ever faster, while others believe that EV drivers do not require faster charging as they can charge during their normal 'resting' periods. For example, a trip to a supermarket provides an average 40 minutes to charge a car, making a five-minute charging option redundant. Additionally, not every EV will necessarily have 400kW charging capability. The most advanced batteries announced today are limited to around 350kW charging for passenger vehicles, although there could be advancements in the decade ahead. If fast-charging technology in cars changes quickly, this will put more burden on operators to update their networks and increase the number of replacement chargers sold into the market.

Multi-megawatt charging

Multi-megawatt charging is highlighted as a key technology for the adoption of electric trucks, enabling them to charge the many hundreds of kilowatt-hours they require for long journeys in a short period of time. However, the number of megawatt truck chargers required by 2040 in our outlook is just 51,000 in the ETS and 72,000 in the NZS. By 2050 in the NZS this number rises to 254,000 (Figure 285). In total, the megawatt chargers serve just 2-3% of total EV electricity demand between 2040 and 2050, as they are solely used for public charging for trucks and buses.

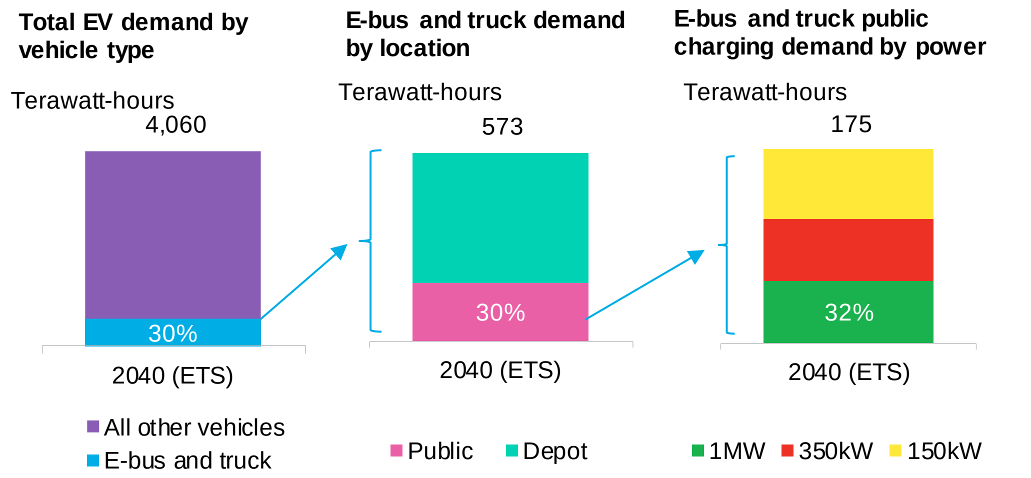
Figure 285: Number of megawatt chargers in the outlook, by scenario



Source: BloombergNEF. Note: ETS is Economic Transition Scenario, NZS is Net Zero Scenario.

Electric trucks and buses account for 20% of total EV electricity demand in 2040 in the ETS. We assume around 30% of that to public charging of trucks, and 32% of that subset is then assigned to megawatt charging; the remaining charging is assumed to occur at 350kW and 150kW chargers (Figure 287).

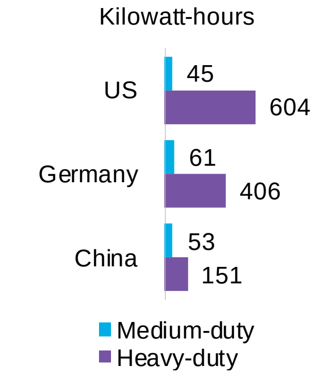
Figure 287: Assumed electricity demand for e-buses and trucks in 2040, broken down by location and charger power in the Economic Transition Scenario



Source: BloombergNEF. Note: MW is megawatts, kW is kilowatts.

In total there are 5.7 million chargers in the ETS for e-buses and trucks in 2040, but just 554,000 of those are for public charging while the rest are at depots (Figure 288). More than half of the depot chargers are 22kW chargers. These low-power chargers are suitable for many trucks and buses in the fleet that do a small amount of daily driving. For example, in our outlook, medium-duty trucks in the US, Germany and China consume between 45kWh and 61kWh a day on average (Figure 286). This could be satisfied with a 22kW charger overnight.

Figure 286: Assumed average daily electricity consumption, by truck type and country



Source: BloombergNEF

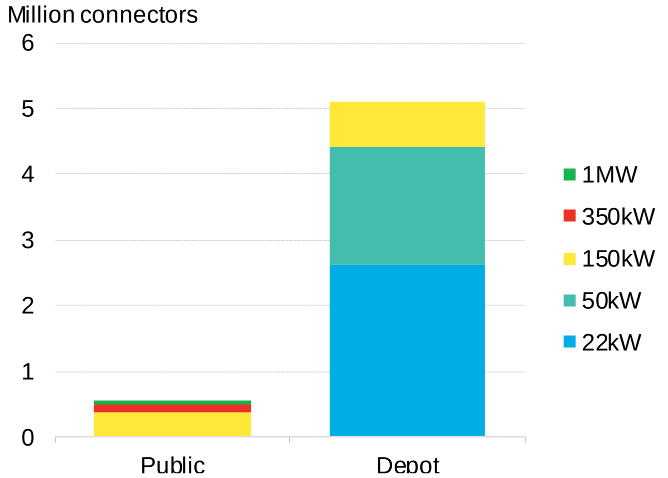
However, higher-power chargers are still necessary, as they provide flexibility for operators who want to charge their fleets in a short amount of time and meet the large demands of heavy-duty vehicles. The demands on these chargers vary greatly by region, with the average daily electricity demand from heavy-duty trucks reaching 604kWh in the US, compared with 406kWh in Germany and 151kWh in China. This means higher-power charging will be more important in the US.

The charging mix for trucks is still uncertain due to the large numbers of stakeholders and routes. In our outlook we assume that most trucks will have at least four hours to charge overnight and therefore 50kW or 150kW chargers would be suitable at depots. We also assume that 150kW chargers will join 350kW and 1MW chargers in the public charging mix, as drivers stop for extended periods on their journeys.

Globally, there are a combined 196,000 of 350kW and multi-megawatt chargers in public locations in the ETS in 2040 (Figure 289). We assume that the 350kW chargers deliver an average of 240kW of power and that the 1MW chargers deliver an average power of 700kW. The average power of the two types of chargers combined is 471kW in the outlook.

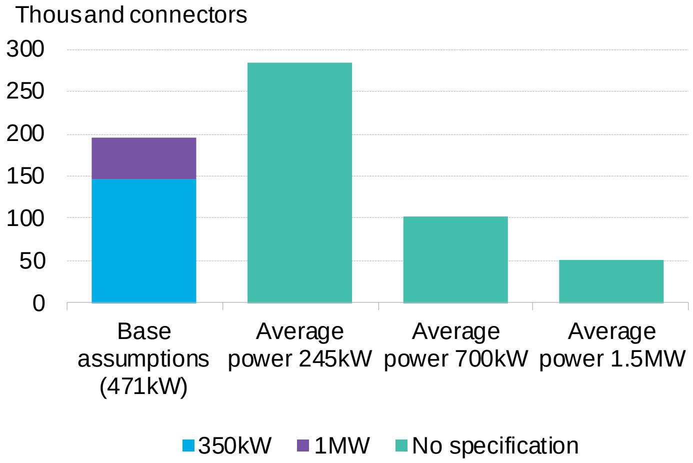
When varying the combined average power of 350kW and 1MW chargers between 245kW and 1.5MW, the number of chargers needed varies dramatically. At 245kW, 284,000 chargers are required, a figure that drops to less than 50,000 when the average power of charging is increased to 1.5MW.

Figure 288: E-bus and truck chargers required in 2040 in the ETS, by charger power and location



Source: BloombergNEF. Note: MW is megawatts, kW is kilowatts.

Figure 289: Required multi-megawatt public e-bus and truck chargers depending on average power in 2040



Source: BloombergNEF. Note: Scenarios only change the average power for 350-kilowatt and 1-megawatt public e-bus and truck chargers.

In the real world the lines between depot and public charging will be more blurred, and companies may find depots suitable for megawatt charging – meaning the technology could gain more market share. Pepsi, for example, has installed Megawatt Charging System (MCS) chargers, said to be capable of multi-megawatt charging, at its depots where it is running the Tesla Semi. If megawatt charging accounted for 25% of depot charging for trucks, then compared with the baseline numbers in Figure 285, 100,000 more megawatt chargers would be required by 2040 and 150,000 by 2050 in the ETS and 117,000 by 2040 and 332,000 by 2050 in the NZS.

10.4. Regional charging infrastructure overview

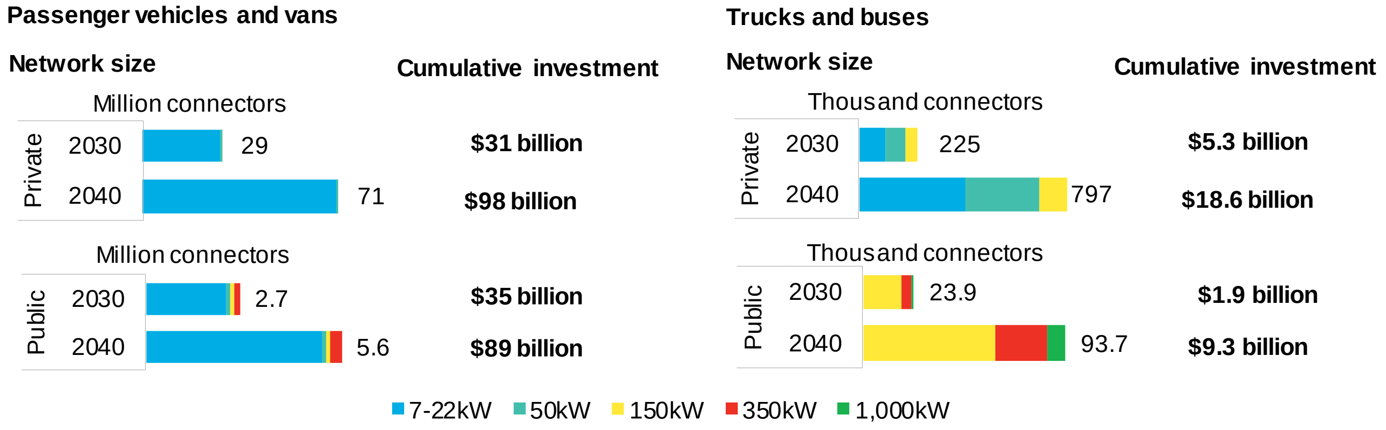
This section outlines the amount of charging infrastructure required in Europe, the US and China under the ETS. A breakdown of the required infrastructure is provided by charger power and location, as well as which vehicles chargers serve. A discussion is included on the influence of government targets and regulations on rollout plans.

This year we have produced results for every country in Europe. BNEF clients can find the full results in our Electric Vehicle Charging Infrastructure Outlook dashboard (web) and can also complete their own sensitivity analysis using our *Charging Infrastructure Forecast Model* (web).

Europe

Between now and 2040, over $250 billion is required for public and private charging for passenger vehicles and vans in Europe, with an additional $35 billion required for charging for trucks and buses (Figure 290). The largest share of this investment, amounting to $98 billion, is needed for the 71 million private chargers required by 2040; this is followed by $89 billion for a network of 5.6 million public chargers.

Figure 290: Electric vehicle charging infrastructure rollout in Europe to 2040 in the Economic Transition Scenario



Source: BloombergNEF. Note: Investment figures include hardware, installation and maintenance investment; kW is kilowatt.

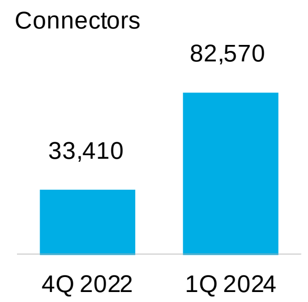
Public charging installations have been increasing in Europe; around 200,000 connectors were installed in 2023, and 65,000 were installed in the first three months of 2024. If that installation rate continues for the rest of 2024, around 260,000 connectors will be installed this year. This is close to the 275,000 connectors that must be installed annually in the ETS to have a network of 2.7 million chargers by 2030.

This is below the European Commission's target of 3.5 million chargers by 2030. Still, in the ETS the network expands quickly and reaches 5.6 million public connectors by 2040, highlighting that the European Commission has ambitious targets to set the EV market on an upward trajectory. The analysis conflicts with the European Automobile Manufacturers Association which says 8.8 million chargers are required by 2030. We find this to be a vast overestimate, one that feeds the narrative that the charging industry in Europe is not on track, when many indicators suggest it is growing well.

The EU has delivered funding to achieve its ambitions. The second phase of the Alternative Fuels Infrastructure Facility (AFIF) opened in February, with €1 billion available to support the deployment of alternative fuel infrastructure along Europe's key roads, called the Trans-European Transport Network (TEN-T). The first phase of the fund awarded €1.3 billion between 2021 and 2024, and combined with funding from European countries – such as the nearly €2 billion awarded by the German government for a network of fast chargers – it has contributed to a competitive market.

BloombergNEF is tracking over 500 companies installing ultra-fast chargers in Europe, and the European network has grown 2.5 times in the last 15 months, to 82,570 ultra-fast chargers at the end of 1Q 2024 from 33,410 at the end of 4Q 2022 (Figure 292).

Figure 291: Installed ultra-fast chargers in Europe



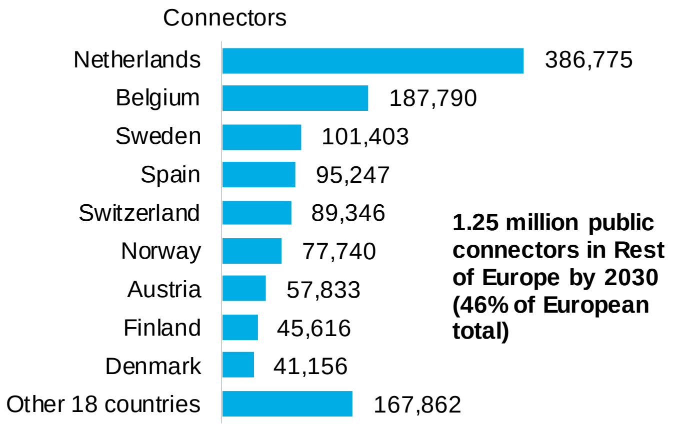
Source: BloombergNEF, Ecomovement.

The distribution of funding in urban areas is more sporadic, but additional funding is coming based on the Renewable Energy Directive III, which includes legislation for every member state to roll out carbon credit programs for low-emission transport fuels by 2025. These programs can be worth as much as $0.40/kWh to operators today in locations such as Germany, and have the potential to pump billions of dollars into the charging market.

This funding could offer vital support for charging operators in European countries with low electric vehicle adoption. In this year's outlook, we include charging demand outlook for each 'tier 2 country' – defined as all European countries classified as Rest of Europe plus the Nordics – in the main parts of our modeling. For the methodology used for modeling EV adoption in tier 2 countries, please see Section 12.

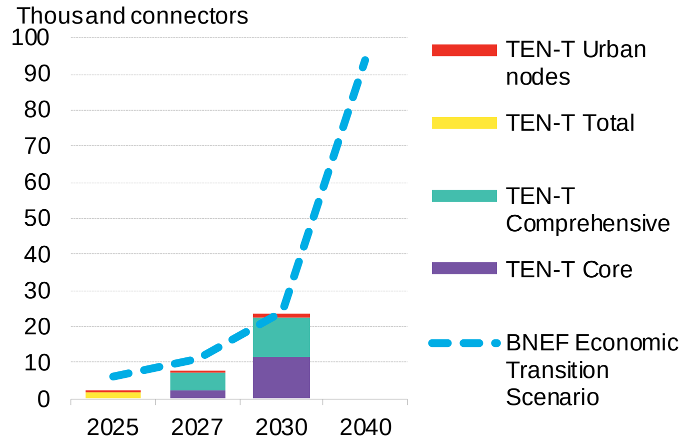
This group of countries requires 46% of total public chargers in Europe by 2030 in the ETS. This high share is due in part to the Netherlands and Belgium having a high number of public slow chargers in their networks and therefore a high total number of public chargers.

Figure 292: Public chargers required by country in the Rest of Europe (tier 2 countries)



Source: BloombergNEF, company announcements. Note: Rest of Europe includes every country in Europe excluding France, Germany, Italy and the UK.

Figure 293: Number of public high-power chargers needed to meet the distance-based target for trucks and buses



Source: BloombergNEF, European Council. Note: Assumes 88 urban nodes. Numbers for 2030 assume one 450-kilowatt (kW) connector per 10 connectors of the Trans-European Transport Network (TEN-T) core network and one 450kW connector per four connectors for the TEN-T comprehensive network. The rest are 350kW, except for 150kW connectors for urban nodes.

The next focus for policymakers is to set the truck charging industry on the same trajectory as the passenger vehicle market. The European Commission has laid out mandatory deployment targets for heavy-duty vehicle public charging in the Alternative Fuels Infrastructure Regulation (AFIR); no other region has such policy. The mandatory targets are for the number of chargers and power of stations on key European roads.

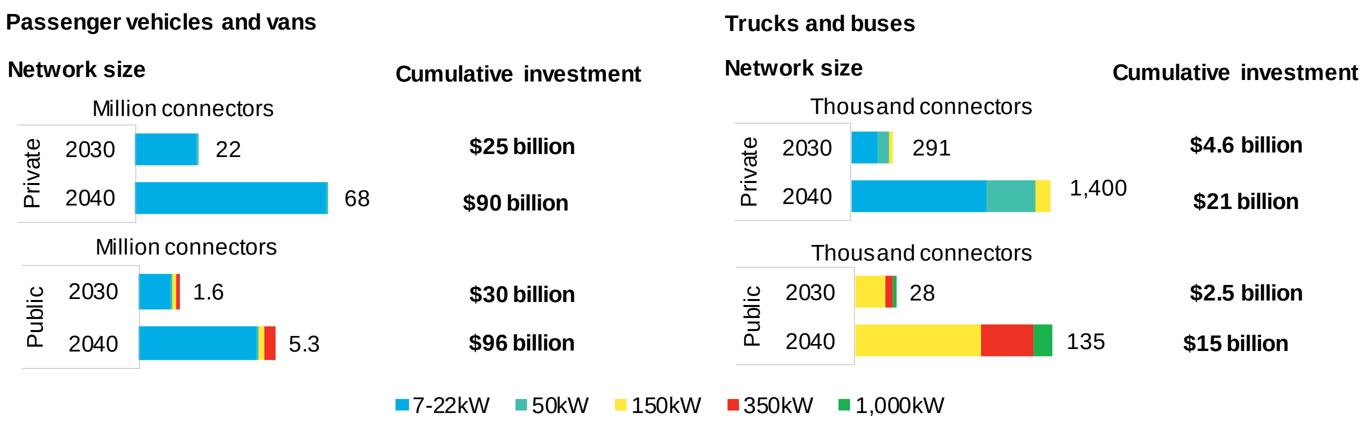
The AFIR targets, if fulfilled, would add over 23,000 public chargers by 2030, which is on track with the ETS (Figure 293). Still, a big scale-up is required by 2040 in the ETS to reach 93,700 public chargers by that point. About 225,000 depot chargers are required by 2030, rising to 797,000 by 2040. Depots do not appear extensively in the regulation but will be a major location for truck charging and also need governmental funding support. This is a focus in the current AFIF funding, and individual countries are also supporting charging for trucks.

The estimation of public chargers needed for trucks is difficult because charger powers may vary from what is assumed in our calculations. The regulation states a minimum requirement of 350kW connectors, but heavy-duty trucks, particularly those doing long-haul routes, are likely to require the megawatt-scale charging that has yet to be rolled out.

US

Between now and 2040, over $240 billion is required for public and private charging for passenger vehicles and vans in the US, with an additional $43 billion required for charging for trucks and buses (Figure 294). By 2030, the US needs 22 million private chargers and 1.6 million public chargers in the ETS. This rises to 68 million private chargers and 5.3 million public chargers by 2040. Cumulative investment in public infrastructure reaches $126 billion by 2040, superseding the $90 billion of cumulative investment in private charging infrastructure. This is despite home charging serving a substantial proportion of demand and is due to the large road network and long travel distances in the US.

Figure 294: Electric vehicle charging infrastructure rollout in the US to 2040 in the Economic Transition Scenario



Source: BloombergNEF. Note: Investment figures shown are cumulative and include hardware and installation investment; kW is kilowatt.

The required number of public chargers in the ETS in 2030 is more than triple the 500,000 targeted by the Biden administration for the same year, and the industry needs to scale up quickly to meet the figures in our outlook. In 2023 around 30,000 chargers were installed in the public network in the US; this would need to rise to over 200,000 installations annually over the next seven years in the ETS.

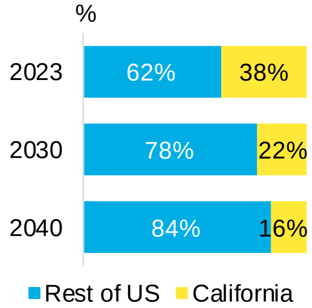
The $7.5 billion approved for public charging infrastructure from the federal government – the National Electric Vehicle Infrastructure (NEVI) Formula Program – will help the industry and accounts for around 25% of the public charging investment by 2030 envisioned in our outlook. It should provide momentum to the US public charging market, which has suffered from a lack of competition. Tesla's recent announcement that it will scale back its supercharger team and ambitions is also a negative sign for the market, but over 50 new companies have been awarded funds from the NEVI to date. Urban charging installations are an area of concern in the US: although they have attracted some funds, they are not a regulatory or commercial focus, and the lack of charging around work and residential environments may deter some prospective EV buyers.

E-buses and trucks require 28,000 public chargers in the US by 2030 in the ETS. That figure rises to 135,000 by 2040, amounting to a cumulative investment of $15 billion. A further $21 billion is required for infrastructure at depots for these vehicles during that time.

The US Joint Office of Energy and Transportation set out its plan, the "National Zero-Emission Freight Corridor Strategy", in March 2024. The plan outlines four phases of charging deployment across key roads, starting with what it defines as establishing hubs for 12,000 miles of roads between 2024 and 2027. It then progressively makes the networks denser, covering 49,000 miles of road by 2040. The plan is a north star for the many stakeholders in infrastructure installation, including federal and local governments, utilities, logistics and fleet operators. However, it does not have any new funding attached to achieving it at this point.

Several initiatives are already present across the US, including the West Coast Clean Transit Corridor Initiative. This is a collaboration among 16 utilities and has outlined key sites for truck charging, coordinating the group to apply for government funds. Utilities are also creating rate-based programs for truck charging. Southern California Edison's Charge Ready Transport Program, for example aims to electrify 8,500 trucks and has funding available to support the grid upgrades required to install charging infrastructure.

Figure 295: California's share of US electric vehicle electricity demand

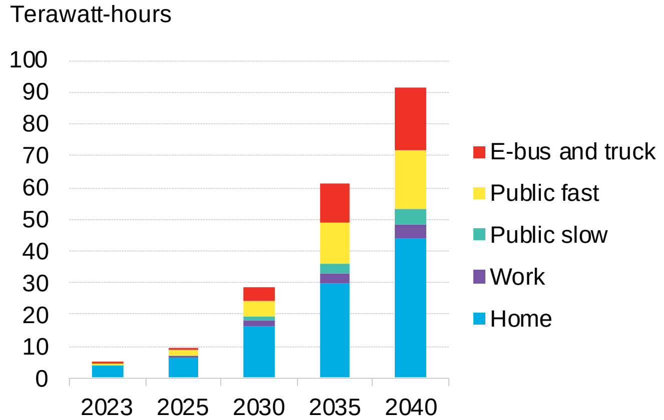


Source: BloombergNEF

California

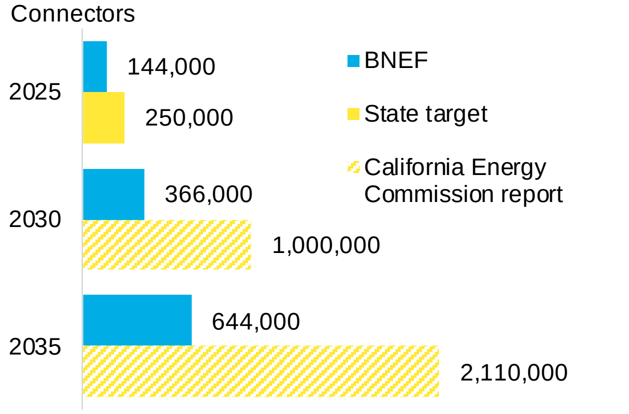
California currently accounts for around 38% of total EV electricity demand in the US. This decreases to around 16% by 2040 as EV adoption rises across the country (Figure 295), opening up opportunities for charging companies in other states.

Figure 296: California's electric vehicle electricity demand in the Economic Transition Scenario



Source: BloombergNEF

Figure 297: Comparison of BNEF's and California's charger outlooks (excluding homes)



Source: BloombergNEF, California Energy Commission. Note: Results from Assembly Bill 2127 Second Electric Vehicle Charging Infrastructure Assessment.

In the ETS, demand for electricity from EVs in California rises from 5TWh in 2023 to 29TWh in 2030 and 61TWh by 2035 (Figure 296). By 2025, 144,000 chargers are installed in the state outside of homes. This is less than the state's target of 250,000 chargers by 2025, which is reached in our outlook in 2028 (Figure 297).

The number of chargers in the ETS is also less than estimates reported by the California Energy Commission (CEC) for public and shared private chargers by 2030 and 2035, although both BNEF and the CEC assume a similar number of electric vehicles.

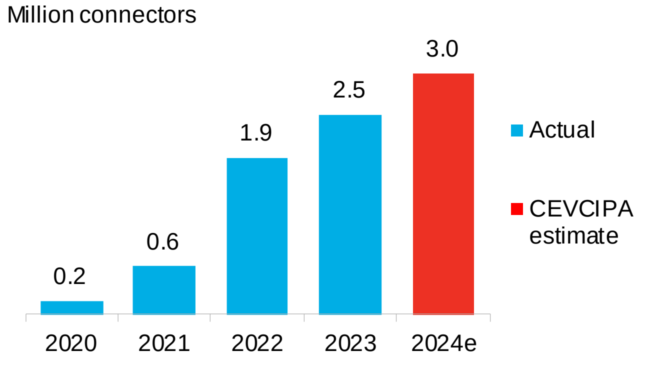
Three key factors account for this difference. The ETS has a higher number of DC charging installations, which can serve more vehicles than a slow charger, than the CEC's report. BNEF does not clearly break out charging for apartment buildings, which may contribute to the shortfall. And public charging installations in California have slowed in the past year, undercutting confidence that the network can grow from around 86,000 in 2023 to 250,000 in two years. The CEC does, however, state that funding for an additional 167,000 chargers has been allocated across California, possibly suggesting that a growth in installations is coming.

China

China has the most extensive charging network globally, with annual private installations reaching 2.5 million connectors in 2023 (Figure 298) and public installations reaching 930,000 (Figure 299). The number of private installations was lower than the 3.4 million chargers that had been forecast by the China Electric Vehicle Charging Infrastructure Promotion Alliance (CEVCIPA) at the beginning of 2023 and suggests challenges scaling private installations. The alliance is expecting three million private installations this year.

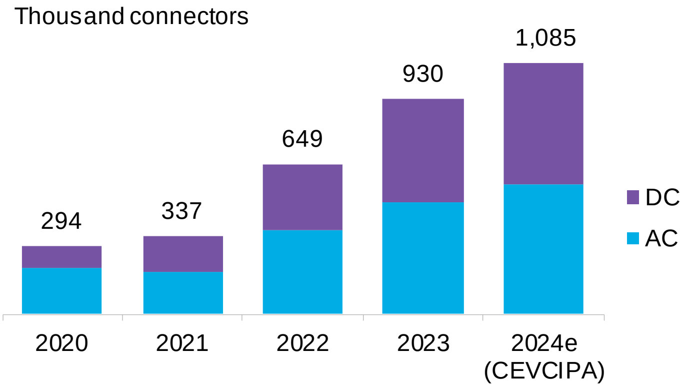
Public charger installations grew to 930,000 in 2023 from 649,000 in 2022, continuing the rapid growth of the last few years. In 2024, the CEVCIPA is expecting just less than 1.1 million public installations, indicating a slowing rate of growth. In our ETS, we expect installations to decrease slightly in 2024 to 918,000, below the alliance's outlook. Our model shows that the high rate of installations is saturating the market and can be detrimental to operators due to the risk of low utilization. The decrease in installations in our model is also because we assume higher-power chargers reduce the need for as much infrastructure.

Figure 298: Annual private charger installations in China



Source: BloombergNEF, China Electric Vehicle Charging Infrastructure Promotion Alliance (CEVCIPA).

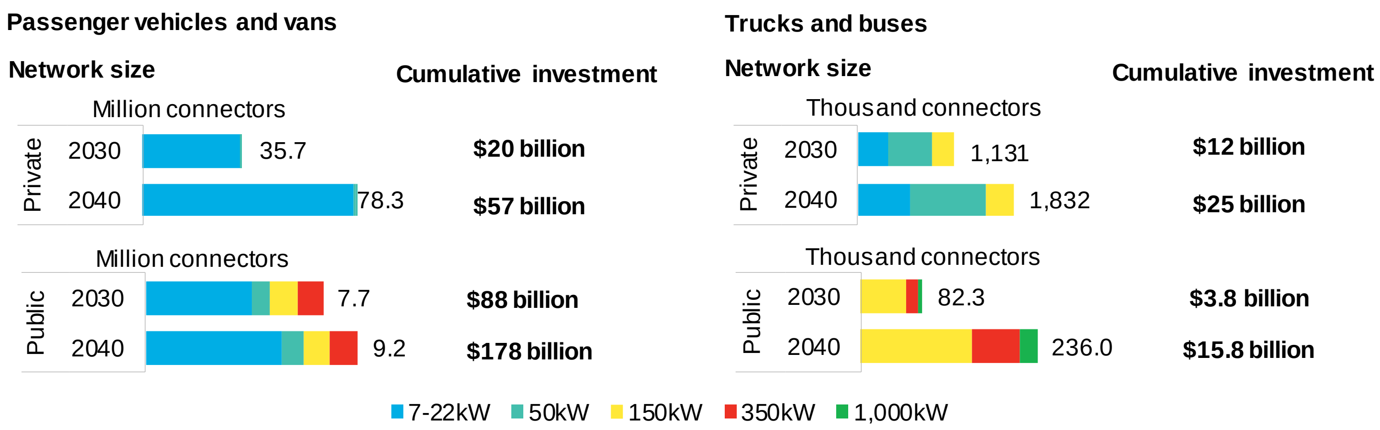
Figure 299: Annual public charger installations in China



Source: BloombergNEF, China Electric Vehicle Charging Infrastructure Promotion Alliance (CEVCIPA). Note: AC refers to alternating current; DC is direct current.

The slower growth in public installations will challenge DC charger manufacturers, which will look to exports and faster replacements of older chargers. As early as 2021, China's fast-charging network already had about half a million chargers, but technology is evolving fast and some of these chargers may be replaced before the ten-year lifetime assumed in our model.

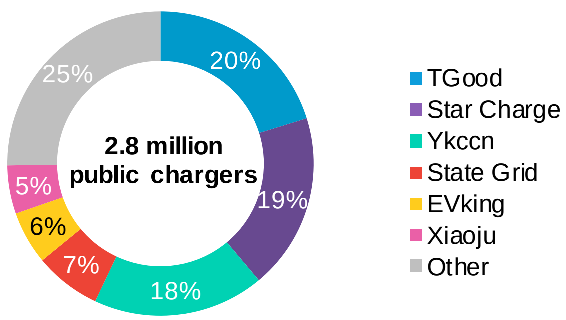
Figure 300: Electric vehicle charging infrastructure rollout in China to 2040 in the Economic Transition Scenario



Source: BloombergNEF. Note: Investment figures shown are cumulative and include hardware and installation investment; kW is kilowatts.

Both the private and public network still grow in the ETS, however. Private installations reach 36 million in 2030, requiring $20 billion in investment, rising to 78 million chargers and $57 billion in cumulative investment by 2040. The public charging network more than doubles by 2030 to reach 7.7 million connectors and expands to 9.2 million connectors by 2040. Such growth would require $178 billion in investment between 2023 and 2040, although a substantial portion of this goes to replacing millions of chargers installed 10 years earlier, rather than expanding the network (Figure 300). Over two million chargers are required for trucks and buses by 2040, with 236,000 of those in public locations. Battery swapping is gaining traction in the Chinese truck market and could reduce the number of chargers required.

Figure 301: Public chargers in China, by operator



Source: BloombergNEF, China Electric Vehicle Charging Infrastructure Promotion Alliance.

The competitive landscape will also change over the next 10 years. Today five companies, TGood, Star Charge, Ykccn, State Grid and Evking, account for 70% of chargers in the China public network. It is noticeable that oil and gas companies, which control a large share of the petrol station market, such as Sinopec, PetroChina, Shell and TotalEnergies (in a joint venture with China Three Gorges Group), have entered the EV charging space. Still, they currently account for only a small share of total chargers in the country. Even after building a planned

11,000 chargers with China Three Gorges Group, TotalEnergies' share would only be 0.4% of the market.

Oil and gas companies will be hoping that the key locations they already have are premium sites that can lead to high utilization. Not every site will be suitable though. Shell announced in its *Energy Transition Strategy 2024* report that it would divest around 1,000 gas stations globally over the next two years as it transitions to offering more EV charging. Since oil and gas majors in China lag in the EV charging market, they may also look to acquisitions. PetroChina bought charging provider Potevio New Energy in 2023, and more acquisitions are likely in 2024 and beyond.

Further reading

- *Charging Infrastructure Forecast Model (CIFM)* (web)
- *Data Hub: EV Charging Infrastructure* (tool)
- *EV Charging Utilization 2023: Tesla Beats Chinese Giants* (web | terminal)
- *EV Charging Companies Are Finally Turning a Profit* (web | terminal)
- *Vehicle-to-Grid Tech Inches Closer to Commercialization* (web | terminal)
- *Fast Charging EVs Need Network to Deliver on Big Promise* (web | terminal)
- *Scaling EV Battery Swapping Needs All Hands on Deck* (web | terminal)
- *The Strategies Shaping Europe's EV Charger Rollout: Q&A* (web | terminal)
- *Quarter of a Million Ultra-Fast Chargers Coming to Europe* (web | terminal)
- *Carbon Credits Could Be the Key to EV Charging Conundrum* (web | terminal)
- *Volatile Charging Prices Threaten EV Rollout* (web | terminal)

Comparison with EVO 2023

BloombergNEF

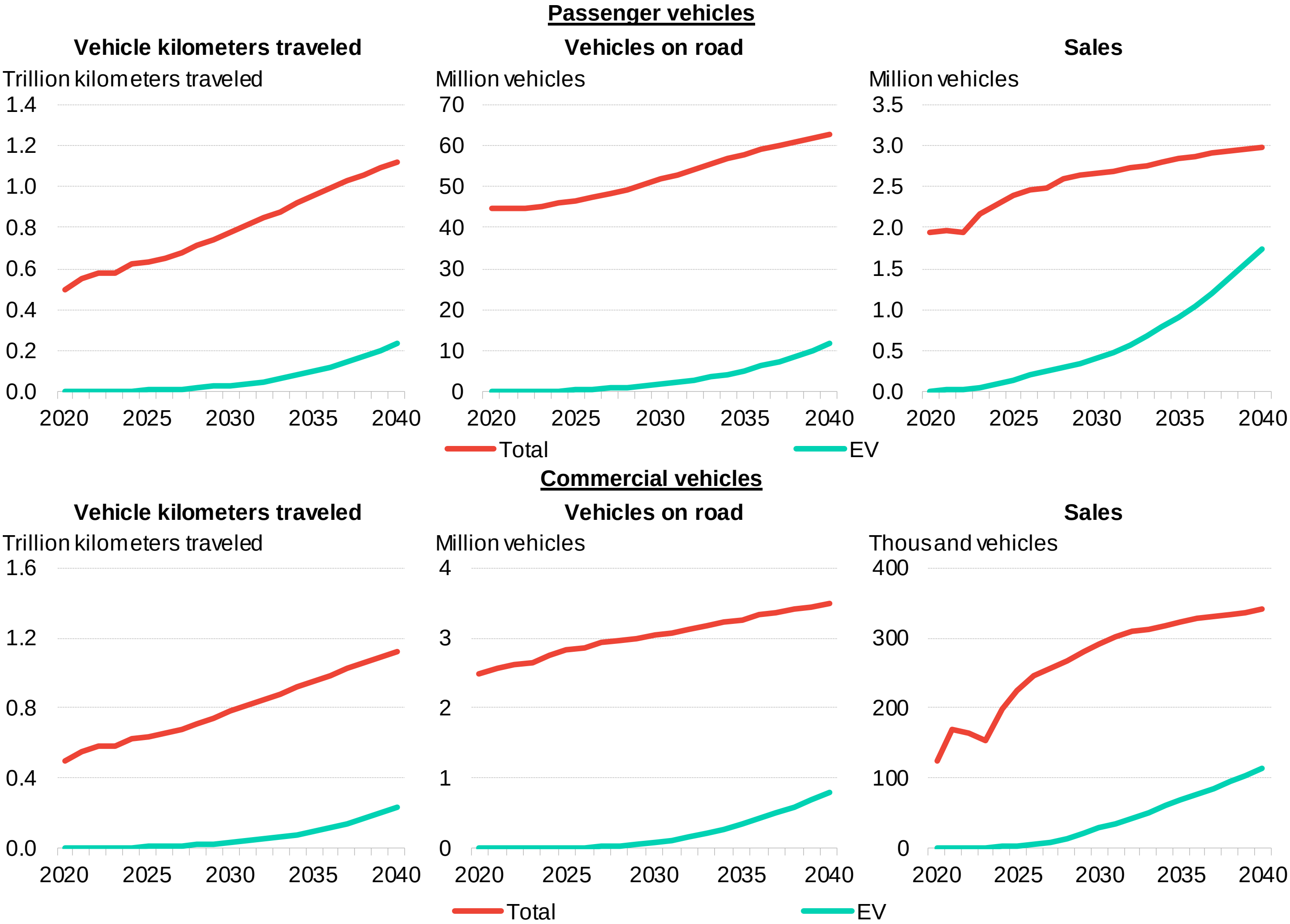
Section 11. Comparison with last year's outlook

Each year, we revise our outlook based on new learnings and updated data. We also attempt to add more detail to our outlook through greater specificity on key inputs and consideration of regional variations.

Brazil and Rest of World

This year's EVO adds Brazil to our list of modeled countries, in the process removing it from our 'Rest of World' category. That said, tallying the Brazil and Rest of World categories in this year's report generates data not substantially different to the Rest of World category in 2023.

Figure 302: Brazil passenger and commercial vehicle kilometers traveled, vehicles on the road and sales in the Economic Transition Scenario

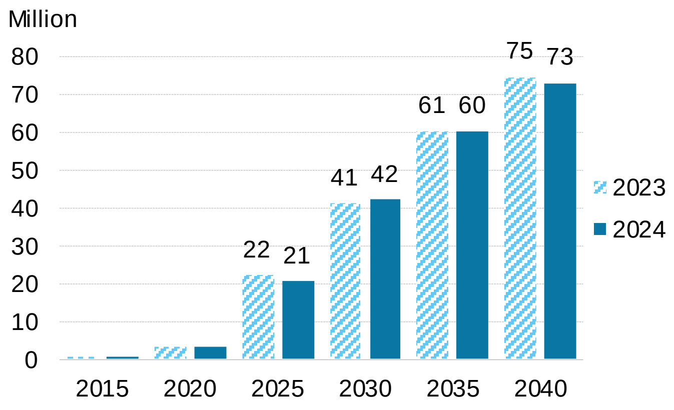


Source: BloombergNEF

Passenger cars

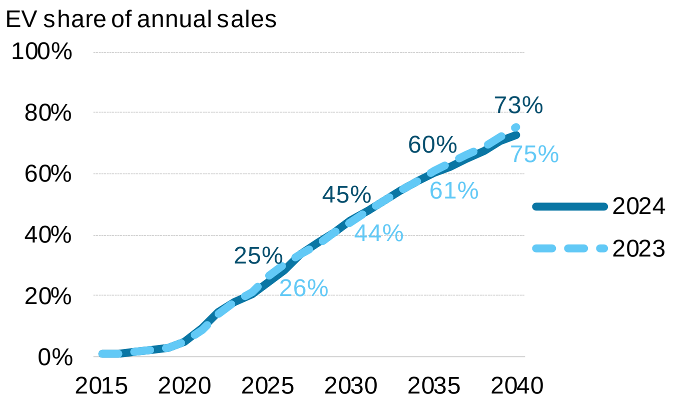
EV uptake globally is lower in the 2024 edition of our outlook compared to 2023 (Figure 303). While some markets have been revised upward, such as India and Southeast Asia, the lower than expected EV sales in markets like Germany and Japan affect the near-term outlook and have implications for the long term. Global passenger EV adoption surpasses 30% of sales by 2027 and 73% by 2040 in our Economic Transition Scenario.

Figure 303: Comparison of global EV sales outlook between EVO 2023 and EVO 2024



Source: BloombergNEF

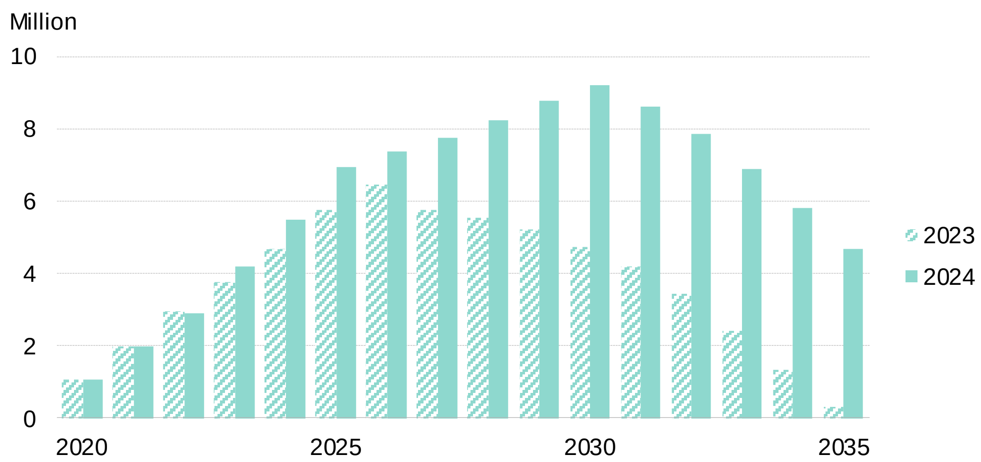
Figure 304: Comparison of global EV share of sales between EVO 2023 and EVO 2024



Source: BloombergNEF

Due to the surge in sales of plug-in hybrids and a range of new models announced by automakers, we have increased the share of PHEVs in our outlook. PHEVs still do not surpass more than 35% of total EVs sold in any given year globally, although this can vary significantly by market.

Figure 305: Comparison of global plug-in hybrid sales outlook between EVO 2023 and EVO 2024



Source: BloombergNEF

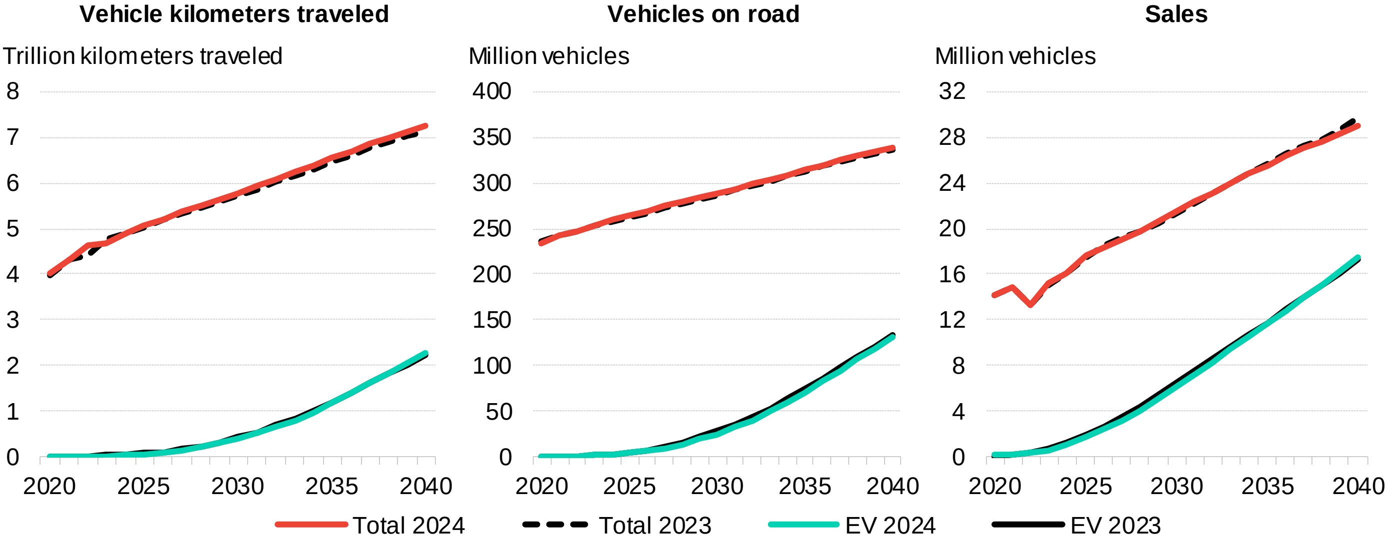
Figure 306: Comparison of passenger EV sales outlook in select markets between EVO 2023 and EVO 2024

Source: BloombergNEF

Commercial vehicles and buses

Global demand for goods movement is marginally higher in the 2024 outlook compared to the 2023 version, partially due to modest growth in markets with large demand for freight such as China. Near-term sales of electric trucks and vans is down from the 2023 edition after sales in China in 2023 were lower than expected. The longer term view in the outlook is not affected.

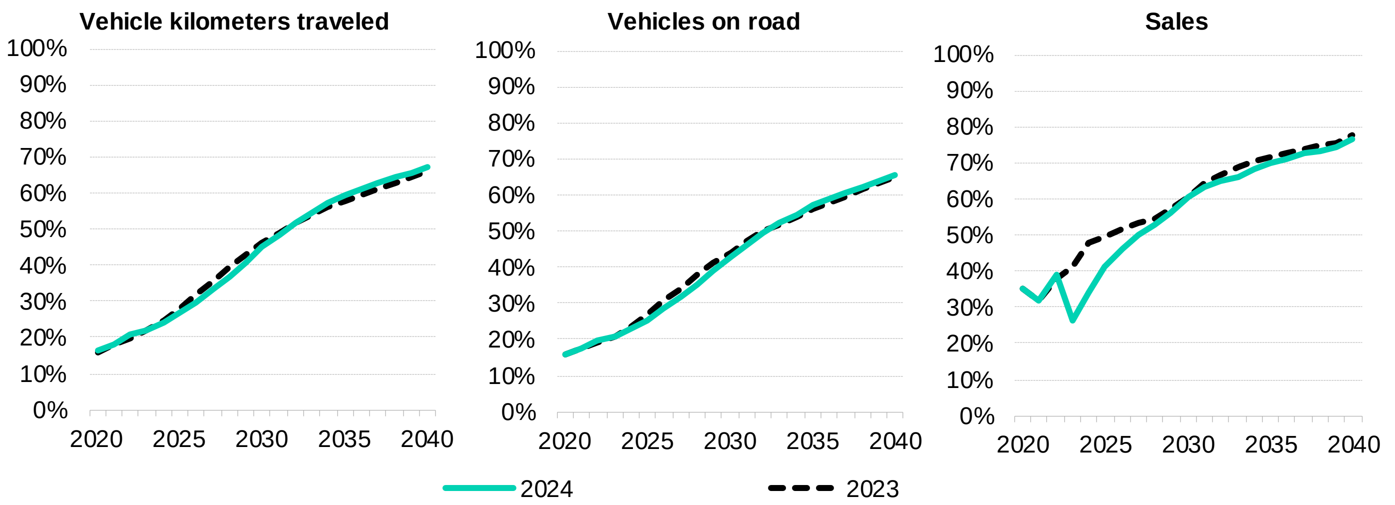
Figure 307: Comparison of global commercial vehicle kilometers traveled, commercial vehicle fleet and annual sales in EVO 2023 and EVO 2024 – Economic Transition Scenario



Source: BloombergNEF

Globally, battery-electric and fuel cell bus sales dropped by 27% in 2023, primarily due to a decline in China sales. By 2030, our outlook for electric bus sales returns to similar levels to the 2023 edition (Figure 112).

Figure 308: Comparison of electric bus shares of vehicle kilometers traveled, vehicles on road and sales in EVO 2023 and EVO 2024



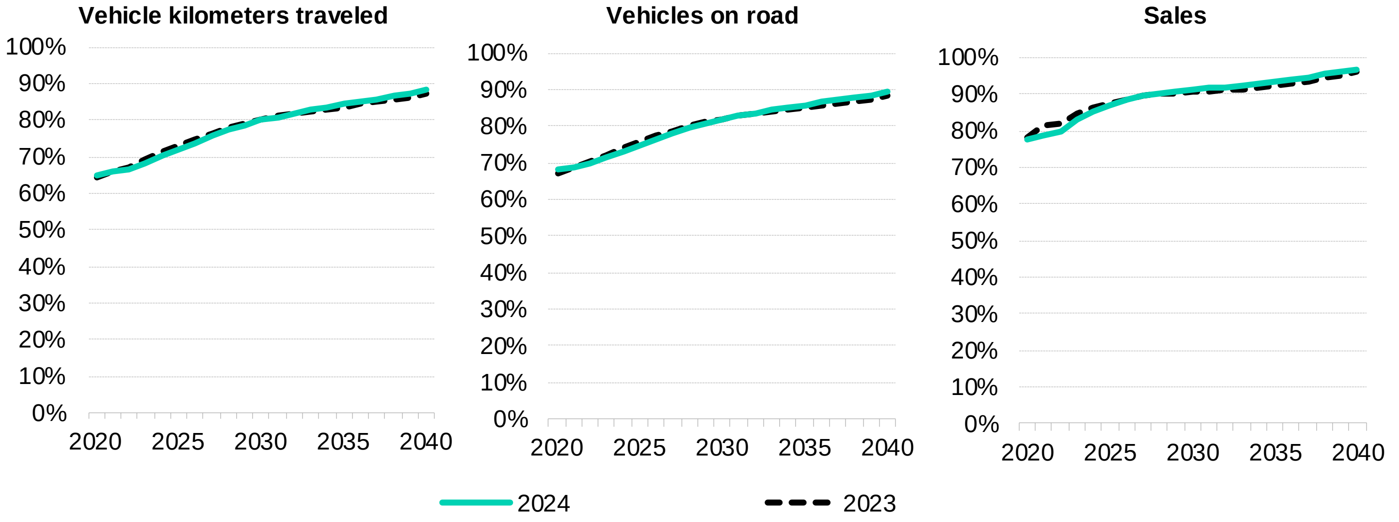
Source: BloombergNEF

Two- and three-wheelers

Our outlook for the total two-wheeler market remains largely unchanged. However, we have increased the total for electric kilometers traveled as the capabilities of two-wheelers continues to improve and batteries increase in size. We have made minor changes to historical figures to better account for the differences between mopeds and e-bikes, as classified in 0.

The outlook for sales of electric three-wheelers and their share of vehicles on the road are similar to last year's outlook (Figure 309). We have made changes to historical figures as new data sources for three-wheeler sales have become available.

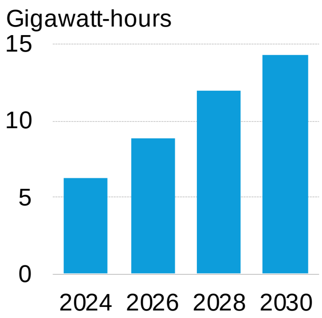
Figure 309: Comparison of electric three-wheeler shares of vehicle kilometers traveled, vehicles on road and sales in EVO 2023 and EVO 2024



Source: BloombergNEF

Changes to battery demand outlook

Figure 310: Hybrid lithium-ion battery demand outlook in the Economic Transition Scenario

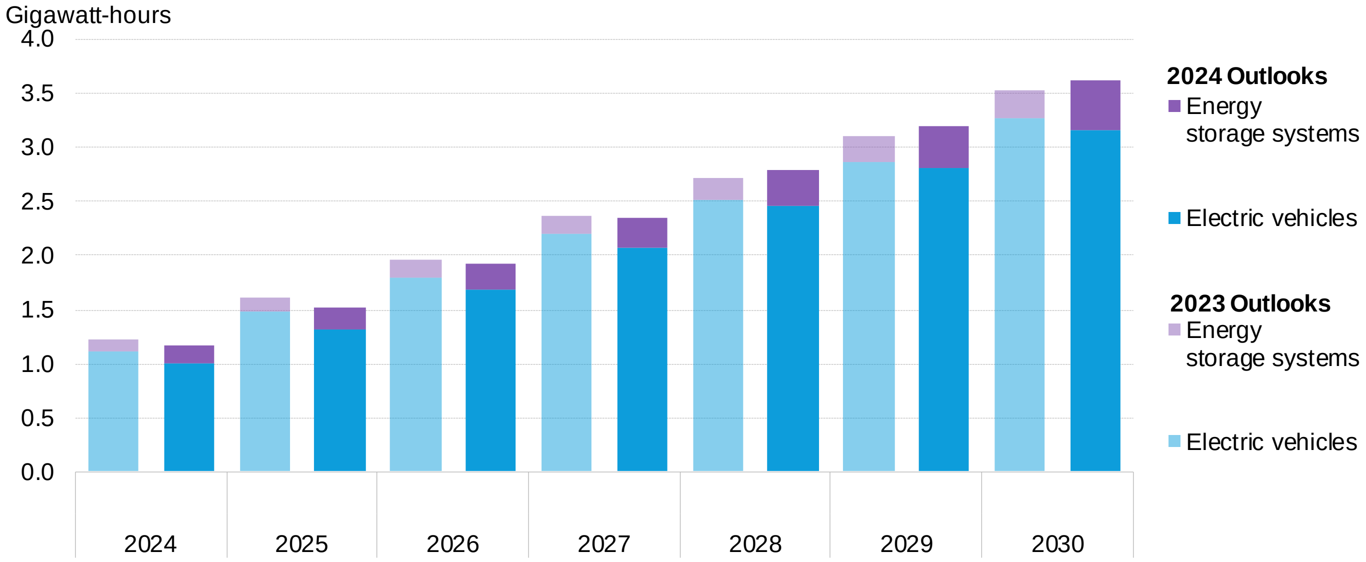


Source: BloombergNEF

We now include hybrid electric vehicles in our outlook for battery demand. While sales of hybrid vehicles accounted for more than 20% of the passenger cars sold in 2023 in markets like Japan, South Korea and France, these battery packs are typically small in size at around 1-1.5kWh. Therefore, adding hybrids does not make a large difference to total battery demand, making up just 0.8% of the global passenger EV battery demand in 2023. Growth is expected but does not significantly impact the long-term outlook (Figure 310).

Due to the surge in sales of plug-in hybrids and automaker announcements of a range of new models, we have increased the share of PHEVs in our outlook. While the total number of EVs is similar to the 2023 edition, the smaller battery packs of PHEVs lowers our outlook for lithium-ion battery demand for road transport. However, there has been a significant jump in demand for lithium-ion batteries for energy storage systems (ESS). With BNEF seeing an increase in ESS applications, therefore, our outlook for lithium-ion battery demand is not significantly different from previous iterations.

Figure 311: Outlook for lithium-ion battery demand for vehicle and energy storage applications in the 2023 and 2024 editions of the Economic Transition Scenario



Source: BloombergNEF

Further reading

- *1H 2024 Energy Storage Market Outlook* (web | terminal)

Section 12. Full methodology

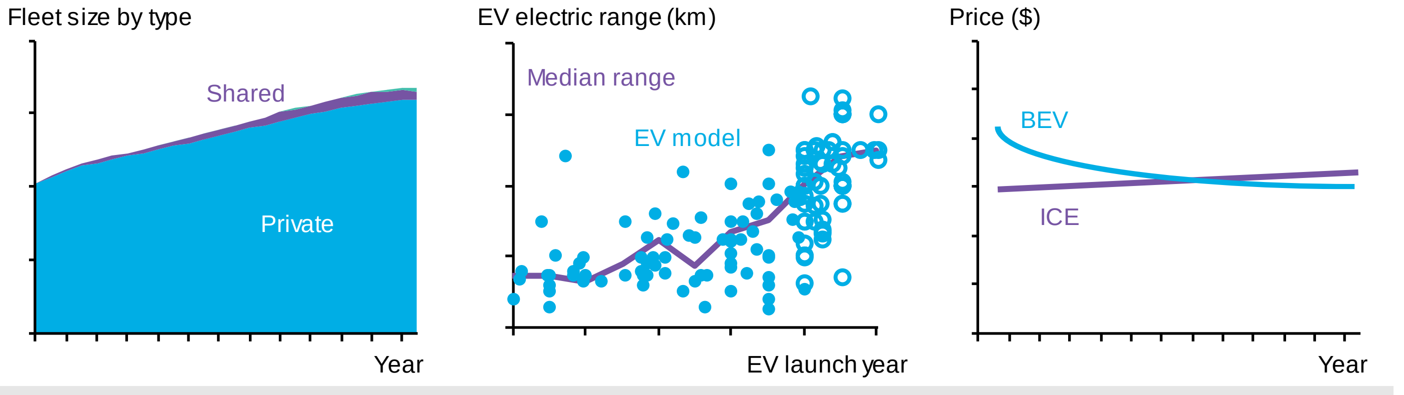
This section provides more detail on the outlook methodology for different vehicle segments used in this report, and on how we calculate charging infrastructure needs. The descriptions below primarily reflect our Economic Transition Scenario. Our Net Zero Scenario modeling follows a similar approach but requires that the vehicle fleet in each segment is comprised entirely of vehicles capable of zero-emissions driving by 2050 and builds an adoption curve required to meet that goal. This means 100% of vehicles in the passenger-vehicle and two-/three-wheelers segments are battery electric vehicles. Hydrogen fuel cells play a role only in commercial vehicles, most notably in heavy-duty long-haul trucking and bus applications in some countries.

12.1. Passenger vehicles

Our passenger EV outlook has two main components. The first analyzes the outlook for the overall passenger-vehicle market for all drivetrain types, considering how demand for mobility changes as populations and economies grow, and the impact of shared-mobility services and autonomous vehicles on the passenger vehicle fleet. For autonomous vehicles, we only consider Level-4 or higher levels of autonomy, and we assume such vehicles will be only used for shared-mobility services ('robotaxis').

The second component looks at drivetrain adoption within the privately owned vehicle category. Our near-term (2024-2027) EV sales forecast is based on EV model availability, local policies and historical sales trends. In the longer term (2028-2050), the outlook for privately owned EVs is driven by a consumer adoption model that takes the economics of electric vehicles in different segments into account.

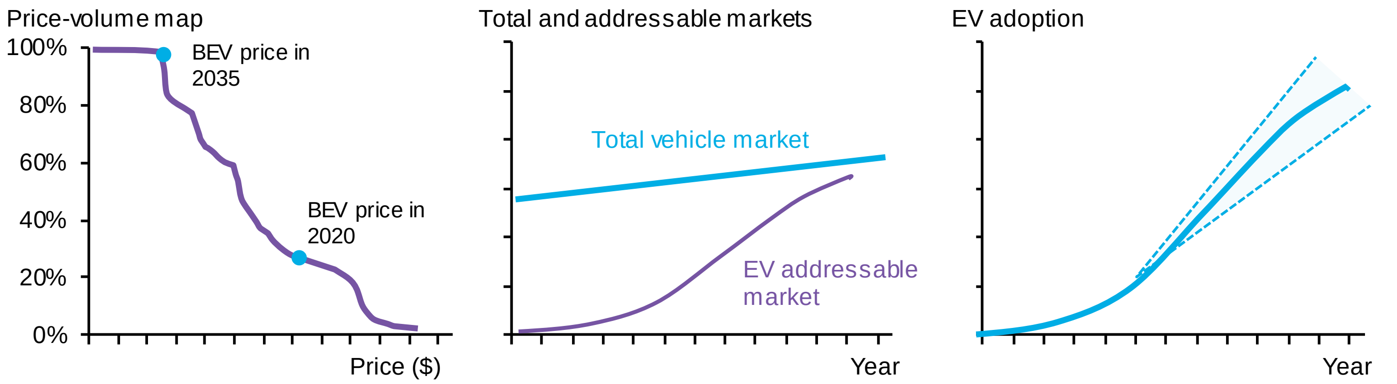
Figure 312: Simplified passenger EV outlook methodology



1 Taking into account the impact of **GDP, demographics, shared mobility services, autonomous vehicles and other factors** on kilometers traveled, we estimate the size of future car fleet and sales by country.

2 Examining current **country-level policies, purchasing behavior and upcoming EV model launches**, we estimate EV sales over the short term (2024-2027).

3 Using our **lithium-ion battery experience curve and other cost data**, we estimate when the **retail prices and cost of ownership of EVs** become cheaper than those of combustion engine vehicles.



4 By creating **'price-volume maps'** for each country, we analyze how different consumer segments spend their money on cars in every region and market segment.

5 By adjusting country-level vehicle markets by EV retail prices in a given year, we estimate the **total addressable market** for EVs over the long term (2028-2040).

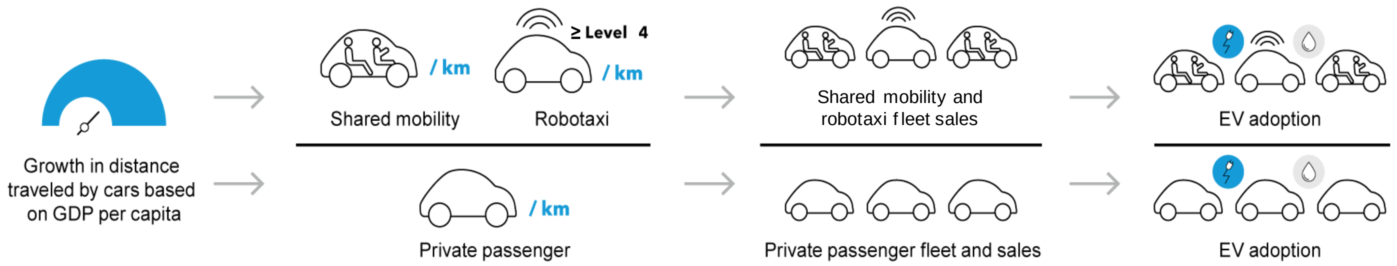
6 Using a cost-based total addressable market, short-term trajectory and historic market dynamics, we calibrate adoption parameters for a **generalized Bass diffusion** model to create the long-term outlook.

Source: BloombergNEF. Note: Charts are illustrative only. BEV stands for battery-electric vehicle, ICE stands for internal combustion engine vehicle.

Estimating demand for passenger vehicles

The first step in our passenger vehicle outlook is to examine the historical relationship between the annual number of kilometers traveled by the passenger vehicle fleet and GDP per capita for each major auto market (Figure 313).

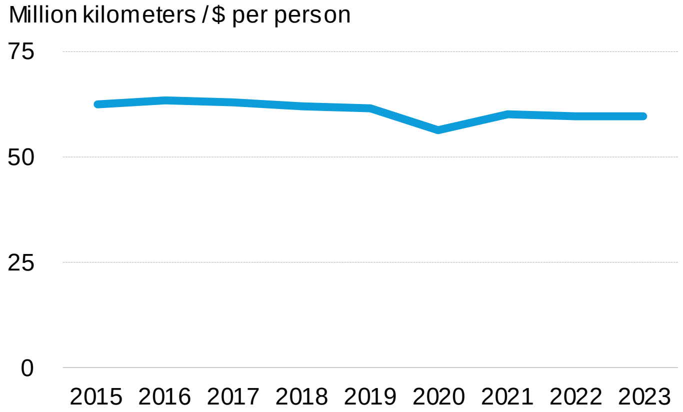
Figure 313: Simplified outlook methodology for passenger vehicle demand, sales and fleet size



Source: BloombergNEF

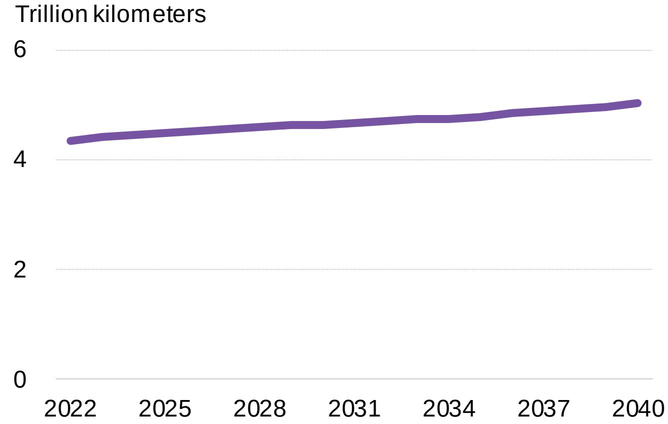
The annual distance traveled by the passenger vehicle fleet strongly correlates with GDP per capita (Figure 314). Based on this historical relationship, as well as World Bank GDP per capita forecasts and population forecasts, we estimate annual vehicle kilometers traveled in each major auto market (Figure 315).

Figure 314: Historical annual distance traveled by passenger vehicles in the US divided by GDP per capita



Source: BloombergNEF, Federal Highway Administration, World Bank.

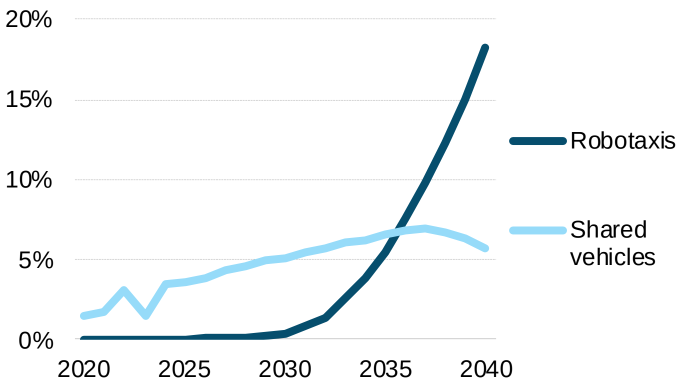
Figure 315: Annual distance traveled by the US passenger vehicle fleet



Source: BloombergNEF

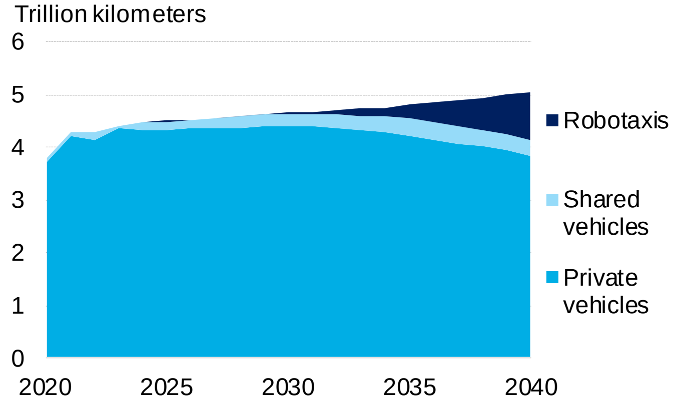
The next step in our passenger vehicle outlook is to examine historical data on the use of shared-mobility services (taxis, ride-hailing and fleet-based car-sharing) to determine the share of annual vehicle kilometers traveled that will be delivered by privately owned vehicles, shared-mobility services and (in the future) robotaxis (Level-4 shared autonomous vehicles) (Figure 316). To distribute the total distance traveled, we utilize historical data as well as adoption curves based on the addressable market for shared-mobility services and the potential timelines for robotaxi deployment in each market (Figure 317). These estimates reflect the local legal factors and technology readiness levels that can affect the adoption of robotaxis and shared-mobility services, although there is significant uncertainty as to how quickly these services will scale.

Figure 316: Shared-mobility service and robotaxi share of annual distance traveled by the US passenger vehicle fleet



Source: BloombergNEF

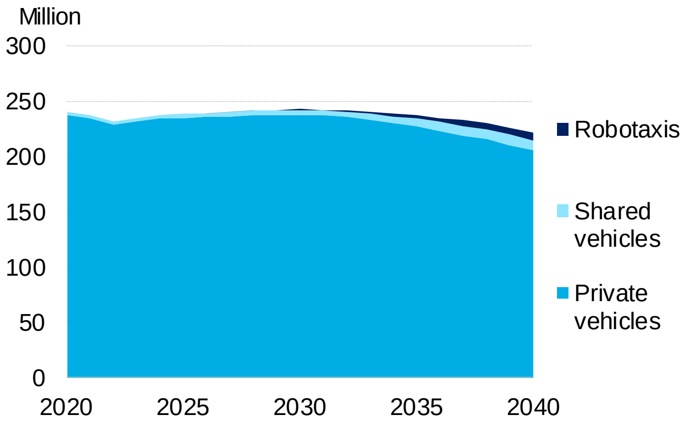
Figure 317: Annual distance traveled by the US passenger vehicle fleet, by vehicle type



Source: BloombergNEF

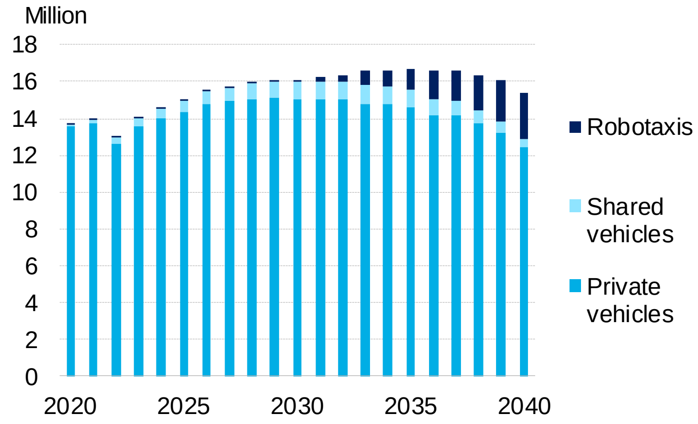
Once the total annual distance traveled is categorized, the kilometers in each category are converted to fleet sizes (Figure 318) based on annual vehicle-kilometers-traveled assumptions derived from historical trends. We then convert the fleet size in each category to new vehicle sales (Figure 319) by taking into account the annual difference in fleet size, expected fleet retirement rate based on the age of the fleet, and demographics.

Figure 318: US passenger vehicle fleet, by type



Source: BloombergNEF

Figure 319: US passenger vehicle sales, by type



Source: BloombergNEF

The last step is to calculate EV adoption by shared-mobility services and robotaxi companies. For the short-term outlook, we take into account local and regional policies, for example, China allowing testing and piloting of Level 3 and Level 4 vehicles on public roads, as well as the strategies of the individual companies and the distances they cover in testing and operations.

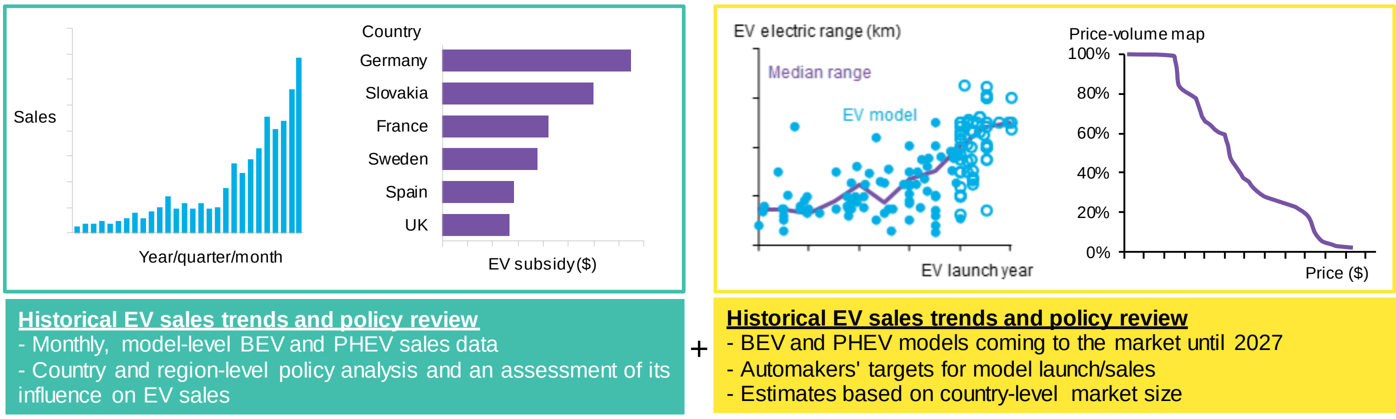
Further reading

- *Automated Vehicles: State of the Industry 2024* (web | terminal)
- *Peak Car? BNEF Light-Duty Vehicle Outlook 2023* (web | terminal)

Forecasting near-term passenger EV adoption: 2024-2027

Our near-term EV sales forecast methodology, which remains unchanged from prior years, follows a bottom-up approach. We begin by updating our database of upcoming global EV model releases (tool). To compile this database, we rely on company announcements, filings and third-party data. We then project EV sales for each market included in the report, by taking into account historical EV sales trends, model availability and any active relevant policies, including purchase subsidies and regulatory mandates (Figure 320).

Figure 320: Near-term EV adoption forecast methodology



Source: BloombergNEF. Note: BEV stands for battery-electric vehicle, ICE is internal combustion engine

In the review of models, we take into account upcoming EV models that have been announced and will be introduced to the market by 2027. Considering these models' characteristics – drivetrain type, segment, range and price[16] – we use regression analysis to estimate their addressable market in any given country, and their potential sales in their specific segment through 2027. Although we do not take concept models into consideration, we do account for various automakers' announcements as to their targeted sales or planned model introductions. For example, Kia plans to introduce 15 new BEV models globally by 2027; in our near-term forecast, we have estimated their sales in each country based on an assumed segment those vehicles will address.

In the policy review, we look at the availability of purchase subsidies in the analyzed countries to understand the eligibility criteria – price caps, EV range, etc. – and their influence on the upfront price of an EV model. We use that data to buffer model-level sales for markets where we believe that generous subsidies can potentially boost a specific model's sales beyond what historical sales trends would indicate.

Long-term passenger EV outlook: 2028-2040

Battery prices fall to $80 per kilowatt-hour (real 2023) by 2030 and $64 per kilowatt-hour by 2035 in our Economic Transition Scenario.

The methodology for our long-term private passenger EV sales outlook remains similar to prior years. We first use the results of our *2023 Lithium-Ion Battery Price Survey* (web | terminal) to estimate the expected upfront cost of EVs in each segment. We then compare expected future retail prices of EVs with equivalent internal combustion engines (ICEs) in each market. Based on the upfront comparison of EV and ICE retail prices as well as updated price-volume maps for each auto market, we calculate the addressable market for EVs in each segment and region. We reduce this addressable market to take into account charging infrastructure challenges. Finally, the adjusted addressable market size is used by a generalized Bass diffusion model to come up with the adoption curve for future EV sales.

Vehicle prices, total cost of ownership and vehicle kilometers traveled

In this year's outlook, we adjusted our assumptions on BEV efficiency and range as regional differences became increasingly apparent (Table 20). These changes affect the modeled battery pack sizes, which this year vary by segment and region as a result.

Table 20: Battery pack energy density in BEVs, 2023-2035

	2023	2025	2030	2035
Pack energy density	198 Wh/kg	216 Wh/kg	253 Wh/kg	300 Wh/kg

Source: BloombergNEF. Note: Wh/kg stands for watt-hours per kilogram, BEV is battery-electric vehicle.

Table 19: Assumed real-world BEV driving range for passenger vehicles in Europe

Segment	Kilometers (miles)
Small	250 (155)
Medium	450 (280)
Large	500 (311)
SUV	400 (249)

Source: BloombergNEF

As battery-pack prices have also changed compared with our previous outlook we have adjusted the upfront vehicle prices, total cost of ownership (TCO) and vehicle kilometers traveled (VKT) numbers, which determine how competitive EVs are compared with ICE vehicles in any given year. These changes affect the manufacturing economics of battery electric vehicles and alter the year in which EVs reach price parity with ICE vehicles in various segments and geographies.

We determine the battery capacity for BEVs by first assuming the required real-world driving range. This varies by segment and geography, but we keep it constant between 2023 and 2040

[16] We use various inputs to estimate the prices of upcoming BEVs: manufacturers' suggested prices, where available; prices for comparable vehicles in the same segment; and/or manufacturers' expectations as to the vehicles with which a given BEV will compete.

(Table 19). We then estimate efficiency using the relationship between weight and the energy required to move a vehicle. As the battery energy density rises over the years, the required capacity – and hence vehicle weight – for a given range decreases. In turn, vehicle efficiency improves, which implies a lower required battery capacity. We iterate this process to arrive at the final battery capacity (Table 21). The efficiency of BEVs in all regions increases by around 15-20% between 2023 and 2035, as the required battery capacity decreases over the years (Table 22).

Table 21: Expected average battery pack sizes in EVs by segment, Europe 2023-2035 (kWh)

Segment	2023	2025	2030	2035
Small	41	40	37	35
Medium	74	71	67	63
Large	95	92	87	80
SUV	72	70	66	62

Source: BloombergNEF. Note: kWh refers to kilowatt-hours.

Table 22: Electric vehicle range efficiency, Europe 2023-2035 (kWh/km)

Segment	2023	2025	2030	2035
Small	0.16	0.16	0.15	0.14
Medium	0.16	0.16	0.15	0.14
Large	0.19	0.18	0.17	0.16
SUV	0.18	0.17	0.16	0.15

Source: BloombergNEF. Note: kWh/km refers to kilowatt-hours per kilometer.

The upfront prices of BEVs fall 18-30% from 2023 to 2035, depending on the segment and country, as battery prices drop by about two-thirds over the same period. The upfront-cost price parity years between BEVs and equivalent ICEs range from 2025 to 2031 (Table 23). In some countries, such as the US, SUVs are the first segment to reach price parity, while in China, it is small vehicles that are first to reach parity.

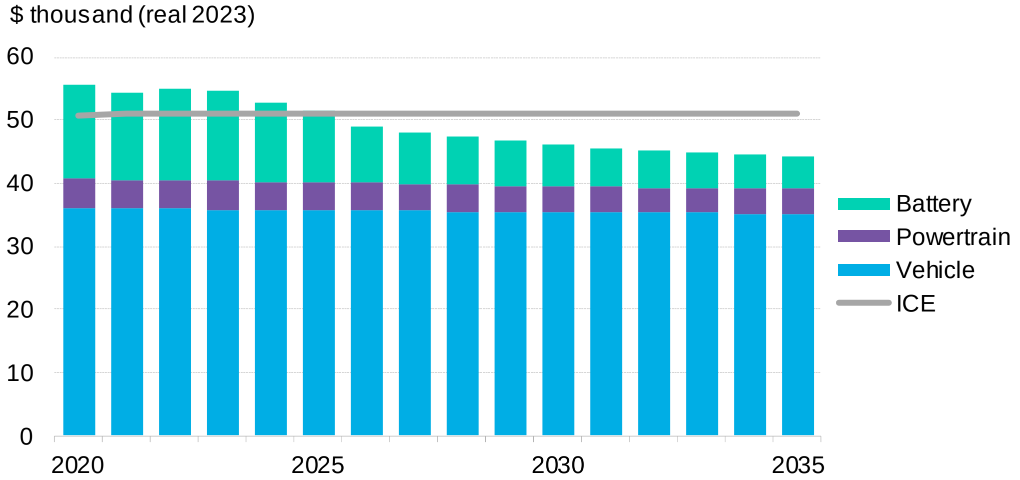
Table 23: BEV upfront price parity with ICE vehicles

	Year of price parity				
Segment	US	Europe	China	Japan	India
Small	2028	2026	2026	2026	2029
Medium	2028	2026	2026	2027	2032
Large	2026	2024	2030	2031	-
SUV	2026	2024	2028	2026	2032

Source: BloombergNEF, US Environmental Protection Agency, International Council on Clean Transportation, FEV, Oak Ridge National Laboratory. Note: Refers to the price parity years, with no additional home charger costs. Large vehicles in India have not been analyzed in this report, since most of the large vehicles in the country are imported premium brands; this significantly increases the average price of a large vehicle in the country, implying battery-electric vehicles (BEVs) outcompete internal combustion engines (ICEs) in that segment. There are no BEVs in the large segment currently manufactured in India.

We estimate that the costs of ICE cars will rise by about 0.5% per year until the mid-2020s, due to the additional development needed to meet stringent fuel-economy and emissions regulations. However, growing EV sales after this point mean automakers will not have to keep increasing investment, and we expect ICE costs to remain relatively flat beyond 2025 (Figure 321).

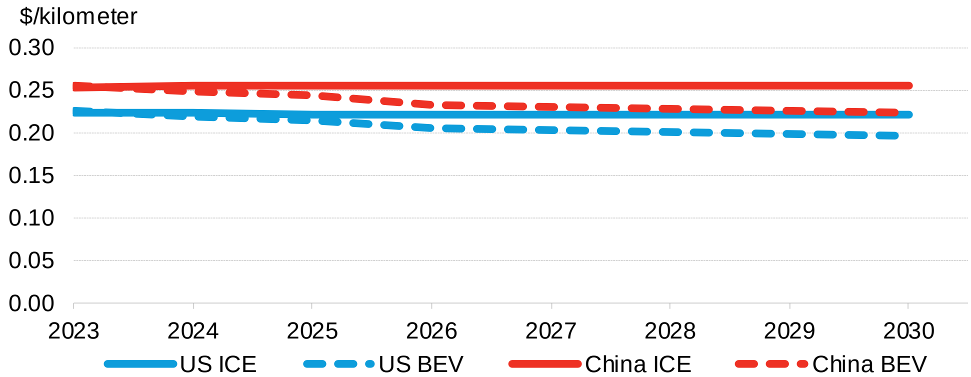
Figure 321: SUV segment BEV and ICE pre-tax prices and share of battery cost in the US



Source: BloombergNEF. Note: ICE refers to internal combustion engine.

The total cost of ownership of BEVs follows the rapid decline in upfront prices. At the same time, the improving efficiency of ICE vehicles – which we expect to be quite rapid to 2025 but which slows afterward – counteracts the rising technology costs, and the overall TCO of ICEs also falls slightly during the outlook period. TCO parity is typically achieved one or two years earlier than that of upfront costs (Figure 322). However, in some cases TCO parity may be achieved at the same time or even later than parity with upfront costs. This variation is due to different assumptions on the residual values for BEVs, which we still assume lose their value faster than equivalent ICEs, based on the evidence so far.

Figure 322: Total cost of ownership of medium ICEs and BEVs in the US and China



Source: BloombergNEF. Note: BEV is battery-electric vehicle, ICE is internal combustion engine.

The price of oil is also an input in the TCO calculation. We assume $2.8 per gallon in 2025 (in real 2023 US dollars), which decreases to $2.6 per gallon in 2030 and remains constant to 2040. The resulting retail gasoline and diesel prices range from $2.4/gallon in 2025 to $2.5/gallon in 2030 in the US. In Europe, we use a gasoline-diesel price average, which remains roughly constant at around €1.1 ($1.2) per liter throughout the 2020s.

Bass diffusion model

The above analysis enables us to form a detailed picture of the relative economics of conventional vehicles versus EVs. We can therefore form a view as to when EVs become the cheapest option for a given sales segment and regional market. Our hypothesis is that, in the absence of policy intervention, mass-adoption of EVs begins after they become the cheapest option in any given market.

In the short term, we think that the adoption of privately owned EVs over 2027-2040 is fundamentally a question of consumer technology diffusion. In our modeling of this diffusion, we use the generalized Bass model, given here in discrete form:

$$s_t = \left(p + q\frac{S_{t-1}}{M}\right)(M - S_{t-1})\, x(t)$$

Where

$$s_t = \text{annual sales at time } t$$
$$S_{t-1} = \text{cumulative sales at time } (t-1)$$
$$M = \text{adjusted adressable car fleet}$$
$$p = \text{coefficient of innovation}$$
$$q = \text{coefficient of imitation}$$
$$x(t) = \text{price function} = \left(\frac{TCO_{BEV}}{TCO_{ICE}}\right)^{\alpha}$$
$$\alpha = \text{price elasticity } < 0$$

Using this equation, we can extrapolate from the near-term forecast by building year-on-year sales figures iteratively from the previous year's cumulative sales. Two forces drive adoption of EVs for a given year, one of which is independent of previous adoption (innovation), while the other depends on previous adoption (imitation). In addition to capturing both consumer innovation and imitation effects, this version of Bass diffusion enables us to include a pricing factor, which can accelerate or slow the technology diffusion.

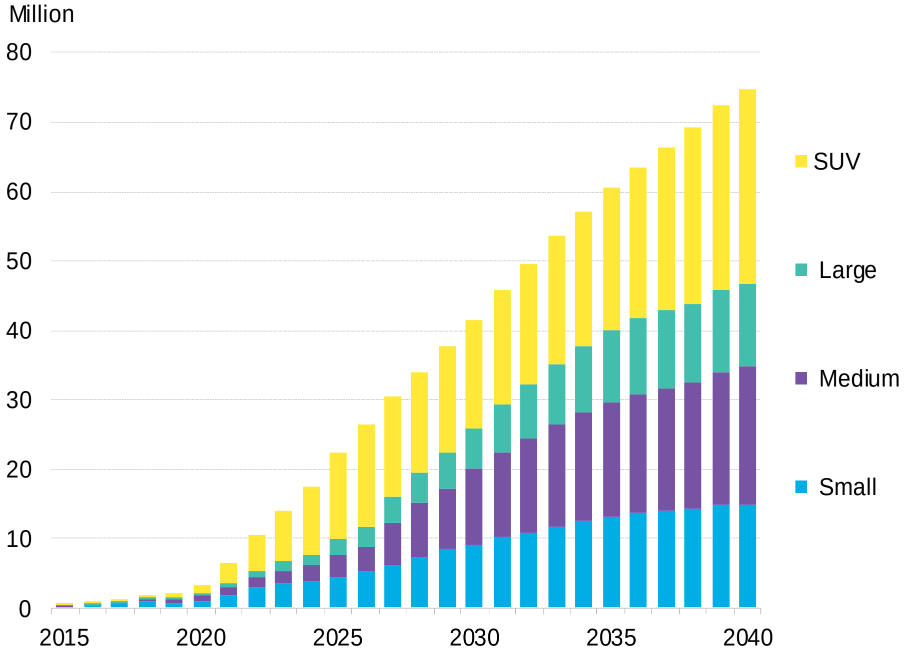
In each time step, we take this price function to be the ratio of the total cost of ownership of EVs to ICEs with a price-elasticity assumption. Before TCO parity is reached, this price-elasticity function will be less than one, slowing the diffusion of EVs due to consumers' TCO considerations. There will still be some adoption, but less than could be expected if the TCOs were equal. Once EVs reach TCO price parity, this price-elasticity function will become greater than one, accelerating the diffusion.

The values of our consumer-imitation and innovation parameters are derived from analysis of historical EV adoption data.

The total addressable market for EVs is derived from a car-fleet outlook, which is derated to capture several dynamics. First, we derate the total addressable market and sales to account for limitations on viable EV charging infrastructure. A cap is also applied to annual sales with a view to the volume of cars that will be sold at the given upfront cost of the EV in that time period. Finally, we derate the total addressable market and sales to account for vehicles not purchased by private buyer but instead purchased for applications like shared mobility.

The above methodology is applied across the market segments of small, medium and large vehicles and SUVs in each of the countries covered in the report. Our cost assumptions and market-size estimates vary across both segment and region in our analysis. For each geographic region, we produce a segment-level outlook like the one shown below (Figure 323).

Figure 323: Global private passenger EV sales outlook by segment in the Economic Transition Scenario



Source: BloombergNEF

Net Zero Scenario for passenger cars

The outlook includes a scenario investigating what a potential route to net-zero emissions might look like for the road transport sector by 2050. The Net Zero Scenario (NZS) is one of a number of possible pathways that could meet this goal, and we are not claiming this is the most probable. In practice, there are likely to be different sets of technologies and approaches, country by country, consistent with existing competitive advantages and industrial priorities.

We built this scenario in three steps:

1. We introduced a constraint that the global vehicle fleet must be 100% zero-emissions capable by 2050 across all segments.
2. We analyzed the cost-competitiveness of different drivetrain options for different segments of road transport in each year and built adoption curves with the above constraint that all options need to be capable of zero-emissions by 2050. The cost-competitiveness is slightly different for each segment, since adoption curves are influenced by total cost of ownership or upfront price competitiveness differently. Other factors also impact adoption.
3. We worked back from these fleet shares to come up with annual sales requirements by drivetrain for each segment. We have allowed for a small amount of early retirements or conversions of combustion vehicles in the 2040-2050 period.

BNEF's Net Zero Scenario for road transport

In the *Electric Vehicle Outlook*, the Net Zero Scenario shows one possible pathway to achieving a global vehicle fleet with no direct tailpipe CO2 emissions. The Net Zero Scenario does not explicitly bring upstream emissions from electricity generation, hydrogen production, or vehicle manufacturing to zero. The results from this exercise are best viewed as a *net zero-capable* fleet. For more on the decarbonization of the entire energy system, see BNEF's *New Energy Outlook* (web | terminal).

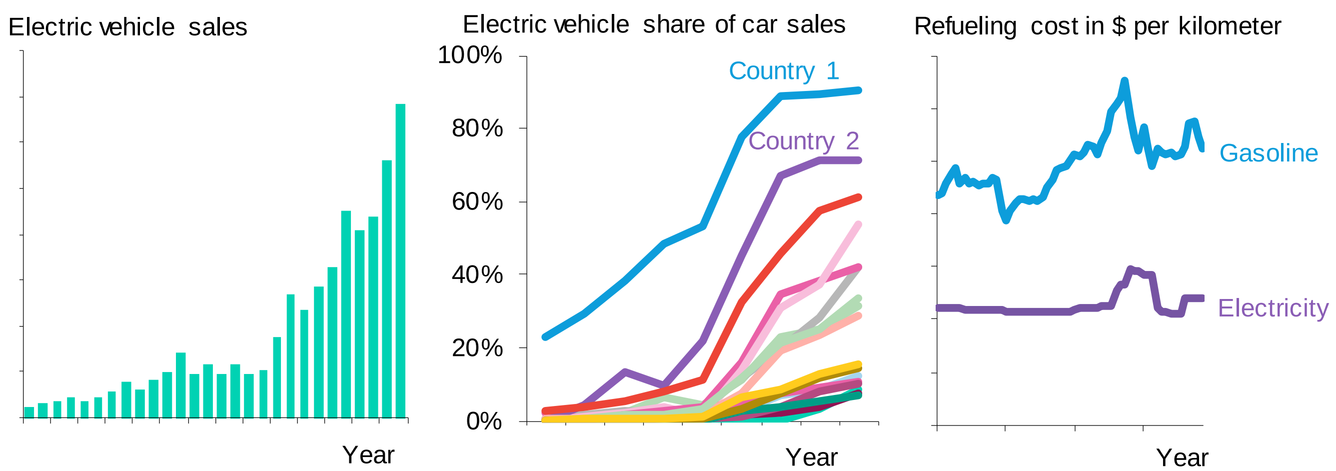
In the *New Energy Outlook's* Net Zero Scenario, all sectors in the energy economy need to reach carbon neutrality and must collectively stay within a global temperature target. To achieve this, the road transport sector needs to meet a 1.75C-aligned sectoral carbon budget. Net-zero transport results in NEO 2024 are best understood as achieving a 1.75C-compliant fleet. This requires a faster ramp-up of production capacity, faster uptake in emerging economies and accelerated phase-out of new ICE vehicle sales.

The Net Zero Scenario in the *Electric Vehicle Outlook* is broadly consistent with a 2C-aligned sectoral carbon budget. While the scenario achieves a global vehicle fleet with no direct tailpipe CO2 emissions by 2050, it is not compatible with an overall temperature outcome of well below 2C. Net-zero road transport results in the *Electric Vehicle Outlook* are therefore best understood as achieving a net-zero-capable fleet.

Tier 2 markets

We have added a new 'Tier 2' country approach for all EU and EFTA countries outside of the UK, Germany, Italy and France, that allows us to model EV uptake beyond our core country and region coverage. Sales, fleet and kilometers traveled outlook data for these individual markets are available in the accompanying excel for this report by clicking on the data icon on the insight record here, or the tableau data viewer here.

Figure 324: Tier 2 countries methodology



1

We collect historical data on passenger electric vehicle sales and total passenger vehicle sales – through 2023 – for each country in the Tier 2 category. Using the data we calculate percent EV share in total car sales for each country. We also collect historical retail electricity and gasoline prices for each country to calculate the $ per kilometer cost to either charge an EV or refuel an ICE

1. EV adoption and years to milestone

Group	Criteria		Milestone
	EV adoption in 2023		
1	Above 50%	Years to milestone	0-5%
2	Crossed 30%		5-10%
3	Crossed 10%		10-15%
4	Under 10%		Thereafter

2. Average annual percent points change in EV adoption

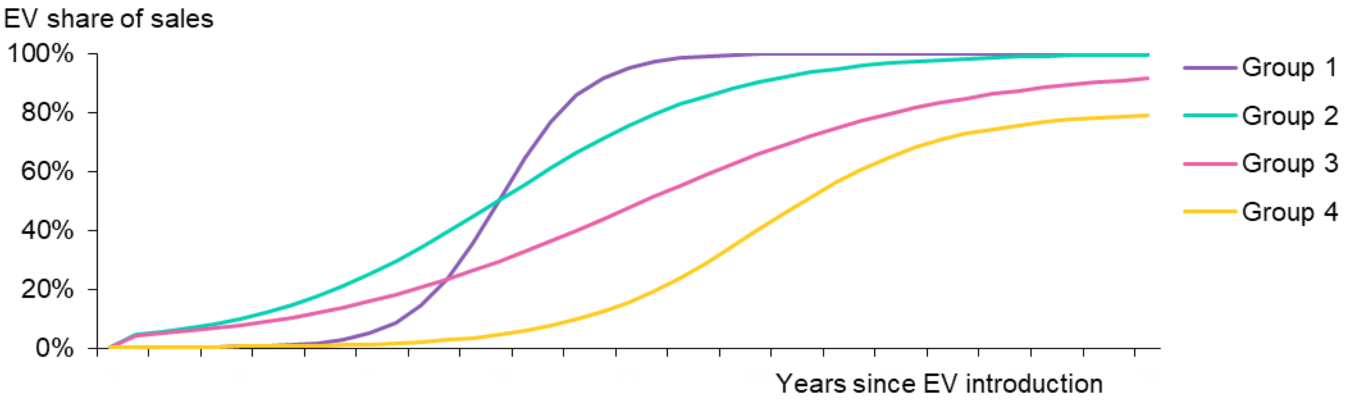
Group	% points change per year
1	7-9%
2	4-5%
3	2-3%
4	1%

3. Accelerator: is charging cheaper than refueling?

	Charging is x% cheaper than refueling
+	Less than 40%
++	40-59%
+++	60% and more

2

Based on the adoption data we group Tier 2 countries into four categories based on: number of years to milestone, where the milestone is the % EV adoption in 5% intervals, and the average annual percent points change in EV adoption.
If, based on the above, a country is assigned to two different groups, we use the delta in refueling costs to determine whether a country should be moved to a higher group: the cheaper per kilometer to recharge, the better.



3

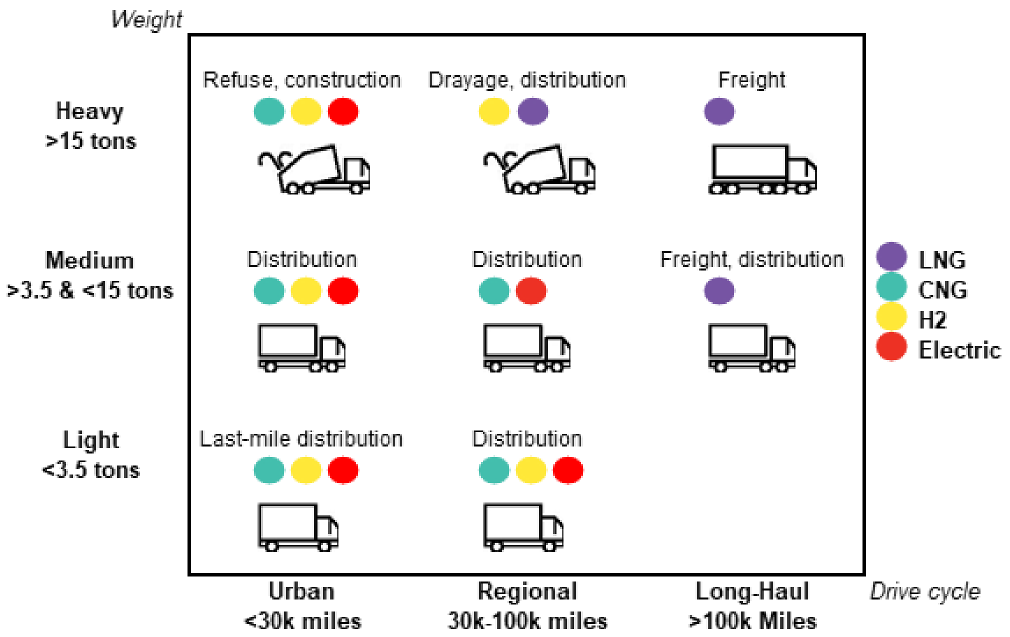
We then assign archetype adoption curves to each of the groups based again on their past performace. We use those curves to forceast EV sales in each of the tier 2 countries from 2024 to 2040.

Source: BloombergNEF

12.2. Commercial vehicles

Commercial road transportation covers a wide range of applications, reflected in a diversified market for vehicles. Our framework divides trucking into eight different segments across two dimensions: vehicle weight and duty cycle. Vehicles are bundled into three weight classes: light-, medium- and heavy-duty. The cutoffs for these classes differ between regions. We also segment by duty cycle, which describes the vehicle's function – distance driven, load carried, fuel efficiency, etc. – into urban, regional and long-haul. The distance boundaries in this categorization are less uniform, as trucks may be used on a variety of routes and differ by region (Figure 325).

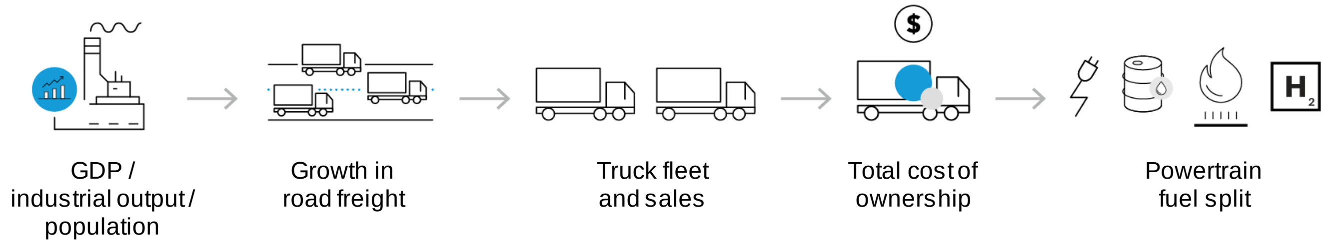
Figure 325: The trucking market and current activity of alternative fuels, by truck segment



Source: BloombergNEF. Note: Drive cycle definitions in Appendix D; drive cycles refer to annual mileage. LNG refers to liquefied natural gas, CNG is compressed natural gas, H2 is hydrogen.

Our methodology for commercial vehicles has not changed materially from previous years. It begins with an estimate of road-freight demand. We split that demand across urban, regional, long-haul and utility segments (Table 30) and derive the fleet and sales in each segment needed to meet it. Finally, we use the relative TCO of different drivetrains – adjusted for model and fueling infrastructure availability – to estimate the annual adoption of each alternative fuel (Figure 326).

Figure 326: Freight demand, commercial vehicle sales and fleet simplified outlook methodology



Source: BloombergNEF

Measuring road freight demand

Truck activity is measured using freight ton-kilometers (ton-km), which combine the weight of cargo transported and the distance cargo travels. One ton-kilometer results from a ton of load moved over a distance of one kilometer. Changes in freight demand result from changes either in the product mix and weight being transported or the distance traveled. So a given load split between several trips does not change demand, even though the number of trucks needed and the fuel efficiency could differ between transportation practices.

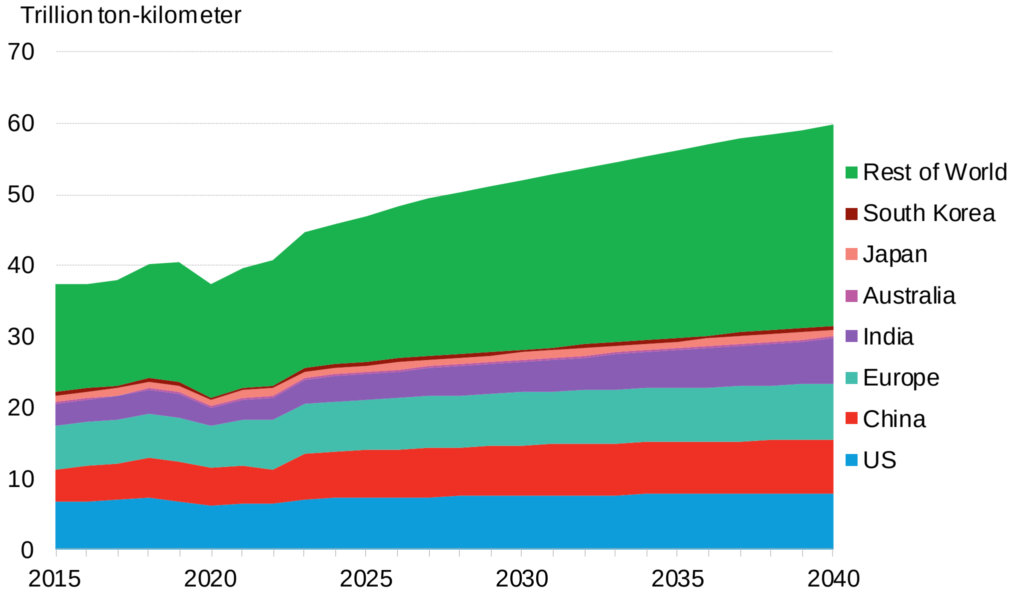
Measuring road freight ton-km typically relies on surveys of transportation companies; the results are then mapped onto the total registered fleet of trucks. This process can introduce errors, and biases have been found in past national statistics. Time series generally show the correct trend, but may contain breaks or have biases in the absolute measurement level.

In our analysis, we consider the registered fleet and the amount of fuel consumed in road transportation as the more trustworthy data points. We have adjusted (within reason) the reported values of road freight ton-km. We also make adjustments to reported total kilometers driven, which are sometimes also found in national statistics.

Freight demand

Historical growth for road transportation has been similar in the US and Europe over the last couple of decades. We estimate that demand grew by about a third in both places between 2000 and 2022. During the same time, total gross domestic product (GDP) growth was close to 40% in the US and 50% in Europe. We estimate that global freight demand fell by about 10% in 2020 due to Covid-19, but by 2022 was back above 2019 levels.

Figure 327: Road freight demand outlook in the Economic Transition Scenario



Source: BloombergNEF

We expect that future freight demand will grow as GDP grows, but at a slower rate than GDP. Freight demand growth is closest to GDP growth in developing economies. Demand for goods transportation in China has grown in parallel with the country's rapid economic expansion but is beginning to be decoupled from GDP growth, and by 2040, average wealth in China will be similar to wealth levels in countries such as Spain and South Korea in 2017. At these income levels, the share of an economy's industrial and agricultural output varies between 15% and close to 40% of GDP.

Looking ahead, as China attempts to rebalance its economy toward consumption rather than investment, it is challenging to estimate its exact future structure. A rising proportion of services in the economy may be the natural progression of rising incomes, while the government plans to support high-value-add, advanced manufacturing, among other sectors. Still, China's population is projected to peak by the late 2020s. If the country manages to accelerate productivity growth, the share of industrial output could remain relatively high as a result of higher-value output. Otherwise, a declining population and shift to a service economy will depress the industrial contribution to GDP. In our estimates, we use a relatively high share of industrial and agricultural output for China in 2040, but still lower than the recent levels of 55-60% of GDP. As a result, we expect rising freight demand to the late 2020s and a marked slowdown thereafter – when freight will grow at less than half the rate of GDP growth.

Road freight demand depends on the type of goods moved, the physical setup of logistics infrastructure and the development of alternative transport modes. These tend to move in decade-long time scales, and changes represent structural economic and societal shifts in a country. While we expect this framework to largely continue to hold in the future, it is likely to be disrupted from rapid urbanization, new logistics concepts, novel manufacturing technologies and shifting supply chains.

Estimating freight demand

We start by assuming that road freight intensity depends on a country's wealth level, such as economic output per capita. Road freight intensity – measured in ton-km/$ gross value added[17] – is the transportation work performed for each unit of a country's economic output.

We use the gross value added (GVA) from industry[18] and agriculture as the measure of a country's economic output that is more relevant to goods transportation. This macro-economic indicator also provides a proxy for the maturity and the structure of an economy. As GDP increases, the structure of a country's economy changes. In a typical path, agriculture initially dominates; heavy industry then takes over, with an increasing share for lighter, more valuable manufacturing; finally, services currently form the bulk of economic output in many advanced economies.

We believe that industrial and agricultural output is a useful indicator of this transition, as it represents goods that require transportation. The absolute value generated by these economic sectors can rise with a growing GDP and generate additional demand for road freight. At the same time, their share of total output could decline and limit freight demand growth with respect to GDP changes.

Our analysis shows a statistical relationship in which road freight intensity declines with increasing economic output per capita. We also identify a level of wealth – roughly $7,000 in 2017 US dollars of industrial output per person – below which the decline is slow, but above which it accelerates rapidly. This could represent a transition from poor road infrastructure and undeveloped logistics

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[17] We convert all local currencies to real 2017 US dollars.

[18] 'Industry' includes manufacturing, construction, materials, water, electricity and some other segments.

hubs, as well as low-value and heavy goods transport, to a more advanced macroeconomic state characterized by mature infrastructure and lighter, high-value products.

Finally, we use the World Bank's projections of GDP and population growth, and assumptions of the industrial and agricultural contribution to a country's total economic output, to arrive at a projection of future road freight demand.

Fleet and sales outlook

Around a quarter of all trucking kilometers in the US and Europe are currently 'empty kilometers'. We expect this share to drop in all regions thanks to better connectivity, digitalization and new business models

We convert total freight demand to a fleet of vehicles by estimating the cargo weight that trucks carry on a typical trip – the load factor – and the average distance they travel. In the US and Europe, load factors change only little by 2040 and are about 17 metric tons for heavy commercial vehicles (HCV) and 5 tons for medium commercial vehicles (MCV). In China, we expect that the current practice of overloading – trucks carrying above their maximum allowable load – will gradually stop. Heavy-duty trucks will be carrying around 20 tons of cargo by 2040, from close to 24 tons now, and MCVs' load factors will drop to about 6 tons, from more than 7.5 tons at the moment.

Total vehicle kilometers traveled consist of loaded and empty kilometers. We estimate that about a quarter of total travel is done empty in the US and Europe. In China, data are scarce, and we estimate that the share of empty kilometers is closer to around 30%. In every region and country, we expect the share of empty kilometers to reduce in the future, as a result of better vehicle usage. Digital technologies, connectivity and changing logistics practices, such as urban consolidation centers, will push the share of empty kilometers to around 15-17% in the US and Europe and less than 20% in China by 2040.

We expect a shift in demand toward lighter vehicles for urban operation in many large economies, such as in the US, Europe and China, with demand for heavy-duty applications growing fast in the rest of the world. In particular, demand for city deliveries will rise quickly by 2040 – to close to two-thirds higher than 2020 levels – and will lead to a doubling in sales of light commercial vehicles. Delivery vans and trucks typically reach their maximum carrying volume before reaching the maximum load weight they can carry – i.e., their load factors remain relatively flat at around 1 ton. A disproportionate increase of vehicles and average kilometers is needed to meet that additional transportation demand, despite quick advances in logistics efficiencies.

Drivetrain truck sales and fleet outlook

The total cost of ownership analysis drives our sales outlook for new drivetrains. In the first step, we adjust the calculations to penalize alternative fuel drivetrains for low model availability and undeveloped fueling infrastructure. The model availability adjustment is a function of additional technology costs and the current trend of electric and natural-gas vehicles on offer. In most cases, we expect that by the mid- to late-2020s all alternative-fueled trucks will be easily accessible to buyers.

Fueling infrastructure adjustments are more difficult to make. For electric vans and trucks in urban and regional duty cycles, we believe that fleet operators will install the necessary equipment at their depots and will rely less on public or on-route chargers. For regional or long-haul applications, we expect limited initial offerings on intercity routes, but the deployment of fast-charging infrastructure is accelerating globally. By the end of the 2020s, we expect that such networks will exist in different countries. For natural gas, we expect owners of larger fleets to deploy required infrastructure for urban and regional routes to start with, given the high costs. For long-haul routes, liquefied natural gas (LNG) stations will initially be deployed on specific routes between large logistics hubs and expand from there.

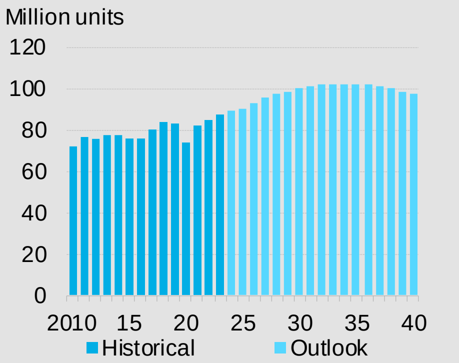
We then compare each adjusted TCO to the cheapest TCO for each segment. Finally, we assign market shares to different drivetrain technologies based on the ranked relative costs. In this process, the share of sales of a particular fuel declines rapidly the further away it is from the cheapest option.

12.3. Two- and three-wheelers

Our two-wheeler outlook has two main components (Figure 328). The first evaluates the overall market, looking at historical wealth and population growth trends in over 30 markets to determine how high country-level moped, scooter and motorcycle sales will rise before eventually falling as consumers opt for other modes of transportation. The second looks at electrification across the moped, scooter and motorcycle segments in selected markets. This second component relies on a consumer adoption model based on historical EV adoption trends observed in leading markets.

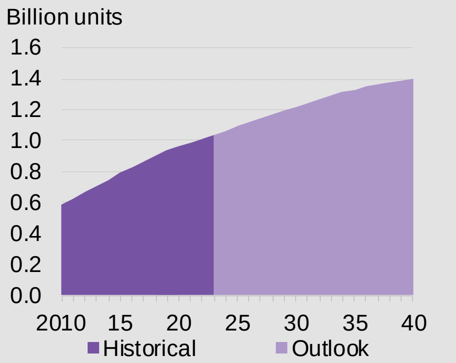
Figure 328: Simplified two-wheeler outlook methodology

Step 1: Total unit sales outlook



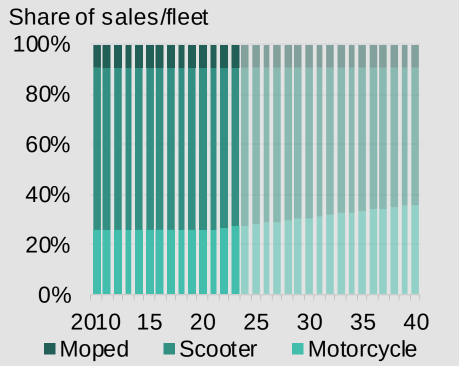
- We estimate annual two-wheeler sales by assessing the correlation between sales, GDP/capita and the population of 15- to 59-year-olds. We assume sales peak after GDP/capita jumps 200-300%.

Step 2: Total fleet size outlook



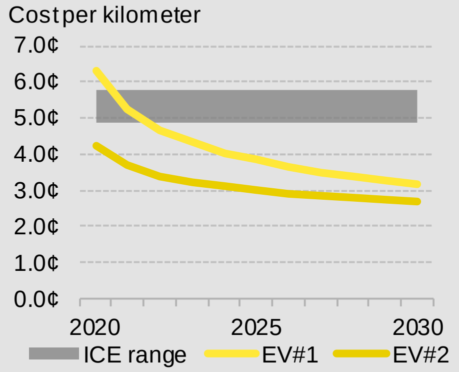
- We estimate annual two-wheeler fleet sizes by subtracting unit retirements from our unit sales in any year and adding the net value to the previous year's fleet size.

Step 3: Segment market share outlook



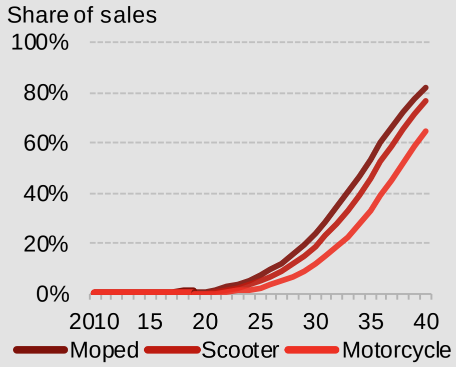
- We estimate the breakdown of two-wheeler unit sales and fleet sizes across mopeds, scooters and motorcycles by looking at historical data and considering local market dynamics.

Step 4: TCO and retail price outlook



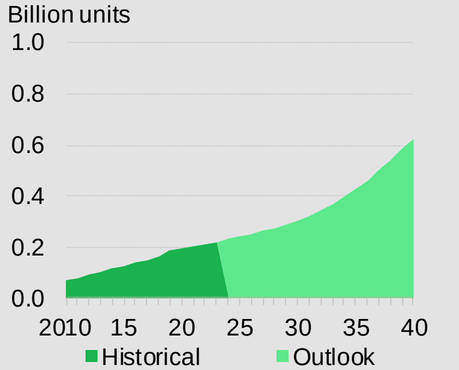
- We estimate the total cost of ownership and upfront prices for various ICE and electric two-wheelers in the top four markets, using BNEF's battery pack, electricity and fuel-price outlooks.

Step 5: EV unit sales outlook



- We estimate EV moped, scooter and motorcycle sales by using a generalized Bass diffusion model.

Step 6: EV fleet size outlook



- We estimate annual EV two-wheeler fleet sizes, using a retirement rate that is estimated based on historical trends in each market and the new sales outlook.

Source: BloombergNEF. Note: TCO stands for total cost of ownership, ICE is internal combustion engine vehicle.

Our three-wheeler outlook for China and India is based on the historical correlation between annual three-wheeler sales, level of urbanization and GDP per capita. Electric three-wheelers already have attractive operating economics in both of these markets. The historical sales of three-wheelers in the 'Rest of World' category is estimated based on the exports of three-wheelers from China and India; the long-term outlook for three-wheelers in this category is based on GDP growth in emerging markets such as Pakistan, Bangladesh, Sri Lanka, Southeast Asia, South America and Africa.

12.4. Buses

Scope

Our bus outlook mainly covers medium and large municipal buses except in China, where we include coaches in addition to municipal buses. Electric coaches are more common there than in other countries. Light buses are excluded, as these vehicles are grouped under our passenger EV and ride-sharing fleets.

The bus model covers more than 16 countries and regions. In addition to those specifically listed, the 'Rest of World' country group includes Mexico, Chile, and Colombia. While Brazil used to be in the RoW category, we have listed it independently from 2024 onwards.

Calculations

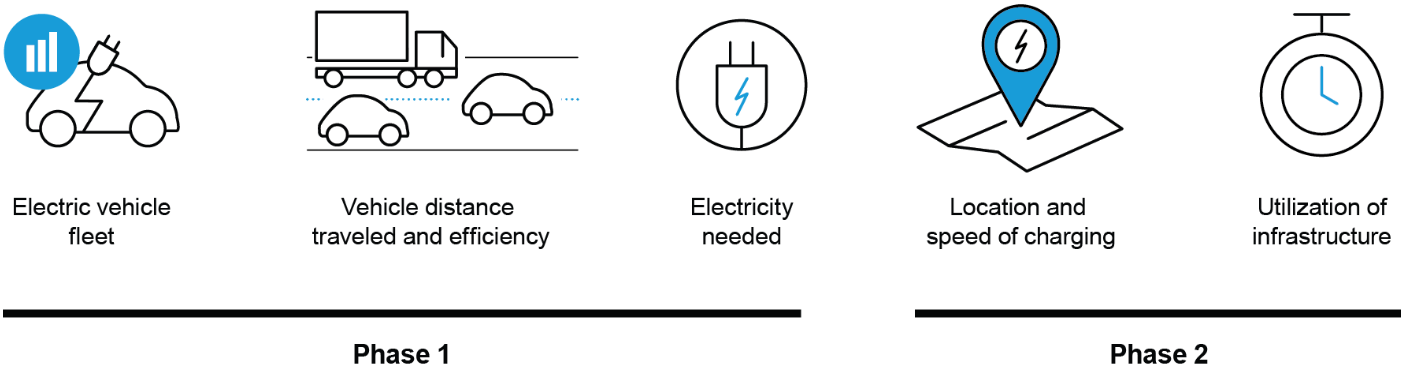
The country-level methodology differs based on availability of data. For countries like China and the US, where municipal bus fleet data are available, we use actual historical data on municipal fleets. For markets with no fleet split between city buses and coaches, we estimate the municipal bus fleet size based on the total bus fleet. For electric bus fleet and sales, we currently assume that e-bus sales outside of China have been municipal buses. Therefore we take real world historical e-bus sales and fleet statistics directly.

The bus outlook for each country is based on the historical correlation between annual municipal bus fleet and estimated urban population (depending on national population and urbanization rate) or GDP. The annual total municipal bus sales outlook is derived from the renewal of the estimated fleet. We estimate the annual e-bus sales share outlook for each country separately and use the shares to calculate future e-bus sales from estimated total bus sales. For countries and regions with zero-emission bus adoption targets in place, such as California, we provide in our Economic Transition Scenario an estimate of sales levels that can be realistically achieved. In our long-term outlook, we calculate the projected e-bus fleet for most countries based on the estimated sales minus retirements.

12.5. Charging infrastructure

To determine how much charging infrastructure will be needed, we first calculate the energy demand required by each vehicle in the fleet across all the segments we cover. This energy demand is then divided between charging locations and hardware power ratings, and infrastructure demand is calculated based on the assumed utilization rates of chargers (Figure 329).

Figure 329: Simplified charging infrastructure forecast methodology



Source: BloombergNEF. Note: Electric vehicle fleet includes passenger and commercial EVs.

Split of charging by location and power of chargers

How much charging takes place at home (or depot), at workplaces and at public charging stations differs across all the vehicle segments we cover. The required public charging infrastructure in each country will vary based on the size of the EV fleet, the mix of BEVs and PHEVs, the building stock and power of installed infrastructure. Countries with a high percentage of detached and semi-detached houses are more likely to have parking where they can install a home charger (Figure 330 and Figure 331). To account for regional differences in where charging takes place countries are categorized in four groups, listed in Table 18, according to the share of charging in a given location.

Figure 330: Distribution of population by housing type across Europe

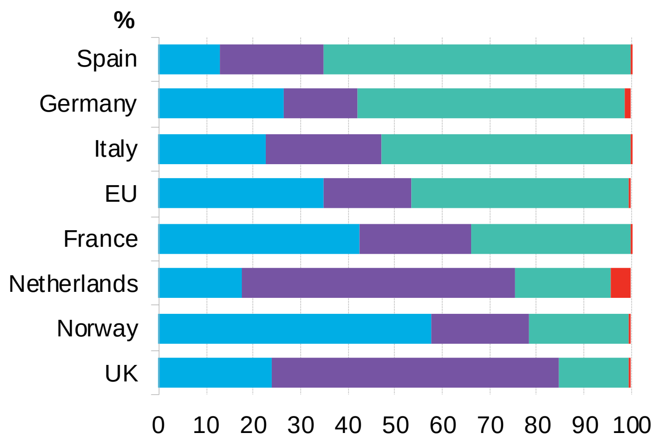
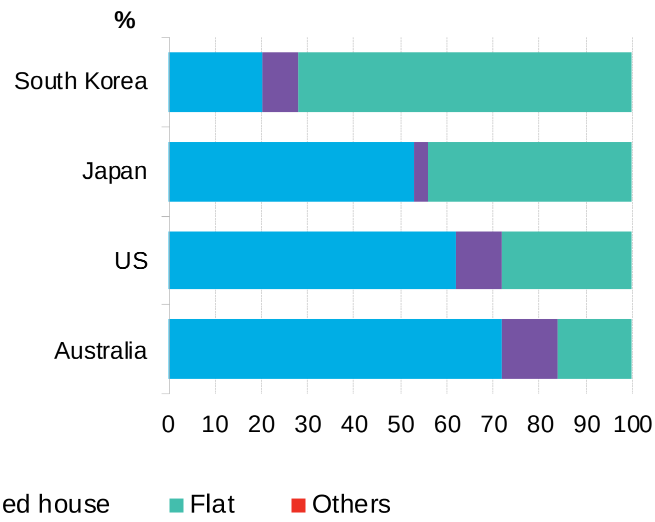


Figure 331: Share of housing by type for select countries



Source: BloombergNEF, Eurostat.

Source: BloombergNEF, US Census Bureau, Japanese Statistics Bureau, Korean Statistical Information Service, Australian Census. Note: Building type aggregated for display, but categorization can vary across studies.

In Section 10.3 we show charging location assumptions for battery electric vehicles across category A countries. We have assumed a high prevalence of home or depot charging across all vehicle types for this category to reflect mostly North American countries. Over time there is an increase in the use of public fast charging withing category A countries. This is driven by an increase in vehicles' maximum charge capabilities, the adoption of electric vehicles by drivers who cannot install a home charger and the rise of cheap and available fast charging.

China and South Korea comprise category B; our decision to group these countries separately reflects the increased share of apartments within their building stocks. In this category, charging outside the home is assumed to take up more of the total energy demand, with public fast charging being the dominate type. Home charging access is assumed to increase over time as some of the hurdles to installing home chargers in apartment buildings are overcome.

In categories C and D, home charging is still the dominant charging location but there is a higher amount of public charging than category A. This category encompasses many European countries that have less detached housing than North American countries. The difference between categories C and D is the prevalence of public slow versus public fast charging.

The assumptions are also varied for plug-in hybrid electric vehicles, which are assumed to do more charging on standard electric sockets due to their lower energy requirements. We assume that e-buses and trucks do the majority of charging at depots – but that the share of public charging increases over time, as battery technology advancement and growth in the charging network allow drivers to take on longer routes (Figure 333).

Figure 332: Energy demand split for battery-electric passenger vehicles and vans by charger location for category A countries

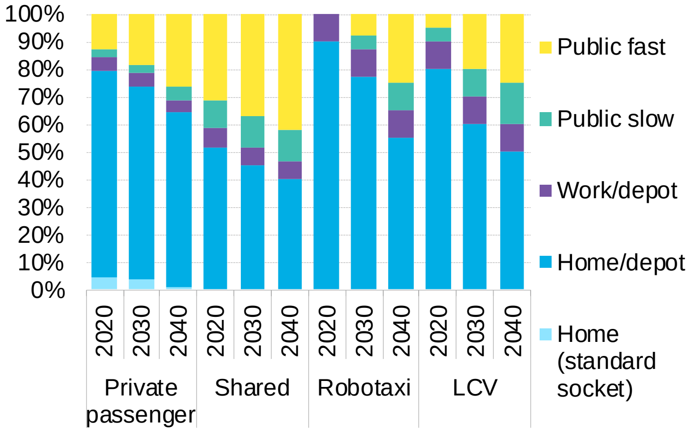
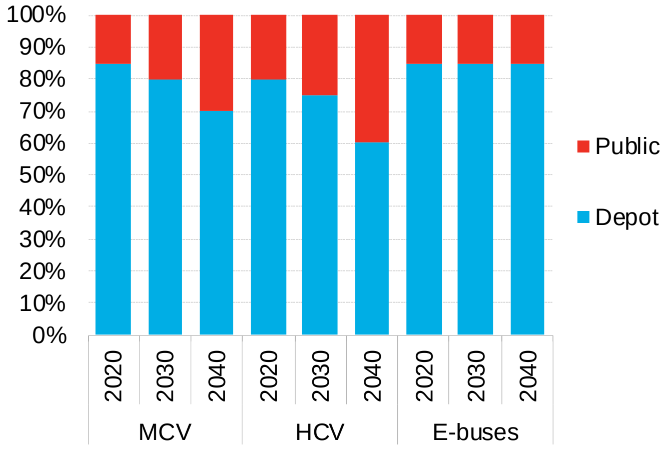


Figure 333: Energy demand split for battery-electric medium- and heavy-duty commercial EVs and e-buses, by charger location

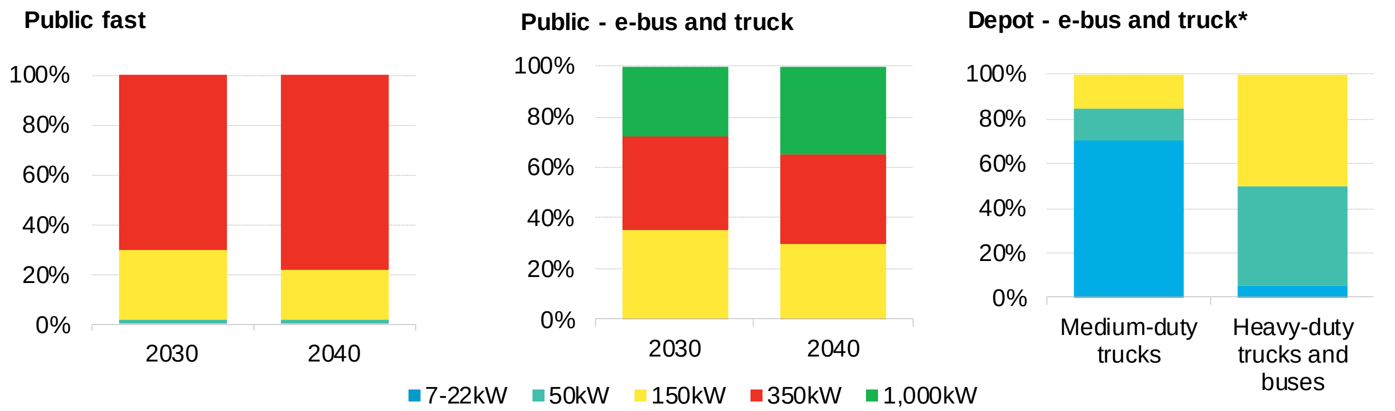


Source: BloombergNEF. Note: LCV, MCV and HCV denote light-, medium- and heavy-duty commercial electric vehicles, respectively.

Split of energy demand by hardware power

The assumed energy demand for each charger location is then split across the various types of hardware we model. For home and workplace chargers, the demand split is largely assumed to be constant over time and is dominated by chargers of 7-22 kilowatts (kW). For public chargers and depot chargers, higher-powered chargers are assumed to take a greater share of the energy demand. This includes chargers of powers of up to 350kW for passenger vehicles and vans, and chargers up to 1,000kW for e-buses and trucks (Figure 334).

Figure 334: Share of electricity supplied to EVs from different chargers, by power rating and location



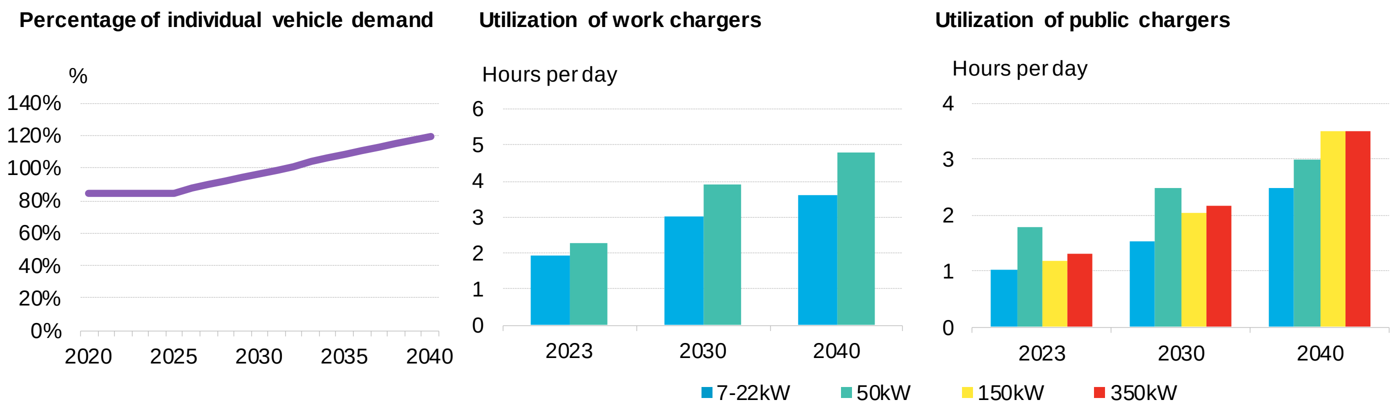
Source: BloombergNEF. Note: 'Public fast' is just for passenger vehicles and vans; kW denotes kilowatts. (*)Depot e-bus and truck inputs remain constant over the modeled timeframe.

For depots, 7-22kW chargers are included, as a significant portion of vehicles will be able to use slower chargers to replenish daily range. This is particularly true for medium-duty trucks, which do not travel as far as their heavier-duty counterparts. Heavy-duty trucks and buses, by contrast, have a higher share of chargers that are 50kW or greater, since the higher power is needed to replenish the range in a short enough time.

Utilization of charging infrastructure

The utilization of charging infrastructure is assumed to increase over time. We calculate the number of home chargers based on the percentage of an individual vehicle's total demand that any given charger will serve in a year. This is assumed to be 85% in 2020; the number rises to 120% in 2040, as more home chargers serve multiple vehicles in two-car homes (Figure 335).

Figure 335: Usage assumptions for passenger vehicle and van chargers



Source: BloombergNEF. Note: Public charger utilization rates vary by geography. Utilization rates above 100% are possible for home chargers, since multiple cars in one home may use the same charger; kW denotes kilowatts.

We calculate the number of work and public chargers needed based on the number of hours they will be utilized in a day. This number starts low but increases as the EV fleet grows. The utilization of slow chargers is assumed to grow more gradually than that of fast chargers, as they are assumed to be more consistently blocked by cars that have finished charging – for example, in the evening or over the workday.

We similarly assume rising utilization rates for e-bus and truck chargers, but we assume a higher initial utilization rate than we do for passenger vehicles. This is because we assume a fleet manager will only purchase chargers they need (Figure 336 and Figure 337). We assume that all chargers have an asset life of 10 years, after which they will be replaced.

Figure 336: Usage assumptions for e-bus and truck chargers at depots

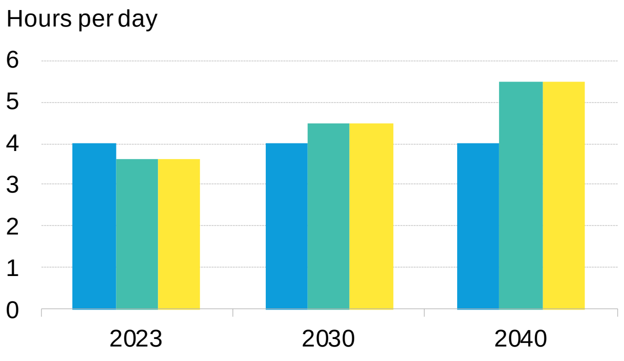
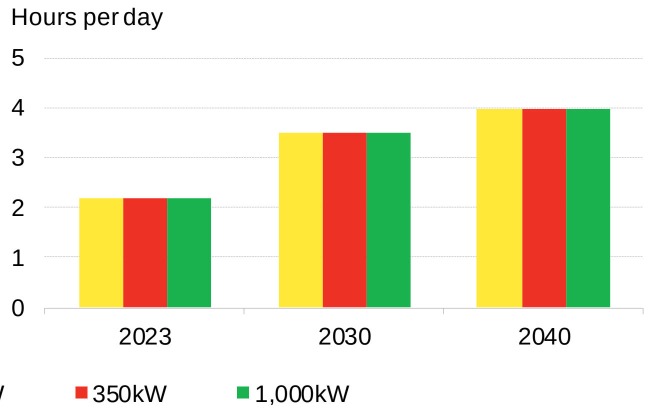


Figure 337: Usage assumptions for public e-bus and truck chargers

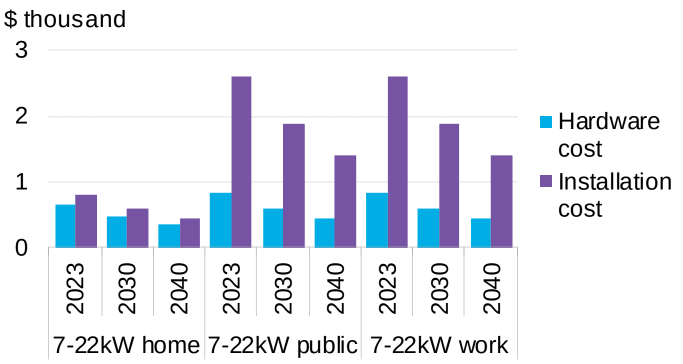


Source: BloombergNEF. Note: kW denotes kilowatts.

Cost assumptions

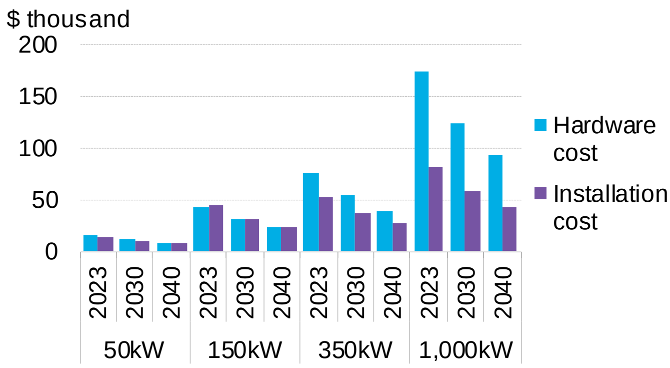
Finally, we calculate investment in hardware and installation from the charging unit demand numbers. Prices of hardware and installation in 2022 are taken from our commercial charger price survey. Annual cost reductions are then assumed over time.

Figure 338: Prices and installation cost assumptions for 7-22kW chargers, excluding China



Source: BloombergNEF. Note: kW denotes kilowatts.

Figure 339: Prices and installation cost assumptions for 50-1,000kW chargers, excluding China



Source: BloombergNEF. Note: kW denotes kilowatts.

From 2023, hardware prices are assumed to decrease by 8% a year, with annual reductions tapering to 2% by 2040. These large reductions are in line with data submitted in our pricing survey, which shows manufacturers reducing prices by up to 40% for volume orders. Our survey also indicates that some companies are achieving project costs per connector that are a mere 20% of the most expensive providers' costs. We believe competition from Asian hardware manufacturers on the global market will also play a part in pushing prices down.

The cost of installation reduces by 5% a year from 2023, as the industry scales up and larger infrastructure installations bring efficiencies to the process. Annual reductions in cost will drop to 2% by 2040. The final hardware and installation costs can be seen in Figure 338 and Figure 339 for all regions other than China. Costs in China are assumed to be 40-50% of those in the rest of the world in our modeling.

Appendices

Appendix A. Glossary

Table 24: Glossary

Term	Definition
EV	Electric vehicle; includes battery-electric vehicles (BEVs) and plug-in hybrid electric vehicles (PHEVs)
BEV	Battery-electric vehicle
PHEV	Plug-in hybrid electric vehicle
FCV	Fuel cell vehicle
LCV	Light-duty commercial vehicle
MCV	Medium-duty commercial vehicle
HCV	Heavy-duty commercial vehicle
NEV	New energy vehicle; includes BEVs, PHEVs and fuel cell vehicles. Term used in China.
Robotaxis / AVs	Autonomous vehicles. We use the two terms interchangeably.
ETS	Economic Transition scenario
NZS	Net Zero Scenario
LFP	Lithium iron phosphate
LMFP	Lithium manganese iron phosphate
NMC	Lithium nickel manganese cobalt oxide
NCA	Lithium nickel cobalt aluminum oxide
NMCA	Lithium nickel manganese cobalt aluminum oxide
LNO	Lithium nickel oxide
LNMO	Lithium nickel manganese oxide spinel
LMR-NMC	Lithium-manganese rich NMC
LMO	Lithium manganese oxide spinel
Na-ion	Sodium ion
LiNiPO4	Lithium nickel phosphate
FeF3	Iron fluoride

Source: BloombergNEF

Appendix B. National internal combustion vehicle phase-out targets

Table 25: Countries that have announced plans to phase out sales of internal combustion vehicles

Country/region	Target year	EV share of car sales in 2023	Vehicles included in the target	Legislative enforcement	Position on hybrids (HEVs)
Norway	2025	91%	Passenger cars, light commercial vehicles	No	Vague
Austria*	2030	31%	Passenger cars, light commercial vehicles, buses	No	Hybrids and PHEVs are banned
Denmark*	2030	42%	Passenger cars	No	Hybrids banned as of 2035
Greece*	2030	12%	Passenger cars	No	Hybrids and PHEVs are banned
Iceland	2030	71%	Passenger cars	No	Vague
Israel	2030	18%	Passenger cars (trucks and buses can be natural gas or electric)	No	Vague
Netherlands*	2030	44%	Passenger cars	No	Vague
Singapore	2030	13%	Passenger cars	No	Vague
Slovenia*	2030	12%	Passenger cars, light commercial vehicles	No	Yes, hybrids included
Canada	2035	11%	Passenger cars, light commercial vehicles	No	Vague
Cape Verde	2035	n/a	Passenger cars	No	Vague
Chile	2035	0.70%	Passenger cars, light commercial vehicles, buses	No	Hybrids and PHEVs are banned
European Union	2035	23%	Passenger cars	Yes	100% reduction of CO2 emissions by 2035, so hybrids included; exemption for carbon-neutral synthetic fuels
Italy*	2035	9%	Passenger cars, light commercial vehicles	No	Vague
UK	2035	25%	Passenger cars, light commercial vehicles	No	Now aligned with the EU-wide phaseout, bans PHEVs as of 2035
France*	2040	27%	Passenger cars, light commercial vehicles	No	Vague
Spain*	2040	15%	Passenger cars, light commercial vehicles	No	Vague
Vietnam	2040	11%	Passenger cars, commercial vehicles	No	Vague
Costa Rica	2050	7%	Passenger cars, taxi, trains, buses	No	Vague

Source: BloombergNEF. Note: Unless otherwise mentioned, bans refer to new sales of ICE vehicles. Asterisks (*) indicate countries in the EU that could see their ICE phaseout impacted by EU-wide ICE phaseout policy. Iceland exempts some rural vehicles from its ICE phaseout. Italy issued a statement in 2021 indicating that new combustion cars would be banned from 2035; the country's commitment to this goal is now less certain, given its change of government in 2022, the fact that the commitment was not enshrined in national legislation and the fact that Italy has been among EU member states to oppose a bloc-level ban for 2035. Passenger EV share of sales rounded to nearest percent. List as of May 15, 2024.

Appendix C. Country and segment outlook coverage

Table 26: EVO 2023 country and segment outlook coverage for Europe, Middle East and Africa (EMEA)

Segment	UK	Germany	France	Italy	Nordics
Passenger vehicles	✓	✓	✓	✓	✓
Buses	Covered jointly under Europe				
Commercial vehicles	✓	✓	✓	-	-
Two- and three-wheelers	Covered jointly under Europe				

Source: BloombergNEF. Note: Europe is the grouping of the European Union, the European Free Trade Association and the UK. All European countries not listed in the table above comprise our 'Rest of Europe' category. All other regions in EMEA are included in our 'Rest of World' category.

Table 27: EVO 2023 country and segment outlook coverage for the Americas (AMER)

Segment	US	California	Canada	Brazil
Passenger vehicles	✓	✓	✓	✓
Buses	✓	-	✓	✓
Commercial vehicles	✓	✓	-	✓
Two- and three-wheelers	✓	-	✓	✓

Source: BloombergNEF. Note: Other regions in AMER are included in our 'Rest of World' category.

Table 28: EVO 2023 country and segment outlook coverage for Asia-Pacific (APAC)

Segment	China	Japan	South Korea	India	Southeast Asia	Australia
Passenger vehicles	✓	✓	✓	✓	✓	✓
Buses	✓	✓	✓	✓	✓	✓
Commercial vehicles	✓	✓	✓	✓	-	✓
Two- and three-wheelers	✓	✓	✓	✓	✓	✓

Source: BloombergNEF. Note: Southeast Asia includes Indonesia, Malaysia, Philippines, Singapore, Thailand and Vietnam. All other regions in APAC are included in our 'Rest of World' category.

Our Tier 2 countries this year are:

Table 29: Countries and regions covered at a Tier 1 and Tier 2 level

Tier 1 grouping	Rest of Europe	Nordics
Tier 2 name	Austria	Denmark
	Belgium	Finland
	Bulgaria	Iceland
	Croatia	Norway
	Cyprus	Sweden
	Czech Republic	
	Estonia	
	Greece	
	Hungary	
	Ireland	
	Latvia	
	Liechtenstein	
	Lithuania	
	Luxembourg	
	Malta	
	Netherlands	
	Poland	
	Portugal	
	Romania	
	Slovakia	
	Slovenia	
	Spain	
	Switzerland	

Source: BloombergNEF

Appendix D. Drive cycle definitions and market segmentation for commercial vehicles

Table 30: Drive cycle definitions for commercial vehicles

Urban	Regional	Long-haul	Utility
<30,000 miles (~48,000 kilometers) per year	30,000-100,000 miles (~48,280 – 160,000 kilometers) per year	>100,000 miles (~160,000 kilometers) per year	*Mileage varies greatly*

Source: BloombergNEF

Urban

Urban trucks operate within a limited geographic area with a stop-and-start driving style, traveling more frequently but on shorter routes. This results in less-fuel-efficient driving, with mileage around 3-6 miles (8-14 km) per gallon. Routes are flexible and can change from day to day. Delivery trucks account for the majority of miles covered in this segment. Mileage for urban trucks is lower than other cycles on an annual basis. Gross vehicle weight (GVW) is generally low.

Regional

Regional trucks operate over a medium range and are capable of hauling larger volumes than urban trucks. Routes are more predictable and trucks stop and start less than urban trucks. This improves fuel economy to 5-9 miles per gallon. Regional trucks operate on a centralized hub-and-spoke distribution model. Companies distributing goods from central warehouses to local centers account for the majority of miles covered in this segment. Mileage for regional cycle trucks can vary considerably, depending on the location of each hub. GVW is limited to allow trucks access to destinations in urban settings where weight restrictions apply.

Long-haul

Long-haul trucks can operate over distances in excess of 250 miles from origin to destination. Routes are predictable and often dictated by highway infrastructure. Long-haul trucks are larger and more efficient than regional or urban trucks on a fuel per ton-kilometer basis.

Utility

Utility vehicles operate on a variety of drive cycles, such as port operating drayage trucks, garbage trucks and forklifts. While vehicles in this segment vary in weight, they operate on a hub-and-spoke model similar to that of regional trucks. Like regional trucks, predictable routes to and from a hub allow utility trucks to adopt a centralized refueling model, provided the distance from hub to destination and back can be covered without refueling. Mileage varies but mirrors that of urban and regional trucks.

The segmentation of commercial vehicles according to gross vehicle weight rating (GVWR) differs between countries and follows the classification used by statistics agencies in every country or region.

Table 31: Commercial vehicle segmentation according to Gross Vehicle Weight Rating (GVWR)

Country	LCV	MCV	HCV
US	<4.5t	4.5-12t	>12t
Europe	<3.5t	3.5-12t	>12t
China	<6t	6-14t	>14t
India	<3.5t	3.5-16t	>16t
Japan	<5t	5-9t	>9t
South Korea	<5t	5-12t	>12t

Source: BloombergNEF. Note: LCV, MCV and HCV denote light-, medium- and heavy-duty commercial vehicles, respectively; t denotes metric tons.

Appendix E. Two- and three-wheeler vehicle definitions

Table 32: Two- and three-wheeler definitions

Type	Class	Image	Description	Included in the 2/3W outlook
Micromobility	Electric kick-scooter		Two-wheeled kick scooter with electric propulsion. Also called stand-up scooter or kick-stand scooter Examples: Segway-Ninebot ES1	No
	Bicycle		Bicycle with no propulsion system other than through pedals. Examples: Specialized, Giant	No
	E-bike		Includes pedelec e-bikes and non-pedelec e-bikes. Motor size typically ranges from 250-750W. Examples: Rad Power, VanMoof	No
Two-wheeler	Moped		Engine size: Typically less than 50cc. Motor size for e-mopeds usually around 1kW. Most are pedal assisted. Example: TVS XL super	Yes
	Scooter		Engine size: Up to 150cc and typically above 75cc. Most are automatic (gearless) vehicles. Motor size for e-scooters is usually 1-10kW. Examples: Vespa, Honda Activa and Suzuki Access	Yes
	Motorcycle		Engine size: Typically between 90cc and 350cc. The engine capacity can also go beyond 1,000cc. Motor size for electric motorcycles is usually 15-100kW. Most are manual-geared vehicles. Examples: Yamaha R1, Kawasaki Ninja, Hero Splendor.	Yes
Three-wheeler	Auto rickshaw		Engine size: Typically between 100cc and 400cc. Motor size: 500 -2000 W Examples: Bajaj RE Auto Rickshaw and Piaggio Ape Auto Rickshaw	Yes
	Motor tricycle		Engine size: Typically between 100cc and 900cc. 500 - 5000 W Example: Shifen 3-wheel truck	Yes

Source: BloombergNEF. Note: W refers to watts, kW is kilowatts, cc is cubic centimeters, and 2/3W is two- and three-wheelers.

Micromobility

Micromobility can refer to all vehicles under 500 kilograms, but for our purposes we limit it to mean vehicles that are primarily intended to be used in bike lanes rather than on public roads. Broadly speaking, this includes lightweight vehicles such as bicycles, motorized kickstand scooters and e-bikes. These vehicles are useful for short distance travel and can play a meaningful role in the transportation landscape. However, we do not include them in the two- and three-wheeler modeling. The impact of micromobility is an important consideration in our light-duty vehicle and bus outlooks.

Two-wheeler

Two-wheelers are classified as mopeds, scooters and motorcycles depending on engine or motor size. While e-bikes and mopeds share many similar characteristics, we make a distinction based on engine size. Mopeds are mostly pedal assisted with an engine less than 50 cubic centimeters (cc) and motor size around 1kW if they are electric. Scooters have a larger engine of 75-150cc or 1-10kW motor. Motorcycles typically have a 90-350cc engine or a 15-100kW motor. The specific classifications of these segments can vary region depending on local regulation.

Three-wheeler

Three-wheelers are classified as auto rickshaws and motor tricycles depending on engine or motor size. They are commonly used for commercial purposes, transporting passengers and goods over short trips. China and India are the largest three-wheeler markets.

Appendix F. Total cost of ownership assumptions for plug-in hybrid thematic highlight

The following assumptions were used for the total cost of ownership (TCO) analysis for the US and China, referenced in Section 4.6.

Table 33: Assumptions for total cost of ownership of vehicles in the US and China for drivetrain analysis

Country	Vehicle	Efficiency (kilometers)	Upfront Cost	Fueling cost	Annual kilometers travelled assumed	Electricity use share (daily)
US	Tesla Model Y	5.7 km per KWh	$42,990 (or $35,490 w/ credit)	Electricity at $0.14 per kWh Gasoline at $2.93 per gallon for gasoline	18,215	100%
	Toyota RAV4 Prime PHEV	5.2 km per kWh 61 km per gallon	$43,690			50%
	Toyota RAV4 HEV	63 km per gallon	$31,725			0%
	Toyota RAV4	48 km per gallon	$28,765			0%
China	BYD Song Plus BEV	7.67 km per kWh	$24,883	$0.09 per kWh for electricity $3.66 per gallon for gasoline	12,943 kilometers	100%
	BYD Song Plus PHEV	8.3 km per kWh 86 km per gallon	$23,010			50%
	Great Wall Motor Haval H6	50.5 km per gallon	$13,489			0%
	Great Wall Motor Haval H6 HEV	77.3 km per gallon	$17,976			0%

Source: BloombergNEF, US Department of Energy. Note: Values are rounded; kWh refers to kilowatt-hour.

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