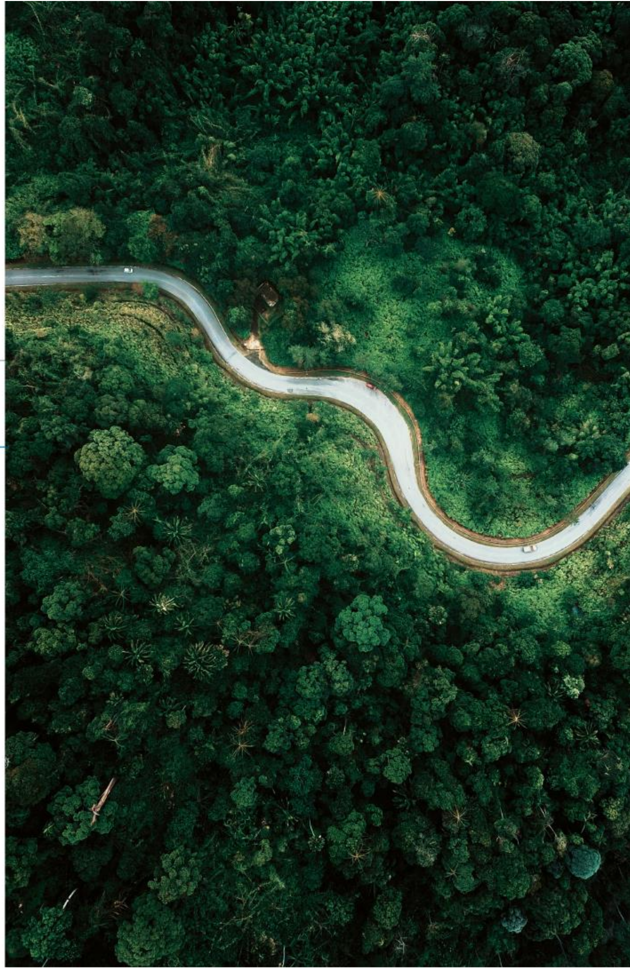

Electric Vehicle Outlook 2023

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This is an excerpt from BloombergNEF's 2023 Electric Vehicle Outlook. To find out more about the full report, please contact our team.

Executive Summary

730 million

Number of passenger EVs on the road in 2040 in the Economic Transition Scenario

2029

Year road transport emissions peak

$1.9 trillion

Charging infrastructure market opportunity between today and 2050 in the Economic Transition Scenario

The transportation and automotive sectors are undergoing a period of profound transformation. Electrification is now spreading rapidly in almost all segments of road transport, from passenger cars to commercial vehicles, buses and two- and three-wheelers. Each country has its own unique mix of vehicles and while progress varies across them, the overall direction of travel is increasingly clear.

Technology changes are at the core of this transition as battery prices have fallen dramatically over the last decade. Battery prices rose for the first time in 2022 but innovation in the area is not slowing down, with advances in areas like solid-state batteries, next-generation cathode and anode chemistries, and sodium-ion technology all reaching commercialization in the next few years.

Yet technology changes alone are not enough to keep the road transport sector on track for net-zero emissions by mid-century. Policymakers have an important role to play in driving the automotive market toward zero-emissions options, improving fuel efficiency, getting the power system ready for electric vehicles, and in reducing overall car dependency. Eliminating emissions from road transport will require all hands on deck, including automakers, battery manufacturers, charging companies, grid operators, miners, large fleet operators and consumers.

As momentum grows, new economic opportunities are taking shape. Batteries and electric vehicles have taken center stage in new discussions on industrial policy, with countries now competing to attract investment and build new clusters of high-value manufacturing. Meanwhile, regulators and grid operators are looking at ways to ensure EVs benefit the power system.

Electrification is not the only vector of change. Shared mobility, vehicle connectivity and, eventually, autonomous vehicles are also set to reshape automotive and freight markets around the world. Urbanization also continues its steady march, leading to increased concerns around vehicle congestion and urban air quality.

This report draws on BloombergNEF's team of sectoral and regional experts around the world. It updates our outlook for how road transport could evolve over the next 30 years. It 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.

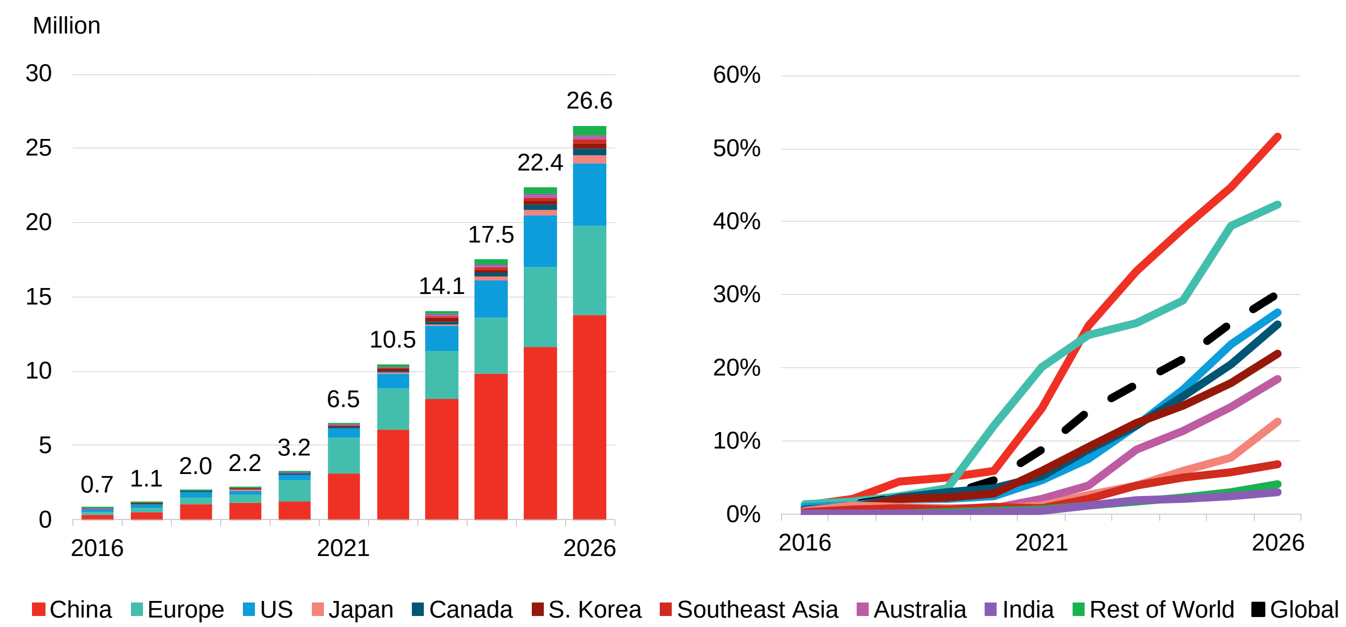
The key findings are as follows:

- **Direct electrification via batteries is the most efficient, cost-effective and commercially available route to fully decarbonizing road transport.** Fuel cell vehicles play a role in some hard-to-electrify long-haul trucking applications but play no meaningful role in the passenger vehicle market. Synthetic fuels do not arrive at scale in time or at a price point needed to have a material impact on road transport.

- **EV sales continue to surge in the next few years, rising from 10.5 million in 2022 to almost 27 million in 2026.** The EV share of global new passenger vehicle sales jumps from 14% in 2022 to 30% in 2026. Shares in some markets are much higher, with EVs reaching 52% of sales in China and 42% in Europe. Some European car markets move even faster, with the Nordics at 89% and Germany at 59%. In the US, a major push from the Inflation Reduction Act means EVs make up nearly 28% of passenger vehicle sales by 2026, up from 7.6% in 2022. The EV adoption gap between wealthy and emerging economies continues to grow in the near term, but Japan significantly lags other wealthy countries.

  The fleet grows even faster, rising from 27 million passenger EVs on the road at the end of 2022 to over 100 million by 2026.

Figure 1: Global near-term passenger EV sales and share of new passenger vehicle sales by market

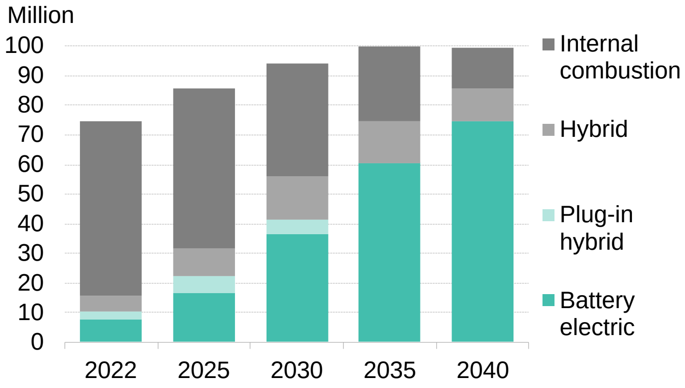


Source: BloombergNEF. Note: Europe includes the EU, the UK and EFTA countries. EV includes BEVs and PHEVs.

- **Combustion vehicle sales have peaked.** Sales of internal combustion vehicles peaked in 2017 and are now in long-term decline. By 2026, sales of combustion vehicles are 39% lower than their peak in 2017. The combustion vehicle fleet peaks in 2025.
- **The long-term picture is getting brighter, but challenges remain.** EVs reach 44% of global passenger vehicle sales by 2030 and 75% by 2040 in our Economic Transition Scenario. After increasing rapidly from 2022 to 2035, EV sales growth slows down slightly in the late 2030s in the main EV markets like Europe, China and the US as they begin to saturate. Although public charging infrastructure is growing at pace globally, it still presents a potential barrier to electrifying the last 10-20% of the market in many countries.

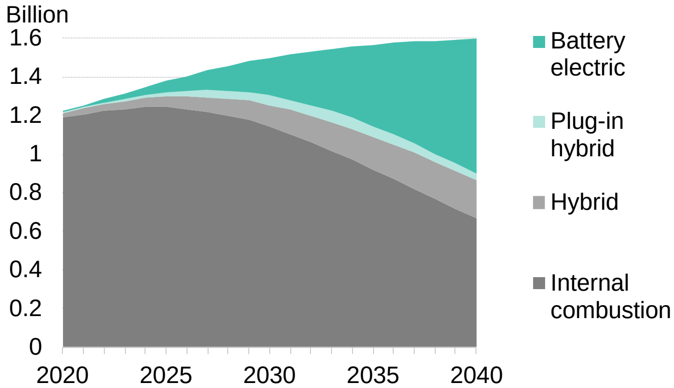
  While EV sales exhibit a traditional 'S-curve' for adoption, each country and region starts on this trajectory at different times. The varied start time and slowdown points between countries mean that the global average appears more linear than any individual country. Despite rapid EV adoption, less than 50% of the global passenger vehicle fleet is electric by 2040.

Figure 2: Global passenger vehicle sales by drivetrain – Economic Transition Scenario



Source: BloombergNEF.

Figure 3: Global passenger vehicle fleet by drivetrain – Economic Transition Scenario

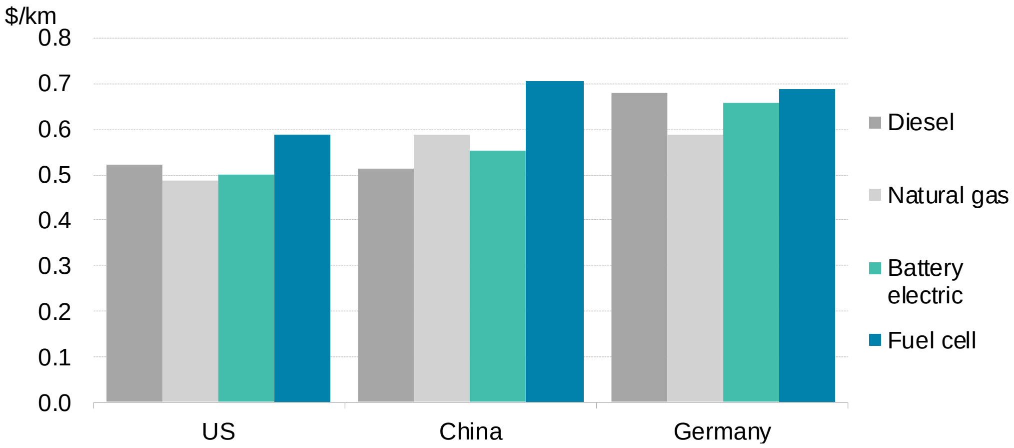


Source: BloombergNEF.

- **Electrification is now spreading quickly to all areas of road transport.** Light commercial EV sales are set to rise quickly due to attractive economics, more models available, growing fleet commitments and city policies, reaching almost 70% of global sales by 2040, led by China. The economics of electric heavy trucks improve rapidly throughout the 2020s and become as cheap as diesel equivalents even for long-haul applications. However, fuel costs still matter and natural gas remains economically competitive. Fuel cell truck costs decline as well, but uncertainty on their trajectory is high. Overall road freight demand rises 46% from 2020 to 2040, highlighting the need for competitive zero-emissions options in this segment.

  Municipal buses are also electrifying quickly. Europe and the US begin to catch up with China in this market and EVs reach 36% and 24% of municipal bus sales respectively by 2026. Two- and three-wheeled vehicle sales also continue to rise in emerging economies and are set to be almost all electric globally by 2040.

Figure 4: Total cost of ownership of heavy-duty truck in long-haul duty cycle in 2030



Source: BloombergNEF. Note: The heavy-duty truck is modeled on a Class 8 vehicle with 800 kilometers of real-world driving range.

- **Reaching net-zero road transport emissions by 2050 is still possible but much faster progress is needed.** The gap between BNEF's Economic Transition Scenario and the Net Zero Scenario is smaller than in any of our previous projections. This is due to new stronger policy support in the US, early EV progress in a few emerging economies like India, Thailand and Indonesia, growing global investment in charging infrastructure and the battery supply chain, and technology innovations like sodium-ion batteries.

  A stronger push is still needed. Heavy trucks in particular are far behind the net-zero trajectory and should be a priority focus for policy makers. Grid investments, grid connections and permitting processes also need to be streamlined to support the large number of charging points needed for the transition.

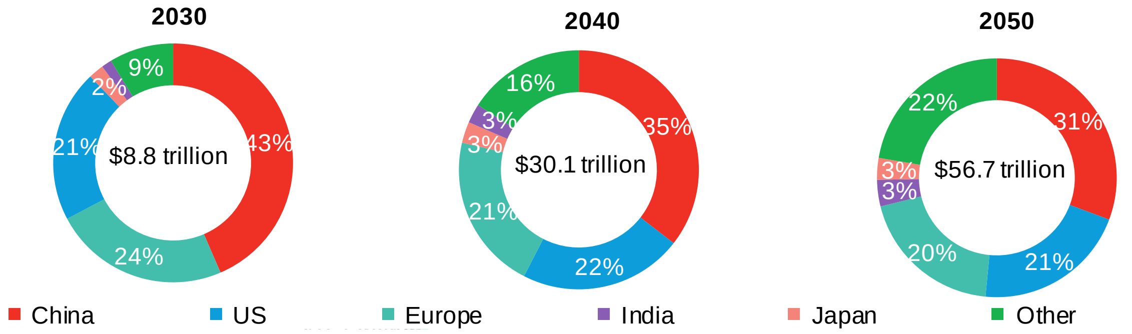
Table 1: Road transport segment progress toward net zero

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%	119 million	95%	On track
Two-wheeled vehicles	5%	1 billion	78%	Almost on track: minor additional measures needed
Municipal buses	1%	3.5 million	87%	Almost on track: minor additional measures needed
Light commercial vehicles	11%	165 million	76%	Positive trajectory: moderate additional measures needed
Passenger vehicles	53%	1.3 billion	70%	Positive trajectory: moderate additional measures needed
Medium + heavy commercial vehicles	30%	82 million	32%	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 2022.

- **The shift to electrification creates a very large economic opportunity.** The cumulative value of EV sales across all segments hits $8.8 trillion dollars by 2030 and $57 trillion by 2050 in the Economic Transition Scenario. This jumps to over $88 trillion by 2050 in the Net Zero Scenario. EVs and batteries are now a central part of many countries' industrial policy and competition to attract investment is likely to increase in the coming years.

Figure 5: Cumulative global EV market opportunity by region – Economic Transition Scenario

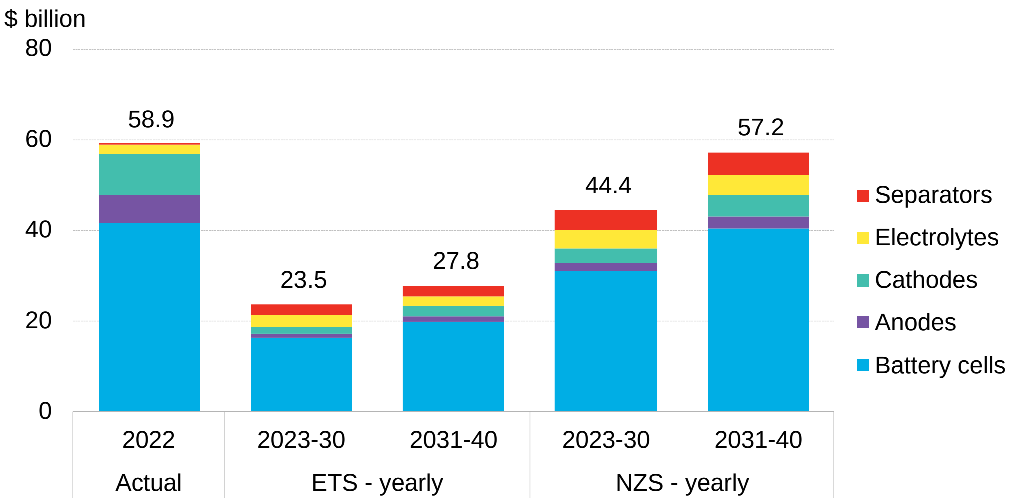


Source: BloombergNEF. Estimates are cumulative spending starting in 2023. Dollars are in real 2022.

- **Large investments are needed in all areas of the battery supply chain.** Annual lithium-battery demand grows rapidly, approaching 5.7TWh annually by 2035 in our Economic Transition Scenario. Meeting this demand requires large but achievable increases in materials, components and cell production. There is over 7.4TWh of nameplate cell manufacturing capacity planned by 2025. This is more than projected demand in the same year, but actual excess supply will be lower due to varying utilization rates, commissioning delays and abandonments.

  Increasingly, governments and automakers are seeking to localize their respective supply chains through a number of policies ranging from direct subsidies to battery 'passports'. Sustained investment will be required in the second half of the decade to keep up with demand. At least $188 billion needs to be invested in battery cell and component plants by the end of the decade.

Figure 6: Annual battery factory investment by scenario

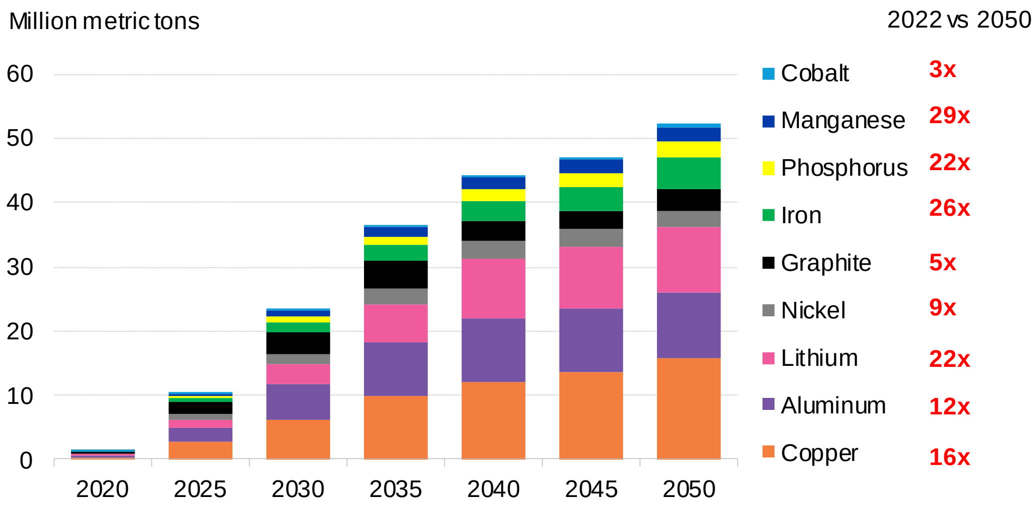


Source: BloombergNEF. Note: ETS = Economic Transition Scenario. NZS = Net Zero Scenario. Battery factory requirements include investment needed to meet EV demand as well as stationary energy storage.

Under the Net Zero Scenario, new demand for lithium-ion batteries is 1.7 times that of our Economic Transition Scenario, reaching 244TWh cumulatively by 2050. Thanks to increasing reserves and a reduction in use in batteries, cobalt and nickel reserves are now enough to supply both our Economic Transition and Net Zero Scenarios. Lithium looks more challenging and currently known reserves would be depleted in our Net Zero Scenario even with recycling.

New battery chemistries and reductions in pack sizes can help offset this pressure. Scaling new resource development and refining capacity will be key to keep up with demand in any given year.

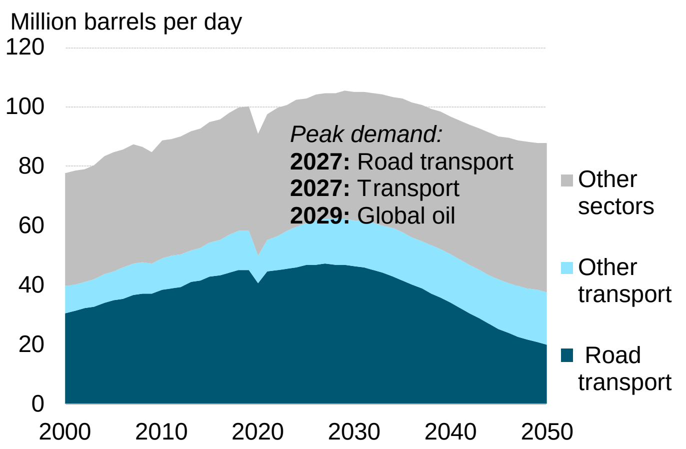
Figure 7: Annual metals demand from lithium-ion batteries under the Net Zero Scenario



Source: BloombergNEF. Note: Lithium is expressed in million metric tons lithium carbonate equivalent (LCE). Demand occurs at the mine mouth, one year before battery demand. Multiples between 2022 and 2050 are based on annual demand in the given year.

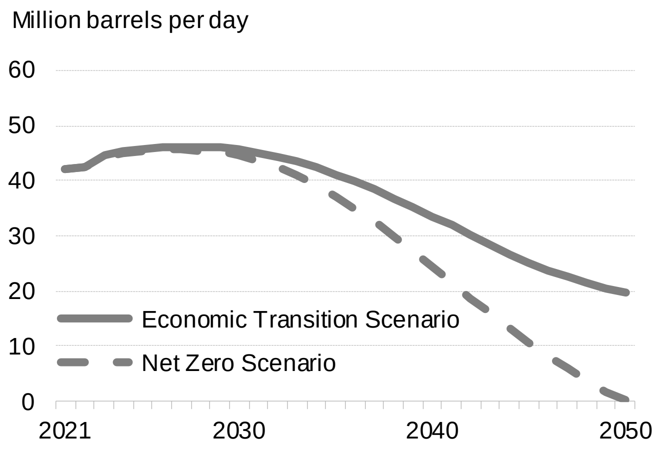
- **Oil demand from road transport is very near its peak.** Electric vehicles of all types are already displacing 1.5 million barrels/day of oil demand. This rises dramatically in the years ahead, leading to a peak in overall road fuel demand in 2027. Demand in the US and Europe has already peaked, while demand in China is set to peak in 2024. Global oil demand from two-wheelers, three-wheelers and buses has also already peaked and demand from passenger cars is set to peak in 2025. Commercial vehicles take longer to shift as heavy trucks continue to rely on diesel to move booming freight demand.

Figure 8: Global oil demand – Economic Transition Scenario



Source: BloombergNEF. Note: Includes biofuels.

Figure 9: Oil demand from road transport by scenario



Source: BloombergNEF. Note: Includes biofuels.

In the Economic Transition Scenario, oil demand from road transport declines to 33.5 million b/d in 2040, some 21% lower than 2022 levels. Fuel efficiency improvement of combustion vehicles and the uptake of shared mobility also play an important role in reducing oil demand.

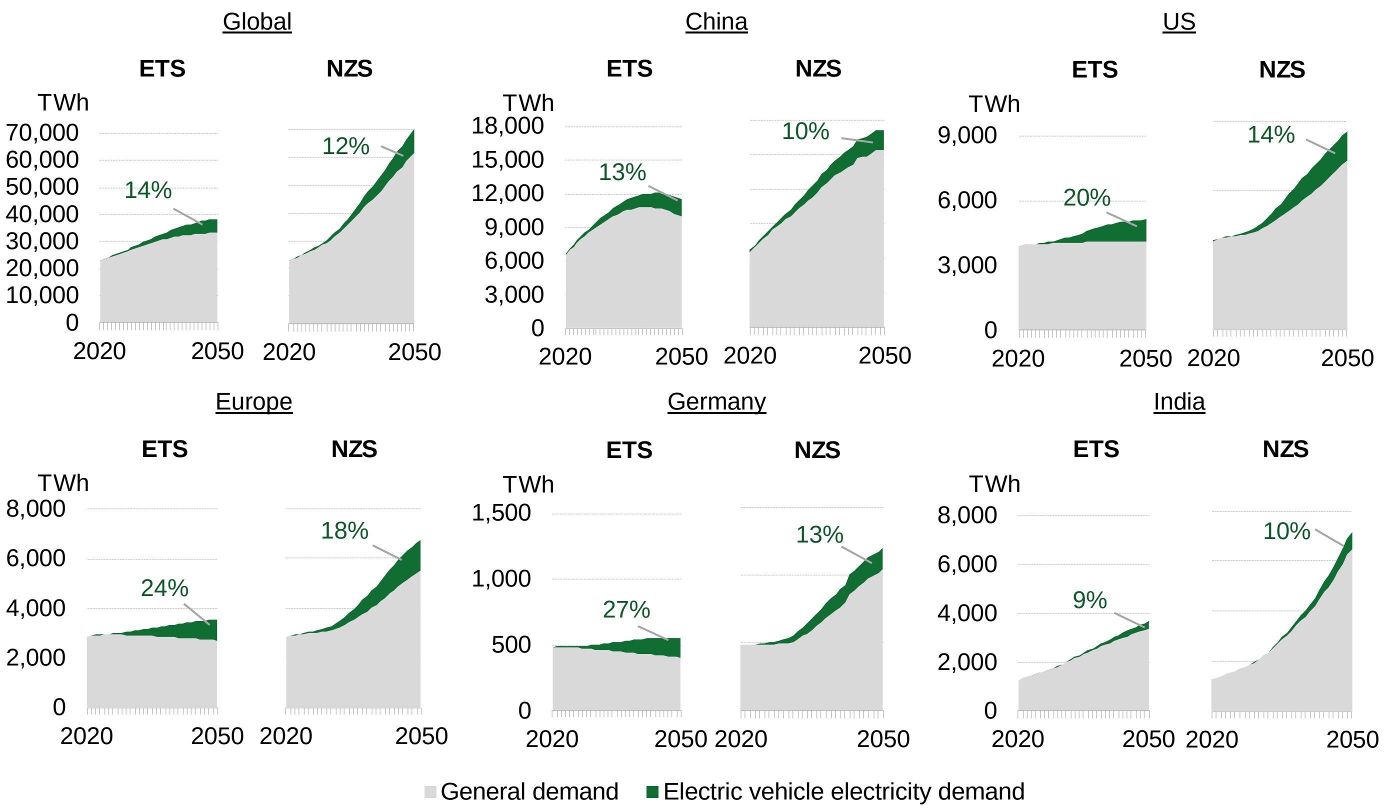
The fall in oil demand does not necessarily mean a collapse in oil prices. If investments in new supply capacity fall faster than demand, prices could remain elevated and volatile.

The Net Zero Scenario sees a much sharper decline in oil demand en route to a full phase-out from road transport in 2050.

- **Additional electricity demand from EVs is part of a broader electrification push to reach net zero**. Global electricity demand from all types of EVs increases five times from 210TWh in 2022 to 1,027TWh in 2030 in the Economic Transition Scenario, before a further tripling in demand to 3,251TWh in 2040. EVs add about 14% to global electricity demand in 2050 in the Economic Transition Scenario, but only 12% in the Net Zero Scenario despite more vehicles on the road. This is because the Net Zero Scenario includes additional electricity demand from electrification of heating, industry and electrolyzer use for hydrogen production used in other sectors. For more, see our New Energy Outlook (web | terminal). In some fast-growing countries like India EVs add just 9-10% to total electricity demand.

  Over $1 trillion in cumulative investment in EV charging infrastructure is required globally over this period. There are growing reasons for optimism that this can be achieved, with some countries now building chargers ahead of the required pace. The required charger investment is still small compared to overall auto sales. For example, China requires $453 billion of cumulative investment in charging infrastructure to 2040, compared to automotive sales revenue from domestic car sales and exports of $750 billion in 2022 alone.

Figure 10: Electricity demand outlook for selected regions by scenario



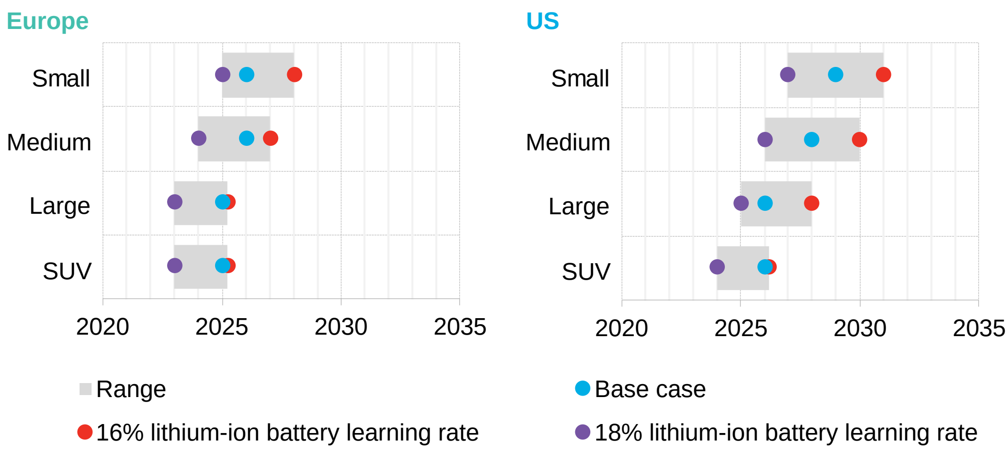
Source: BloombergNEF. Note: Uses general electricity demand projections from BNEF's New Energy Outlook 2022. This is final energy consumption and excludes any losses in transmission. Percentages refer to percentage of EV electricity demand of total in 2050. Net Zero Scenario includes additional demand from electrification of heating, industry, and electrolyzer use for hydrogen.

- This year's EV Outlook includes five new Thematic Highlights, each of which explores a different part of the transition in vehicle markets around the world. The topics are:
  - EV price parity under different battery price scenarios
  - Will average EV ranges keep rising?
  - Emerging battery technologies: sodium-ion batteries, solid-state batteries, and next-generation anode technologies
  - High-powered charging for trucking fleets
  - The impact of autonomous vehicles
- **EV price parity is getting closer but progress varies by segment and country.** Prices for lithium-ion batteries increased for the first time in 2022 and are likely to remain elevated in 2023. This delays the upfront price parity of battery electric vehicles with combustion cars. Despite the near-term increase, EVs still reach up-front price parity with comparable combustion vehicles, without subsidies, by the end of the decade in most segments.

  Even in BNEF's base-case scenario there is a wide variation in purchase economics between geographies, dictated by the differences in the average battery size of BEVs sold or how price-sensitive any given car market is. While electric SUVs in Europe start achieving price parity as early as 2025, BEVs in the same segment in India do not hit parity until after 2030, due to very low average purchase prices in these segments. Larger batteries in US electric cars mean that upfront price parity in the country is one to three years later than for BEVs in Europe.

  Accelerating battery-pack price declines – using an 18% learning rate scenario – pushes upfront price parity of EVs forward by an average of one to two years. Delaying it using a 16% learning rate scenario would set the industry back by an average of two to three years. If prices remain elevated for longer, EV adoption will slow. Regardless of the scenario discussed, regional differences remain, and those will dictate the pace of electrification and the type of BEVs adopted in each region.

Figure 11: Impact of lithium-ion battery learning rate scenarios on year of price parity between EVs and combustion vehicles by region and segment



Source: BloombergNEF. Note: Dots represent year of up-front price parity without subsidies. Price parity year for base-case overlaps with the 16% learning rate scenario for large and SUV segments in Europe, SUV in US and SUV in Japan.

- **Average EV ranges are rising quickly, adding pressure to the battery supply chain.** Globally, BEV models launched in 2022 had an average range of 337 kilometers, up from 230km in 2018. Average battery pack sizes have increased 10% annually over this period, going from 40kWh to 60kWh. Still, ranges remain below consumer expectations in most markets and segments, prompting automakers to launch longer-range models to ease range anxiety. Continued improvements in battery and powertrain technologies could quickly push range up to consumer expectations, while improved charger density and charging speed could reduce range requirements in the long term.

  Increasing BEV ranges will further boost demand for lithium-ion batteries as EV adoption accelerates, putting more pressure on the battery materials supply. An annual BEV range increase of 5% in China, the US and Europe from 2023 to 2030 would add nearly 50% more demand for lithium, nickel and cobalt in those markets, compared to our base case scenario where BEV ranges remain flat. This would also push out the date for EV price parity. Wide adoption of advanced battery technologies and recycling could help mitigate materials supply constraints while enabling automakers to deliver long BEV ranges. Governments should direct investment toward supporting dense public charging networks as a cost-effective way to help avoid an EV range 'arms race'

Figure 12: Lithium-ion battery demand for passenger BEVs in China, the US and Europe by battery pack size scenario

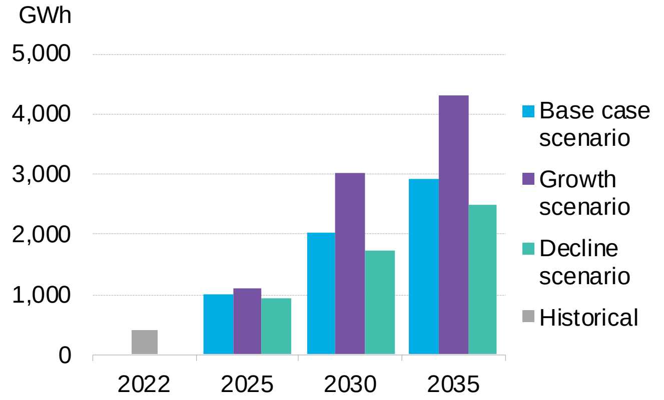
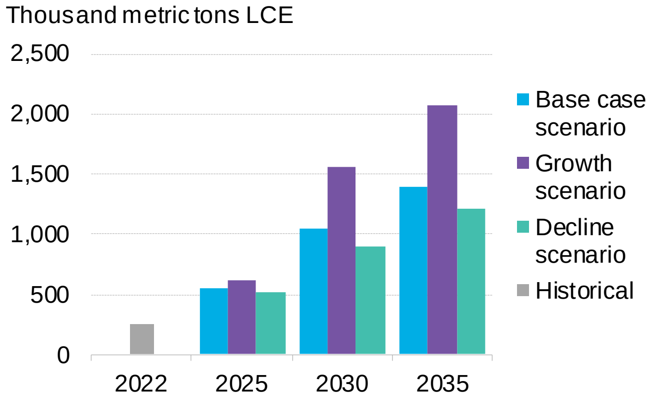


Figure 13: Lithium demand for passenger BEVs in China, the US and Europe by battery pack size scenario

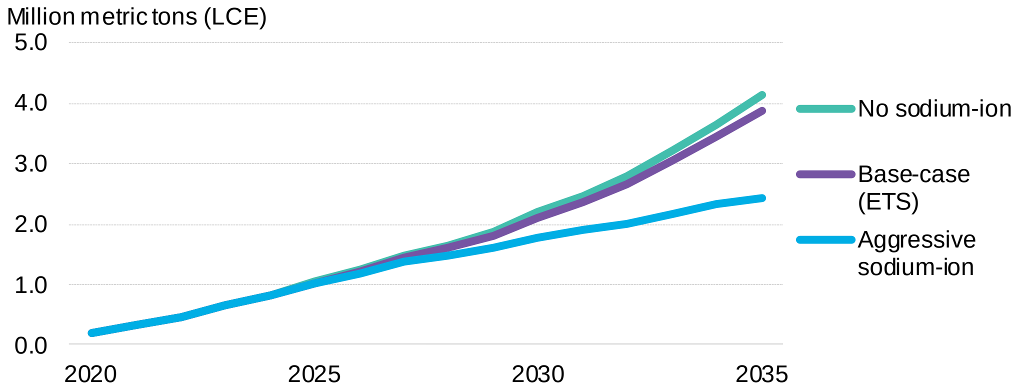


Source: BloombergNEF. Note: Growth scenario assumes 5% growth in average BEV range from 2023 to 2030. Decline scenario assumes 2% annual decline in average range from 2025 onwards. Includes lithium carbonate and lithium hydroxide.

- **Several important next-generation battery technologies are entering the commercialization phase.** These will drive further performance and cost improvements. Improvements in battery energy density to date have been driven by advances in cathode materials, such as the move toward chemistries with higher nickel content. Next-generation technologies including silicon anodes, solid-state batteries and sodium-ion batteries will bring further improvements in performance and cost. They will also shift raw material supply chains. The next generation anode technologies in our base case displace 46% of graphite in 2035 compared with an all-graphite scenario. Similarly, in our base case sodium-ion cells displace 7% of lithium demand in 2035, compared to a no sodium-ion scenario. However, in the case of solid-state batteries, BNEF estimates that 45% to 130% more lithium would be needed on a battery-cell level if the solid-state electrolyte were to substitute both the liquid electrolyte and separator. Solid electrolytes contain more lithium due to slower diffusion of lithium ions through the solid electrolyte than a liquid one.

These newer technologies either involve new battery components or products, new manufacturing processes or establishing new raw material supply chains. Their success will be determined by how easily they can be scaled up and integrated into current manufacturing technology and processes.

Figure 14: Impact of sodium-ion battery uptake scenarios on lithium demand



Source: BloombergNEF. Note: LCE = lithium carbonate equivalent. ETS = Economic Transition Scenario.

- **Charging is a challenge and opportunity for long-haul electric trucking**. The total ownership costs of electric heavy commercial vehicles are set to approach those of diesel equivalents around 2030, even for long-haul applications. Creating a sufficient charging network, however, brings challenges for vehicle owners, charging station developers, utilities and grid operators.

  Truck charging stations will draw multi-megawatts of power and operators today are already developing stations exceeding 25 MW. Developing such stations can generate high returns, but this will be based on many locational factors, such as the availability of a grid connection, the cost to acquire a site and the structure of electricity tariffs.

  There is currently a wide variability in pricing for peak-time electricity consumption that changes the business model. The internal rate of return of such projects varies widely. It can exceed 40% with moderate upfront investment and electricity tariffs but can also quickly become negative when trucks attempt to charge at peak times and demand charges hit.

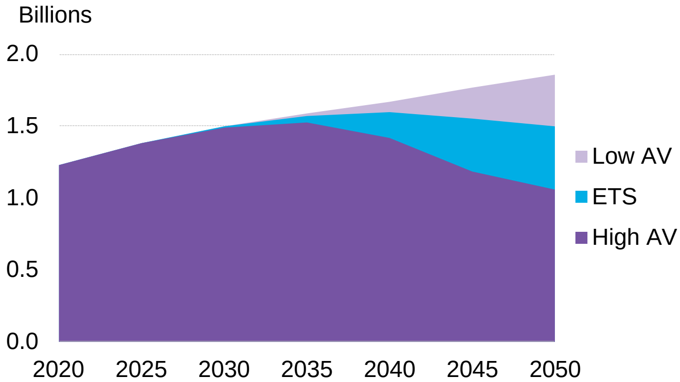
  To smooth the roll-out of charging for trucks, grid operators should focus on electricity tariffs that are suitable for high power consumption and regulators should assess how 'least regret' investments in grid infrastructure can be made ahead of time to limit roll-out delays. Such investments can be large and, depending on whether they are done on the distribution or the transmission level, can range from $100,000 to $800,000 per kilometer.

- **Autonomous vehicles are still a wildcard for the global vehicle market.** Steady progress is still being made on autonomous vehicle (AV) technology. AV fleets covered over 80 million kilometers in 2022 and operators are expanding services to new cities. The rollout of AVs could have big impacts on the size and distribution of the passenger vehicle fleet. Due to the uncertainty around autonomous vehicle deployment, we have laid out two scenarios in which the timeline of AV adoption varies significantly from our Economic Transition Scenario (ETS).

  Depending on the region in which they operate, robotaxis can cover three to five times the annual distance compared to private passenger vehicles, meaning that in a high AV adoption scenario, fewer vehicles are required to offer the same level of mobility to consumers. Our high-AV scenario results in a 2050 fleet that is 29% smaller than in our ETS. Our low-AV scenario results in the passenger vehicle fleet continuing to grow out to 2050, ending up at over 1.8 billion vehicles, over 29% greater than in the ETS.

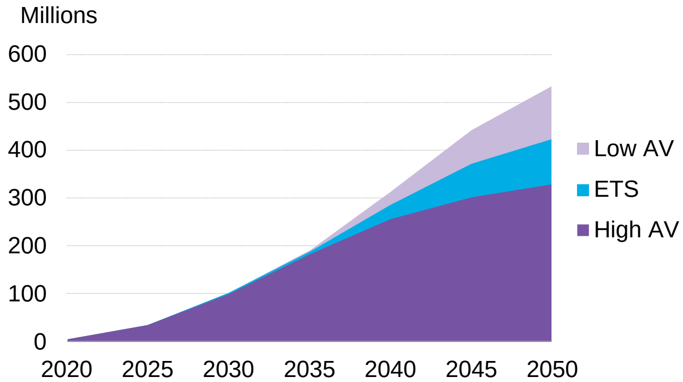
This will have an impact on investment decisions across all transport infrastructure. In particular, charging infrastructure companies will need to make strategic choices on the number, type and location of chargers based on different AV uptake scenarios. The high-AV scenario requires 40% fewer EV chargers than the low-AV scenario by 2050. Approximately 200 million low-speed chargers can be eliminated from the outlook through the addition of less than 1 million high-speed chargers that are optimized for a large robotaxi fleet.

Figure 15: Global passenger vehicle fleet outlook under varying autonomous vehicle adoption scenarios



Source: BloombergNEF. Note: ETS is BNEF's Economic Transition Scenario. High and Low AV scenarios reflect varying AV adoption.

Figure 16: Outlook for number of charging connectors under varying autonomous vehicle adoption scenarios



Source: BloombergNEF. ETS is BNEF's Economic Transition Scenario. High and Low AV scenarios reflect varying AV adoption.

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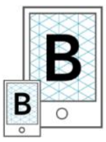

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