Zero-Emission Commercial Vehicles
The Time Is Now

A factbook for investors

September 18, 2024

Smart Freight Centre

Ministry of Infrastructure and Water Management of the Netherlands

BloombergNEF

Contents

About this report

Road freight remains central in supporting economic activity around the world, but the trajectory of the sector's carbon emissions currently does not align with net-zero targets set by governments globally.

This report documents the state of the zero-emission commercial vehicle market to help decision-makers navigate the nascent sector. It shows that despite economic and infrastructure challenges, the transition to cleaner road freight has started and is gathering pace. While progress varies widely between countries and segments, opportunities are emerging for market participants in all parts of the value chain including fleet financing.

The report was produced by BloombergNEF commissioned by the Dutch Ministry of Infrastructure and Water Management and in partnership with Smart Freight Centre.

Ministry of Infrastructure and Water Management of the Netherlands

Dutch Ministry of Infrastructure and Water Management, responsible for the implementation of the mobility agreements of the Dutch Climate Agreement.

Smart Freight Centre

Smart Freight Centre (SFC) is a globally active non-profit organization for climate action in the freight sector. Our goal is to mobilize the global logistics ecosystem, in particular our members and partners, in tracking and reducing its greenhouse gas emissions. We accelerate the reduction of logistics emissions to achieve a zero-emission global logistics sector by 2050 or earlier, consistent with 1.5° pathways.

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BloombergNEF (BNEF) is a strategic research provider covering global commodity markets and the disruptive technologies driving the transition to a low-carbon economy. Our expert coverage assesses pathways for the power, transport, industry, buildings and agriculture sectors to adapt to the energy transition. We help commodity trading, corporate strategy, finance and policy professionals navigate change and generate opportunities.

Introduction and key messages

Sales of medium and heavy trucks with zero tailpipe emissions are growing fast, but the market is still in the early stages. Adoption varies widely between countries and vehicle use cases, though economics are steadily improving as battery prices fall. There is a growing opportunity for creative financing and business models to help this market scale up.

- Emissions from commercial vehicles are set to become the largest contributor to road transport's CO_2 footprint, surpassing passenger cars in the coming years. Without further action, the medium- and heavy-duty truck sector is far from a trajectory consistent with net-zero carbon emissions by 2050.
- Zero-emission truck sales were close to 38,000 units globally in the first half of 2024 and are set to be just over 1.5% of total sales in 2024. Sales in China account for more than 80% of global volume, with adoption approaching 5.5% in the first half of 2024. In Europe, sales are concentrated in a handful of countries, while the US market shows only limited market growth.
- Battery-electric trucks accounted for more than 90% of zero-emission medium and heavy truck sales in 1H 2024. Fuel-cell trucks have mostly been sold in China, where subsidies and availability of hydrogen fuel as a by-product from industrial operations have supported the market. Battery swapping is also playing a role.
- Prices for commercial vehicle batteries in China are the lowest globally at $100 per kilowatt-hour, but prices elsewhere have been declining faster. BNEF expects battery packs for trucks to cost as little as $88/kWh by 2030.
- Electric trucks are quickly becoming economically competitive to equivalent diesel vehicles, starting with shorter routes. Even before 2030, heavy-duty long-haul battery trucks can also reach total cost of ownership parity. Fuel-cell truck costs may also drop by that time, but the decline trajectory is far less certain.
- Manufacturers have set ambitious targets for zero-emission truck sales by 2030 and beyond. However, progress varies and remains limited for some large truckmakers. Strict emissions standards in Europe and the US should kickstart stronger growth.
- While zero-emission vehicle economics improve, capital cost and refueling challenges remain. But new business models and financing structures are emerging to tackle such hurdles. These include partnerships between fleet owners and operators to co-develop refueling stations, raising financing supported by fleet utilization agreements, and extending the revenue potential of vehicle batteries by reusing them in stationary energy storage applications. Fleet owners and investors that grab the early opportunities help create the necessary scale for themselves and the market to sustain further growth.

Zero-emission commercial vehicle market

Sales grow fast, but progress varies

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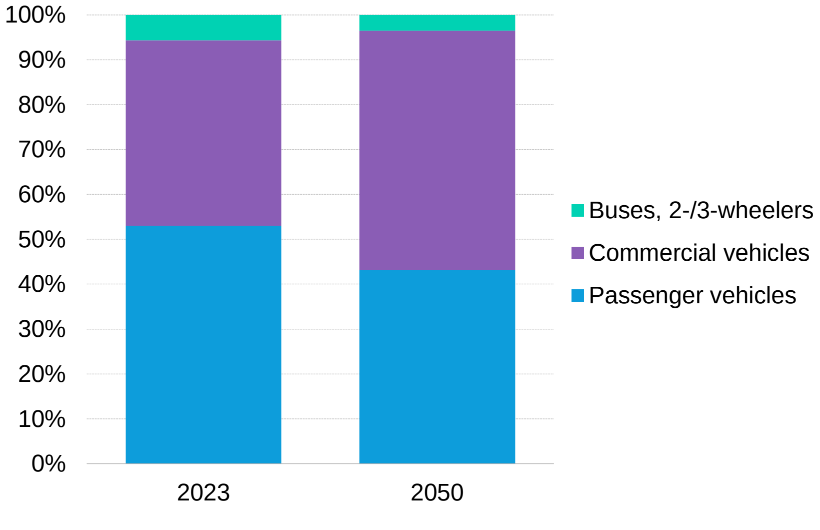
Commercial vehicles are a growing share of road transport emissions

Distribution of CO2 emissions from road transport



Source: BloombergNEF's 2024 Electric Vehicle Outlook Economic Transition Scenario (ETS). Note: Includes emissions from fuel combustion and upstream emissions from electricity generation. The ETS assumes no new policy intervention.

Global road transport emissions reached 6.3 gigatons of CO2 (GtCO2) in 2023, surpassing their previous high set in 2019.

The global fleet of 1.3 billion passenger cars emitted the bulk of that CO2 last year. Electric vehicles are starting to impact these emissions in the passenger car segment. EV sales this year will reach 16.6 million, accounting for just under 20% of new car sales and about 4% of the global car fleet according to recent BNEF analysis.

CO2 emissions from commercial vehicles are set to overtake passenger cars as the largest emitting sector in road transport by 2040, despite the fact that the commercial vehicle fleet remains just under a quarter the size of that of passenger cars.

More than 250 million vans and trucks were on the road at the end of 2023, and accounted for just over 40% of CO2 emissions from road transport. Low- and zero-emission technologies are being adopted at a much slower rate than in cars, buses and other vehicles.

By 2050, the commercial vehicle fleet will grow by more than a third. While efficiency improvements and electrification can offset some of that growth, without further progress such vehicles would emit almost 2.2GtCO2, only slightly less than in 2023.

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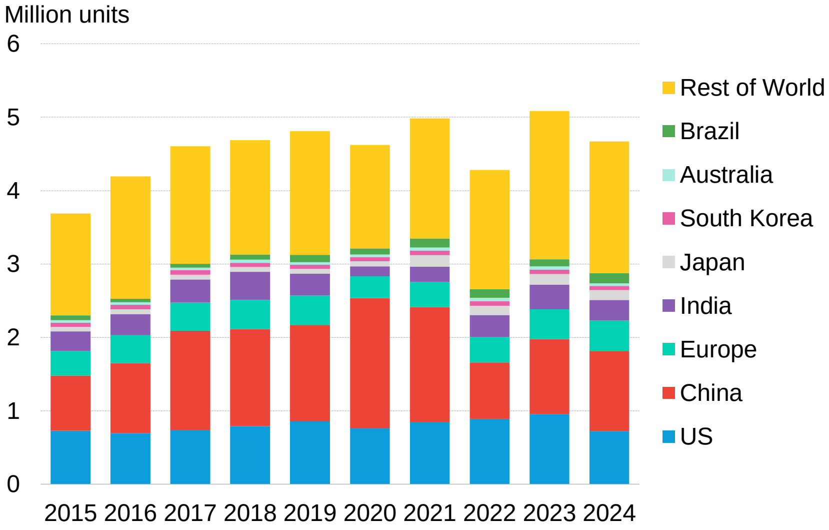
Global heavy commercial vehicle sales stabilize from 2023 highs

Global sales of commercial vehicles by region



Source: BloombergNEF; see full list of sources in the Appendix. Note: Figures for 2024 are BNEF estimates. 'Europe' is the EU 27, the UK, Norway, Switzerland, Iceland and Liechtenstein.

Global medium- and heavy-duty truck sales grew nearly 20% and exceeded 5 million vehicles in 2023, surpassing their previous highs in 2021. Fleet replacements and solid levels of economic activity supported demand for goods transport and other activities in several countries.

China and the US are by far the largest truck markets globally, accounting for 17-22% of total 2023 and 1H 2024 sales. India and the combined European market were at about 7-8% of global sales each.

Growth patterns differs markedly between countries. In more mature markets like some European countries, the US and even China, sales are driven by replacements and modest growth. In emerging and developing countries, truck sales follow overall economic growth.

In this report, we account for medium- and heavy-duty commercial vehicles and exclude light-duty commercial vehicles, such as delivery vans, and buses. Sales and fleet in the latter segment are about twice as large as those of all kinds of trucks combined. While vans and trucks share some similar technology options to reduce emissions, they also differ markedly in engineering, manufacturing, energy requirements and customization.

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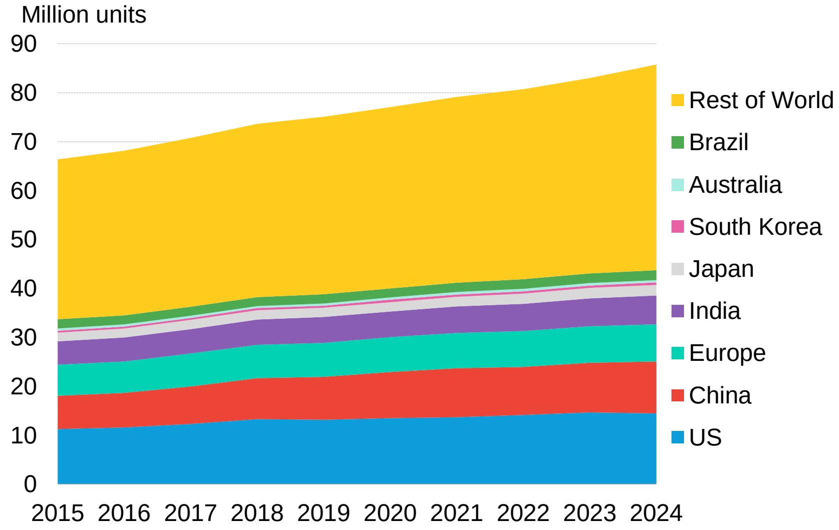
The global commercial vehicle fleet continues to grow

Global fleet of commercial vehicles by region



Source: BloombergNEF; see full list of sources in the Appendix. Note: Figures for 2024 are BNEF estimates. 'Europe' is the EU 27, the UK, Norway, Switzerland, Iceland and Liechtenstein.

The global truck fleet, including medium- and heavy-duty trucks and excluding delivery vans and buses, exceeded 83 million vehicles in 2023, growing just under 3% from the previous year. The US is home to most medium- and heavy-duty trucks, at about 18% of the global fleet, followed by China, Europe and India.

The global fleet size depends on the demand for goods movement, which increased 1.7% in 2023, with activity levels now back on their pre-2019 long-term trajectory. Growth centers are gradually shifting towards developing and emerging economies, where heavier trucks become more common as logistics infrastructure continues to improve.

Such growth patterns are affecting the adoption of cleaner propulsion technologies for commercial vehicles. In countries with more modest sales and fleet growth, such as the US and some European markets, new powertrains enter the mix by substituting existing vehicles.

In contrast, in many countries that are set to experience the strongest demand, especially for heavier vehicles, new trucks are also used to satisfy additional demand for goods movement and services.

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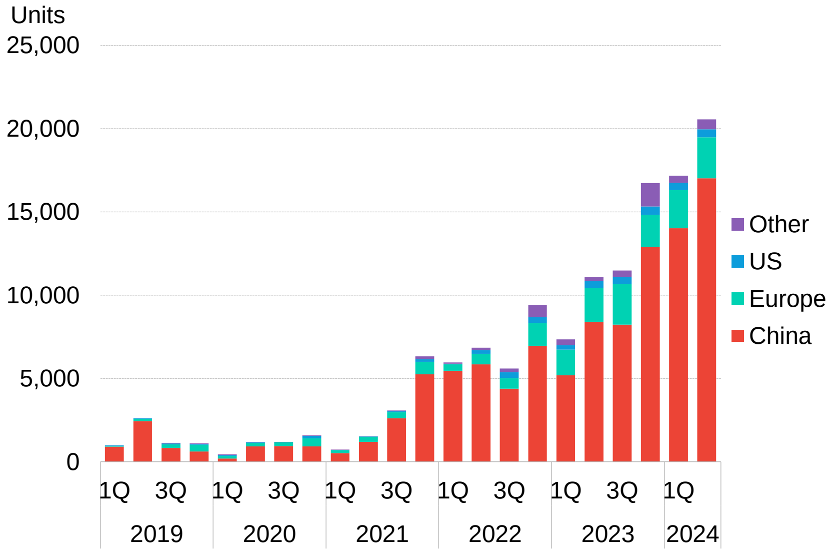
Low- and zero-emission commercial vehicle sales are growing, but are relatively low outside of China

Global sales of zero-emission medium- and heavy-duty trucks by region



Source: BloombergNEF; see full list of sources in the Appendix. Note: Europe is the EU 27, the UK, Norway, Switzerland, Iceland and Liechtenstein.

The global market for low- and zero-emission trucks has been steadily growing over the last three years. In 1H 2024 it was more than 16 times larger than in the same period of 2021.

China is the largest market for battery and hydrogen truck, accounting for more than eight out of 10 such vehicles sold globally in 1H 2024. Sales of zero-emission trucks in the country have grown continuously year-on-year since 2021. Domestic manufacturers including SANY, XCMG and others dominate the market with advanced products benefiting from the country's mature battery supply chain.

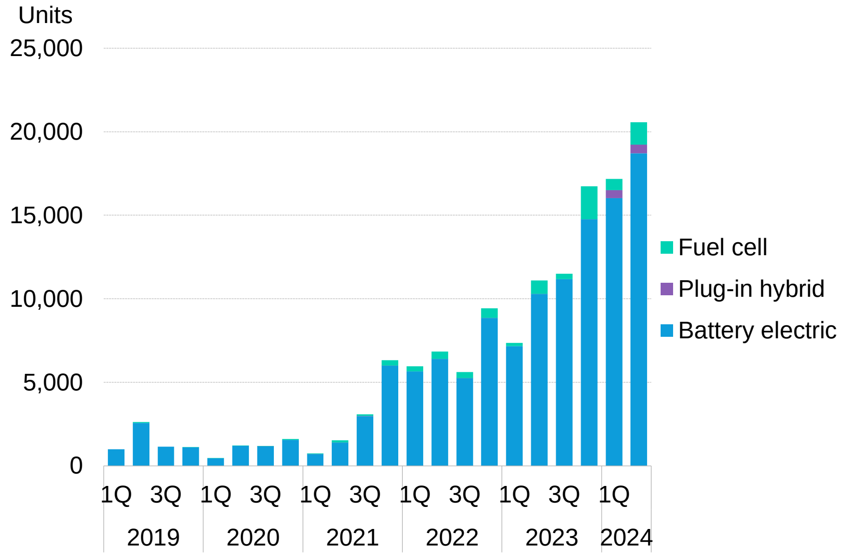
Sales in Europe picked up in 2022 and 2023 from a low base to about 8,000 e-trucks. Incumbent truck manufacturers – particularly Volvo, but also Daimler and Ford – hold large market shares in the region.

The US market for zero-emission trucks is small, with about 1,000 units sold in 1H 2024. The market lacks supply of suitable models, and a few startup manufacturers have failed yet to scale-up production.

In other countries, electric trucks remain a niche market, with just a few dozen units sold in Japan, India, Canada and Australia. Chinese e-truck makers are already looking to global markets in Southeast Asia and South America to export their battery trucks.

Battery trucks account for most of commercial ZEV sales globally

Global sales of zero-emission medium- and heavy-duty trucks by fuel



Source: BloombergNEF; see full list of sources in the Appendix.

Fully electric vehicles (battery-electric vehicles, or BEVs) account for most low- and zero-emission trucks globally. Mature battery supply chains and deep know-how gained through the passenger car industry have made batteries the technology of choice for zero-emission trucks.

Battery technology experience and maturity has led to performance capabilities that can satisfy an increasingly wide range of use cases. Short-haul and urban routes are most of the early applications. Vehicles with least 500 kilometers of driving range from one charge have been launched in Europe and the US, but their availability remains low.

While such trucks haven’t been in operation for long, e-bus and e-truck fleet operators spoken to for this research indicated that battery performance is as good as, or better than, manufacturer specifications.

Fuel-cell trucks were about 5% of global low- and zero-emission truck sales in 1H 2024. Volumes outside of China are minimal, as manufacturers have yet to increase production, while hydrogen supply remains uncertain and expensive.

Plug-in hybrid trucks were about 3% of global ZEV sales in 1H 2024. Sales took place almost exclusively in China, and these models were barely available in previous years.

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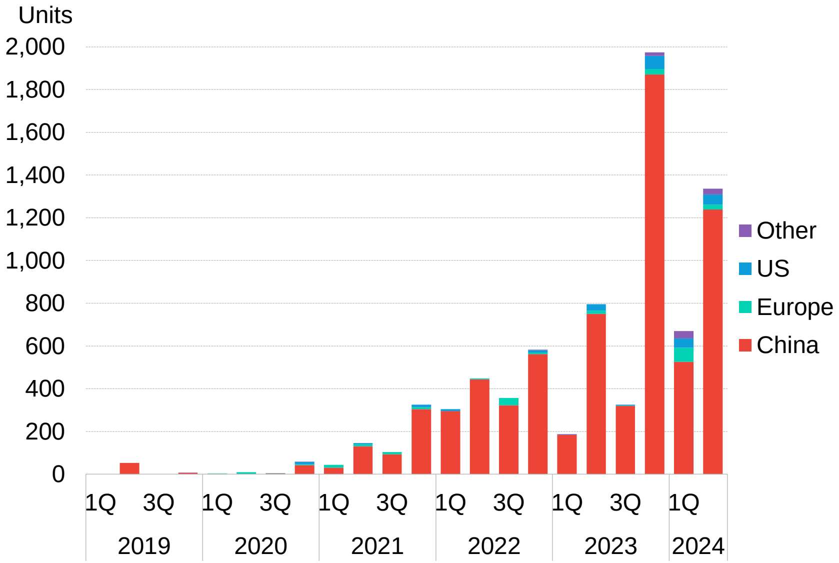
Fuel-cell truck sales are concentrated in China

Global sales of fuel cell commercial vehicles



Source: BloombergNEF; see full list of sources in the Appendix. Europe is the EU 27, the UK, Norway, Switzerland, Iceland and Liechtenstein.

Many global manufacturers have plans to offer fuel-cell trucks, but sales have been concentrated in China so far. High upfront vehicle costs and refueling costs have been the major barriers to wider adoption. China's fuel-cell truck market is dominated by local players such as Yutong and FAW. Manufacturing subsidies offered by some provincial governments helped to scale production in the past two years, driving China's total fuel-cell truck sales to over 3,000 vehicles in 2023.

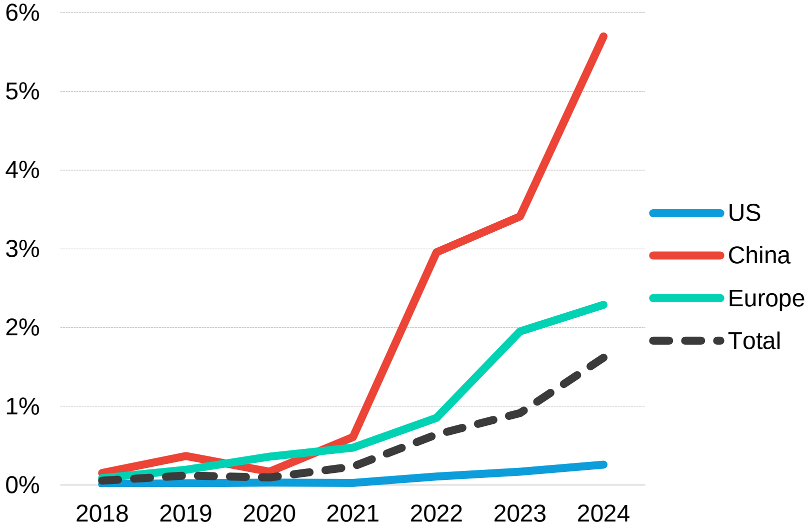
Current use cases for hydrogen trucks are mostly confined to urban and closed loop settings due to lack of refueling infrastructure. In China, some companies use grey hydrogen, an industrial by-product, to operate their fuel-cell trucks, since green hydrogen is expensive and rarely available.

Some Chinese provinces started exempting H2 trucks from road tolls in 2024 to encourage their use in regional and long-haul duty cycles. This could somewhat alleviate the high operating costs of these vehicles.

In the US, Nikola has delivered over a hundred hydrogen trucks so far in 2024, while providing customers with mobile refuelers as a temporary solution. The market in Europe was of similar size in 1H 2024, with a few dozen fuel-cell trucks registered.

Adoption rates differ widely between countries, with China and the Nordics far ahead of the rest

Sales share of low- and zero-emission commercial vehicles by region



Source: BloombergNEF; see full list of sources in the Appendix. Note: adoption rate in 2024 is between January and June. Includes battery-electric, fuel-cell and plug-in hybrid vehicles.

Electric truck adoption is rising globally, but patterns vary widely by country. E-trucks were just under 2% of total truck sales in 2Q 2024.

Catalysts to early adoption in different countries include the presence of manufacturers, value chain maturity, availability of charging infrastructure and policy incentives.

China leads e-truck sales globally in absolute volume. The country's mature battery supply chain supports standardization of batteries and charging, which have enabled sales of trucks with swappable batteries.

Norway boasts the highest adoption rate of e-trucks in 2024. The presence of Volvo and Scania in Nordic countries, has helped lift e-truck sales in the region. However, adoption in Europe is highly uneven between countries.

In the US, the zero-emission truck sales share is among the lowest among advanced trucking markets. Current policies, such as financial support for purchasing trucks in some states and California's mandates, have yet to kickstart the market.

Elsewhere, electric and hydrogen truck sales are patchy and low. A few Chinese manufacturers expanding beyond their domestic market have delivered most e-trucks in other countries.

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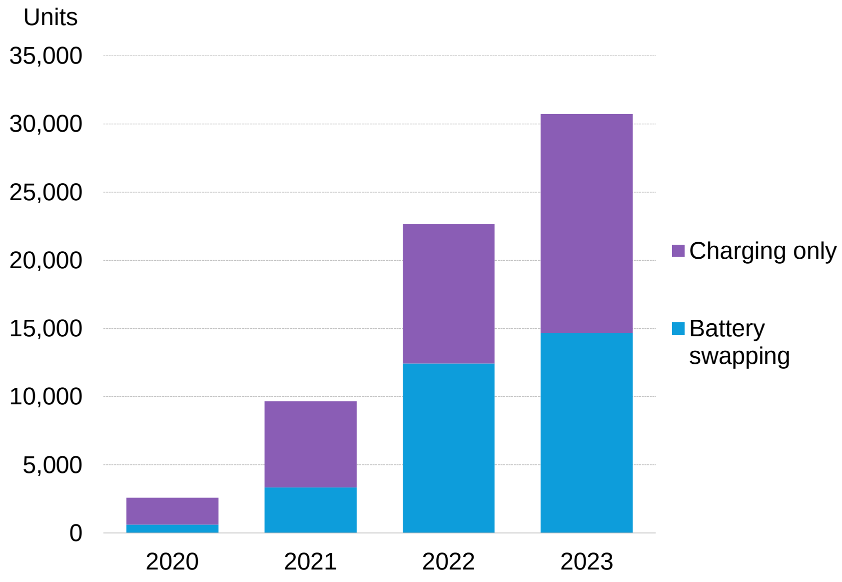
A pragmatic approach to zero-emission trucks has supported sales in China

Sales of battery-electric heavy-duty trucks in China by refueling type



Source: BloombergNEF, Evpartner.

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

The technology offers short refueling time, lower upfront cost and the potential to optimize the timing and cost of charging. All these can improve an e-truck's utilization and lower its total cost of ownership.

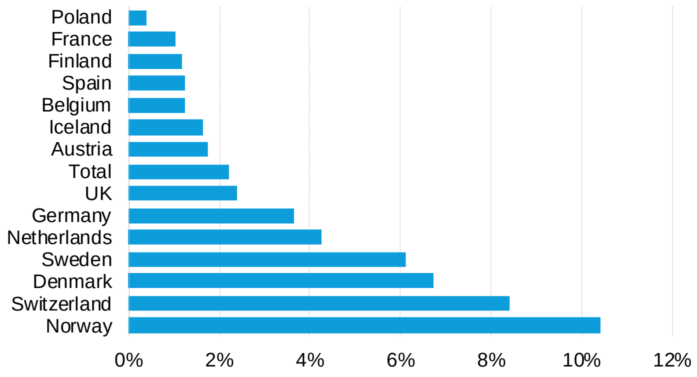
Battery swapping can also help separate the cost of the truck from that of the battery, and lower the electrification requirements for smaller fleets by as much as two-thirds of the cost of an e-truck in China. Battery swapping banks can potentially help stabilise the grid.

This 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.

Government backing is important in deploying and scaling up the technology, due to the high initial capital costs for the swap stations, the need for standardization and the requirement for electric utility involvement.

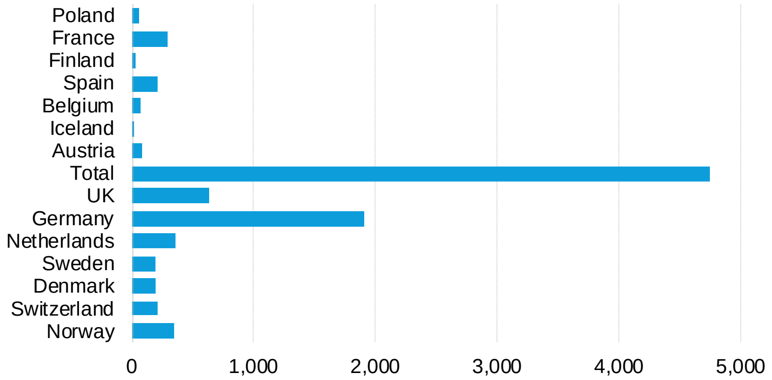
E-truck adoption is high in some European countries, but the market remains fragmented

Electric and fuel-cell truck share of sales, 1H 2024



Source: BloombergNEF; see full list of sources in the Appendix.

Electric and fuel-cell truck sales, 1H 2024



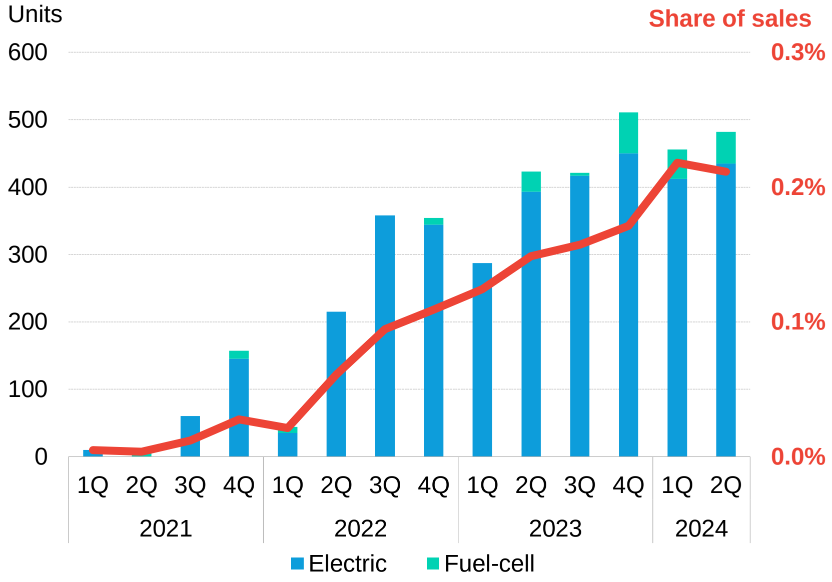
Source: BloombergNEF; see full list of sources in the Appendix.

The European zero-emission truck market grew 2.5 times from 2022 to 2023. Growth has since slowed to 30% in 1H 2024 and adoption has been around 2.1-2.3% of total sales for the last four quarters until 2Q 2024. Adoption and growth rates differ widely between countries. E-trucks exceeded 4% of sales in several countries, with over 10% in Norway in 1H 2024, and they were comparatively high in the UK and Germany at around 2.5% and 3.5% respectively. But for many countries sales remain very low. In Poland, which has the largest truck fleet in the Union, e-truck sales were just a few tens of units in 1H 2024.

Early adopters and companies with green obligations, such as decarbonization targets or zero-emission terms in contract bidding, mostly support the market, with operations in urban distribution, municipal services and construction.

The US e-truck market struggles to grow despite California's upcoming mandates

Electric and fuel-cell truck sales and share of sales in the US



Source: BloombergNEF; see full list of sources in the Appendix.

The market for electric and hydrogen trucks in the US remains far smaller than in Europe and China, with fewer than 1,000 vehicles sold in 1H 2024 across the country.

California's sales mandates, which have been adopted by another 10 states, are already in place and require between 5% and 9% of sales to be zero-emission already in 2024. Sales in California accounted for over 6% of the trucks sold in the US in 2023.

Battery trucks are mostly used as drayage vehicles in and around ports, and for distribution of food, beverage and consumer products. In particular, ports have been an area of focus for fleets and manufacturers, following funding programs including those provisioned by the Inflation Reduction Act.

Fleet buyers are based in California, but also in various other states such as Texas, and along the East Coast, including in New York and New Jersey.

Hydrogen trucks are deployed in the US in larger numbers than in Europe, thanks to sales from Nikola. Since hydrogen refueling infrastructure is patchy, the company is providing products to store and dispense hydrogen as well.

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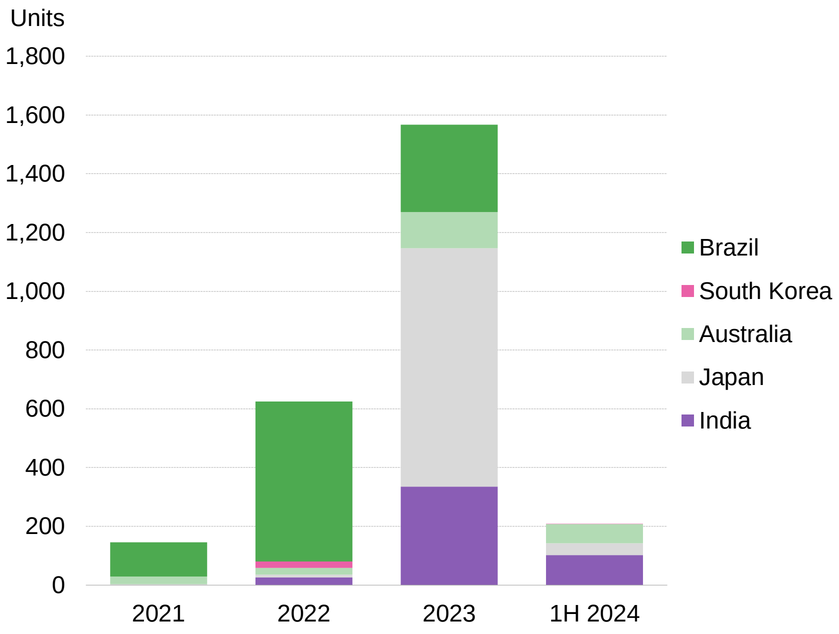
Electric truck sales in other countries are low, but in some ambitions are high

Zero-emission truck sales



Source: BloombergNEF; see full list of sources in the Appendix.

Zero-emission trucks have also been sold in Japan, India, Australia and Brazil. The market for such vehicles remains small and patchy, as one-off deliveries to larger fleets distort quarterly volumes.

In Japan, the recent introduction of Fuso's updated eCanter contributed to a spike in sales in 2023. Beyond that vehicle, few suitable electric and hydrogen truck models are available and sales in 1H 2024 have been far fewer.

In Brazil, a market for electric trucks has existed since at least 2021. The few hundred units sold annually come mostly from Chinese manufacturers. Companies such as JAC and Foton captured most of the electric truck market with models in the medium-duty segment.

In India, cleaner commercial vehicles have started to get some attention as well. The electric van market has been growing on the back of a new model introduced by Tata, while a new heavier-vehicle manufacturer, Tresa Motors, recently received an order for 1,000 heavy-duty electric trucks from logistics company JFK Transporters.

Such examples of early adoption demonstrate the importance of suitable model availability in the nascent zero-emission commercial vehicle market.

Policies

Pressure ramps up

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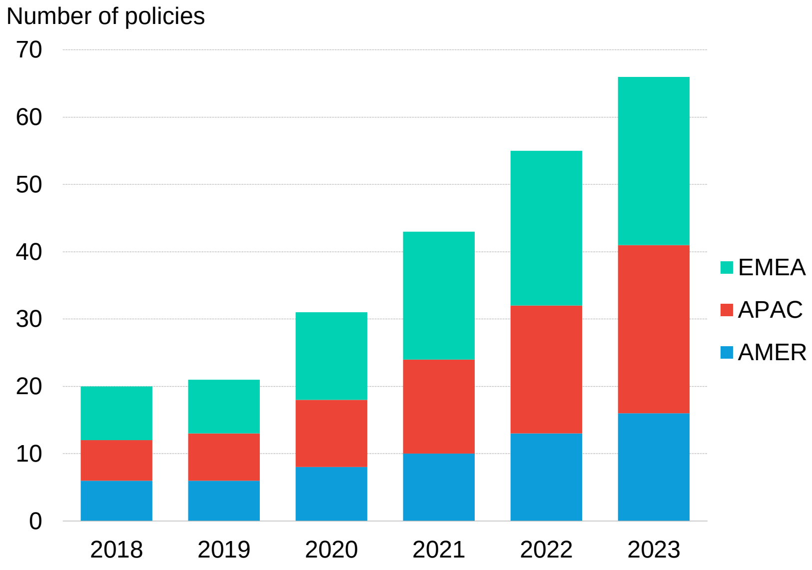
Global policies aimed at cleaning up road freight are rising

Number of policies for low- and zero-emission commercial vehicles



Source: BloombergNEF, government filings, news reports. Note: 'EMEA' refers to Europe, Middle East and Africa; 'APAC' is Asia Pacific; 'AMER' is Americas.

Policy support for zero-emission commercial vehicles has been uneven globally but is rising. More than 60 related policies are in place worldwide, spanning a combination of vehicle, infrastructure and operational incentives.

Manufacturing or purchase subsidies for electric trucks have been available in China, Europe, and the US, such as point-of-sales vouchers in California and New York. These can help small fleets cover the high upfront costs of e-trucks.

As subsidies become costly to sustain longer term, governments in China and Europe have transitioned to offer operational incentives. For example, the EU is rolling out emissions-based road tolls for trucks starting in 2024.

Refueling infrastructure incentives are also being implemented that include standalone truck charging targets, such as the Alternative Fuels Infrastructure Regulation in the EU and the National Zero-Emission Freight Corridor Strategy in the US. However, subsidies in some countries bundle truck purchasing and charging installation. This can delay deployments due to the typically longer timelines for infrastructure setup.

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Ambitious CO2 emissions targets for trucks are in place in major markets

CO2 emissions targets and zero-emission truck sales and fleet mandates

Country or Region	Period	Target by the end year of the period shown
EU	2019 to 2035	65% lower tailpipe CO2
US	2027 to 2032	15-53% lower tailpipe CO2
California	2024 to 2035	• 55-75% ZEV sales share for manufacturers • 100% ZEV purchase share for certain fleets
China	2019 to 2025	11-18% lower fuel consumption
Japan	2015 to 2025	3-15% lower fuel consumption

Source: BloombergNEF. Note: ranges refer to changes across commercial vehicle sub-segments; several of these targets extend beyond the years shown; California's Advanced Clean Fleets regulation hasn't yet received a waiver from the US Environmental Protection Agency and applies to certain fleets in the state.

Environmental regulations for trucks and buses were more recently implemented compared to equivalent CO2 or fuel economy rules for passenger vehicles. The scope and stringency of such rules vary widely between countries. In some large truck markets, targets require average improvements between 0.3% to over 6% annually, which may reach even 14% for some vehicle types.

Advancements in combustion engines, materials, aerodynamics and tires can help manufacturers cover some distance to the targets. Still, the increasing cost of applying such technologies implies that adoption of zero tailpipe emission trucks and buses will have to increase markedly to meet the rules, for example in the EU and the US.

Most of the rules mentioned here regulate vehicle fuel consumption or tailpipe emissions. Some governments plan to assess the possibility to regulate lifecycle emissions, which will also imply the inclusion of net-zero emission fuels, such as hydrogen or synthetic fuels, as part of such targets.

Most countries do not have sales and/or purchase mandates for ZEV trucks yet, though California does have a demanding quota system in place.

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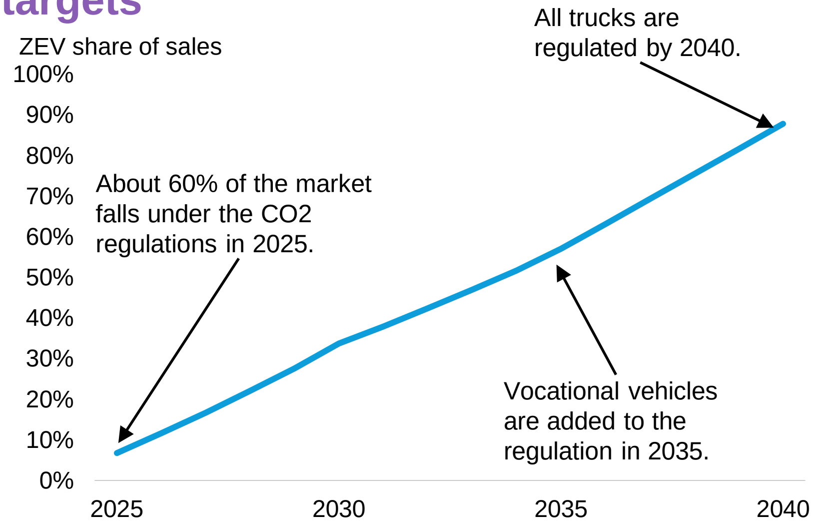
CO2 emissions targets in Europe require a lot of electric and fuel-cell trucks

Required share of zero-emission commercial vehicles to meet EU's CO2 targets



Source: BloombergNEF. Note: Shows the sales share within the regulated vehicle segments. The targets are set versus emissions levels in 2019. 'ZEV' refers to zero-emission vehicle, including battery electrics and fuel cells.

The EU's CO2 emissions limits for medium- and heavy-duty trucks set progressively lower targets for the output of new commercial vehicles sold in the Union, versus 2019 levels. These imply that more than a third of manufacturers' sales should be zero-emission by 2030, growing to 88% by 2040.

The regulation offers various compliance flexibilities that could be helpful in the short term. It also only gradually covers the whole truck market, as medium lorries, trailers and semi-trailers are excluded before 2030, and most vocational vehicles will be excluded up to 2035.

Failing to meet the targets results in financial penalties. In 2025, these can be less than €5,000 ($5,540), but can grow to more than €100,000 per vehicle by 2035, according to BNEF estimates. Such fines are applied to all of a manufacturer's sales in a year.

The Commission will review the rules by 2027 and will explore the option of regulating the lifecycle, rather than tailpipe, emissions.

2025-2029	2030-2034	2035-2039	2040
Targets at -15% versus 2019 for some vehicle groups	Targets at -45%, versus 2019 except for vocational trucks	Targets at -65% versus 2019 for all vehicle subgroups	Targets at -90% versus 2019 for all vehicles subgroups

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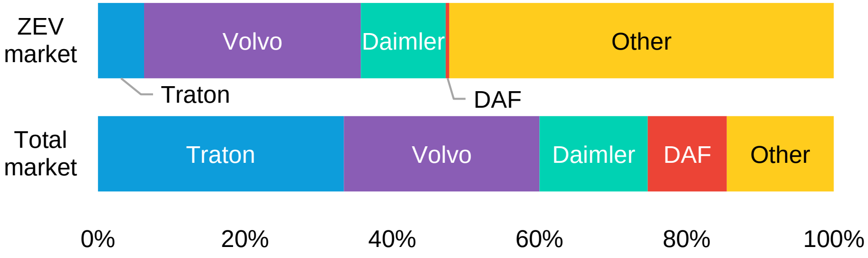
Manufacturers

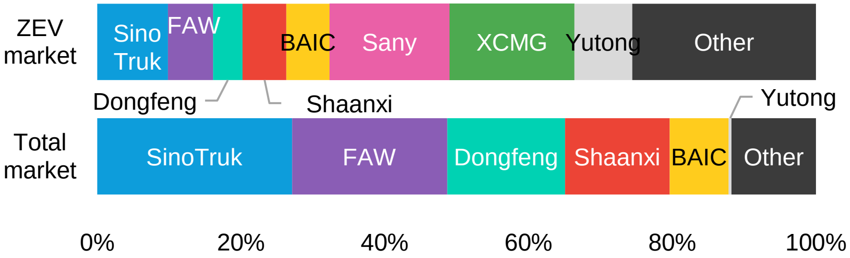
Zero-emission trucks present opportunities, but reality sets in

The zero-emission truck market creates opportunities for new entrants

Manufacturer market shares in Europe



Manufacturer market shares in China



Source: BloombergNEF; see full list of sources in the Appendix. Note: Shows market shares in 1H 2024. 'ZEV' is zero-emission vehicle, including battery electrics and fuel cells. Includes medium- and heavy-duty trucks as defined in the Appendix.

The market for zero-emission trucks is attracting new entrants. These are not necessarily startup manufacturers, which have largely struggled to establish a presence, but incumbent truckmakers.

These manufacturers are finding opportunities to serve segments, such as heavy-duty trucks for urban distribution, in which they may have had low penetration. At the same time, newcomers from adjacent industries are entering the commercial vehicle market.

In China, companies outside of traditional truckmaking command high shares of the e-truck market. Machinery manufacturers XCMG and Sany, as well as bus maker Yutong accounted for more than 40% of electric and fuel-cell truck sales in 1H 2024.

Volvo has a much higher share of the European heavy-duty electric truck market than its overall market share, while it is less active at the lighter end of the market. Traton and Paccar's DAF have yet to scale up e-truck production in Europe and are far behind their overall market share.

Of the potential startup disrupters, Nikola and Tesla have introduced well-received products, while companies such as XoS, REE and others are also selling their vehicles in North America. Still, most have yet to materially increase production output.

Manufacturers are building supply chains for electric and hydrogen trucks

Truckmaker supply chain relationships

Company	BEV	FCV	Battery supplier(s)	Battery chemistry	Fuel cell supplier(s)
Beiqi Foton	✓	✓	CATL, Gotion	LFP, NCM/NCA	Toyota, REFIRE
Daimler Truck	✓	✓	CATL	LFP	cellcentric
Zhejiang Geely	✓	✓	CATL, Eve Energy, Farasis, Gotion	LFP, NCM/NCA	Wuhan Troowin Power System Technology
PACCAR	✓	✓	CATL	LFP	Toyota
SAIC Motor	✓	✓		LFP, NCM/NCA	SHPT
Traton SE	✓	✓	CATL, Northvolt	LFP, NCM	Cummins
AB Volvo	✓	✓	Samsung SDI	NCA	cellcentric

Major manufacturers are establishing internal capabilities and external partnerships to develop and build zero-emission commercial vehicles for various use cases. Many truckmakers based in Europe and North America are developing a multitude of technologies in parallel, including electric powertrains and batteries, as well as hydrogen in fuel cells and combustion engines.

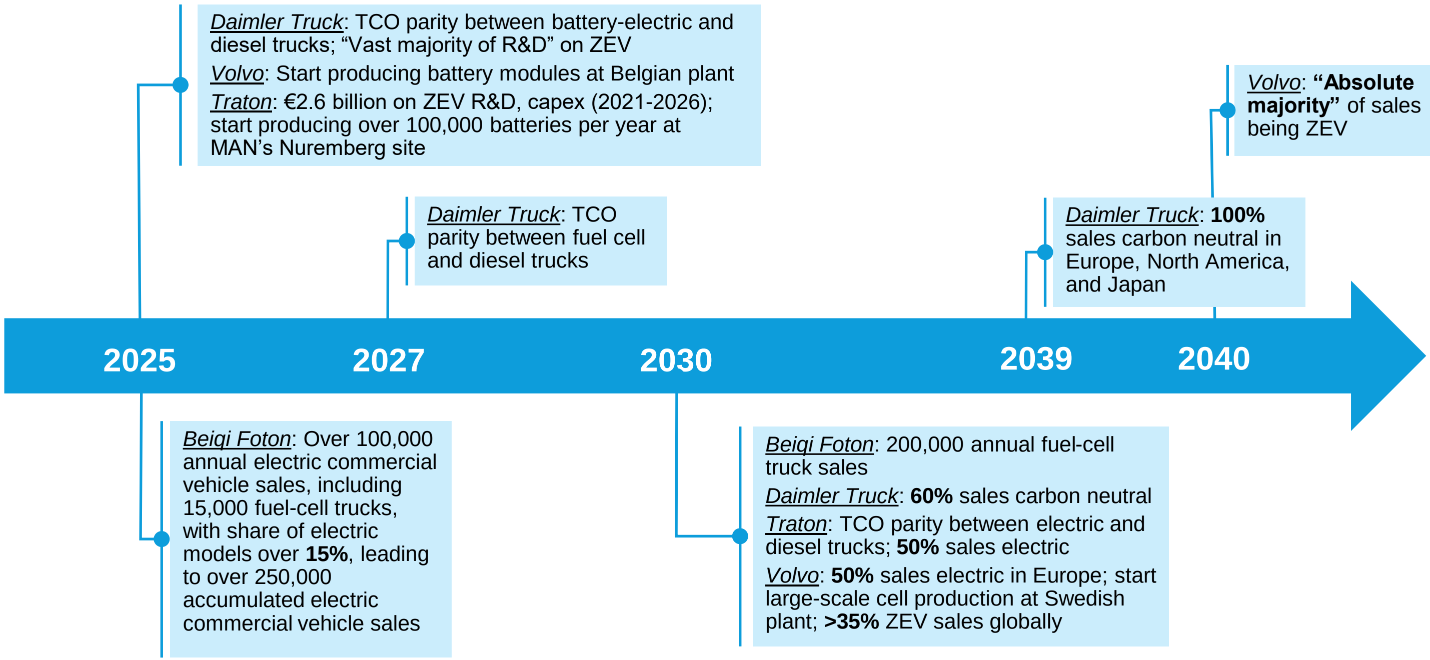
Most of these companies procure battery cells from outside suppliers, while they produce their own packs. Some, such as Volvo, Daimler and Paccar, plan to bring cell manufacturing in-house later in the 2020s, while Traton has invested in a supplier, cell maker Northvolt.

Chinese truckmakers have taken advantage of the advanced battery supply chain in the country to develop expertise and suitable products. From early on, they adopted lithium-iron phosphate (LFP) cells to produce affordable vehicles with long lifetimes.

Fuel-cell technology is at an earlier stage and, given cost and infrastructure uncertainties, is mostly developed through partnerships and joint ventures.

Source: BloombergNEF, company announcements. Note: 'LFP' refers to lithium iron phosphate battery. 'NCM' refers to lithium nickel manganese cobalt oxide cathode battery. 'NCA' refers to lithium nickel cobalt aluminum oxide cathode battery. 'BEV' refers to battery-electric vehicles. 'FCV' refers to fuel cell vehicles. Color shade indicates commitment level, with deeper shade signifying more commitment. List is not comprehensive.

Truckmakers are setting ambitious targets for zero-emission vehicle sales

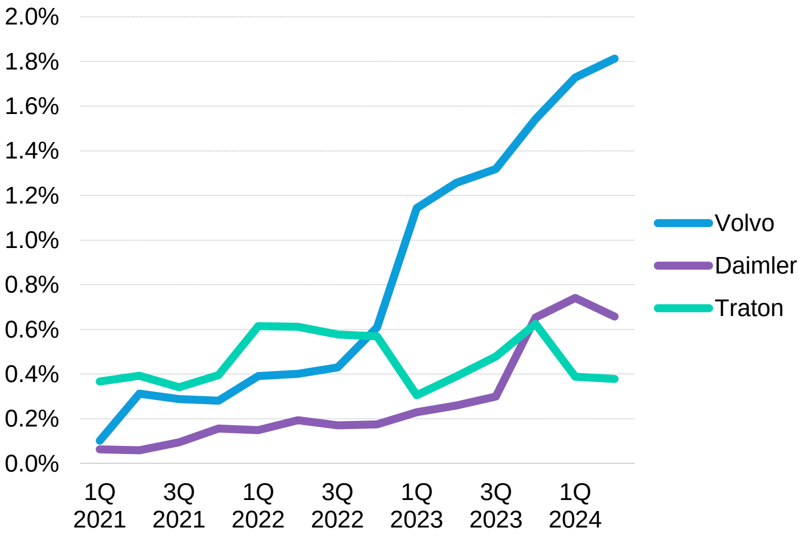


Source: BloombergNEF, company press releases. Note: ‘TCO’ refers to total cost of ownership, ‘ZEV’ is zero-emission vehicle, and ‘R&D’ is research and develoment.

BloombergNEF

ZEV sales remain low for many large truckmakers and far from their targets

Zero-emission vehicle sales shares for Volvo, Daimler, Traton and Paccar



Source: Bloomberg Terminal, BloombergNEF, company reports. Note: Shows cumulative share of sales within a year.

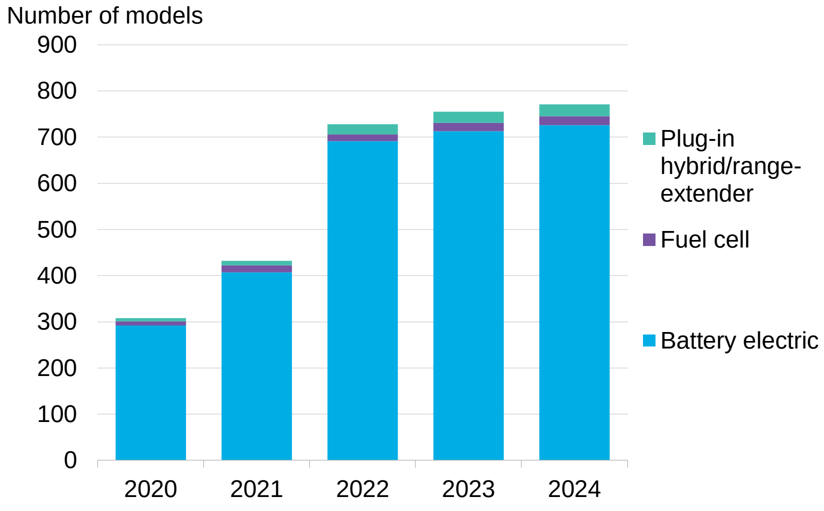
In the first half of 2024, Volvo sold over 2,100 all-electric vehicles, more than Daimler and Traton combined. E-trucks and e-buses also account for nearly 2% of Volvo's truck and bus sales, while equivalent shares for Daimler and Traton are near 0.5%.

For Daimler, Volvo and Traton, Europe and the US together accounted for around 70% of their 2023 revenue; that share was about 85% for Paccar. The European Union's efficiency targets could require zero-emission trucks to be around 2-2.5% of Volvo's sales by next year, while for Traton, Daimler and Paccar's DAF that figure is 4-6%. California's mandates - which another 10 states have also adopted - require between 5% and 9% of medium- and heavy-duty truck sales to be electric or fuel-cell vehicles by the end of this year.

Scaling up manufacturing capacity, especially in batteries and electric drivetrains, is the vital next step as companies establish the supply chain necessary for higher sales in the years ahead. Such expansion of the technology portfolio requires high investment and can also be challenging. Traton's Scania, for instance, has faced delays getting battery cells from its supplier Northvolt AB as of 1H 2024.

Some 750 commercial ZEV models are available in China, Europe and North America

Zero-emission commercial vehicle models available



Source: BloombergNEF, company announcements, CALSTART, 360che.com. Note: 'BEV' is battery-electric vehicle, 'FCV' is fuel-cell vehicle, 'PHEV' is plug-in hybrid vehicle, and 'REX' is range-extender vehicle. PHEV/REX are zero-emission vehicles for part of their operation, when relying on battery power alone.

Around 750 battery and fuel-cell vans and trucks are available globally for purchase, with more than half offered in China only.

Light-duty commercial vehicles, such as battery electric delivery vans, dominate the global offering, with close to half of all models available. Just over a third of models are heavy-duty trucks, which for now mostly target urban and suburban operations.

Manufacturers have focused on battery trucks, as fuel cells have longer lead times and are available from a few truckmakers only.

Battery electric models outnumber those using hydrogen by about 22-to-1, reflecting technology maturity of battery-based powertrains versus those using fuel cells, and also the concentration of H2 truck offerings in the heavy-duty class.

Fuel-cell trucks drive farther with one refill, but long-distance battery heavy trucks also are also becoming available.

Average range across fuel-cell models is around 500km, which can extend to almost 1,500km for some models. For BEVs, the average range is around 250km. A handful of models with over 500km of range are available to order, and some have already been delivered, but their number remains small.

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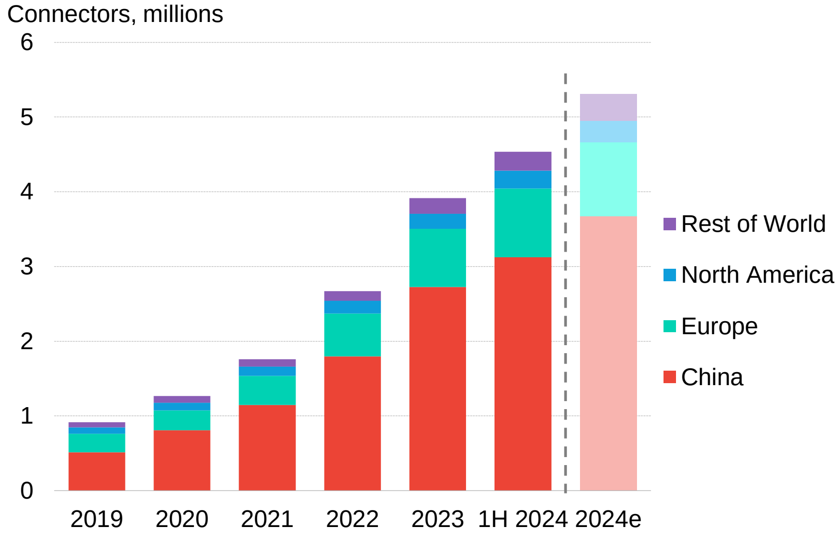
Charging

Ultra-fast chargers lead strong growth

BloombergNEF

Annual installations of public chargers are growing quickly

Global public EV charging connectors by region



Source: BloombergNEF, Ecomovement, China Electric Vehicle Charging Promotion Alliance. Note: Data updated through 2Q 2024.

Almost 600,000 public chargers were installed in 1H 2024, bringing total installed chargers globally up to 4.5 million.

China accounted for 70% of global chargers at the end of June 2024, with installations increasing 12% year-on-year in 1H 2024. The rate of deployment has been about 66,000 chargers per month so far in 2024. This typically peaks at the end of the year, as it exceeded 110,000 units in the last three months of 2023.

Europe added 146,000 new connectors in 1H 2024, with growth mainly in Germany, the Netherlands, Belgium, and France. This was twice as many connectors as installed in all other European countries combined.

In Europe, public ultra-fast chargers (100 kilowatts or faster) have grown more than seven times since 2021, and deployment has been accelerating, with 89,000 such chargers in place by June 2024.

The installation pace increased in the US in the first six months of 2024, at a time when electric vehicle sales in the region are slowing. Some $7.5 billion in public funding is available for charging infrastructure projects. Just over $1 billion has been awarded as of June 2024. In January 2024, four projects aiming to install medium- and heavy-duty EV charging stations received $241 million in government funding.

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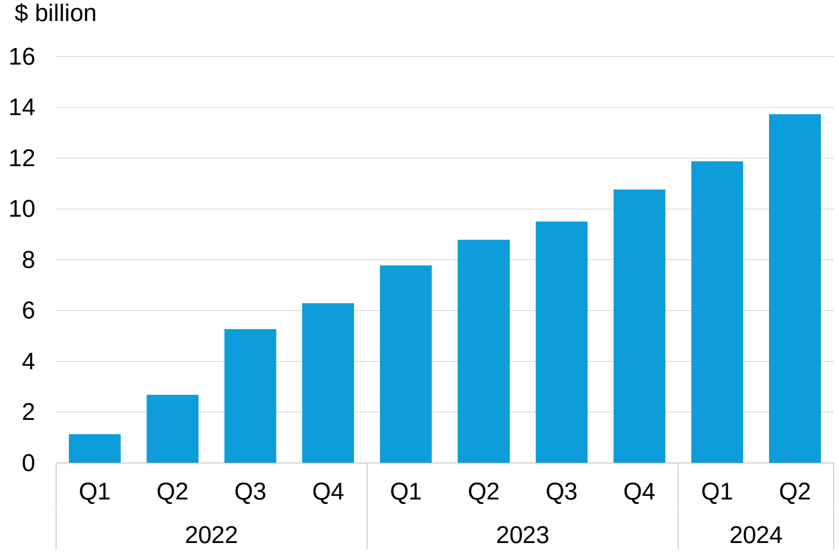
Charging companies have raised close to $14 billion since the start of 2022

Disclosed cumulative investment activity in EV charging companies



Source: Bloomberg Terminal MA <GO> & IPO <GO>, BloombergNEF Climate Investment Tracker, CB Insights, various press releases.

Over $3 billion was invested into EV charging companies in the first half of 2024, bringing the total since 1Q 2022 to almost $14 billion globally.

These investments span acquisitions and venture capital and private equity (VC/PE) funding, and reflect a broad interest across the value chain, including different business models and geographies. The disclosed deals in the first half of 2024 were spread geographically across 19 countries, with the US and UK leading with a dozen deals each.

Truck charging is part of such investment activities. China's Qiyuan Green Power, a subsidiary of state-owned State Power Investment Corporation (SPIC), closed its 1.5-billion-yuan ($210 million) Series B to roll out truck battery swapping and charging stations. The company currently has 600 battery swapping and charging stations in the country.

In the US, Terawatt raised $1 billion in 2022 to build truck charging stations along freight corridors in the US. WattEV, also a California-based station developer, raised both debt and equity from Apollo and Vitol in late 2023. Beyond building charging stations, WattEV also offers electric trucks through leasing to fleets.

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Technology and economics

Battery technology is the foundation for cleaner trucking

BloombergNEF

Electric truck capabilities are improving quickly

	eCanter 2017	eCanter 2024
GVWR	7.5 metric tons	7.5 metric tons
Battery capacity	83kWh	124kWh
Range	100km	200km
Implied minimum fuel consumption	0.83kWh/km	0.62kWh/km

Source: BloombergNEF, Mitsubishi Fuso, Daimler Truck. Note: range is an 'up to' value provided by the manufacturer; 'GVWR' is gross vehicle weight rating, 'kWh' is kilowatt-hour, and 'km' is kilometer.

Battery technology has been improving rapidly over the last 15 years due to improved engineering know-how and expansion of manufacturing scale. Energy density for batteries used in automotive applications has improved by just under 6% annually since 2010.

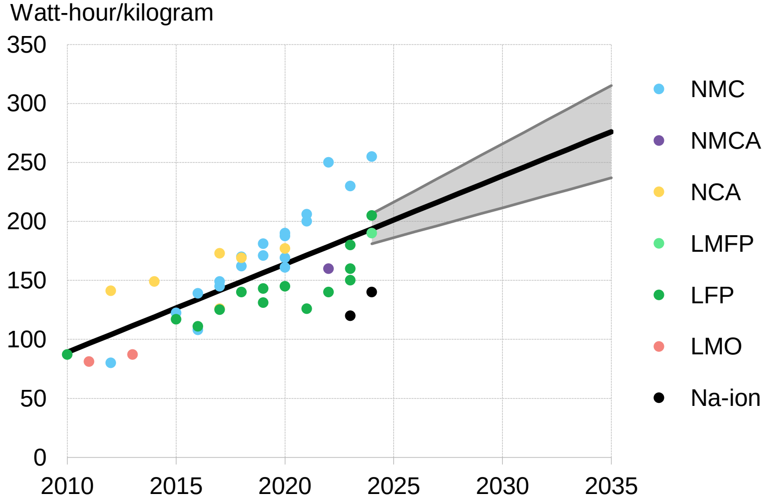
Such strides in the technology are starting to have an impact in the nascent electric-truck market as well. Following limited production products in the late 2010s, which were mostly used in trials with relatively low genuine customer demand, recent vehicle launches are far better from a technical standpoint.

Manufacturers and fleets also indicate good performance from newer electric truck models. For example, Daimler stated that its first long-haul electric truck, the eActros 600, "exceeds our expectations in terms of range and energy consumption", while Tesla's Semi seems to fare as well or better than its expected efficiency of 1.7-1.8 kilowatt-hours (kWh) per mile.

The e-truck industry is still at an early stage. Several projects in the US, Europe and China are gathering real-world data on e-truck performance. As the industry scales, such statistics will provide a clearer picture of ongoing technology improvements in the sector.

Battery energy density improvements will underpin further efficiency gains

Historical and estimated changes to battery-pack energy density



Source: BloombergNEF. Note: NMC = nickel manganese cobalt oxide; NMCA = nickel manganese cobalt aluminum oxide; NCA = nickel cobalt aluminum oxide; LFP = lithium iron phosphate; LMFP = lithium manganese iron phosphate; LMO = lithium manganese oxide; Na-ion = sodium ion.

The average battery pack energy density in battery-electric vehicles has more than doubled since 2010, to 194 watt-hours per kilogram (Wh/kg). Batteries with higher energy density have lower material and manufacturing costs, are lower weight, and result in higher vehicle efficiency.

NMC is a high-performing chemistry, with some packs achieving 250Wh/kg in 2022, and CATL's Qilin battery entering the market in 2023 at 255Wh/kg.

LFP technology continues to improve rapidly. CATL launched the Shenxing Plus in April 2024, capable of superfast charging, while BYD's next-gen Blade EV battery is set to have an energy density of 190Wh/kg.

By 2025, large cell producers aim to introduce cells with energy densities of 350-500Wh/kg, such as CATL's "condensed battery" *. That could correspond to pack-level energy density of 280-300Wh/kg. For these, manufacturers will need to use silicon or lithium metal anodes, solid electrolytes and high-voltage cathodes.

**While this target is for aviation applications and details of any automotive version are unclear, it helps contextualize what is possible with new cell designs.*

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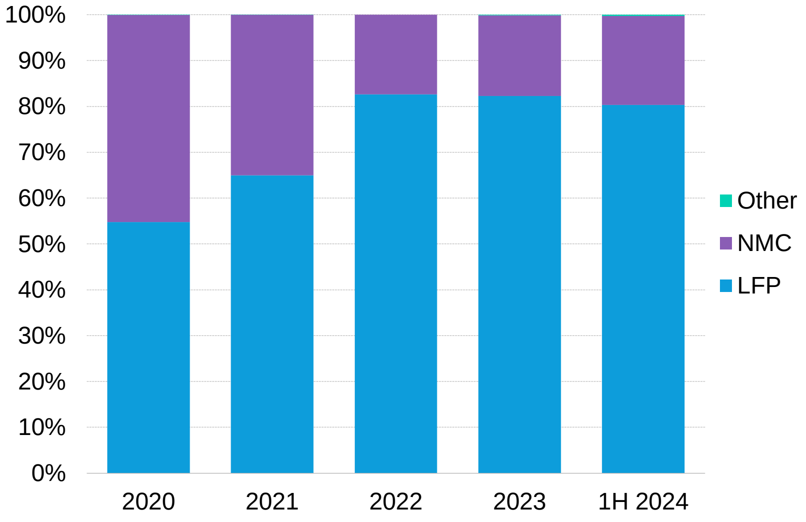
LFP becomes the main choice for electric truck batteries, within a narrow mix of chemistries

Battery chemistry of electric and fuel cell medium- and heavy-duty trucks



Source: BloombergNEF, EV-Volumes. Note: 'LFP' is lithium iron phosphate; 'NMC' is nickel manganese cobalt oxide. Includes batteries used in vans, trucks and buses.

The lithium-ion batteries powering most commercial vehicles and buses use lithium iron phosphate (LFP) cathodes. Since 2022, LFP share has grown rapidly and now accounts for more than 80% of capacity deployed in the sector globally.

In China, companies such as Beiqi Foton Motor, SAIC Motor and Zhejiang Geely Holding Group use LFP, while Geely also uses lithium-ion batteries that use nickel-based cathodes (NMC and NCA) for some longer-range vehicles.

Outside 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 nickel manganese cobalt (NMC) from LG Chem and SK Group. Alongside Paccar and Cummins, Daimler plans to produce LFP cells in the US with the help of Chinese battery manufacturer EVE Energy. Volvo is using nickel cobalt aluminium oxide (NCA) cells supplied by Samsung SDI, and Traton's Scania procures NMC cells from Northvolt.

LFP is cheaper than nickel-based alternatives, as it uses less-expensive materials and has a higher cycle, meaning it can be charged and discharged more times. However, its energy density can be 30% lower than NMC.

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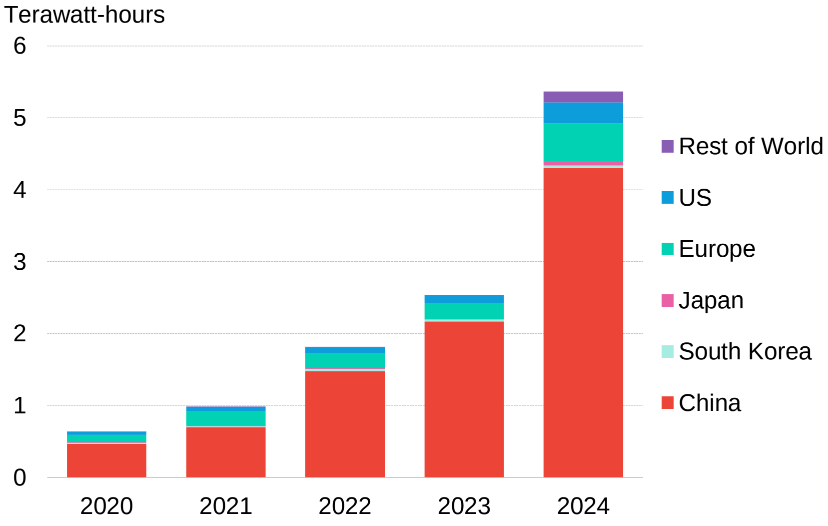
Battery manufacturing capacity keeps increasing globally

Commissioned and announced annual Li-ion battery cell manufacturing capacity



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.

By the end of 2023, there was 2.5TWh of annual lithium-ion battery cell manufacturing capacity globally. This will more than double in 2024, if company announcements are delivered on time. More than 80% of that capacity is based in China, but new cell-making capacity is also being planned closer to demand centers in the US and Europe.

The volume of batteries produced can differ from nameplate capacity and will depend on plant utilization rates. For example, while China had 2.2TWh of commissioned cell manufacturing capacity in 2023, utilization rates only averaged around 43%. For newer battery manufacturing facilities in regions with less-mature battery supply chains, the utilization rates could be even lower. Higher production costs, competition with low Chinese battery prices, and less manufacturing expertise is challenging manufacturers in non-Chinese markets.

The upstream battery value chain, including cathodes, anodes, separators and electrolytes, is also highly concentrated in China. 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. The country also accounts for a high share of battery-metal refining capacity.

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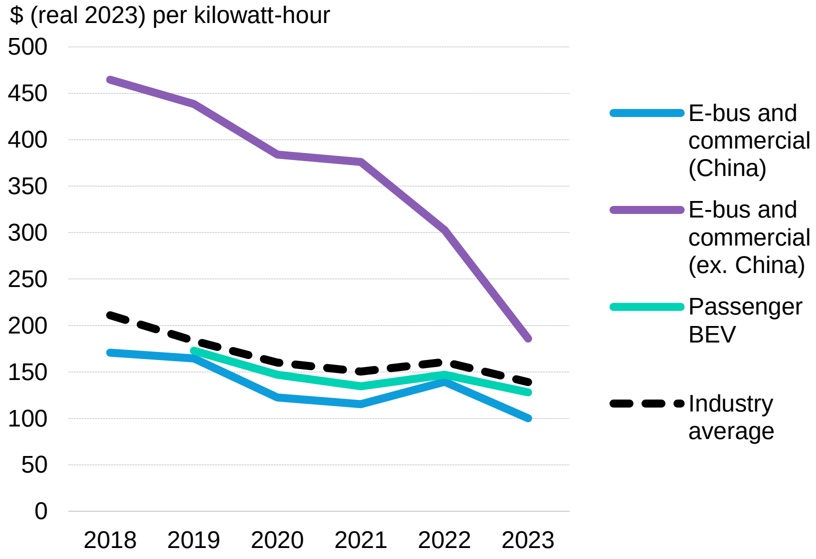
Battery prices continue to fall and are converging across sectors

Historical volume-weighted average lithium-ion battery pack prices by sector



Source: BloombergNEF. Note: Passenger battery-electric vehicle figures are a global average.

The volume-weighted industry-average battery pack price was $139/kWh in 2023. That was 14% less than the previous year, due to lower material prices and more capacity coming online.

Pack prices in China are the lowest globally. The supply and demand mismatch continues in the country so far in 2024, with capacity five times as large as demand and low utilization rates for many manufacturers.

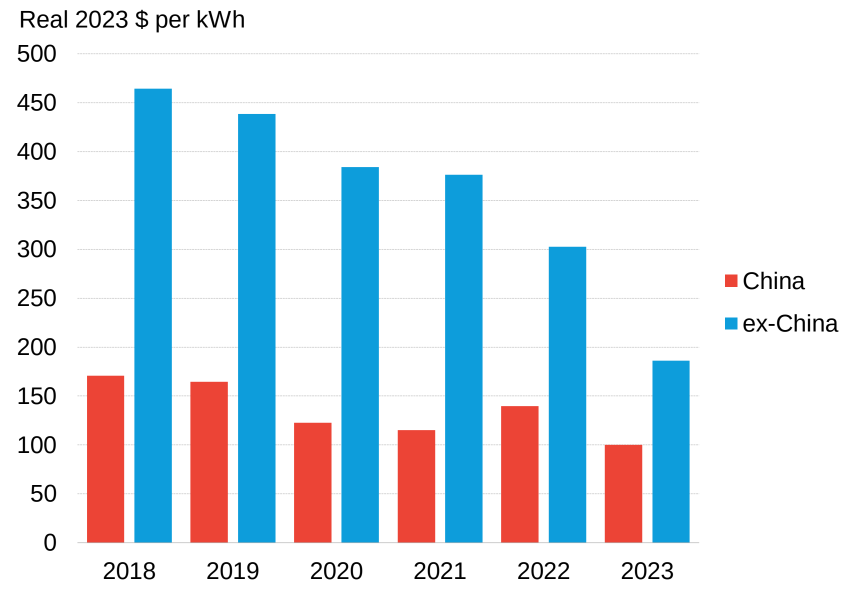
Lithium-ion phosphate packs and cells were the cheapest, at $130/kWh. In 2023, LFP average cell prices fell below $100/kWh for the first time. Prices have fallen further in 2024, with cells from some suppliers in China hitting $50/kWh. Average prices for nickel manganese cobalt oxide (NMC) batteries were $130/kWh globally in 2023.

Prices have been converging across sectors as the industry grows. Differences depend on maturity of the technology and order volumes, but also varied cell and pack design and manufacturing requirements.

Falling prices for battery metals, the turn to cheaper LFP chemistries, and growing order volumes pushed truck battery prices steeply down in 2023, even outside of China. Larger cells used in trucks and buses also help further spread the $/kWh costs.

Truckmakers still pay more for their batteries outside of China

Lithium-ion battery pack prices for commercial vehicles and buses



Source: BloombergNEF.

Volume-weighted average electric truck and bus battery prices followed the industry trajectory of decline in 2023 as prices for battery metals dropped.

Packs costs outside of China saw the steepest price drop in 2023, down 39% to $186 per kilowatt-hour. Still, that is 86% higher than commercial vehicle battery prices within China, which were only $100/kWh, the lowest across all vehicle segments.

The price difference is primarily due to the prevalence of cheaper LFP batteries in China. Commercial vehicles also have the price advantage of using larger LFP cells, up to 280 ampere-hours (Ah), compared to the typical 60Ah cells used in passenger EVs. Large cells require fewer connections, reducing the time and costs of assembling packs.

While more-expensive high-nickel chemistries have had a higher share in markets outside China in past years, global vehicle and battery manufacturers are increasingly turning to LFP. That explains some of the price declines and the closing of the gap with battery costs in China.

Still, smaller e-truck battery order volumes outside of China continued to constrain prices in 2023, as it is more costly to produce customized cells in small batches.

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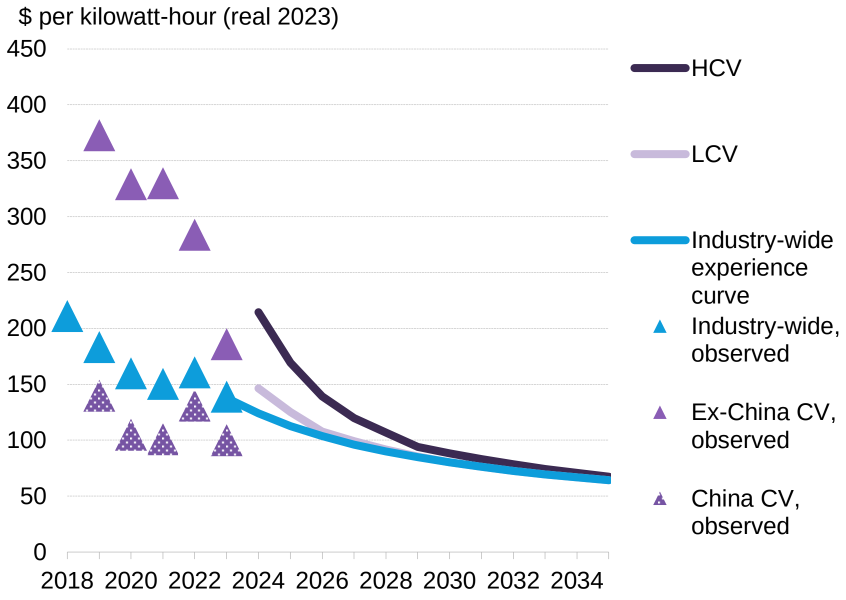
Battery prices are set to drop further with truckmakers' premium reducing

Lithium-ion battery pack price outlook



Source: BloombergNEF. Note: 'CV' is commercial vehicle; 'LCV' is light-duty commercial vehicle; 'HCV' is heavy-duty commercial vehicle.

BNEF expects battery costs to decline further over the coming years due to technology and manufacturing advancements, movement to lower-cost chemistries and heavy competition.

Historical battery prices have dropped at a learning rate of 17%. This quantifies the percentage price decline every time the cumulative volume of delivered batteries doubles. Assuming this continues to hold, industry-average battery pack prices would hit about $80/kWh by 2030.

Commercial vehicle manufacturers are likely to continue paying more for batteries. The premium for truckmakers over industry-average costs should decline but will also depend on segment and duty cycle.

For lighter vans and trucks, that gap should not persist for long, as volumes are already increasing, and operating characteristics do not pose undue strain on the batteries.

In heavier segments, a cost difference could persist for longer due to the additional engineering effort required to adapt batteries for specific use cases. For heavy electric trucks, BNEF expects batteries to be about 10% more expensive than the industry average by 2030, with the gap closing further in the 2030s.

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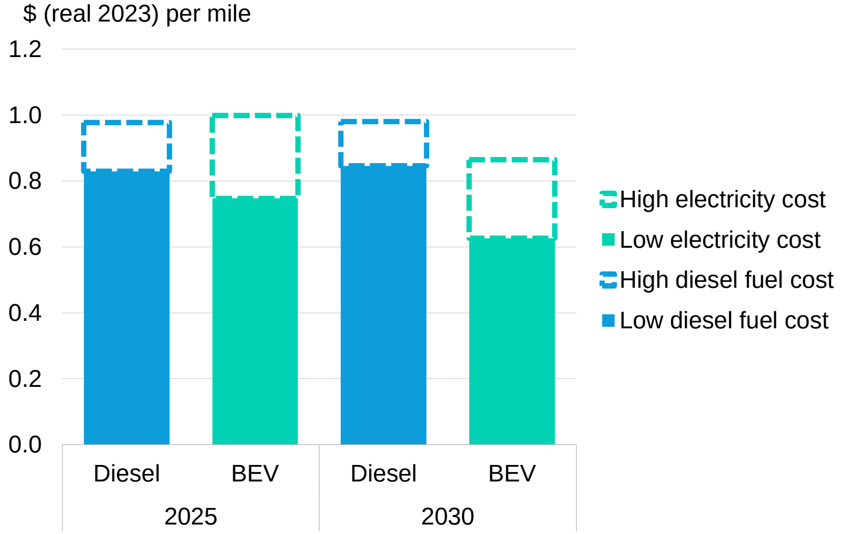
Battery trucks within cities become economically competitive soon in the US, China and Europe

Total cost of ownership of Class 4-5 trucks with range of 200 miles (320km) in the US



Source: BloombergNEF. Note: For diesel, fuel costs are $3/gallon and $6/gallon; for electricity, fuel costs are $0.2/kilowatt-hour and $0.75/kWh. 'BEV' revers to battery-electric vehicle.

Medium-duty trucks in urban duty cycles are used in distribution, sanitation, municipal services, construction and other applications. Battery electric trucks in this segment can operationally substitute diesel vehicles and could be as cheap to own and operate in the next few years, without subsidies.

The cost of the electric truck is currently higher than the equivalent combustion vehicle, and the relative costs of diesel fuel and electricity determine economic competitiveness.

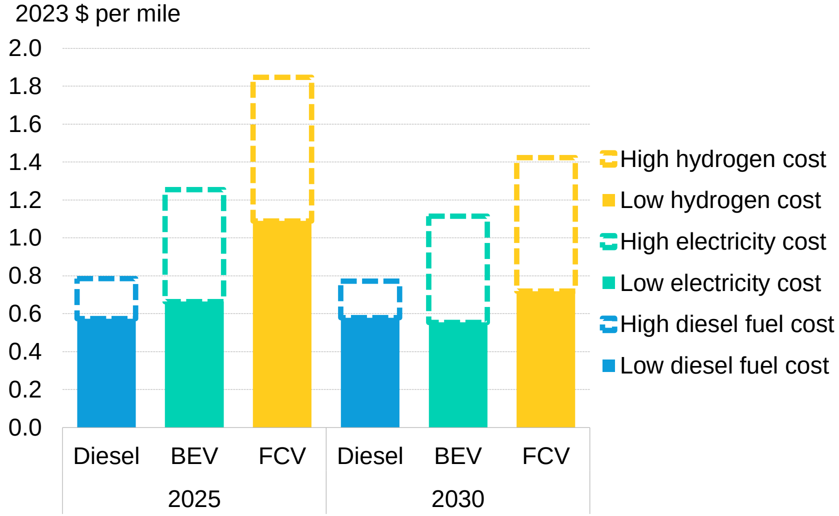
For high refueling costs with electricity, the battery truck remains more expensive. However, in the mid-range of fuel costs – $4.5/gallon for diesel and $0.5/kWh for electricity – the total cost of ownership can be similar between the two technologies within the next couple of years. In areas with very low electricity costs, they are already competitive.

By 2030, even with the highest electricity costs, the battery truck TCO can be roughly the same as that with the lowest diesel fuel costs.

Such relative economics and the potential for battery trucks to soon displace diesel equivalents within cities also holds for China and countries in Europe, as well as for heavier trucks.

Zero-emission, long-haul trucks can also become competitive around 2030 by controlling fuel costs

Total cost of ownership of Class 8 trucks with range of 500 miles (800km) in the US



Source: BloombergNEF. Note: For diesel, fuel costs are $3/gallon and $6/gallon; for electricity, fuel costs are $0.2/kilowatt-hour and $0.75/kWh; for hydrogen, fuel costs are $5/kilogram and $15/kg. 'BEV' refers to battery-electric vehicle, and 'FCV' is fuel-cell vehicle.

Zero-emission heavy trucks for long-haul operations have been introduced in the market, albeit at low volumes. This segments accounts for about half of energy demand in trucking.

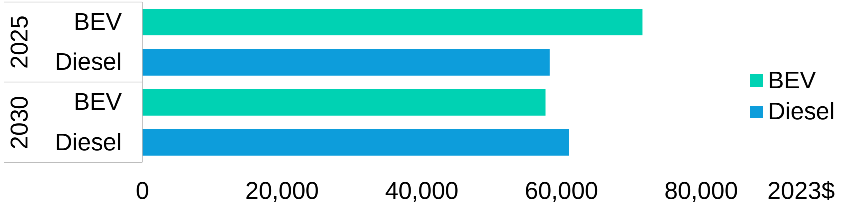
In the near term, battery trucks could approach the total costs of diesel when low electricity costs are combined with high diesel fuel prices. Economics for fuel-cell trucks are more challenging, given high capital costs. By 2030, zero-emission trucks in the segment start to become economically competitive:

- Battery trucks can be as cheap as diesel within a wider range of electricity costs. However, at the higher end of diesel and electricity prices, battery trucks remain more expensive to own and operate.
- Fuel-cell trucks have a narrower window of competitiveness versus diesel and all-battery vehicles, requiring low hydrogen costs to coincide with high diesel and mid-range electricity prices.

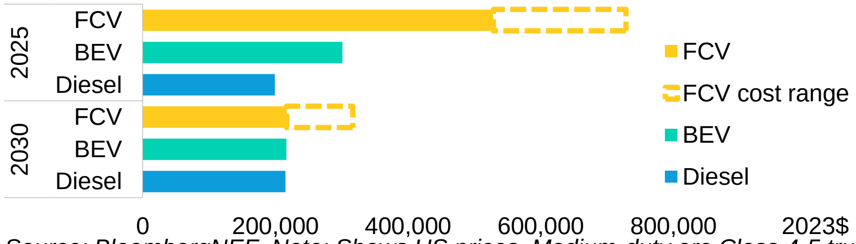
A critical aspect of competitiveness for heavy-duty zero-emission trucks is the cost of fuel. By securing relatively low and stable electricity or hydrogen costs, fleets could operate such trucks at costs similar to equivalent diesel vehicles. Such economics are at play not only in the US but also in European countries.

Battery trucks are more expensive now, but price parity could be near in some segments

Prices of medium-duty trucks for urban operations



Prices of heavy-duty truck for long-haul operations



Source: BloombergNEF. Note: Shows US prices. Medium-duty are Class 4-5 trucks with 250 miles of range, and heavy-duty are Class 8 trucks with 500 miles of range. 'BEV' refers to battery-electric vehicle, and 'FCV' is fuel-cell vehicle.

The prices of zero-emission commercial vehicles are higher than comparable diesel trucks and could deter some fleet buyers. Still, as costs decline, battery and fuel-cell vehicles in different segments should gradually reach upfront price parity with equivalent diesels.

- Medium-duty battery trucks can be about a quarter more expensive than equivalent diesels. However, that gap rapidly closes and before 2030 they could be as cheap or cheaper to produce due mainly to falling battery costs.
- Heavy-duty battery trucks for long-haul operations are about 1.5-2 times as expensive as equivalent diesels, but could approach their prices around 2030. While their total cost of ownership may become favorable earlier under some conditions, taking advantage of that depends on the ability of fleets to pay the higher upfront price and spread the cost over the usage period.
- Heavy-duty fuel-cell trucks for long-haul operations may cost 2.5-3 times as much as diesel equivalents. These costs are also set to decline and could approach those of diesel around 2030. However, the cost trajectory of fuel-cell stacks is highly uncertain, as the industry is at a very early stage.

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How to interpret battery truck manufacturing cost estimates

- Current prices for heavy-duty battery electric trucks can be 2-3 times those of equivalent diesel vehicles, while our estimated near-term future price premium is 1.5-2 times. Our pricing methodology is a cost-based approach and shows the unsubsidized price at which a manufacturer could theoretically build and sell a battery electric truck. The pre-tax retail price is the sum of direct and indirect production costs, plus a profit margin. We do not account for subsidies or any other policy measures that could affect the final price of an electric vehicle.
- The actual selling prices of future electric trucks would be similar to our estimates under certain conditions, where the vehicle specifications as well as manufacturer costs, battery prices, production volume, and cost allocation are the same as in our assumptions. An additional assumption is that truckmakers choose to price vehicles based on cost. We acknowledge that these conditions will not always be true for all electric truck models or for individual manufacturers. However, we expect they will be sustained on average across the industry and even more so as the market grows.
- We use average production cost structures, and we expect electric truck manufacturing to converge to meet these as volumes increase; in our assumptions, economies of scale are reached with production volumes between 20,000 and 40,000 trucks annually. However, companies outside of China are at relatively earlier stages in developing their electric truck manufacturing processes and expertise, which also affects their battery costs. Manufacturers further ahead in production scale up may have a price advantage and be able to recoup high upfront investments faster than their competitors.
- The price estimates also rely on the technical characteristics of electric trucks, such as electric range and motor power. Some of our assumptions, such as driving range, reflect our expectations based on typical duty cycles, although this is challenging to predict. We have assumed that electric trucks have 150 miles of real-world driving range for urban duty cycles, 250 miles for regional duty cycles and 500 miles for long-haul duty cycles.
- Truck batteries sizes for heavy trucks can range from about 300 kWh to over 900 kWh depending on duty cycle, but are dropping fast as battery energy density increases. In 2025, our battery price assumption for these vehicles is about $170 per kWh, which drops to about $90 per kWh by 2030.

Financing fleet electrification

Innovative business and financing models can help the market scale up

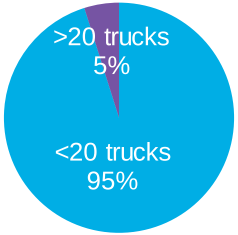
BloombergNEF

The industry addresses perceived risks for large-scale zero-emission truck adoption

Capital costs

The total cost of ownership is the main tool used to determine truck economics. However, even if the TCO becomes favorable, high vehicle prices can deter small operators. These form the bulk of fleets in many countries.

Size breakdown of commercial vehicle fleets in the US

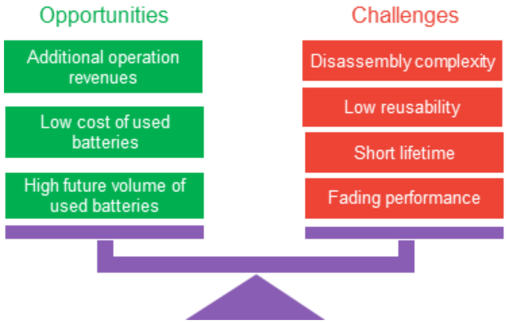


Source: BloombergNEF, US Department of Transport.

Perceptions of battery residual value

Battery repurposing, reuse and recycling happen at low volumes today across the automotive industry. Relatively few electric trucks have been on the road long enough to fully understand the long-term performance of their batteries and their corresponding residual values.

Second-life battery opportunity outlook

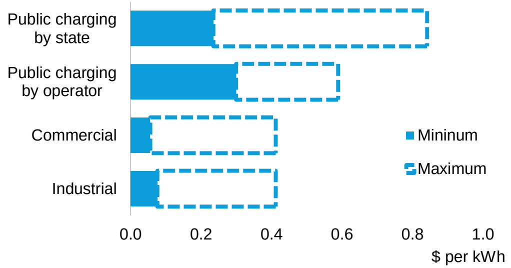


Source: BloombergNEF.

Electricity and hydrogen costs

Refueling costs can range from just over 10% to more than 70% of the total cost of ownership of zero-emission trucks, reflecting the wide variability of use cases. For electricity, the price at high-power charging stations can be far higher than typical industrial rates.

Public charging, industrial and commercial electricity rates in the US



Source: BloombergNEF, US Energy Information Administration. Note: Data for 1Q 2024; commercial and industrial rates show the spread across states.

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Zero-emission fleet deployment and financing strategies today

Fleets have been largely deploying electric or hydrogen trucks in known and repeatable routes, in areas with zero-emission vehicle mandates, or when they receive contractual payments for using such vehicles. Use cases include electric buses operated on behalf of a local authority, electric trucks in urban deliveries, and those going in and out of California's ports and in the announced zero-emission zones in the Netherlands. In the past few years, two main deployment models for zero-emission commercial vehicle fleets have been used.

Fleets acquire electric trucks and set up refueling infrastructure in their depots.

These fleets can rely on traditional sources of funding to acquire the vehicles and install the infrastructure, such as their own equity, vehicle leasing or loans, as well as government grants and environmental credits. They use the services of charging providers, including local utilities, to setup refueling equipment in locations they control. Typical use cases are electric trucks moving cargo on relatively short routes, aiming to charge every couple hundred miles of driving. China's battery swapping stations and some fleet deployments in California's ports and in the Netherlands' announced zero-emission zones fall under this model.

Fleets outsource parts of electric truck operations to service providers.

As above, fleets may own or lease the vehicles and install charging equipment in their depots. However, they contract with companies to not only build but also manage the refueling infrastructure and guarantee fuel costs. These are mostly newly established operators and can be funded by a combination of equity from investors such as infrastructure and real estate funds, and debt such as credit lines from traditional financial institutions. Grants and environmental credits are also used by both parties. This method has been one of the blueprints for deploying municipal electric buses, whose purchase may also be underwritten by contracts with transit authorities. Recently, the model is expanding to the deployment of heavy-duty electric trucks.

Zero-emission fleet deployment and financing strategies: The next stage (1/2)

Complexities in the zero-emission truck and bus market abound, and relate to costs, energy availability and technology maturity. However, rapid technology development and declining costs, as well as long experience with, primarily, the electricity markets create a dynamic environment in the trucking world. New business and financing models have already appeared, including fleet operators partnering with fuel providers more closely than is typical in the industry or refueling station developers raising financing secured on utilization agreements with fleets. Here, we present emerging models of addressing the real and perceived risks in mass deployment of zero-emission trucks and buses.

Capital costs: Electric and hydrogen truck prices are high, but already follow declining cost trajectories, which also differ between segments. With high-volume manufacturing, some medium-duty electric trucks can reach upfront price parity with equivalent diesels within the next few years, putting them within reach of capital-constrained smaller fleets. Longer-range trucks could approach such points around 2030, even though their TCO could be favorable earlier. Larger fleets are more likely to benefit from the economics in the short term, but stacking up various subsidies and, potentially, environmental credits could also alleviate some of the cost pressure for smaller operators. For smaller fleets, financing concepts such as aggregating procurement and creating a leasing platform or a separate entity holding those vehicles, are being explored by the World Bank in Poland and Mexico.

Fuel costs, grid connections and land availability: Deploying fleets of electric trucks in some applications could require high amounts of electricity, and station developers are adopting new approaches to secure energy availability and control fuel costs. Projects that include on-site microgrids, potentially coupled with stationary energy storage, are already being built to balance the cost and time delays of establishing high-power grid connections. Such endeavours have attracted funds from institutional asset managers, vehicle manufacturers and energy providers.

In many such cases, acquiring the right land is also critical to ensure locations that combine proximity to freight routes with enough space and adequate local grid capacity. These requirements are already drawing real estate investors, who become partners in refueling station and fleet deployment projects in the US and Europe.

Existing practices in the electricity markets, such as power purchase agreements and price hedging, also become part of the toolbox for securing and supplying the required energy.

Zero-emission fleet deployment and financing strategies: The next stage (2/2)

Battery residual value: The technical challenges of repurposing and reusing batteries relate to low performance once they reach their end of life. The packs that become available now were produced and deployed a few years ago when battery development was focused more on optimizing vehicle efficiency, and reuse was not a central part of producers' considerations.

Manufacturers are now starting to design batteries and vehicles with a view to the whole lifetime, to both increase their second-life potential and to comply with environmental regulations. At the same time, more data on real-world battery utilization and performance become available as lithium iron phosphate (LFP), with its long cycle life, becomes a main chemistry choice. While early data come mostly from passenger battery vehicles, they tend to show lifetime performance as good as, or even better than, expected at the time of initial deployment.

Operators already bank on such developments to repurpose batteries and use them in stationary energy storage applications. The extension of a battery's useful life can create additional revenue streams to the degree that some developers extend those batteries' warranties beyond the manufacturer's original ones. These early developments may also imply that fleet and station operators and lenders are able to extract value along various stages of a battery's useful life and gradually address the corresponding uncertainties and risks.

The value of offtake agreements: Several of the emerging business and financing models for zero-emission trucks and buses require enough volume of vehicles, batteries and energy to make their economics work. For truck manufacturers, high production volume is also paramount to reduce zero-emission trucks' capital costs.

Fleet owners, refueling station developers and service operators are already partnering in an attempt to achieve economies of scale by, for example, ensuring charging station utilization. These 'offtake' agreements, albeit few for now, can provide some certainty on the costs and returns for fleets and refueling stations. Similarly, efforts to aggregate demand for zero-emission road freight for shippers and carriers are also taking shape; for example, as part the e-FAST initiative in India and Smart Freight Centre's Sustainable Freight Buyers Alliance. In turn, such visibility on operational economics can underpin the financing of large and long-term capital projects, including electric truck procurement and station development costs.

Case study: Zenobe EV Delivery Truck Charging Facility

Zenobe EV Delivery Truck Charging Facility, Australia

Project partners	Zenobe and Woolworths
Fleet	60 medium-duty battery-electric trucks
Use case	Last-mile delivery
Refueling infrastructure	22 dual direct-current (DC) chargers, 120kW per charger
Energy storage	150kWh battery storage
Station land	Leased

Financing

Equity	Debt	Grants/Other
	Receivables financing	AUD8.5 million ($5.7 million) from Arena
67% (combined equity and debt)		33%

Source: BloombergNEF, companies. Note: 'Arena' is Australian Renewable Energy Agency. Conversion to US dollars as of September 9, 2024.

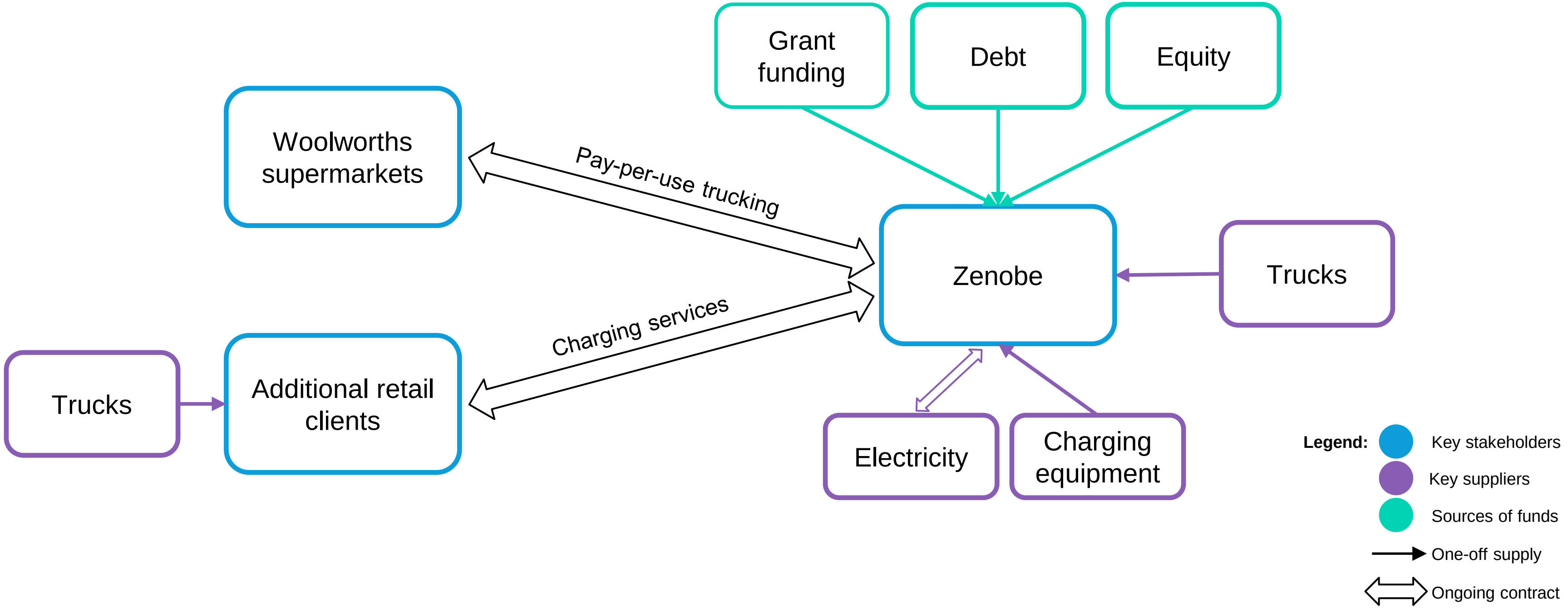
The Zenobe EV Delivery Truck Charging Facility includes in a single investment project with everything needed to operate a fleet of medium-duty battery-electric delivery trucks. Beyond building and operating the station, funding was used for a batch of 60 trucks, owned by Zenobe, that are leased to the supermarket chain Woolworths.

The project required the support of a government grant for about a third of the cost, while it also raised debt based on more traditional tools, such as receivables financing. While Zenobe is currently exploring the possibility of raising concessional finance, it sees a pathway to deploying a future stack of funds supported solely by the economics of using and operating such vehicles.

Some forms of utilization agreements for the charging station are in place and being planned. Woolworths is set to only use around half of the site's chargers, and Zenobe plans to attract additional fleets as clients. These may use the station within specific time slots throughout the day.

As with other early deployments of electric trucks, the project's primary risks centre on the residual value for both the truck and its battery. Zenobe has been using vehicle batteries in stationary energy storage projects and has indicated that it will do so in this one as well.

Case study: Zenobe EV Delivery Truck Charging Facility



Case study: Forum Mobility FM Harbor

Forum Mobility FM Harbor

Project partners	Forum Mobility, CBRE Investment Management, Homecoming Capital
Fleet	Class 8 battery-electric trucks
Use case	Drayage
Refueling infrastructure	19 dual and 6 single chargers, 360kW per charger
Energy storage	Not installed
Station land	Leased

Financing

Equity	Debt	Grants/other
100%	Not used at this phase	Not used at this phase

Source: BloombergNEF, companies. Note: LCFS is California's Low Carbon Fuel Standard.

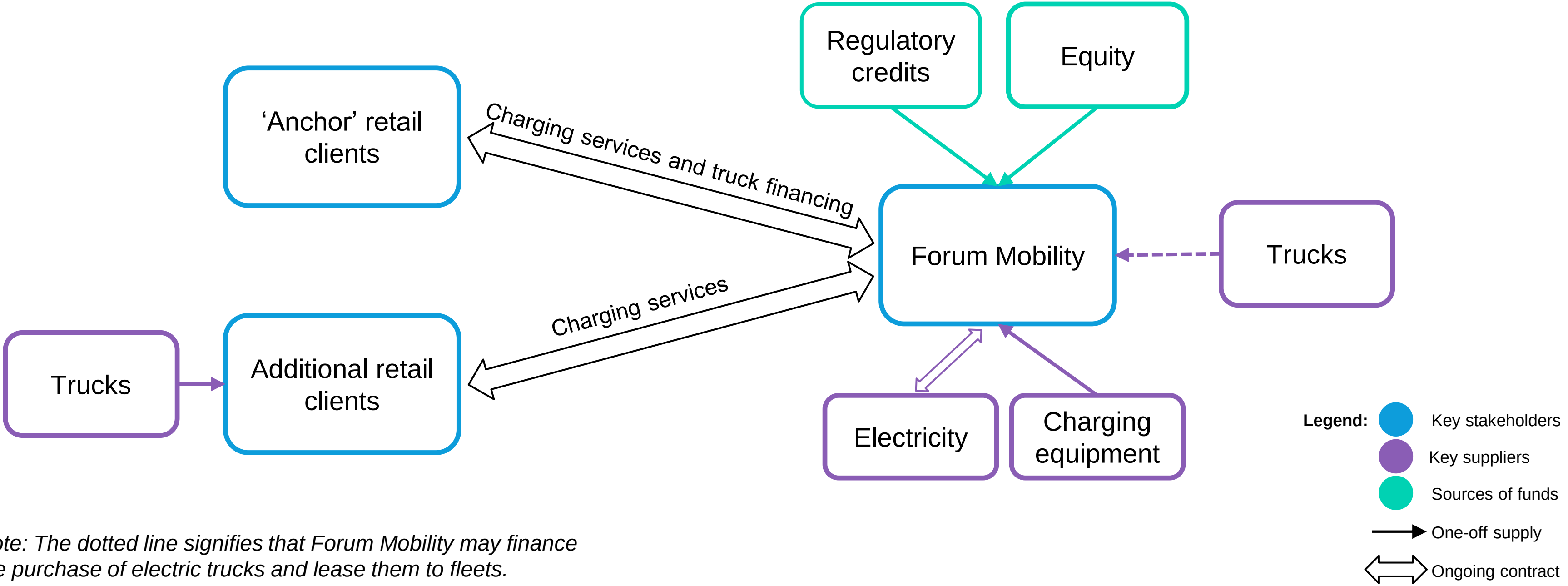
Forum Mobility's FM Harbor project serves California's target to replace trucks moving containers in and out of the state's ports with zero-emission vehicles. Forum developed the charging site as well as financed the purchase of heavy-duty battery-electric trucks. It charges fleets a combination of a fixed and a variable fee, with operators buying time slots throughout the day.

Financing the construction of the charging station and truck purchases was based on equity without a debt component. Regulatory credits from one of California's main environmental programs will also provide recurring revenue to the station. To invest in such projects, Forum Mobility has formed a $400 million joint venture, which includes infrastructure investors CBRE Investment Management and Homecoming Capital.

One of the project's main risks is again the electric truck's residual value, while increasing station utilization is also a concern. As with other electric fleet deployment projects, required rates of return can well exceed 10%.

To address such concerns, offtake agreements – whereby a fleet commits to some specific use of the charging site – were part of the project development. These could provide some certainty on station usage, and also help raise traditional types of debt to replace part of the project's equity.

Case study: Forum Mobility FM Harbor



Note: The dotted line signifies that Forum Mobility may finance the purchase of electric trucks and lease them to fleets.

Case study: Zero-emission vehicles on Zeti's platform

Zeti aggregated fleet of commercially operated passenger cars

Project partners	5 lenders, 7 fleets
Fleet	50-1,000 BEVs per fleet
Use case	25-35,000 miles/year for cars
Refueling infrastructure	Not part of project or financing
Energy storage	Not part of project or financing
Station land	Not part of project or financing

Financing

Equity	Debt
	Loan – senior or mezzanine debt
5-15%	85-95%
Internal rate of return	7-10%

Source: BloombergNEF, companies. Note: 'BEV' is battery electric vehicle.

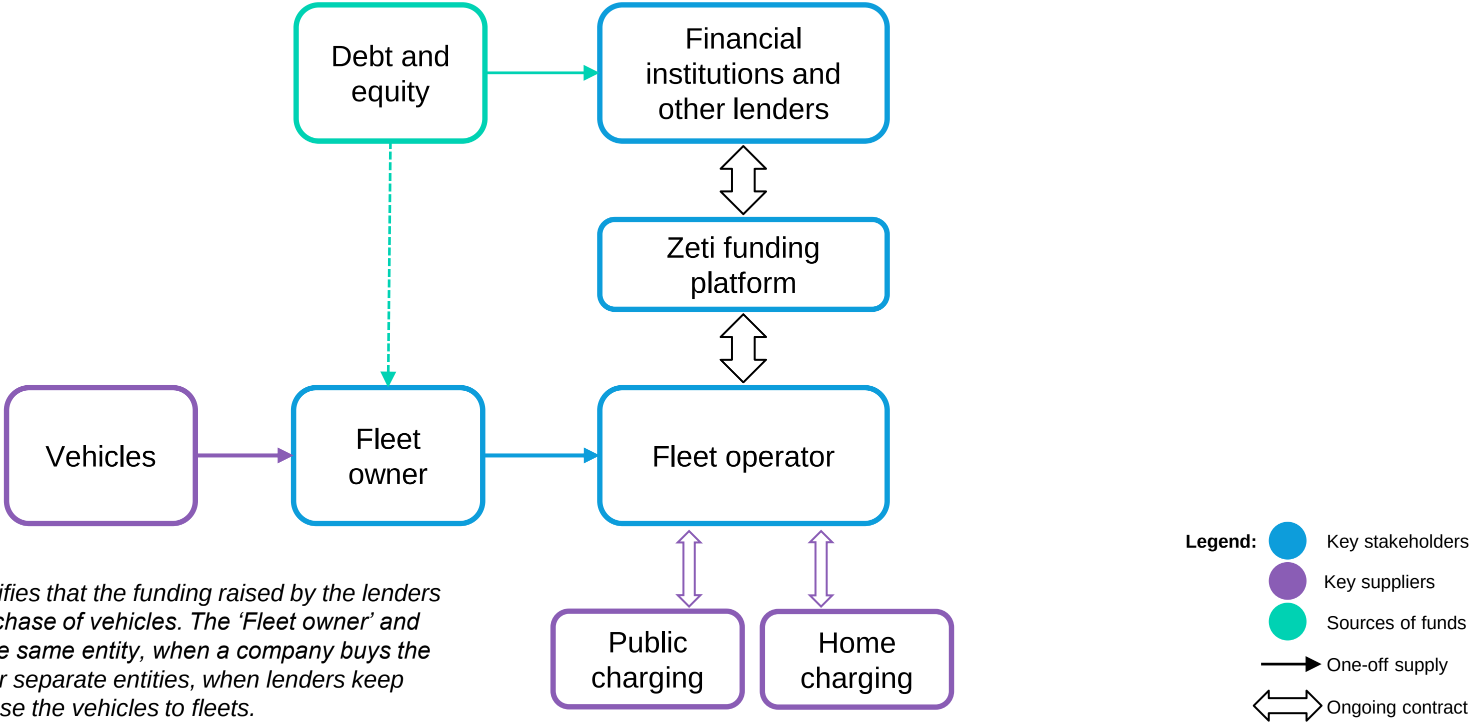
Battery-electric passenger cars operated on a commercial basis are part of Zeti's platform, while the pipeline of additional fleets includes those operating zero-emission buses and trucks. Financing differences emerge between vehicle types, as high-utilization cars may already have favorable economics, while those of commercial electric vehicles vary across applications.

Lenders use common tools to fund purchases, while for passenger cars more-flexible lines of credit also start to be used. But uncertainties over residual value and higher purchase costs pose challenges, especially for trucks and buses. That may lead to investment horizons of 14-15 years or more to cover the full useful life of the vehicle. Because of the higher costs and longer timeframe, the fleet operator's cash flow visibility matters. For example, contracts between bus operators and local authorities or logistics providers and retailers, may result in lower financing costs for such fleets.

Expected returns are typical for similar projects, but they may be somehow higher and within a wider range for commercial vehicles.

Charging approaches, and hence funding needs, between vehicle segments. The refueling infrastructure is part of electric bus and truck projects. These may include stationary energy storage and, potentially, power purchase agreements for larger fleets.

Case study: Zero-emission vehicles on Zeti's platform



Note: The dotted line signifies that the funding raised by the lenders is used to finance the purchase of vehicles. The 'Fleet owner' and 'Fleet operator' may be the same entity, when a company buys the vehicles for its own use, or separate entities, when lenders keep vehicle ownership and lease the vehicles to fleets.

Appendix

Defining commercial vehicles

Main focus of the report

Vehicle segment	Typical use cases
Heavy-duty commercial vehicle (HCV)	Refuse, drayage, construction, freight
Medium-duty commercial vehicle (HCV)	Distribution, utility and municipal services, freight
Light-duty commercial vehicle (HCV)	Last-mile delivery, distribution
Municipal buses and coaches	Urban and inter-city people transport

Commercial vehicles come in many types and perform several functions. Their operations vary widely, even for similar vehicles in the same weight segment.

Light-duty commercial vehicles are typically vans or small trucks that operate within and around cities. They are the largest segment in terms of fleet and sales within the sector. Zero-emission models mostly consist of battery-electric vehicles, and adoption has been growing globally, albeit at different speeds across countries.

Medium- and heavy-duty trucks are used in several, disparate duty cycles. These include infrastructure maintenance, municipal services, urban distribution, and short- and long-haul goods movement, among others.

While these vehicles' sales and fleet are considerably lower than for light-duty commercial vehicles, they consume relatively more energy.

Source: BloombergNEF. Note: Segmentation is for the purpose of clarifying content in this report. For gross vehicle weight rating thresholds in different countries, see Slide 53.

Defining electric vehicles (EVs) and zero-emission vehicles (ZEVs)

Zero-emission vehicles (ZEVs)

Fuel-cell vehicle (FCV)

Battery-electric vehicle (BEV)

Electric vehicles (EVs)

Plug-in hybrid electric vehicle (PHEV)

Hybrid vehicle (non-pluggable)

(These vehicle types contain combustion engines)

Source: BloombergNEF. Note: Categorisations are only for the purpose of clarifying content in this report.

For the purposes of this report, we define zero-emission vehicles (ZEVs) as those vehicles that never emit carbon dioxide from their tailpipes.

This means that in our categorization, ZEVs only include pure battery-electric vehicles (BEVs) and fuel-cell vehicles (FCVs), neither of which have internal combustion engines.

It is understood that these vehicles should be fueled from clean electricity or hydrogen if they are to be truly zero-emission in operation.

Electric vehicles (EVs) as a category are commonly understood to include plug-in hybrids (PHEVs).

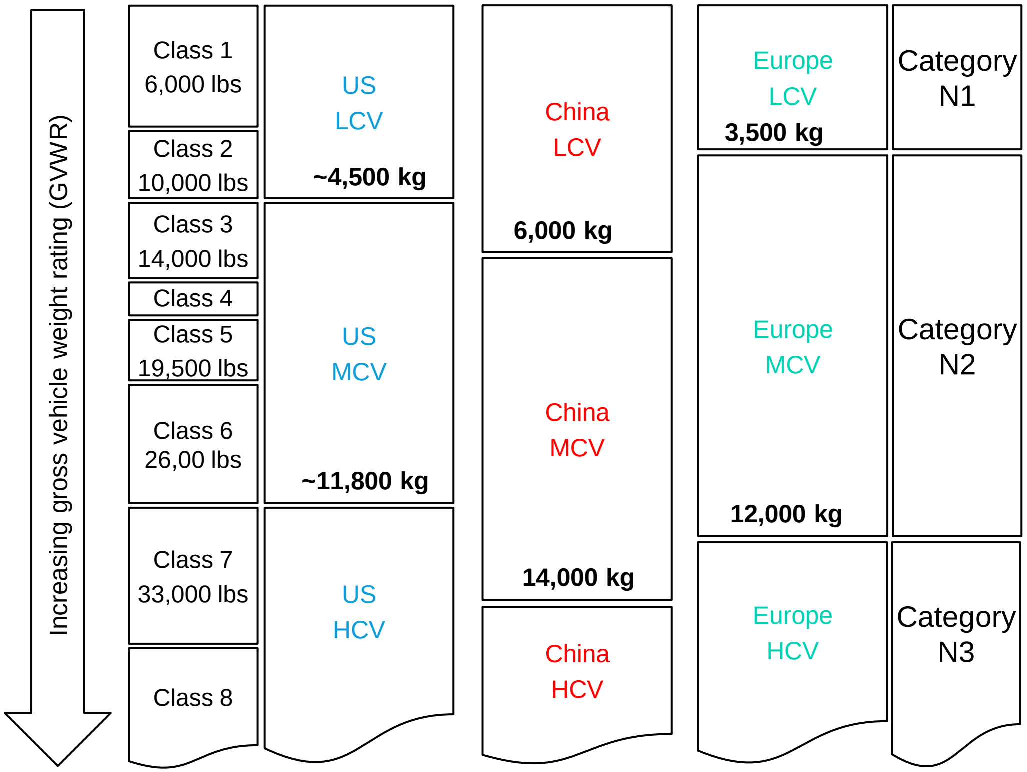
In this report, as in all other BNEF publications, we include PHEVs in our definition of EVs, alongside pure BEVs.

However, PHEVs are excluded in some portions of this report that focus on ZEVs, as defined above.

Pages that focus on the broader category 'EVs and FCVs' encompass all of the above.

Hybrid vehicles that cannot be charged from an external power source are not included in our definitions of ZEV or EV.

Commercial vehicle classification



- The weight thresholds between segments follow the classification of registered commercial vehicles as used in different countries.
- In the US, we choose Class 2 vehicles as the threshold for light-duty commercial vehicles (LCV) to be as close as possible to both the European and Chinese limits.

Note: 'LCV', 'MCV', and 'HCV' refer to low-, medium-, and heavy-duty commercial vehicles.

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Data sources for sales and fleet

- BloombergNEF
- Bloomberg Terminal
- China Automotive Technology and Research Center
- FTR Associates
- Wards Automotive
- European Automobile Manufacturers’ Association (ACEA)
- European Alternative Fuels Observatory
- South Korean Ministry of Trade, Industry and Energy (MOTIE)
- EV-Volumes
- Japan Automobile Dealers Association (JADA)
- 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)
- Various other national registration agencies

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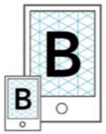

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