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Zero-emission bus and truck market in China: A 2021 update

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Introduction

Heavy-duty vehicles are an important source of GHG emissions and air pollution across the globe (European Environment Agency, 2020). Despite advances in the emissions performance of diesel engines, zero-emission heavy-duty vehicles (ZE-HDV) are an indispensable solution for the decarbonization of transportation in the coming decades. The full transition to ZE-HDVs is essential if China is to meet its decarbonization goals.

Although global competition on ZE-HDVs is quickening, China is clearly the global leader in the production and adoption of battery electric and fuel cell electric buses and trucks: 91.6% of the world's total electric HDVs were sold in China in 2021. The ZE-HDV market in China saw rapid growth in the past decade, and ZE penetration of China's domestic HDV market reached 4% in 2021 (Tencent News, 2022). Chinese manufacturers are also deploying e-models to international markets such as North America, Europe, and Latin America (Koop et al., 2020; Sustainable Bus, 2022a; Xinhua News, 2022). By 2021, China supplied more than 90% of the world's e-buses, clearly dominating the market (Mao & Rodríguez, 2021).

The last "Race to Zero" report summarized market readiness information about the ZE-HDV industry with a timeframe covering 2017 to 2019 (Mao & Rodríguez, 2021). As the COVID-19 pandemic broke out at the end of 2019, the automobile industry also tumbled. The ZE-HDV market was no exception; it posted its weakest performance since 2014. However, the ZE-HDV market recovered in 2021, the year on which this study focuses.

Where are we: a snapshot of ZE-HDV market in 2021

Overview

The ZE-HDV market ramped up rapidly during the last decade in China, from almost no sales to more than 200,000 vehicles in 2016 (Figure 1). After that, however, total sales declined for years due to a gradual phasedown of national subsidies for electric trucks and buses. Meanwhile, zero-emission buses—most of which are battery-electric—claimed a growing share of the ZE-HDV market, increasing from 60% to 80% in the last 5 years. In 2021, the market recovered, reaching sales volumes similar to those of 2018, despite 2021 incentives being only about 40% as generous as in 2018 (Figure 1).

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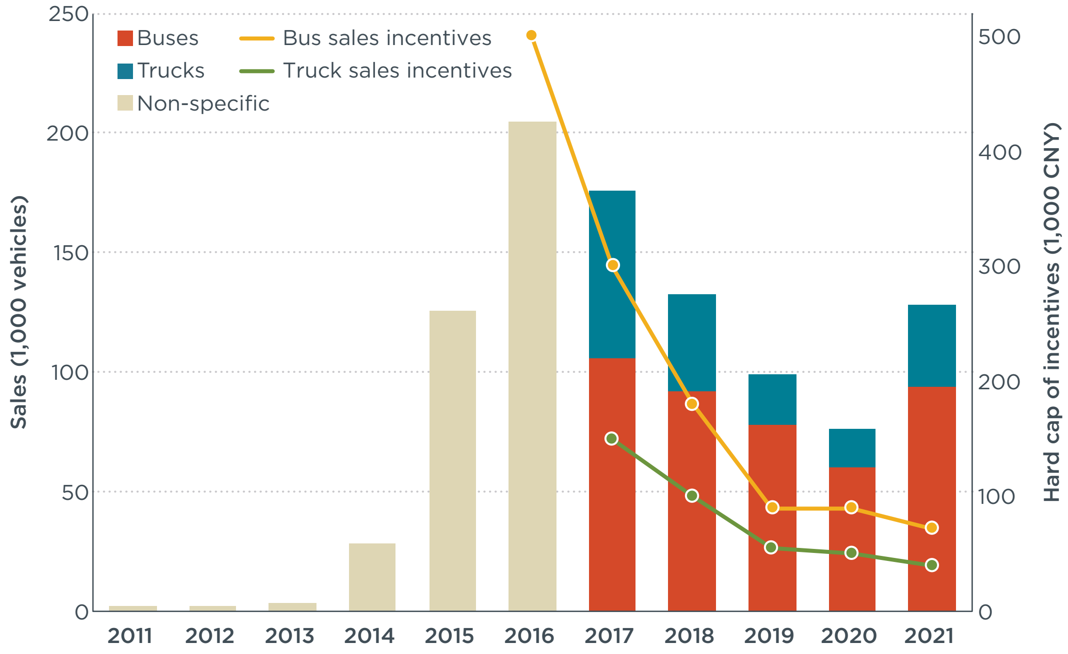

Figure 1. Total sales of ZE-HDVs from 2011 to 2021

From the perspective of manufacturer dominance, the change is large in recent years. Figure 2 illustrates the ups-and-downs of ZE-HDV and diesel manufacturers in 2021. It shows that the top 10 ZE-truck and ZE-bus manufacturers captured about 70% and 85% of market share, respectively, approaching the market profiles of their diesel counterparts. This pattern suggests that China's ZE-HDV market is consolidating, with the top players becoming more dominant as they gain an edge through economies of scale.

This ZE-HDV market consolidation is edging out incumbent manufacturers of diesel HDVs. Most notably, FAW—China's largest diesel truck manufacturer—has been slow to embrace the transition to ZE-HDVs and does not have a substantial share of that market. FAW has announced investments of over 30 billion yuan until 2025, with the goal of becoming a market leader in ZE-HDVs by 2030 (China Daily, 2021). Dongfeng Motor, however, was the leading producer in 2021, supplying ~5,500 ZE trucks and surpassing FAW in the emerging market. Dongfeng Motor set an ambitious strategic plan for electrification in 2018, when it announced it was introducing 20 electric models by 2022, ranging from light duty delivery vans to long-haul tractors (Dongfeng Motor, 2022; Electric Vehicle Research, 2018).

In 2021, the zero-emissions focus of 7 of the top 10 ZE-HDV manufacturers was mainly on buses, a pattern similar to these firms' diesel production. Compared to 5 years earlier, new players such as King Long, Geely, and Ankai were listed among the top 10 manufacturers in 2021. King Long was founded in 1988 and is still a leading manufacturer in the traditional bus market, providing a variety of city buses, coaches, and special vehicles (King Long, 2022a). The transition from diesel to battery power is logical as King Long has developed new energy powertrains for decades; it released the first hybrid coach with a lead acid battery in 2001 (King Long, 2022b). Geely has long been popularly known as an electric passenger car maker in China; its first move into the electric heavy-duty vehicle market came in 2016 with the founding of a new subsidiary known as Geely New Energy Commercial Vehicle Group, which carried a new brand, Farizon. Since then, Geely has manufactured a series of alternative energy commercial vehicles. Besides electric trucks and buses, Geely has also focused its efforts on methane engines for long-haul tractor-trailers (Geely New Energy Commercial Vehicle Group, 2021).

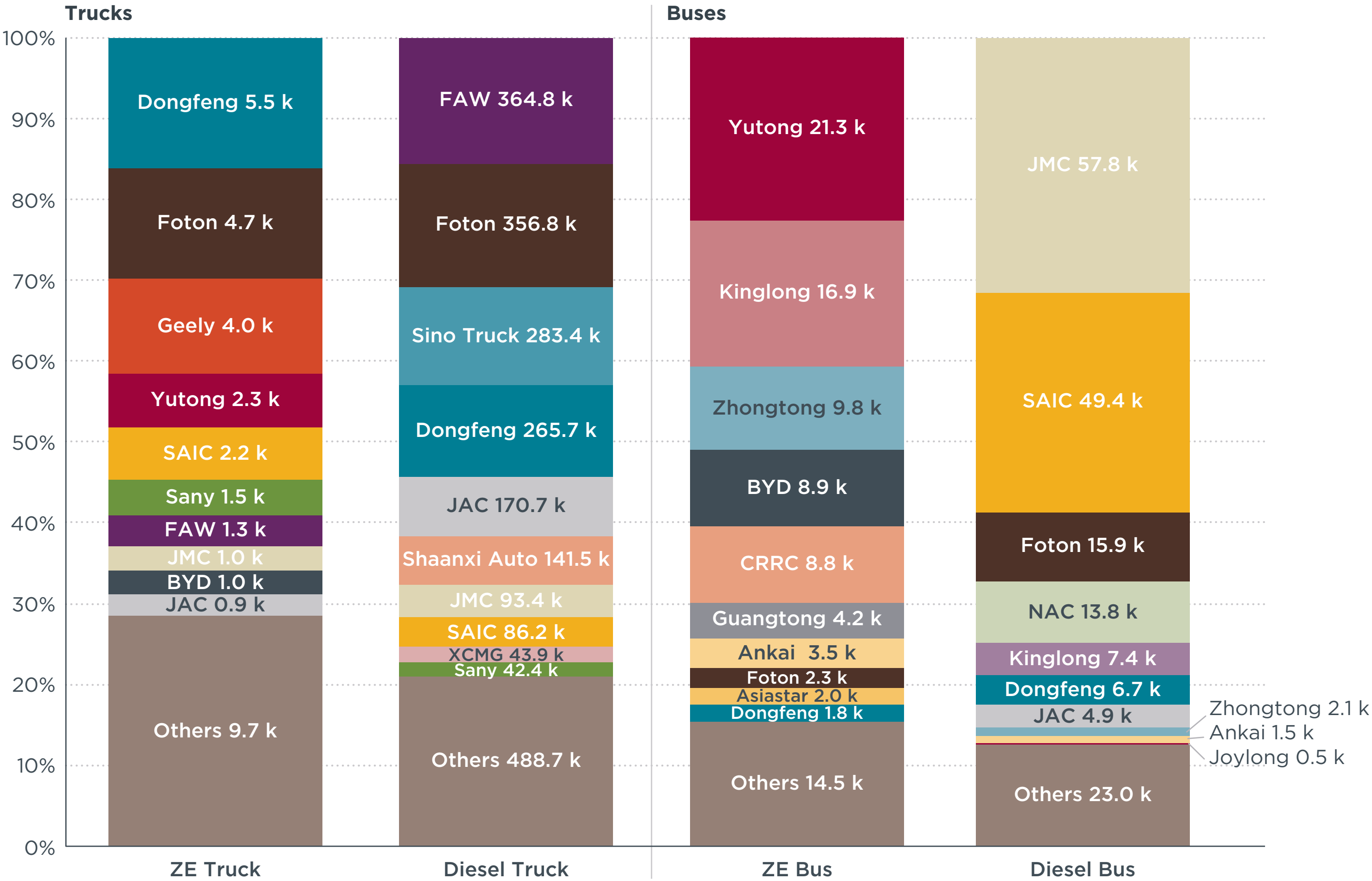

Figure 2. ZE-HDV and diesel HDV sales proportion by manufacturer in 2021 (numbers indicate sales)

Sales by segment

ZE buses continued to dominate the ZE-HDV market in 2021. ZE buses accounted for 73% of total sales of ZE-HDVs, while buses ranging in length between 10m and 12m accounted for 37%.

On the other hand, ZE trucks accounted for 27% of total ZE-HDV sales, of which box trucks were most popular. Compared to earlier years, different truck categories showed varying development trends. Tractor-trailers gained market share from 0.4% (2017) to 16.2% (2021), followed by sanitation trucks whose ZE truck market share increased from 3.9% to 11.1% during the same period.

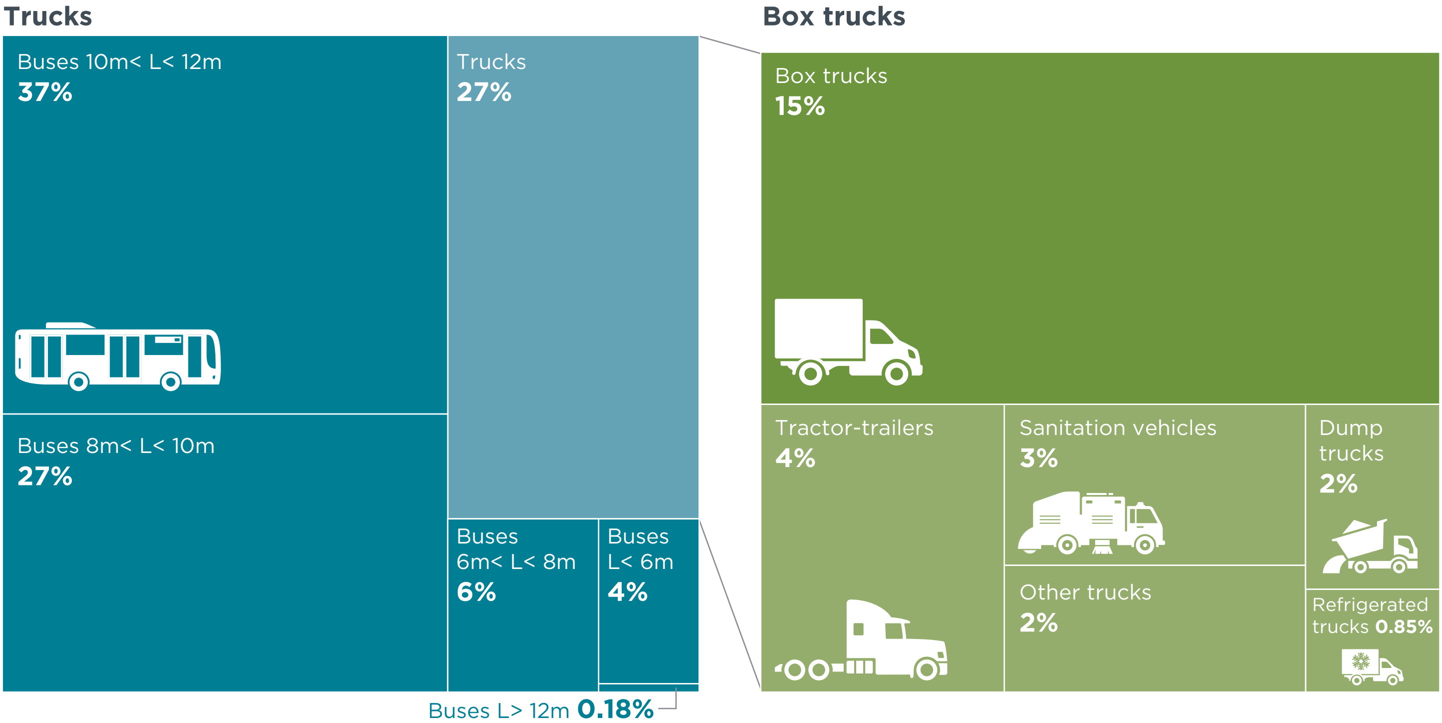

Figure 3. Distribution of ZE-HDVs sales by segment. The percentage value refers to the segment's share of total ZE-HDV sales.

Zero-emission technology pathways

Figure 4 details the structure of fuel technology for buses and trucks in the last 5 years. For buses, while battery electric is still the most popular zero-emission technology, fuel cell electric technology is an emerging alternative, accounting for 2% of sales in 2021. For trucks, battery swapping is rapidly growing as a required technology, and battery swapping trucks accounted for about 25% of total ZE truck sales in 2021. This information is accessible for 2021 only, but some battery swapping models were reportedly available years before that (Lin-Gang Special Area, 2020).

The bars on the right of the figure indicate the sales proportion of selected cities in 2021. Several cities with a heavy steel industry presence, such as Tangshan, Handan and Cangzhou, were favorable to battery swapping trucks/tractors for bulk transport. Of all cities, Tangshan accounted for ~37% of total sales of battery swapping trucks in 2021. Tangshan promoted the innovative technology rapidly because it was funded by a pilot program announced by the Ministry of Industry and Information Technology of China (MIIT). This pilot program aims to build more than 1,000 battery swapping stations and introduce over 100,000 battery swapping EVs (MIIT, 2021; Randall, 2021).

On the other hand, trucks and buses with fuel cell technology were adopted in recent years by several cities. For example, Beijing was the biggest buyer of fuel cell buses in 2021 with a market dominance of 41%, driven by the transport needs of the Winter Olympics in 2022. Beijing reportedly deployed over 800 fuel cell buses to serve the event (Sustainable Bus, 2022b). For trucks, Qingdao introduced the most fuel cell trucks in 2021 in their effort to become the world's first hydrogen-powered and intelligent port, according to announcements by local officials (FuelCellsWorks, 2022).

Battery electric buses were sold to cities evenly across the country, which implies that such technology has become mature and widespread in China. Wuhan, with the highest market share of battery electric buses in 2021, accounted for only 4% of total sales nationwide.

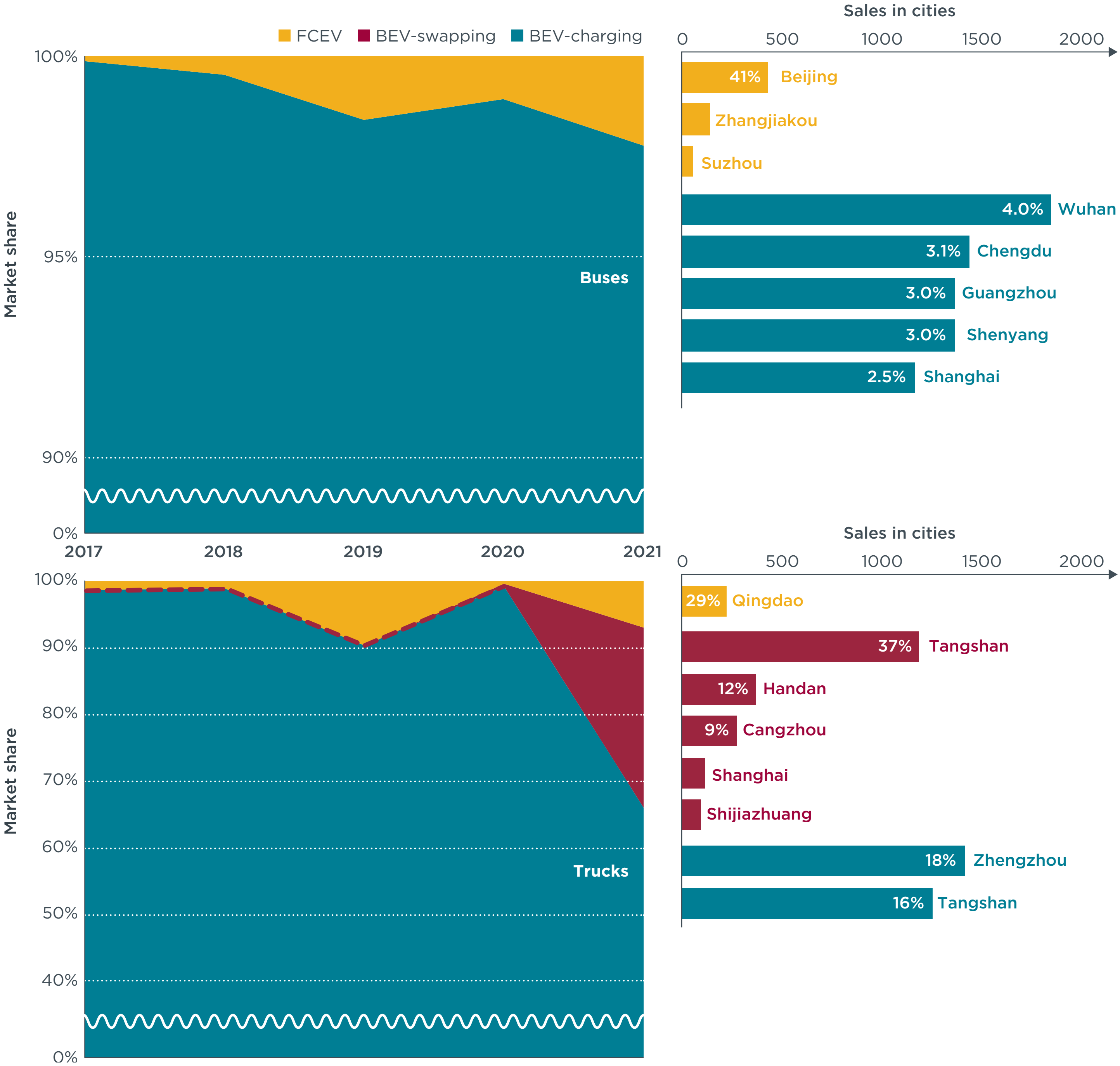

Figure 4. Market share of fuel technologies from 2017 to 2021 with 2021 sales ranking (bars on the right). The dashed red line indicates no data for battery swapping trucks before 2021.

Geographical pattern

Figure 5 illustrates 2021 urban sales of three major zero-emission vehicle categories: buses, rigid trucks, and tractor-trailers. In cities such as Shenzhen, Chengdu, Zhengzhou and Tangshan, zero-emission rigid trucks and tractor-trailers were the most widely adopted vehicle segments. Preference for electric trucks and tractor-trailers in these cities is mostly driven by policy: Tangshan, as mentioned earlier, was heavily funded by the central government to adopt e-trucks and tractor-trailers for use in the steel industry; Chengdu instead established zero-emission zones in 2021 and banned diesel heavy-duty trucks from downtown areas in the daytime, which stimulated their replacement with e-trucks. For other cities, however, electric buses still turned out to be the most popular vehicle category due to their promotion by local government.

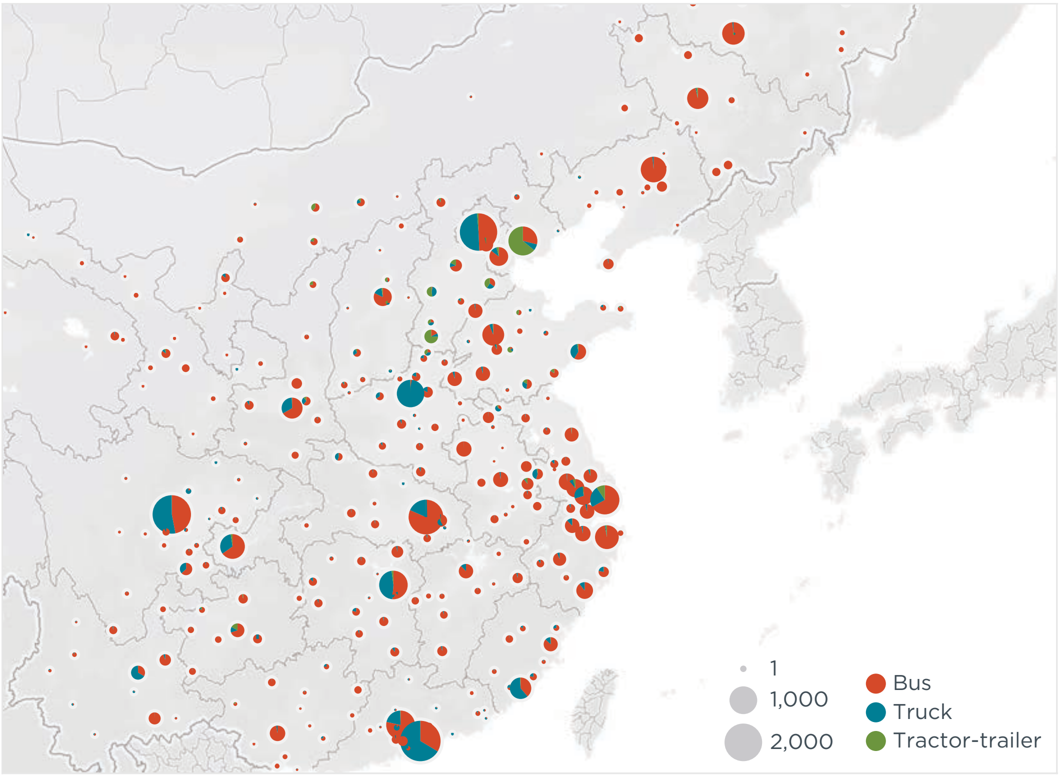

Figure 5. Geographical deployment of ZE-HDVs in 2021

Local authorities usually set discriminatory barriers to non-local OEMs in order to protect local manufacturers, a practice known as local protectionism. This happened in previous years when new energy passenger vehicles were heavily promoted despite the central government's warning against local preferences (Amanda, 2018; Li & Du, 2015). Preference for local companies' vehicle models still exists with regard to ZE-HDVs. Figure 6 shows clearly that local authorities are inclined to procure ZE vehicles from locally based automakers (Company factories or headquarters tend to be found in the darkest squares that indicate the highest sales.) As electric buses are still the most favorable vehicles to be procured by most cities, this phenomenon can be observed most often in the e-bus market.

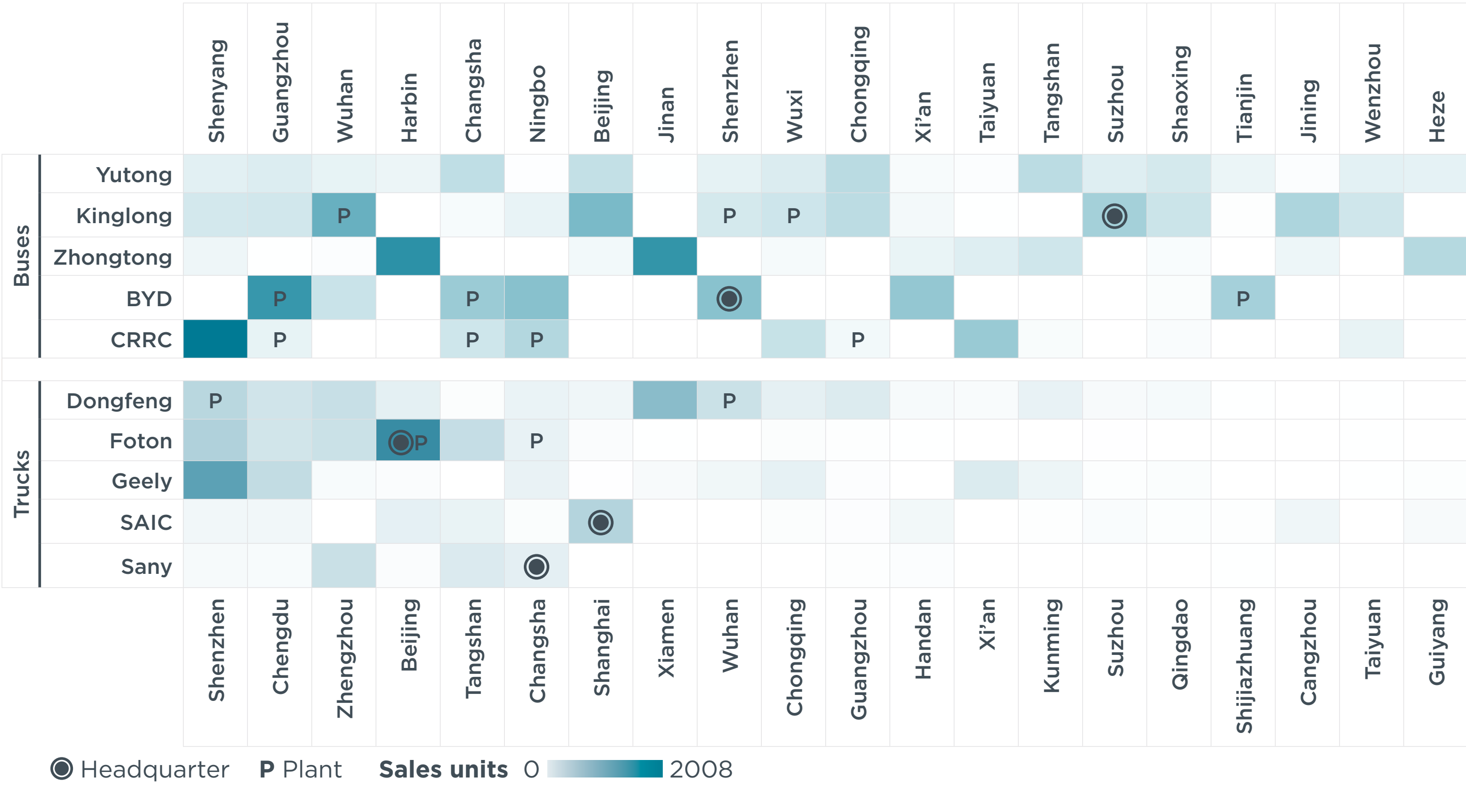

Figure 6. Top 10 OEMs sales across leading cities in 2021

National incentives and subsidies

China has provided national incentives to ZE-HDV OEMs since 2015. Figure 7 illustrates the subsidies given to OEMs in recent years. In 2016 and 2017 OEMs received their greatest levels of support from the central government due to elevated domestic sales (Figure 1). In 2016 and 2017, the central government provided ~10 billion and ~19 billion CNY, respectively, which reflects its ambition to lead in New Energy Vehicle (NEV) development. As most of the models produced and subsidized are electric buses, the bus maker BYD was the biggest winner, receiving over 10 billion CNY. In total, China provided ~48 billion CNY to ZE-HDV OEMs between 2015 and 2021.

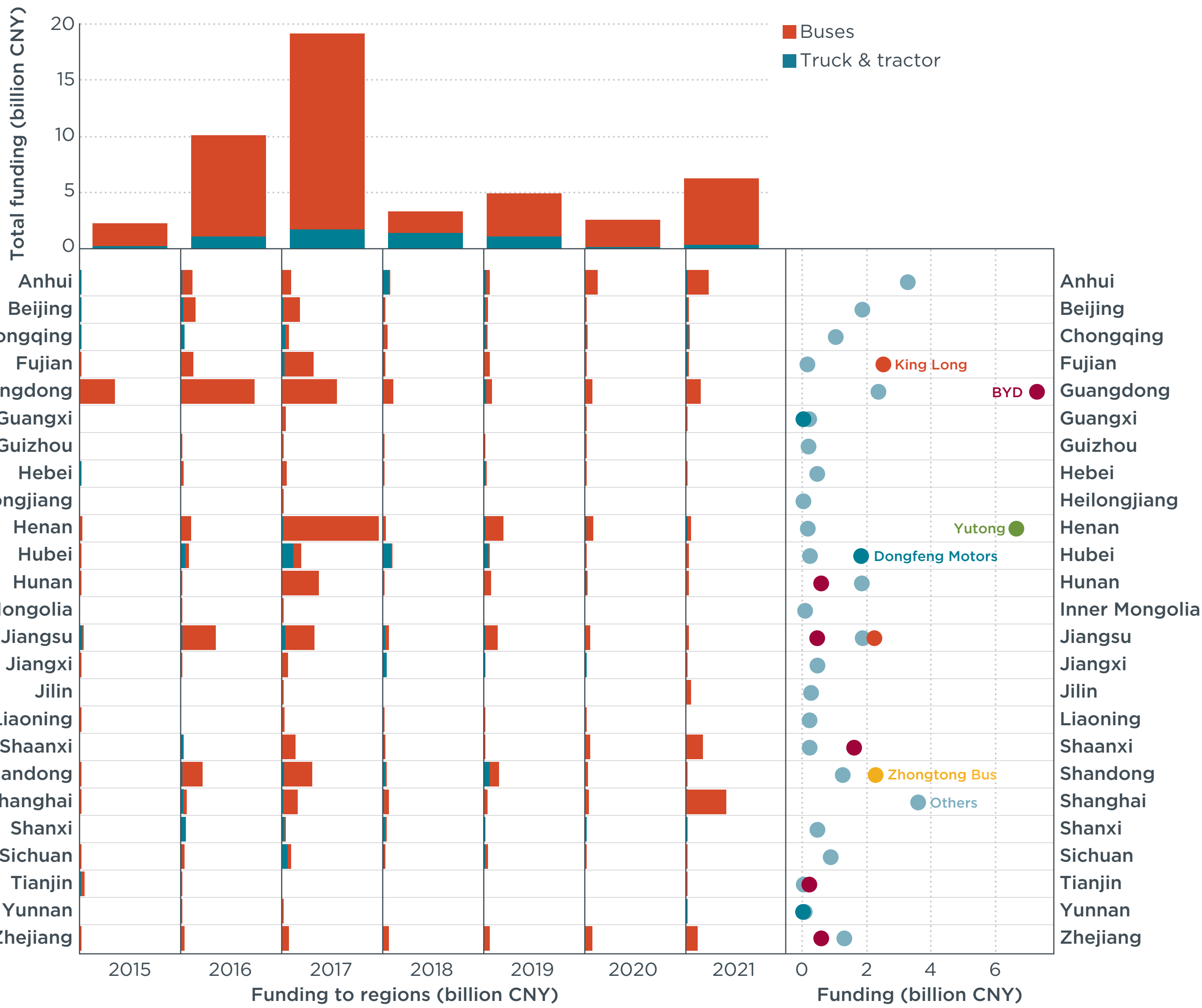

Figure 7. Incentives provided to regions and OEMs, 2015-2021

Are we ready? The position of OEMs and progress of key metrics in 2021

Battery electric technology

Supply chain

Compared to the diverse landscape of ZE-HDV manufacturers, battery suppliers are more consolidated. CATL, the largest battery supplier in the world, accounted for half of the global market share. CATL supplied the largest share of ZE-HDV batteries used in China, followed by Gotion (10.4%), Slanpower (5.5%), Lishen (5.4%), Eve Energy (4.9%), and BYD (4.7%). To date, BYD is the only company covering both vehicle manufacturing and battery supply, and more than 86% of BYD battery production went to BYD's own electric buses and trucks; batteries from CATL supply only a fraction (9.9%) of BYD's total truck sales.

Market consolidation is also a common characteristic of the ZE-HDV supply chain. CATL is ranked first in total production capacity, with 170.4 GWh as of the end of 2021 (Reuters, 2022). Manufacturers such as King Long, CRRC, Zhongtong Bus, Shaanxi Auto, and JMC Motors, among others, procured most of their batteries from CATL. On the other hand, for some battery suppliers, the dependency is reversed. Yutong was the main and only customer for Slanpower's battery production, and Gree Altairnano supplied 99% of products to Guangtong Auto. Both cases are due to ownership overlap between battery suppliers and OEMs: Slanpower is an affiliated company of Yutong and Gree Altairnano fully controls Guangtong Auto.

Buses are equipped with greater battery capacity than trucks, as shown in Figure 8. The average battery capacity on buses was 208 kWh, 45% higher than for trucks (143 kWh), largely because most (~65%) trucks are classified as light duty (3.5-4.5 tonnes), but buses were much heavier (~14 tonnes). Due to constraints on battery capacity, trucks run 100 km less per trip than buses on average (Figure 10), and a more frequent charging scheme is also required. SANY, a company featured in production of off-road equipment, heavy dump truck and tractor-trailers, installed more than 360 kWh of battery capacity, on average, on trucks. Shaanxi Auto produced buses with about 300 kWh and 600 km of range. SAIC, however, produced vehicles with less battery capacity than the average, while still achieving 320 km of range.

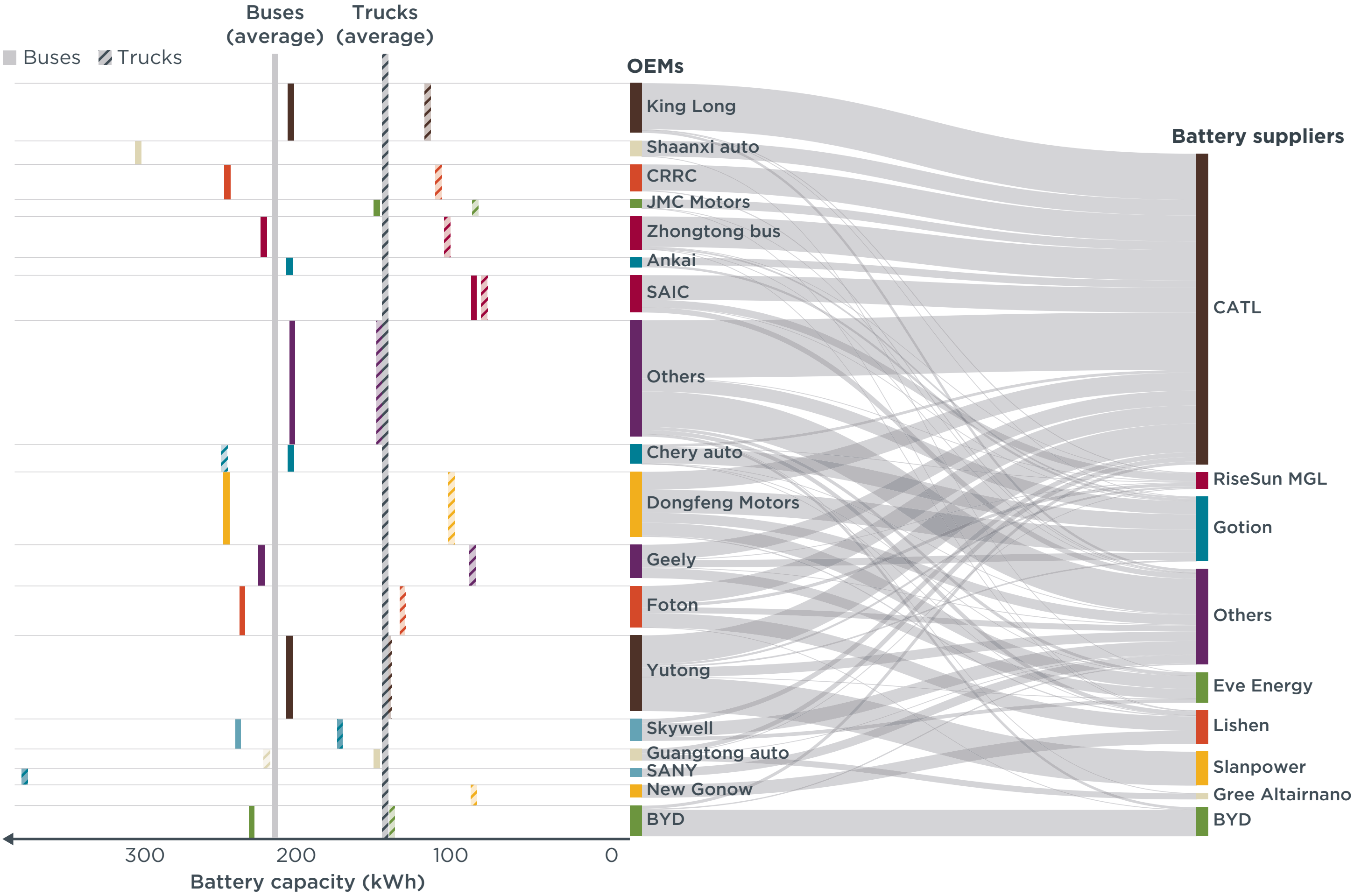

Figure 8. Supply relationship between battery supplier and OEMs. Gray bands on the right side represent battery capacities.

Specific energy of battery packs

The average specific energy of battery packs in electric buses and trucks are 155 and 108 Wh/kg, respectively (Figure 9). OEMs are incentivized to equip batteries with higher energy densities through a national subsidy scheme that sets minimum requirements on this metric, among other requirements. In 2021, the scheme required at least 135 Wh/kg for buses and 125 Wh/kg for trucks to qualify for the national subsidy (MOF, MIIT, MOT, NDRC, 2021).

The specific energy profile of trucks is much more varied than for buses. Some trucks are equipped with the most advanced batteries, at more than 200 Wh/kg, while for buses, the specific energy of battery packs ranges from ~140 to 160 Wh/kg. This also reflects the fact that electric trucks are more diverse in size and weight, and that for particular use cases, batteries of various specific energies are required.

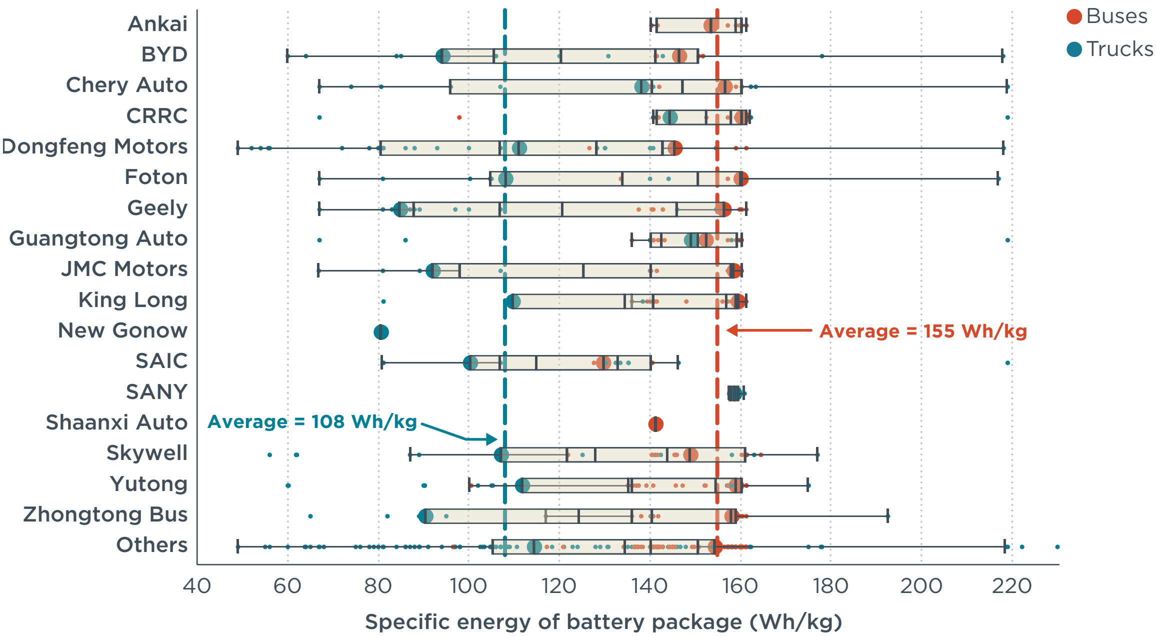

Figure 9. Specific energy of battery packs by OEM in 2021. The dot and bubbles depict individual and average specific energy for each OEM. The dash lines show average values across OEMs for buses (red) and trucks (blue), respectively.

E-range

In 2021, the average range of battery electric buses grew to ~440 km, while the average for trucks reached ~320 km (Figure 10). A study in 2019 reported that electric buses cannot fully support intercity travels. (Xue et al., 2019) Electric buses were not allowed to cover more than 170 km/d in Shenzhen and 100 km/d in Beijing and Tianjin in 2019 due to fleet operators' concerns (Xue et al., 2019). However, electric buses could cover much longer distances in 2021 even considering a ~30% decrease in range due to cold temperatures (Basma, 2020; L. Yang et al., 2022); a range of more than 200 km will fit most intracity transport needs. Shaanxi Auto, BYD, Skywell, CRRC, and Dongfeng Motors are manufacturers whose average e-ranges are greater than 500 km.

Rigid trucks (and tractors) face greater electrification challenges due to heavier payload and more severe working conditions. A more common use case for electric trucks is short-distance drayage and overnight charging. For example, Tangshan, a northern city known as a leading metal and steel production center in China, has adopted 1,000 electric trucks and tractors for delivery of ores and other raw materials (Chinatrucks, 2021). An earlier study by ICCT found that electric dump trucks will be the first vehicle segment to reach a breakeven total cost of ownership (TCO) vis-à-vis its diesel counterpart in China by no later than 2025 (Mao et al., 2021). Thus an electric model with a range of more than 300 km is very close to providing real-world service at an affordable cost.

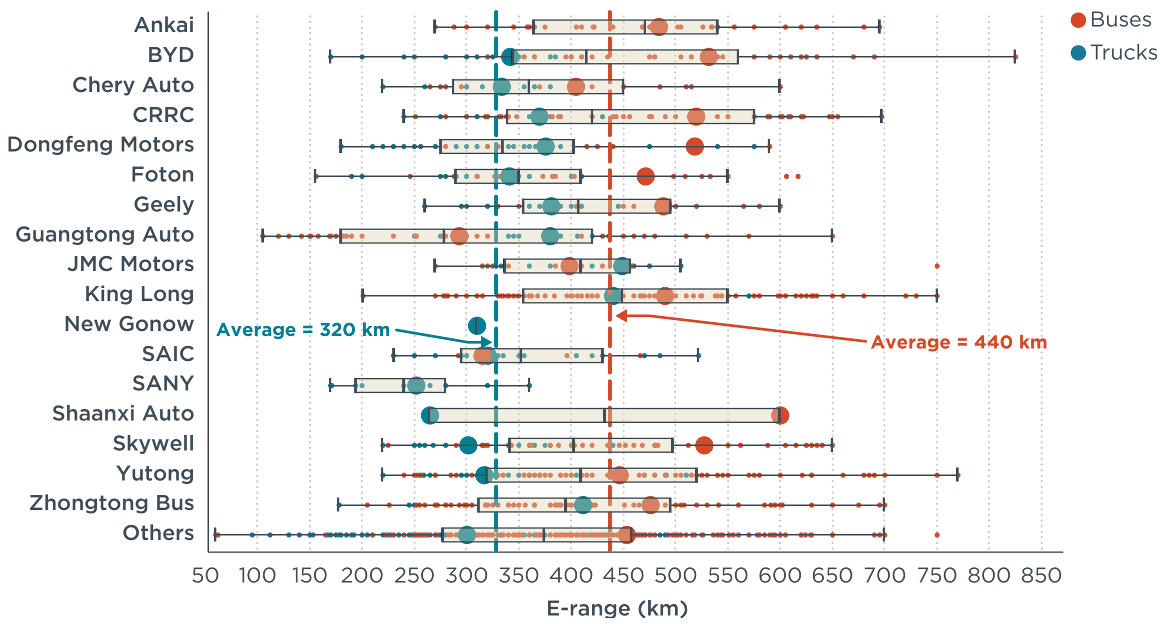

Figure 10. E-ranges by OEM in 2021. The dot and bubbles depict individual and average e-ranges for each OEM. The dashed lines show average values across OEMs for buses (red) and truck and tractor-trailers (blue), respectively.

Battery chemistry

Lithium-ion batteries typically consist of a graphite anode and a cathode that uses lithium-containing transition metal oxide or phosphate. More than 95% of ZE-HDVs in 2021 used lithium iron phosphate (LFP). The remainder of the market corresponds to batteries using lithium nickel manganese cobalt oxide (NMC) or lithium manganese oxide (LMO) at the cathode. Compared to NMC-based batteries, LFP-based batteries have a lower specific energy (kWh/kg) and energy density (kWh/L), but because they are cheaper, more durable, and safer, they are an attractive choice, especially for ZE-HDV applications. As LFP-based batteries contain neither cobalt nor nickel, their production is also less dependent on global supply chains. CATL produced NMC batteries for ~1,000 trucks with more than twice the specific energy compared to LFP counterparts in 2021. Depending on the relative shares of nickel, manganese, and cobalt, NMC111, NMC622, NMC532 and NMC811 can be distinguished. With a higher share of nickel, the energy content of the battery increases. At the same time, a lower cobalt share reduces overall raw material costs. Within the NMC family, the latest NMC811-based batteries are thus most competitive in terms of cost and performance. CATL has reportedly put the high energy NMC811 battery into mass production (Daly & Sun, 2019); in 2020, this battery technology suffered serious safety problems—specifically, spontaneous combustion—that damaged its reputation (Lima, 2020b; Y. Liu & Wang, 2020). However, NMC811 is a very promising technology if thermal management is improved. As of the end of 2021, NMC811 had been adopted by several mainstream OEMs such as BMW and Mercedes-Benz for use in passenger vehicles (Lima, 2020a; Toma, 2021).

The strong preference for LFP batteries in heavy-duty vehicles is different from passenger vehicles. In China, recent years saw a shift from cheaper LFP-based cells to higher-performing NMC-based cells, resulting in a NMC share of over 60% of installed capacity in 2021, according to market statistics (J. L. Liu et al., 2021). However, with increasing costs of nickel and cobalt on one side and improvements in the pack design of LFP batteries on the other, LFP-based batteries could gain back market share for passenger cars (IEA, 2022). In HDVs, the preference for LFP batteries reflects high price sensitivity; more than half of trucks are purchased using personal loans and leasing (CFLP, 2021). Furthermore, LFP batteries are attractive for HDVs because they require more durable batteries than passenger cars. With higher annual mileage over a comparable lifetime (Mulholland et al., 2022) in combination with a typically much lower electric range, electric HDVs need to be recharged at a much higher frequency than passenger cars. In addition, the national subsidy scheme does not ask for battery chemistry but for vehicle and battery performance metrics such as specific energy, driving range and energy consumption per payload, hence LFP is more welcome than NMC in China when performance of LFP batteries is good enough to be accepted through packing technologies such as Cell-To-Pack (CATL, 2022) and blade battery pack (BYD, 2021).

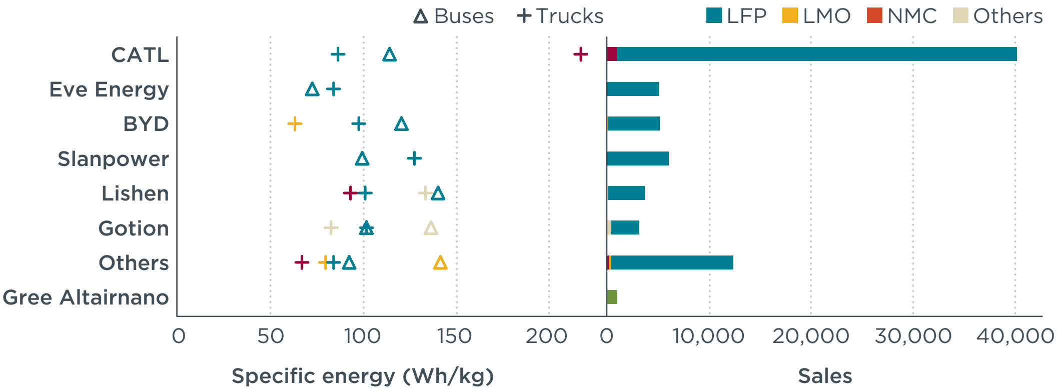

Figure 11. Battery chemistries in 2021

Battery swapping technology

Introduction

Battery swapping is an innovative technology and business model for battery electric vehicles. In contrast to plug-in charging, battery swapping technology replaces the depleted battery with a fully charged one. Figure 12 illustrates the main idea and mechanics for battery swapping technology.

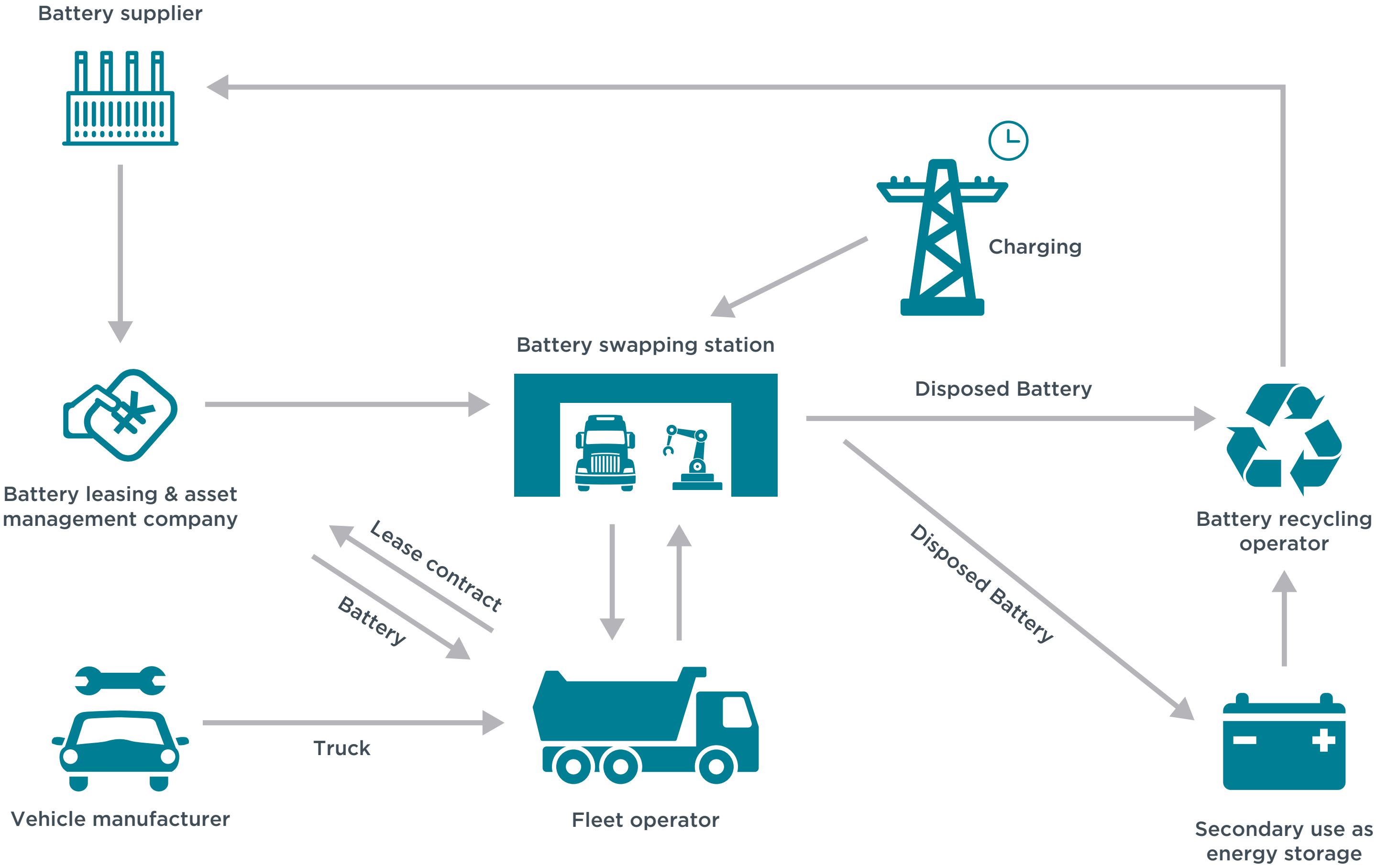

Figure 12. Mechanics of battery swapping business model

Specifically for heavy-duty vehicles, battery swapping technology can have several advantages over charging. First, battery swapping takes a shorter time to repower the truck than with charging technology of up to 10C[1] of charging rate, according to several real-world cases available in different regions (Rachwani, 2021; SANY, 2022; Wannan, 2022). It often takes at least 1 hour[2] to fully charge an electric truck with battery capacity of 300kWh (Gao et al., 2017; Kane, 2021).

Second, battery swapping introduces the concept of Battery-as-a-Service (BaaS). BaaS allows customers to pay for the glider truck and battery separately. Customers sign a lease contract with the battery swapping operator at a low or zero rate to reduce greatly the initial uptake cost. The high purchase cost of electric trucks affects adoption of electric heavy trucks for many local fleet operators (Mao et al., 2021). It is estimated that an electric truck could save up to 50% of initial cost by using a battery swapping service (Mao et al., 2021; Z. Yang, 2020).

Third, from a macro perspective, battery swapping may be regarded as a new way of storing energy that reduces impact on the grid; battery swapping stations can even feed back to the grid during the peak time and earn extra revenue (Hampel, 2022). Battery lifespan can be extended through the healthier charging represented by battery swapping, and by recycling the battery for secondary use after being disposed. Unlike fast charging that may degrade battery capacity and performance (Bhagavathy et al., 2021), battery swapping stations make organized and mild charging schemes more feasible and affordable.

1 10C of charging rate indicates the battery will be fully charged within 6 minutes.

2 Estimate based on a 500 kW/h ultra-fast charger with 300 kW/h of average charging speed in real use, due to decline of charging speed during the process (Siddiqi, 2022).

However, battery swapping also faces some challenges. The greatest barrier is the high capital expenditure of the battery swapping stations. A typical station may cost the equivalent of $230,000 to $630,000 in China (Z. Yang 2022), making it a capital-intensive venture. Also, battery swapping requires holding a stock of extra batteries to meet peaks in demand, so operators incur additional costs to run a battery swapping facility smoothly. The most fundamental concern in the long run for battery swapping technology is that batteries should be standardized across all OEMs in terms of size and capacity, which may pose challenges regarding patents, market access, and other variables in the future.

Policy supports

Rapid growth of battery swapping trucks is also driven by the promotional efforts of authorities and industry leaders, likely dating back to 2010 when the State Grid Corporation of China first introduced the concept of battery swapping (M. Yang, 2022). However, the concept of battery swapping was formally raised again by 2019 when the National Development and Reform Commission (NDRC), the Ministry of Commerce (MOC), and the Ministry of Ecology and Environment (MEE), announced support for promotion of battery swapping technology (NDRC et al., 2019). Dozens of policies were issued thereafter and pushed forward adoption of the nascent technology. Table 1 summarizes the milestone policies that were developed over the past decade.

Table 1. Summary of policies to promote battery swapping technology in recent years

Date	Issuing body	Title	Objectives
2022.03	MIIT	Highlights of automotive standardization work in 2022	• To accelerate the construction and improvement of electric vehicle charging and swapping standardization system • To promote standards of electric vehicle on-board charging and swapping systems, public swapping platform, and swapping battery packs, etc.
2021.10	MIIT	Notice regarding the launch of pilot projects of new energy vehicle battery swapping mode	• To launch the pilot projects of battery swapping in 11 cities • To promote production of at least 100,000 battery swapping vehicles and construction of 1,000 battery swapping stations
2021.05	NDRC	Implementation Opinions on Further Improving the Service Guarantee Capability of Charging and Battery Swapping Infrastructure	• To enhance the public charging and swapping service capacity • To promote the construction of charging and swapping facilities in townships
2020.05	State Council of China	Report on the work of the government	• To accelerate promotion of new facilities such as swapping stations
2020.04	MOF[a], MIIT[b], MOT[c] and NDRC	Notice on improving the financial subsidy policy for promotion and application of new energy vehicles	• To clarify that battery swapping vehicles are not subject to the hard cap[d] on the national subsidy for new type-approved models • To vigorously develop swapping technology
2019.07	MIIT	New Energy Vehicle Industry Development Plan (2021-2035)	• To encourage application of battery swapping mode
2019.06	NDRC, MOC and MEE	Implementation Plan for resource recycling and update of key consumer goods (2019-2020)	• To explicitly promote battery swapping and highlight its potential as an innovative business model
2010.08	State Grid Corporation of China	-	• To propose the concept of battery swapping on a mass scale

[a] Ministry of Finance

[b] Ministry of Industry and Information Technology

[c] Ministry of Transport

[d] OEMs are subject to a hard cap on national subsidies and must meet a set of technical metrics year by year. See Mao & Rodríguez, 2021.

Vehicle models

Demand for battery swapping trucks increased each month in 2021. A seasonal cycle of vehicle sales is also evident. In December, 747 battery swapping vehicles were sold, about a twenty-fold increase compared to January; battery swapping models also grew from 2 in January to 28 in December (Figure 13). Similar to the market pattern of charging technology, LFP batteries also dominated the market of battery swapping technology. As discussed in the section above, LFP batteries are more resilient to battery degradation than NMC batteries are. This characteristic also makes LFP batteries safer and more affordable for battery swapping (GGII, 2020).

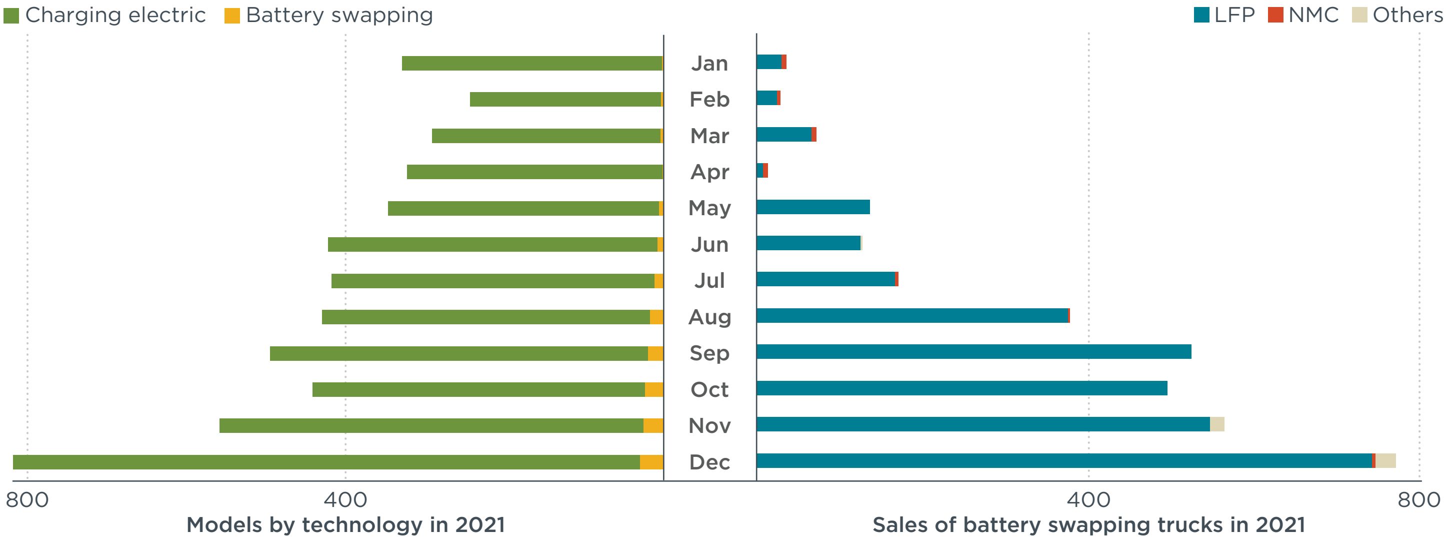

Figure 13. Models by technology and sales of battery swapping trucks in 2021

In 2021, CAMC, Hongyan, and FAW provided more than 500 battery swapping trucks, most of which had ranges of between 150 and 250 km and were shorter than charging models in general (Figure 14). Two models from Hongyan and Dayun are illustrated in Figure 15. Figure 16 presents a model during a battery swapping process.

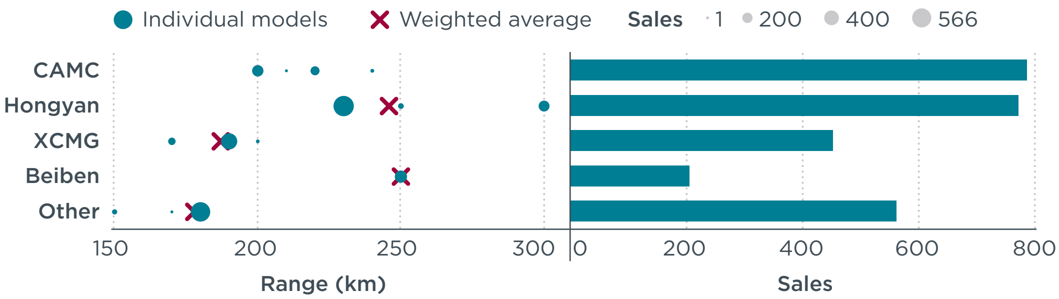

Figure 14. E-ranges of battery swapping vehicles in 2021

Hongyan Jieshi H6 **Dayun N8V**

Figure 15. Battery swapping vehicle models (Dayun, 2022; Hongyan, 2022)

Figure 16. Battery swapping in action (Etrucks, 2020)

Stations

Battery swapping stations also saw rapid growth over the past decade. In 2021, about half of newly set-up stations were for HDV models only (Figure 17). Populous regions, such as Beijing, Guangdong, and Zhejiang province, adopted the most battery swapping stations in 2021. Besides in-house stations operated by OEMs and battery suppliers such as NIO and CATL, a list of station operators also joined the game, including Aulton, Blue Park, and China Tower, among others (Ibold & Xia, 2022).

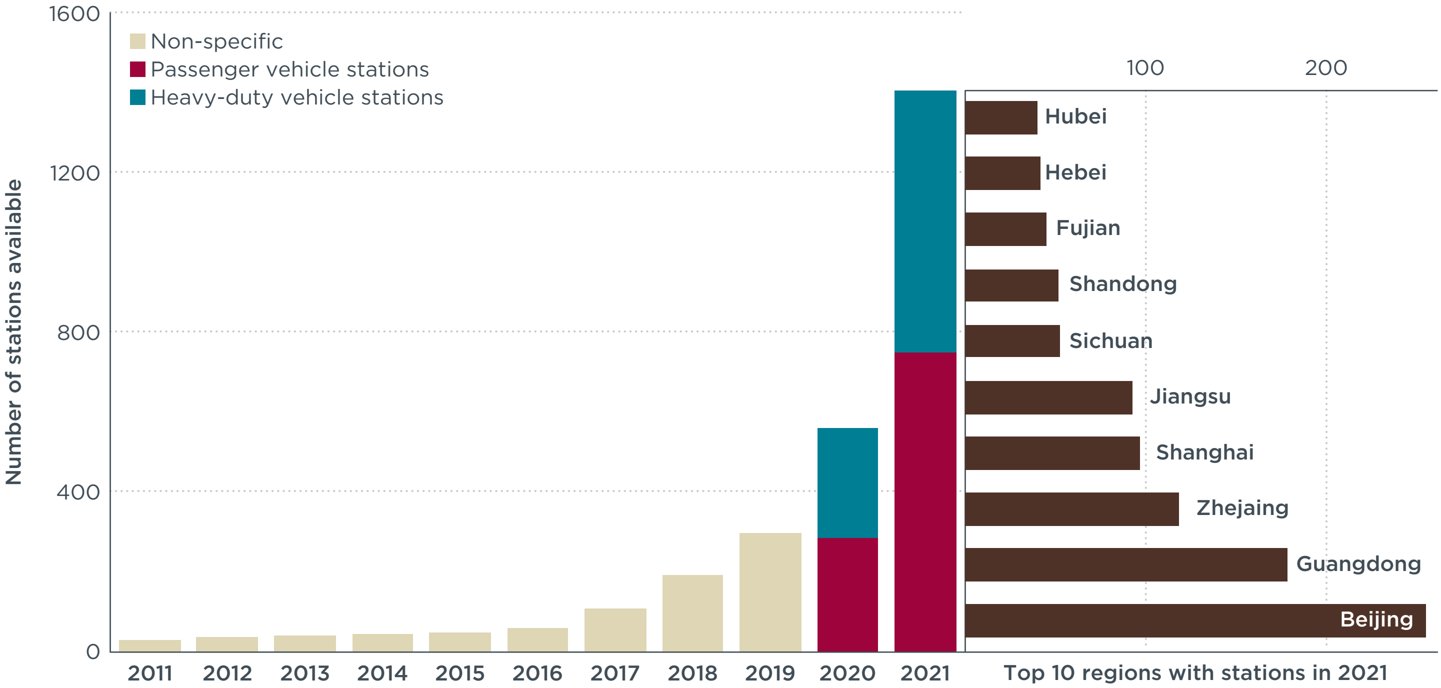

Figure 17. Battery swapping stations growth trend (iResearch Inc., 2022)

Fuel cell electric technology

Fuel cell electric vehicles saw 25% growth in 2021, with 1,876 sold (375 as tractor-trailers) out of ~130k total ZE-HDVs sales. (Figure 1, Figure 18, GGII, 2021). Fuel cell vehicles are still at a nascent stage. In the last 5 years, China sold 8,938 hydrogen-fueled vehicles in total, according to a market survey (The Orange Group, 2022). However, a goal of 50,000 hydrogen vehicles in use by 2025 was set by NDRC (NDRC, 2022), which may look for more supportive and promotional measures to be applied in coming years.

Fuel cell technology still faces difficulties in real-world application. Cost is the primary barrier. Fuel cell electric trucks may fail to achieve a breakeven point of total costs with diesel trucks before 2030 due to expensive hydrogen, according to a previous ICCT study (Mao et al., 2021).

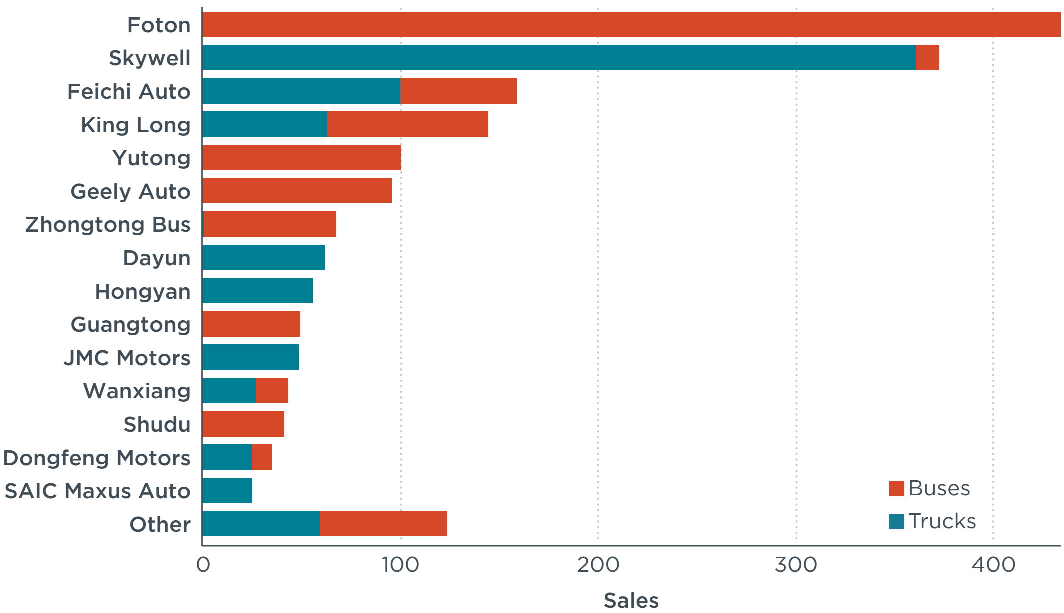

Figure 18. Sales of fuel cell electric HDVs in 2021

Key insights and takeaways

The Chinese market for electric trucks and buses is proliferating but is still small compared to conventional vehicles, accounting for just 4% of the market in 2021.

After a rapid contraction between 2016 and 2020—driven primarily by a reduction in subsidies—the market for zero-emission trucks and buses regained substantial ground in 2021, with about 130,000 units sold. These volumes are comparable to those in 2018 when subsidies were two and a half times greater. This decoupling of sales volumes and state subsidies is an encouraging sign, signaling the beginning of an independent and robust market for zero-emission heavy-duty vehicles.

While subsidies from the central government are important, the market is also driven by the increasing availability of ZE-HDVs, decreasing cost of ZE-HDVs, increasing awareness of the benefits of ZE-HDVs, and increasing number of provinces and cities that are launching pilots and adopting policies to promote the deployment of ZE-HDVs.

Our analysis yields the following findings:

» **The zero-emission truck race is reshuffling the market positioning of China's HDV behemoths**. Over half of the Chinese truck market is currently dominated by four manufacturers: FAW, Foton, Sinotruk, and Dongfeng. FAW and Sinotruk have been slow to embrace electric trucks, allowing Dongfeng to take the lead in the electric truck market and permitting newcomers to the truck market, such as Geely, to gain ground.

» **Buses dominate the ZE-HDV market, but electric trucks are on the rise.** Zero-emission trucks accounted for just over a quarter of all ZE-HDVs in 2021. The deployment has focused on the lighter segments, with small logistic trucks accounting for most electric truck sales. However, compared to 2020, heavier vehicle segments—such as tractor and dump trucks—are increasingly being electrified.

» **National subsidies play a role in picking winners and losers.** China provided large subsidies to ZE-HDV manufacturers to boost the industry. Top Chinese manufacturers of electric trucks and buses, such as BYD, Yutong, King Long, Zhongtong, and Dongfeng received the largest subsidies from the national government. Yutong and BYD were the biggest winners, with more than 6 billion CNY in subsidies awarded to each.

» **Battery suppliers are heavily consolidated, with CATL providing nearly 50% of the batteries in China's ZE-HDVs.** While CATL was the largest ZE-HDV supplier, there are other important players in the market, such as Gotion, Slanpower, Lishen, Eve Energy, and BYD. The latter is an example of successful vertical integration, as BYD is also one of the top electric truck and bus manufacturers.

» **Buses have more advanced battery technology while using the same battery chemistry.** Compared to electric trucks, the batteries in electric buses feature an energy density that, at over 150 Wh/kg, is almost 50% higher than the average of electric trucks. This enables longer ranges for electric buses at nearly 450 km on average, while the electric range of trucks is closer to 300 km. Over 95% of ZE-HDVs are equipped with lithium iron phosphate (LFP) batteries.

» **Fuel cell powertrains are at a nascent stage.** Fuel-cell trucks and buses represented less than 5% of ZE-HDVs in 2021—a 25% growth in market penetration compared to 2020. Foton dominated the fuel cell bus market, and Skywell did so on trucks. Still, each company managed to put around 400 fuel cell HDVs on the road in 2021.

» **Battery-swapping powertrains are skyrocketing in response to policy support.** Battery-swapping trucks represented more than 25% of the market, primarily driven by the pilot program in Tangshan. The leading manufacturers in 2021 were CAMC and Hongyan, each putting about 800 battery-swapping trucks into the market in 2021. The number of battery-swapping stations for trucks increased to 600 in 2021, roughly doubling the number of stations compared to 2020.

References

Amanda. (2018). *China bans local NEV protectionism*. Gasgoo. https://autonews.gasgoo.com/Detail2020.aspx?ClassId=7&ArticleId=70014002

Basma, H. (2020). Energy management strategies for battery electric bus fleet. In Http://www.theses.fr. Université Paris sciences et lettres. http://www.theses.fr/2020UPSLM036

Bhagavathy, S. M., Budnitz, H., Schwanen, T., & McCulloch, M. (2021). Impact of Charging Rates on Electric Vehicle Battery Life. *Findings*. https://doi.org/10.32866/001c.21459

BYD. (2021). *BYD's New Blade Battery Set to Redefine EV Safety Standards*. Https://En.Byd.Com/. https://en.byd.com/news/byds-new-blade-battery-set-to-redefine-ev-safety-standards/

CATL. (2022). *Innovative Technology*. https://www.catl.com/en/research/technology/

CFLP. (2021). *2021年货车司机从业状况调查报告*. https://news.alphalio.cn/PDF/2021%E5%B9%B4%E8%B4%A7%E8%BD%A6%E5%8F%B8%E6%9C%BA%E4%BB%8E%E4%B8%9A%E7%8A%B6%E5%86%B5%E8%B0%83%E6%9F%A5%E6%8A%A5%E5%91%8A%E3%80%8B-%E4%B8%AD%E5%9B%BD%E7%89%A9%E6%B5%81%E4%B8%8E%E9%87%87%E8%B4%AD%E8%81%94%E5%90%88%E4%BC%9A-2021.6-36%E9%A1%B5.pdf

China Daily. (2021). *China's leading truck brand speeds up new energy transformation*. //global.chinadaily.com.cn/a/202109/30/WS61551c20a310cdd39bc6c8ef.html

Chinatrucks. (2021). *SAIC Hongyan Delivers 1,000 Units Electric Heavy-duty Trucks to Tangshan—China Truck News* -www.chinatrucks.com. https://www.chinatrucks.com/news/2021/0519/article_9623.html

Daly, T., & Sun, Y. (2019, April 30). China's CATL starts mass production of high-nickel batteries: Chairman. *Reuters*. https://www.reuters.com/article/us-china-batteries-catl-idUSKCN1S60YM

Dayun. (2022). *N8V 6*4充换一体版牵引车*. https://www.dayunmotor.com/product-productdetail-424-264

Dongfeng Motor. (2022). *Dongefeng Motor products*. https://www.dfm-global.com/pr.jsp

Electric Vehicle Research. (2018, August 16). *Dongfeng Motor Green Plan includes 20 electrified models by 2022*. Electric Vehicles Research. https://www.electricvehiclesresearch.com/articles/15108/dongfeng-motor-green-plan-includes-20-electrified-models-by-2022

Etrucks. (2020). *Battery swap system in action*. https://etrucks.co.nz/battery-swap-system-in-action/

European Environment Agency. (2020). *Carbon dioxide emissions from Europe's heavy-duty vehicles* [Briefing]. https://www.eea.europa.eu/themes/transport/heavy-duty-vehicles

FuelCellsWorks. (2022). *Qingdao Port Becomes The World's First Hydrogen-Powered And 5G Intelligent Port*. https://fuelcellsworks.com/news/qingdao-port-becomes-the-worlds-first-hydrogen-powered-and-5g-intelligent-port/

Gao, Z., Lin, Z., LaClair, T. J., Liu, C., Li, J.-M., Birky, A. K., & Ward, J. (2017). Battery capacity and recharging needs for electric buses in city transit service. *Energy*, *122*, 588–600. https://doi.org/10.1016/j.energy.2017.01.101

Geely New Energy Commercial Vehicle Group. (2021). The Geely Commercial Vehicles You Never Knew Existed. *Media Center - Zhejiang Geely Holding Group*. http://zgh.com/media-center/story/the-geely-commercial-vehicles-you-never-knew-existed/?lang=en

GGII. (2020). *GGII：LFP涌向共享换电 "蓝海"* https://www.gg-ii.com/art-2682.html

GGII. (2021). *2020氢燃料电池汽车销量TOP10城市*. https://www.china5e.com/news/news-1108645-1.html

Hampel, C. (2022, August 23). *Nio's battery swapping stations support China's grid*. Electrive.Com. https://www.electrive.com/2022/08/23/nios-battery-swapping-stations-support-chinas-grid/

Hongyan. (2022). 红岩杰狮—上汽红岩. https://www.hongyantruck.com/html/xnyhyjs/20210831/1464.shtml

Ibold, S., & Xia, Y. (2022). *Overview on Battery Swapping and Battery-as-a-Service (BaaS) in China*. Giz. https://transition-china.org/wp-content/uploads/2022/08/Battery_Swapping_20220809.pdf

IEA. (2022). *Global EV Outlook 2022*. IEA. https://www.iea.org/reports/global-ev-outlook-2022

iResearch Inc. (2022). *2021年中国新能源汽车换电市场研究报告*. https://pdf.dfcfw.com/pdf/H3_AP202205111564927543_1.pdf?1652289946000.pdf

Kane, M. (2021). *Electric Trucks Take Over Fast Charging Station*. InsideEVs. https://insideevs.com/news/486675/electric-trucks-takeover-fast-charging-station/

King Long. (2022a). *Electric City Bus,New Energy City Bus,Large City Bus,Mini City Bus*. https://www.king-long.com/city-buses_c3

King Long. (2022b). *New Energy Vehicle,New Energy Buses,Electric City Bus*. https://www.king-long.com/electric-vehicles_c1

Koop, F., Andreoni, M., Bermudez Lievano, A., & Cuellar, A. (2020, July 6). Chinese electric buses roll out across Latin America. *Dialogo Chino*. https://dialogochino.net/en/climate-energy/36128-chinese-electric-buses-rollout-across-latin-america/

Li, Y., & Du, J. (2015). 调查新能源汽车地方保护主义一：封闭的多数. https://www.diandong.com/news/3943.html

Lima, P. (2020a, July 15). *BMW iX3 gets a NCM 811 battery from CATL*. https://pushevs.com/2020/07/15/bmw-ix3-gets-a-ncm-811-battery-from-catl/

Lima, P. (2020b, September 28). *CATL's NCM 811 battery cells are problematic*. https://pushevs.com/2020/09/28/catl-ncm-811-battery-cells-are-problematic/

Lin-Gang Special Area. (2020). *Battery-swapping electric trucks to operate in Lin-gang*. https://en.lgxc.gov.cn/2020-08/19/c_530121.htm

Liu, J. L., Dong, R., & Danilovic, M. (2021). *Exploring Battery Technology For Electrical Vehicles In China 1.0.* (p. 39). https://www.hh.se/download/18.7eaff88717cab27dfb8c9be2/1635154259390/Sweden-China%20Bridge%20-%20Battery%20Technology%20in%20China%201.0%5B70%5D.pdf

Liu, Y., & Wang, F. (2020). *The NCM811 Battery has Become CATL's Largest Crisis*. EqualOcean. https://equalocean.com/analysis/2020083014673

Mao, S., Basma, H., Ragon, P.-L., Zhou, Y., & Rodríguez, F. (2021). *Total cost of ownership for heavy trucks in China: Battery electric, fuel cell, and diesel trucks*. International Council on Clean Transportation. https://theicct.org/publication/total-cost-of-ownership-for-heavy-trucks-in-china-battery-electric-fuel-cell-and-diesel-trucks/

Mao, S., & Rodríguez, F. (2021). *Race to zero: How manufacturers are positioned for zero-emission commercial trucks and buses in China*. International Council on Clean Transportation. https://theicct.org/publication/race-to-zero-how-manufacturers-are-positioned-for-zero-emission-commercial-trucks-and-buses-in-china/

MIIT. (2021). 工业和信息化部启动新能源汽车换电模式应用试点工作. https://www.miit.gov.cn/xwdt/gxdt/sjdt/art/2021/art_c73f1ade7759456fa18586114b555238.html

MOF, MIIT, MOT, NDRC. (2021). 四部委关于进一步完善新能源汽车推广应用财政补贴政策的通知. https://www.miit.gov.cn/xwdt/gxdt/sjdt/art/2021/art_a42ae2cf64d34e0a9c4bf97a37b71c64.html

Mulholland, E., Miller, J., Braun, C., Sen, A., Ragon, P.-L., & Rodríguez, F. (2022). *The CO_2 standards required for trucks and buses for Europe to meet its climate targets*. International Council on Clean Transportation. https://theicct.org/publication/hdv-co2standards-recs-mar22/

NDRC. (2022). *氢能产业发展中长期规划（2021-2035）*. https://www.ndrc.gov.cn/xxgk/zcfb/ghwb/202203/P020220323314396580505.pdf

NDRC, MOC, & MEE. (2019). *推动重点消费品更新升级 畅通资源循环利用实施方案（2019-2020*). https://www.mct.gov.cn/preview/whhlyqyzcxxfw/yshjxf/202012/P020210119495731498668.pdf

Rachwani, M. (2021, April 28). Swap and go: Electric trucks to run between Sydney and Brisbane using exchangeable batteries. *The Guardian*. https://www.theguardian.com/australia-news/2021/apr/29/swap-and-go-electric-trucks-to-run-between-sydney-and-brisbane-using-exchangeable-batteries

Randall, C. (2021, October 29). *China to introduce battery swapping programme*. Electrive.Com. https://www.electrive.com/2021/10/29/chinese-government-to-introduce-battery-swapping-programme/

SANY. (2022). *SANY's first intelligent battery swapping station debuts*. https://www.sanyglobal.com/press_releases/729/

Siddiqi, S. (2022, March 23). *Not So Fast: EV Charging Rates Make a Difference*. IDTechEx. https://www.idtechex.com/en/research-article/not-so-fast-ev-charging-rates-make-a-difference/26250

Sustainable Bus. (2022a). *70,000 e-buses delivered by BYD worldwide (2.5% of them in Europe). 5.5 billion km covered*. https://www.sustainable-bus.com/electric-bus/byd-70000-electric-buses/

Sustainable Bus. (2022b, February 10). *More than 800 hydrogen buses at the Beijing Winter Olympics: A gold medal result*. Sustainable Bus. https://www.sustainable-bus.com/fuel-cell-bus/more-than-800-hydrogen-buses-at-the-beijing-winter-olympics/

Tencent News. (2022). *中汽协：2021新能源商用车年销18.6万辆，渗透率近4%*. https://new.qq.com/omn/20220113/20220113A02BAF00.html

The Orange Group. (2022). *2021年全国燃料电池汽车产销1777辆/1586辆*. https://libattery.ofweek.com/2022-01/ART-36008-8420-30545694.html

Toma, S. (2021, July 22). *EQS is Just the Beginning—Here's the Future of Mercedes' EV Battery Tech*. Autoevolution. https://www.autoevolution.com/news/eqs-is-just-the-beginning-here-s-the-future-of-mercedes-ev-battery-tech-165791.html

Wannan, O. (2022, September 14). *Electric truck swaps battery faster than it takes to fill a tank*. Stuff. https://www.stuff.co.nz/environment/climate-news/129812483/electric-truck-swaps-battery-faster-than-it-takes-to-fill-a-tank

Xinhua News. (2022). *China's electric automaker BYD witnesses dreams "being built" for China-U.S. cooperation*. https://english.news.cn/20220303/611c7d0777fa4c6fbf4d9d157a10a4fe/c.html

Xue, L., Liu, D., Wei, W., & Liu, P. (2019). *Overcoming The Operational Challenges Of Electric Buses: Lessons Learnt From China*. World Resources Institute. https://wri.org.cn/en/research/overcoming-operational-challenges-electric-buses

Yan, Zhang, Brenda Goh, Christoph Steitz and Christina Amann. (2022, August 12). "China's CATL to build $7.6 bln Hungary battery plant to supply Mercedes, BMW." *Reuters*. https://www.reuters.com/business/autos-transportation/chinas-catl-build-new-756-bln-battery-plant-hungary-2022-08-12/

Yang, L., He, H., Xie, Y., & Mao, S. (2022). *Measures for Reducing Greenhouse Gas Emissions from Motor Air Conditioning in China* (Mobile Air Conditioning System) [Working Paper]. ICCT. https://theicct.org/publication/mac-ghg-china-lvs-feb22/

Yang, M. (2022). 关于换电重卡的相关研究（上）：概述与发展现状 | 龙志刚专栏. https://www.dahecube.com/article.html?artid=127387?recid=4

Yang, Z. (2020). 换电模式下电动重卡即将"起飞." China Battery Enterprise Alliance. https://nev.ofweek.com/2020-12/ART-71011-8120-30477196.html

Yang, Z. (2022, March 21). *EV battery swapping was left for dead. Now, it's being revived in China.* Protocol. https://www.protocol.com/climate/electric-vehicle-battery-swap-china

Appendix – Key metrics of popular OEMs

Trucks

Yutong Group	
Subsidiary entity for HD-NEVs	Zhengzhou Yutong Group Co., Ltd., Zhengzhou Yutong Heavy Industry Co., Ltd.
Business type	Public
Market share	22.30%
GVW range(kg)	6200-32000
Available brand(s)	Yutong
Zero-emission technology	BEV-BC[3]
Sales in 2021	1424
Battery chemistry	LFP
Max range (km)	480
Max battery capacity (kWh)	350
Max specific energy (Wh/kg)	161

Sany	
Subsidiary entity for HD-NEVs	Sany Automobile Manufacturing Co., Ltd.
Business type	Public
Market share	15.7%
GVW range (kg)	25000-33600
Available brand(s)	Sany
Zero-emission technology	BEV-BC
Sales in 2021	1001
Battery chemistry	LFP
Max range (km)	360
Max battery capacity (kWh)	424
Max specific energy (Wh/kg)	161

King Long			
Subsidiary entity for HD-NEVs	Nanjing Golden Dragon Bus Co., Ltd.		
Business type	Public		
Market share	8.0%		
GVW range(kg)	3570-32000		
Available brand(s)	Higer, King Long, King Lv, Skywell		
Zero-emission technology	BEV-BC	BEV-BS	FCEV
Sales in 2021	139	63	310
Battery chemistry	LFP	LFP	LFP
Max range (km)	480	255	450
Max battery capacity (kWh)	350	350.07	--
Max specific energy (Wh/kg)	158	158.69	--

3 Battery Charging

Buses

Yutong		
Subsidiary entity for HD-NEVs	Zhengzhou Yutong Bus Co., Ltd.	
Business type	Public	
Market share	23.25%	
GVW range (kg)	6200-28000	
Available brand(s)	Yutong	
Zero-emission technology	BEV-BC	FCEV
Sales in 2021	21094	200
Battery chemistry	LFP, LMO	LFP
Max range (km)	770	755(+)/170(-)[4]
Max battery capacity (kWh)	564	--
Max specific energy (Wh/kg)	161	--

King Long		
Subsidiary entity for HD-NEVs	HIGER BUS Company Limited, Xiamen King Long United Automotive Industry Co., Ltd.	
Business type	Public	
Market Share	17.75%	
GVW range(kg)	4500-28000	
Available brand(s)	Higer, King Long, King Lv, Skywell	
Zero-emission technology	BEV-BC	FCEV
Sales in 2021	16724	188
Battery chemistry	LFP, LMO, Supercapacitor	LFP, LMO
Max range (km)	750	560(+)/180(-)
Max battery capacity (kWh)	427	--
Max specific energy (Wh/kg)	165	--

Zhongtong Bus		
Subsidiary entity for HD-NEVs	Zhongtong Bus Holding Co., Ltd.	
Business type	State-owned; Public	
Market share	10.27%	
GVW range (kg)	3510-18000	
Available brand(s)	Zhongtong	
Zero-emission technology	BEV-BC	FCEV
Sales in 2021	9692	134
Battery chemistry	LFP, LMO	LFP, LMO
Max range (km)	700	510(+)/165(-)
Max battery capacity (kWh)	350	--
Max specific energy (Wh/kg)	161	--

4 + means “Hydrogen system working”,- means “Hydrogen system not working”.

Tractor-trailers

Foton	
Subsidiary entity for HD-NEVs	Foton Motor, Inc.
Business type	State-owned; Public
Market share	13.1%
GVW range(kg)	25000
Available brand(s)	Foton
Zero-emission technology	BEV-BC
Sales in 2021	722
Battery chemistry	LFP
Max range (km)	200
Max battery capacity (kWh)	282
Max specific energy (Wh/kg)	160

SAIC			
Subsidiary entity for HD-NEVs	SAIC-IVECO Hongyan Commercial Vehicle Co., Ltd.		
Business type	State-owned; Public		
Market share	12.1%		
GVW range (kg)	18000-25000		
Available brand(s)	Hongyan		
Zero-emission technology	BEV-BC	BEV-BS[5]	FCEV
Sales in 2021	2	611	56
Battery chemistry	LTO	LFP	LFP
Max range (km)	--	250	420(+)/90(-)
Max battery capacity (kWh)	--	282	--
Max specific energy (Wh/kg)	--	156.32	--

BEIBEN	
Subsidiary entity for HD-NEVs	Baotou Bei Ben Heavy-Duty Truck Co., Ltd
Business type	State-owned
Market share	9.67%
GVW range(kg)	25000
Available brand(s)	Beiben
Zero-emission technology	BEV-BC
Sales in 2021	533
Battery chemistry	LFP
Max range (km)	210
Max battery capacity (kWh)	282
Max specific energy (Wh/kg)	158

5 Battery Swapping