Smart Freight Centre China

ZERO EMISSION FREIGHT INITIATIVE

北京智慧绿行科技有限公司
BEIJING SMART GREEN TRANSPORT TECHNOLOGY CO., LTD.

ENERGY FOUNDATION 能源基金会
SUSTAINABLE ENERGY, PROSPEROUS FUTURE

China Zero Emission Freight Status Report 2023

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Acknowledgements

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About Smart Freight Centre China

Smart Freight Centre China's vision is an efficient and zero emission global logistics sector. Smart Freight Centre China's mission is to collaborate with the organization's global partners to quantify impacts, identify solutions, and propagate logistics decarbonization strategies. Smart Freight Centre China's goal is to guide the China logistics industry in tracking and reducing the industry's greenhouse gas emissions to reach zero emissions by 2050 or earlier, consistent with a 1.5°C future.

About Zero Emission Freight Initiative

Supported by Energy Foundation, ZEFI is a non-profit, voluntary partnership that aligns research institutions, OEMs, key equipment and parts production and suppliers, energy production and suppliers, shippers, logistics and transportation companies, industry associations and other relevant stakeholders. The vision for ZEFI is to accelerate the adoption of zero emission trucks and related freight efficiency solutions in China by enabling 1) Collaboration between key stakeholders; 2) Supportive policies, programs, and strategies; and 3) Consensus building among stakeholder on ZEFV pathways for China. The secretariat of ZEFI is set in Smart Freight Centre China. Go to https://www.smartfreightcentre.org/en/our-programs/zero-emission-freight-initiative/ to learn more about ZEFI.

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1 Background, Purpose and Scope

Since the Paris Agreement, climate change has remained a central topic in global discussions among governments and world leaders, creating a consensus on the urgency of reaching peak carbon emissions and achieving carbon neutrality as soon as possible. As a key global stakeholder, China announced its Carbon Peaking and Carbon Neutrality Goals in September 2020, which outlined a two-stage strategy to achieve peak carbon dioxide emissions before 2030 and carbon neutrality by 2060.

A critical area of focus for China in this process is the decarbonization of the transportation sector, which currently accounts for about 10% of China's total carbon emissions. Road transportation alone contributes to over 85% of these emissions, making it the primary target for reduction efforts. Despite comprising only 11% of vehicle ownership in China, trucks account for about 47% of transportation-related carbon emissions. The need for transformation in this sector is extremely urgent and China has prioritized the transition to zero-emission freight transportation in achieving what it has termed its "Dual Carbon Goals".

To provide additional insight into the progress of these efforts, Smart Freight Centre China, as the Secretariat of Zero Emission Freight Initiative (ZEFI), in collaboration with Beijing Smart & Green Transport Research Center, has produced *China Zero Emission Freight Annual Status Report 2023*, which examines developments and challenges in zero-emission road freight from 2022 to 2023, focusing on four key areas:

- Policies related to zero-emission freight
- Current technological and market developments in zero-emission trucks
- Development and management of zero-emission freight refueling and charging infrastructure
- Assessment of pollutant and carbon reduction benefits of zero-emission trucks

This report analyzes major trends and summarizes key data, supported by case studies, to provide a point of reference for the freight industry, government decision-makers, cargo owners and research institutions in the development of zero-emission freight in China.

2 An Overview of China's Freight Industry and Zero-Emission Freight Vehicles

Between 2022 and 2023, demand in the freight industry showed positive growth despite fluctuations. In 2022, the freight industry contracted due to the impact of COVID-19 with total freight volume and road freight volume decreasing by 2.9% and 5.1% respectively compared to 2021. However, in 2023, the sector rebounded, with total freight volume and road freight volume increasing by 8.1% and 8.7% year-on-year.

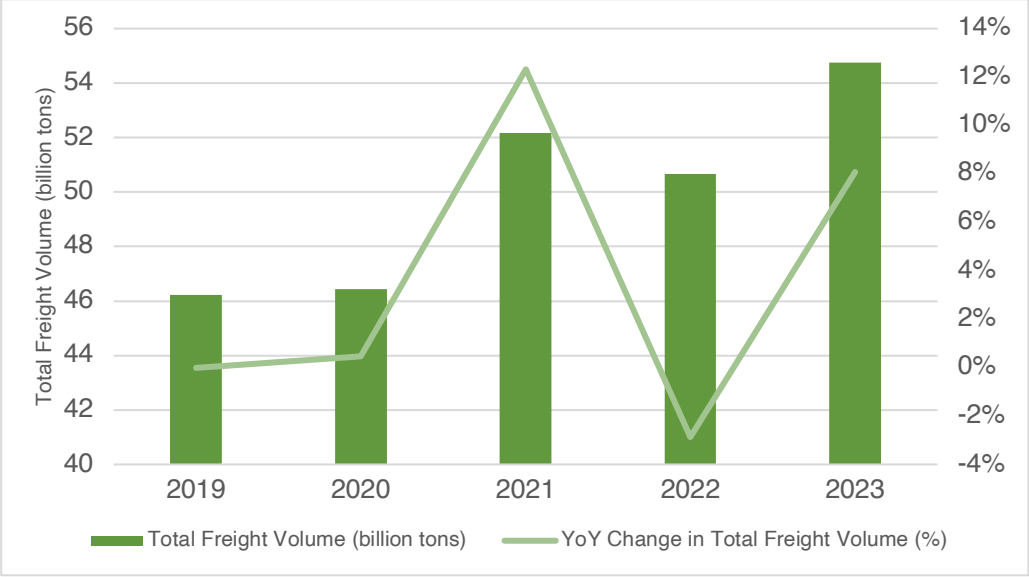

Figure 1: China's total freight volume and year-over-year changes (2019-2023)(Statistical Bulletin on the Development of the Transportation Industry. 2023).

In 2022, the total value of social logistics goods in China—which measures the total value of goods that enter the domestic demand field for the first time, generating the physical flow from the supply location to the receiving location, including industrial products, agricultural products, recycled resources, goods for entities and residents, and imported goods—was RMB 347.6 trillion, an increase of 3.4% in comparable prices. In 2023, the total value was RMB 352.4 trillion, marking a 5.2% increase in volume.

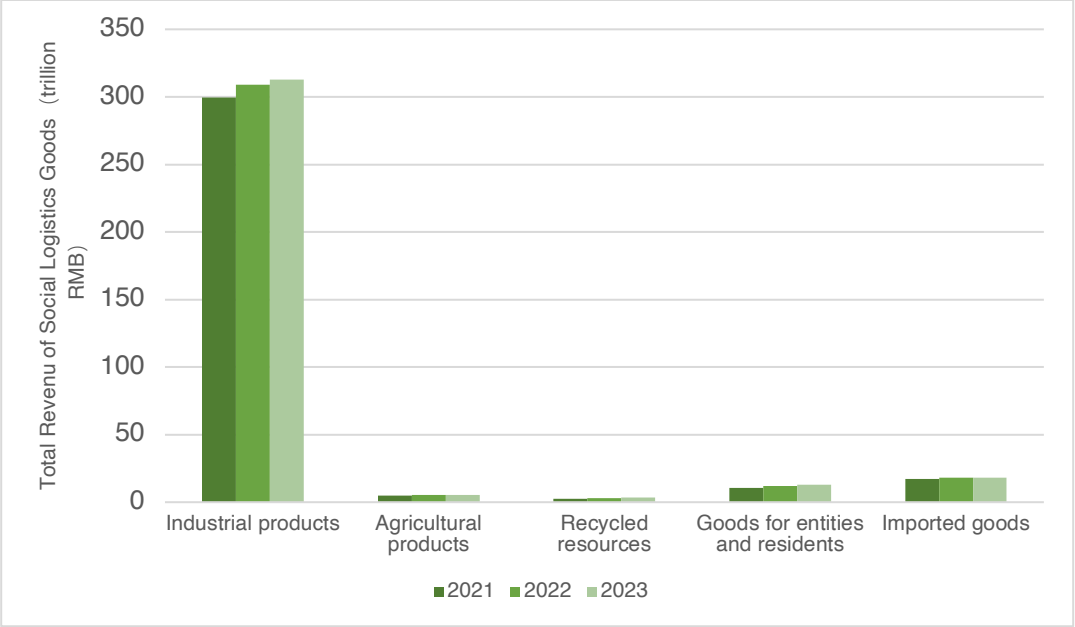

Figure 2: Total Revenue of Social Logistics Goods by Type of Goods in Trillion RMB (2021 – 2023) (Data Source: China Federation of Logistics and Purchasing. 2023).

The overall composition of the transport industry remained stable, with a slight decline in the average transport distance for road freight. In 2023, road freight accounted for 73.7% of total freight volume, down from 74.3% in 2019. Conversely, the combined share of rail and water freight increased to 26.3% from 25.7% in 2019.

Figure 3: Road Freight Volume and Total Freight Volume (2019-2023) (Statistical Bulletin on the Development of the Transportation Industry. 2023).

Changes in demand for logistics services and related policies have influenced the composition of road freight. The average transport distance for road freight fell to 183 kilometers in 2023, a 1.3% decline. Meanwhile, since the second half of 2022, the proportion of long-distance road freight has decreased, while the number of short to medium-distance hauls has increased. For example, routes over 500 kilometers have dropped by 15%, while those over 200 kilometers fell by 8%. These changes reflect recent shifts in structure of the transport sector, related policies, and evolving market demand.

The truck market continues to show development toward opposite ends of the spectrum with increased numbers in light and heavy-duty trucks. Increased specialization has also been observed. Sales of medium-duty trucks have consistently declined by 73% from 2013 to 2022. In contrast, sales of light and heavy-duty trucks have shown growth. The total truck ownership in 2022 increased by 1.8% compared to 2021. In addition, specialized trucks and tractor units have also seen growth.

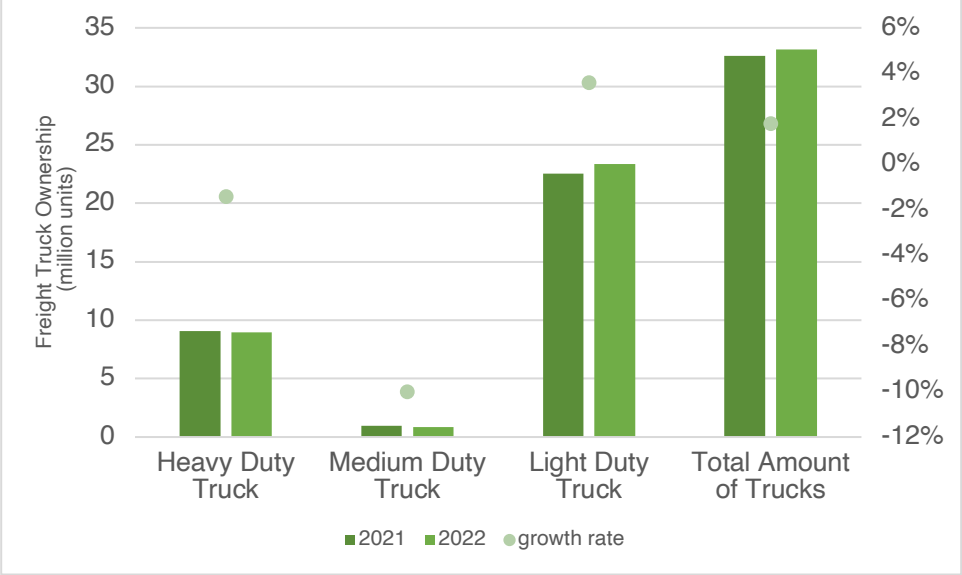

Figure 4: Ownership and growth rate of different types of freight trucks. (Statistical Bulletin on the Development of the Transportation Industry. 2022).

The load capacity of trucks has also increased over the years. The average load capacity of large freight vehicles has increased to 21.8 tons per vehicle. Tractor trucks remain the dominant model in road freight, accounting for 48.6% of the total, followed by dump trucks and stake trucks at 18.6% and 11.4% respectively.

In 2023, the share of market revenue among the top 50 logistics companies increased, but the overall market remained fragmented with small-scale enterprises, individual operators, and contracted fleets dominating the sector. To remain competitive, logistics companies are increasingly forced to reduce costs and increase efficiency. Cost-reduction and efficiency-enhancement measures implemented by the government in the transportation and logistics sectors has achieved notable progress and, in 2023, the ratio of total social logistics costs[1] to GDP was 14.4%, down 0.3% from 2019, and 2.2% compared to 2014.

1. Total social logistics costs refer to the total expenditure across various aspects of the national economy for social logistics activities. This includes expenses paid for each logistics link, such as transportation, storage, loading and unloading, packaging, distribution processing, delivery, and information processing.

3 Zero-Emission Truck Related Policies

In 2022 and 2023, the market share of zero-emission trucks, often referred to as new energy trucks in China, steadily increased compared to previous years. This was largely due to a strong policy drive by both central and local governments. The introduction of a number of development programs, environmental policies, subsidy schemes, road rights policies, and infrastructure initiatives provided critical support and momentum for the transition to zero-emission trucks, collectively driving the increased adoption of zero-emission trucks during this period. The following sections will discuss how individual measures have impacted the development of zero-emission trucks in China.

3.1 Policies on Light-Duty Trucks in Urban Scenarios

For light-duty trucks, which are primarily used in urban delivery, municipal sanitation, and similar applications, policy efforts are mainly focused on promoting the adoption of zero-emission vehicles for newly added and replacement vehicles in the public sector. The main policy efforts include the following:

- Public Sector Fleet Electrification: These measures focus on ensuring that new and replacement vehicles in public sector use are new energy vehicles. In January 2023, the Ministry of Industry and Information Technology launched a pilot program to fully electrify public sector vehicles, which mandates a significant increase in the proportion of new energy vehicles when adding or and replacing vehicles in public sector fleets.
- Targeted Vehicle Categories: These policies target specific sectors such as municipal buses, taxis, sanitation vehicles, postal and courier services, and urban delivery services with the goal of making 80% of vehicles in these categories new energy vehicles.
- Creation of Pilot Cities: In November 2023, 15 cities including Beijing, Shenzhen, and Chongqing were selected as the first batch of pilot cities for the full electrification of public sector vehicles. These cities will lead the transition and set benchmarks for others to follow.

3.2 Policies on Heavy-Duty Trucks Used in the Industrial Sector

Policies targeting heavy trucks have primarily focused on promoting zero-emission trucks in high-emission industrial sectors. In June 2023, the Ministry of Ecology and Environment issued draft opinions to promote ultra-low emission technologies in the cement and coking industries, which include the following requirements for the transportation of raw materials and products:

- Enterprises must use clean transportation methods (rail, water, pipelines, or tubular belt conveyors) for at least 80% of their inbound and outbound materials.
- For companies not meeting this threshold, product transportation should prioritize the use of clean methods and all automotive transport must use new energy vehicles or those compliant with China VI emission standards.
- Within the production facilities, all transport vehicles should be new energy vehicles.

3.3 Policies on Hydrogen Fuel Cell Trucks

The promotion of hydrogen fuel cell trucks has been a key policy focus in recent years, with comprehensive policies covering the entire hydrogen energy chain from production and storage to transportation and utilization. Key initiatives include:

- Building a Comprehensive Hydrogen Energy Chain: These policies focus on the development of standards for the entire hydrogen energy chain, including production, storage, transportation, and utilization, as well as hydrogen fuel cell vehicle trial programs.
- Hydrogen Industry Development Plan: In March 2022, the National Development and Reform Commission and the National Energy Administration jointly released a "Medium and Long-Term Plan for the Development of the Hydrogen Energy Industry (2021-2035)", which sets some ambitious targets. The Chinese government's goal is to master core technologies and manufacturing processes, with the goal of having approximately 50,000 fuel cell vehicles in operation by 2025. It also hopes to build several hydrogen refueling stations capable of producing 100,000-200,000 tons of renewable energy-based hydrogen annually. By 2030, the government also aims to create a comprehensive hydrogen industry innovation scheme and a clean energy system for the production and supply of hydrogen fuel. Finally, by 2035, China plans to diversify application within the hydrogen ecosystem, significantly increasing the proportion of renewable energy-based hydrogen in end-use energy consumption.
- Promotion of Hydrogen Fuel Cell Vehicles: The promotion of HFCVs particularly focuses on medium and heavy-duty vehicles and encourages market expansion in hydrogen fuel cell buses and trucks to create a mutually beneficial development model that integrates both fuel cell electric vehicles and lithium battery electric vehicles. By targeting heavy-duty vehicles and fostering a diverse market, this plan seeks to leverage the strengths of both technologies to accelerate the transition to zero-emission transportation.

3.4 Environmental Policies for Zero-Emission Freight

As China's air quality continues to improve, environmental policies related to zero-emission freight have primarily focused on promoting low-emission and zero-emission trucks in key public sectors and industries. Key policy actions include:

- Air Quality Improvement: In November 2023, the State Council released its "Action Plan for Continued Air Quality Improvement" which calls for:
  - Prioritizing railway and waterway transport for the long-distance transportation of bulk goods and using enclosed belt corridors or new energy vehicles for short-distance transport.
  - Accelerating the adoption of clean vehicles, particularly in key regions.
  - Ensuring that at least 80% of new or upgraded vehicles in the public sector (buses, taxis, urban logistics, sanitation) in key regions are new energy vehicles.
  - Promoting new energy medium and heavy-duty trucks in industries such as thermal power and steel, as well as in logistics parks to create zero-emission freight fleets.

3.5 Financial Policies on Zero-Emission Vehicles

Financial policies for zero-emission vehicles have undergone significant changes, with a shift in focus from subsidies to tax incentives and localized performance-based awards. Current fiscal supports include:

- Vehicle Purchase Tax Exemptions: The primary forms of fiscal support are currently exemptions and reductions in vehicle purchase tax.
- Local Monetary Awards: Some local governments have introduced performance-based incentives as an alternative to direct subsidies.
- Updated Tax Policies: In June 2023, the Ministry of Finance, State Taxation Administration, and Ministry of Industry and Information Technology issued an announcement to extend and optimize the NEV vehicle purchase tax exemption policy:
  - Full Exemption: NEVs purchased between January 1, 2024, and December 31, 2025, are exempt from vehicle purchase tax.
  - Partial Exemption: NEVs purchased between January 1, 2026, and December 31, 2027, will receive a 50% reduction in vehicle purchase tax.
- Enhanced Technical Requirements: In December 2023, the Ministry of Industry and Information Technology, Ministry of Finance, and State Taxation Administration issued an announcement to adjust the technical requirements for NEVs eligible for purchase tax exemptions, which include increased standards for vehicle energy use, driving range, and battery energy density to encourage the production and adoption of more efficient and advanced NEVs.

3.6 Infrastructure Policies Related to Zero-Emission Freight

Infrastructure policies for zero-emission freight primarily focus on developing dedicated charging stations for public sector vehicles and creating a charging network along highways. Key initiatives include:

- Dedicated Charging Stations for Public Vehicles: This measure will focus on building specialized charging stations to support urban public sector vehicles such as buses, taxis, and delivery vehicles.
- Highway Charging Station Development: In August 2022, the Ministry of Transport, National Energy Administration, State Grid Corporation of China, and China Southern Power Grid Company jointly released an "Action Plan to Accelerate Highway Charging Infrastructure Construction." The plan outlined the following targets:
    - End of 2022: Provide basic charging services at highway service areas nationwide, excluding high-altitude areas and extremely cold regions.
    - End of 2023: Provide basic charging services at service areas (stations) along national and provincial trunk highways where conditions permit.
    - End of 2025: Further optimize and increase the number of charging facilities at highway service areas (stations) and provide effective coverage along rural roads to create a comprehensive highway charging network.
- Comprehensive Charging Infrastructure System: In June 2023, the State Council issued its "Guidelines on Continued Construction of a High-Quality Charging Infrastructure System," aiming for the following by 2030:
    - Develop a ubiquitous, appropriately scaled, well-structured, and fully functional high-quality charging infrastructure system.
    - Accelerate the construction of dedicated charging stations in parking lots and other facilities to meet the changing needs of specialized vehicles, including urban buses, taxis, road passenger transport, and logistical vehicles.

3.7 Continuation of Previous Policies

Several policies introduced before 2022 continue to significantly influence the development of zero-emission freight. For example, the "14th Five-Year Plan for Comprehensive Transport Services," released in November 2021, set a target of establishing around 100 green urban freight delivery demonstration projects by 2025, with a steady increase in the proportion of new energy vehicles in urban logistics. By the end of 2023, a total of 77 cities, across three batches, had already initiated green freight delivery demonstration projects.

4 Overview of China's Current Zero-Emission Freight Market

In 2022 and 2023, both sales and market shares of zero-emission trucks saw significant growth. Light-duty trucks remained the primary choice among zero-emission vehicles, but heavy-duty trucks also experienced increased sales. Battery-swapping heavy-duty trucks have become more popular, while zero-emission box trucks led in sales and penetration among all truck types.

In 2022 and 2023, zero-emission truck sales reached 144,000 and 145,000 units respectively, reflecting growth rates of approximately 180% and 182% compared to 2021. Despite the complete phase-out of national purchase subsidies for zero-emission vehicles by the end of 2022, zero-emission truck sales in 2023 remained steady with a slight increase. The overall sales share of zero-emission trucks was 6.3% in 2022, about five times that of 2021, while in 2023, the sales share fell slightly to 5.9%.

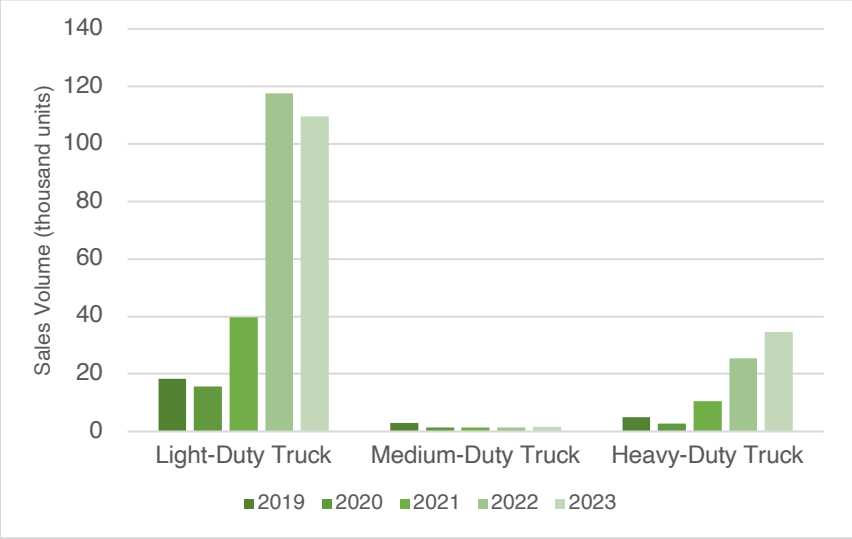

Figure 5: Sales Volume of Zero-Emission Trucks by Type of Trucks (in thousand units)(2019-2023).

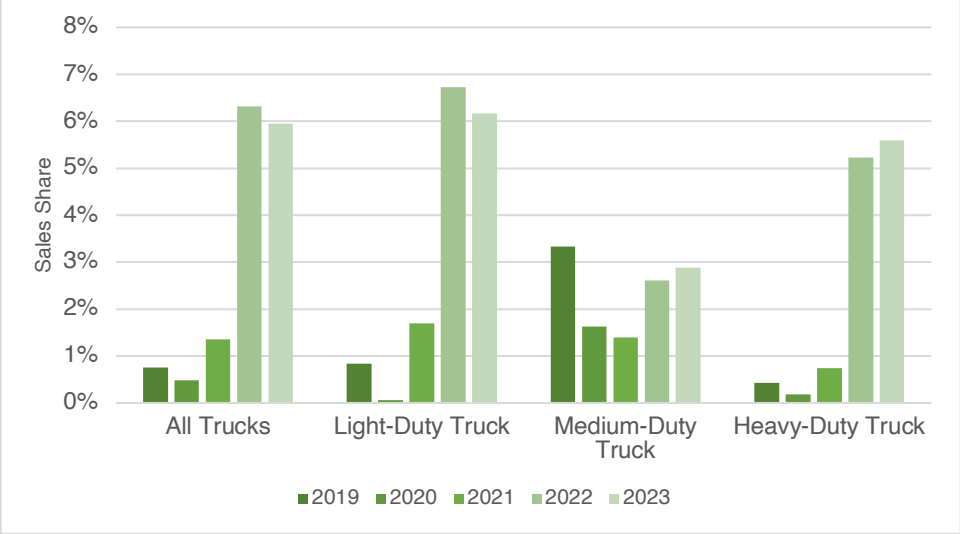

Figure 6: Sales Share of Zero-Emission Trucks by Type of Trucks (2019-2023).

In 2023, among all zero-emission trucks sold, 75.2% were light-duty, 1.1% were medium-duty, and 23.8% were heavy-duty. Compared to 2021, sales of zero-emission light-duty trucks increased by 175%, medium-duty by 18%, and heavy-duty by 229%. The sales share of zero-emission light-duty trucks, as a percentage of all light-duty truck sales, rose from 1.7% in 2021 to 6.2% in 2023. For zero-emission medium-duty trucks, this share increased from 1.4% to 2.9%, and for zero-emission heavy-duty trucks, it grew from 0.7% to 5.6%.

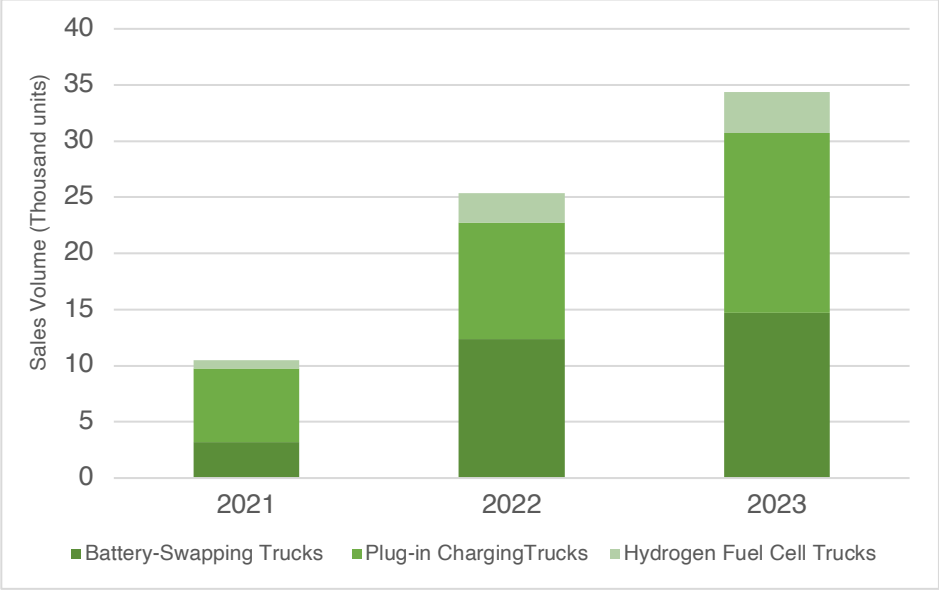

Figure 7: Sales Volume of Zero-Emission Heavy-Duty Trucks by Technology (2021-2023).

In China, zero-emission heavy-duty trucks follow three primary technological pathways: battery-swapping, plug-in charging, and hydrogen fuel cells. Battery-swapping and plug-in charging models are collectively categorized as pure electric heavy-duty trucks. Additionally, plug-in charging heavy-duty trucks are often equipped with battery-swapping capabilities. Battery-swapping heavy-duty trucks increased in popularity significantly, mainly because the battery-swapping model offers advantages such as shorter refueling times, higher operational efficiency, and lower vehicle purchase costs through "vehicle-and-battery separation" and battery leasing options. This model is very popular for short-haul applications. For the years 2021, 2022 and 2023, the share of battery-swapping heavy-duty trucks in overall zero-emission heavy-duty truck sales was 31%, 49%, and 43%, respectively. In contrast, plug-in charging heavy-duty trucks accounted for 62%, 41%, and 47%, and hydrogen fuel cell heavy-duty trucks accounted for 7%, 10%, and 10%.

In terms of application, the top three selling zero-emission truck types in 2022 and 2023 were box trucks, drop-side trucks, and tractor trucks. In 2023, zero-emission vehicles made up 26.9% of newly sold box trucks—the highest proportion among all truck types. This was followed by drop-side trucks at 9.7% and tractor trucks at 9%. Policies such as urban green freight demonstration projects and pilot programs for the full electrification of public sector vehicles have driven the sales numbers and sales shares of box trucks, making them the most popular type of truck sold.

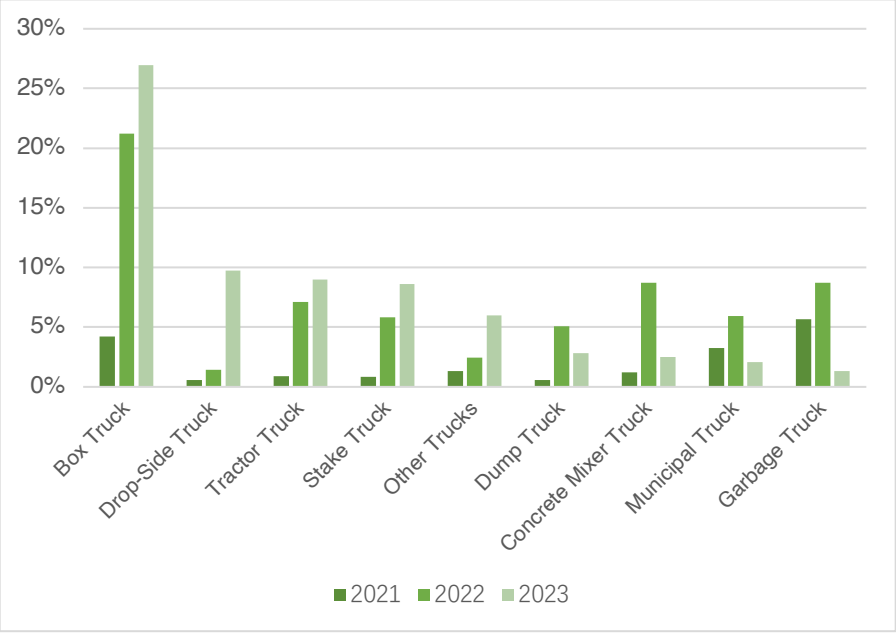

Figure 8: Sales Shares of Zero-Emission Trucks by Use Scenario (2021-2023).

5 Current Development of Zero-Emission Truck Technologies

For freight companies, reducing vehicle costs and improving operational efficiency are critical to achieving cost reduction and enhancing market competitiveness. This dual requirement presents both challenges and opportunities for the development of zero-emission trucks. This section will discuss the current development and challenges in light of the continued call for a more diversified fleet makeup by enterprises and everyday users, which demonstrates foreseeable growth.

Hydrogen fuel cell trucks have already reached the 2020 targets set by China's Energy-Saving and New Energy Vehicle Technology Roadmap 2.0 in key areas including rated power, specific power, and maximum efficiency of fuel cell systems, which meet or even exceed the 2025 targets. Significant progress has also been made in domestic production of basic components, including fuel cell stacks, bipolar plates, proton exchange membranes, and balance of plant (BOP).

Currently, most pure electric trucks use lithium iron phosphate (LFP) batteries, which offer a range of 100-200 kilometers, a charge of between 240-350 kW, and a battery lifespan of approximately 800,000 kilometers. Despite significant progress in medium and short-distance applications, challenges remain for long-distance use, including limited range, slow charging times, and a shorter lifespan compared to diesel trucks. In the coming years, the focus for pure electric truck technology will be on improving battery energy density and lifespan, reducing energy consumption per 100 kilometers, and achieving megawatt-level fast charging.

Meanwhile, hydrogen fuel cell trucks face challenges such as lower power output, a shorter lifespan compared to diesel trucks, the limited range of 35 MPa gaseous hydrogen tanks, and high overall operating costs. Additionally, China is still highly dependent on imported catalysts and carbon paper. Domestically developed hydrogen fuel cell systems also still lag behind international standards in terms of lifespan, reliability, and low-temperature adaptability. Future development is expected to focus on improving key battery technologies, promoting the use of 70 MPa high-pressure tanks and liquid hydrogen technology, and localizing core components.

Despite rapid development, there are several challenges that need to be addressed:

- Technological and Cost Barriers:
  - Pure electric and hydrogen fuel cell heavy-duty trucks have not yet achieved large-scale application in medium- and long-distance transportation scenarios.
  - The economic viability of pure electric and fuel cell trucks still lags behind diesel trucks in certain applications. Therefore, a number of technological breakthroughs still need to make in zero-emission trucks to reduce vehicle costs.
- Infrastructure and Investment:
  - Continued expansion and enhancement of China's refueling infrastructure is necessary to support the growing fleet of zero-emission trucks.

In summary, while China's zero-emission truck sector saw remarkable progress in 2022 and 2023, maintaining this momentum and addressing the existing challenges will be crucial for the sector's continued development and alignment with the national dual carbon goals.

6 Current Infrastructure Support for Zero-Emission Trucks

The development of public DC charging facilities has accelerated, with the coverage rate of charging stations at highway service areas reaching around 90%. Supercharging stations and battery-swapping stations for heavy trucks are also being deployed to test technical feasibility along main highways. The number and capacity of hydrogen refueling stations has also continuously increased, with renewable energy-based hydrogen production growing rapidly, despite having a small base. Generally, there is a need to expedite the construction of high-power public charging facilities, standardize battery-swapping infrastructure, advance 70MPa hydrogen storage and refueling technology, and further reduce the costs of hydrogen production, storage, and transportation.

China has created the largest public charging infrastructure network in the world, accounting for 51% of the global total. By the end of 2023, there were 2.726 million public charging stations in China, an increase of 51.7% compared to 2022. Of these, DC charging stations accounted for 44.1%, an increase of 58.1%, while AC charging stations made up 55.8%, an increase of 47.2%. By the end of 2023, there were 5,987 highway service areas with charging capabilities, covering about 90% of the country's highway service areas.

In May 2023, China Southern Power Grid inaugurated its first supercharging route for heavy-duty trucks in Guangxi. This 180-kilometer route includes three supercharging stations equipped with 360 kW dual-plug DC fast chargers. In terms of battery-swapping facilities, in April 2022, Qiyuan Green Power built a 420-kilometer battery-swapping network in Dazhou (in Sichuan Province), Kaizhou (in Chongqing) and Wanzhou (in Chongqing). In August 2023, the first highway battery-swapping green freight route for heavy-duty trucks was completed, spanning 420 kilometers from Ningde to Xiamen in Fujian Province.

However, the current speed and distribution of public charging facilities is insufficient to meet the commercial needs of medium and heavy-duty electric trucks. Rapidly recharging heavy-duty electric trucks requires megawatt-level charging. Expanding high-power charging infrastructure will face challenges involving technical standards, planning and layout, and grid capacity.

Additionally, the different battery-swapping technologies used by different regions and operators are not interchangeable. To promote the adoption of battery-swapping heavy-duty trucks on highways, it is necessary to standardize battery-swapping facilities and establish an interoperable swapping network.

As for hydrogen fuel cell trucks, in China, 86.5% of operational hydrogen refueling stations support a tank pressure of 35MPa, whereas countries like the United States and Japan commonly support 70MPa tanks. Additionally, current hydrogen transport primarily relies on 20MPa long-tube trailer gas trucks, which is inefficient and increases long-distance transport costs. Regional plans for hydrogen production should be developed and refined to optimize the hydrogen ecosystem, including production, storage, transportation, and usage, which would reduce overall costs and lower the user price of hydrogen.

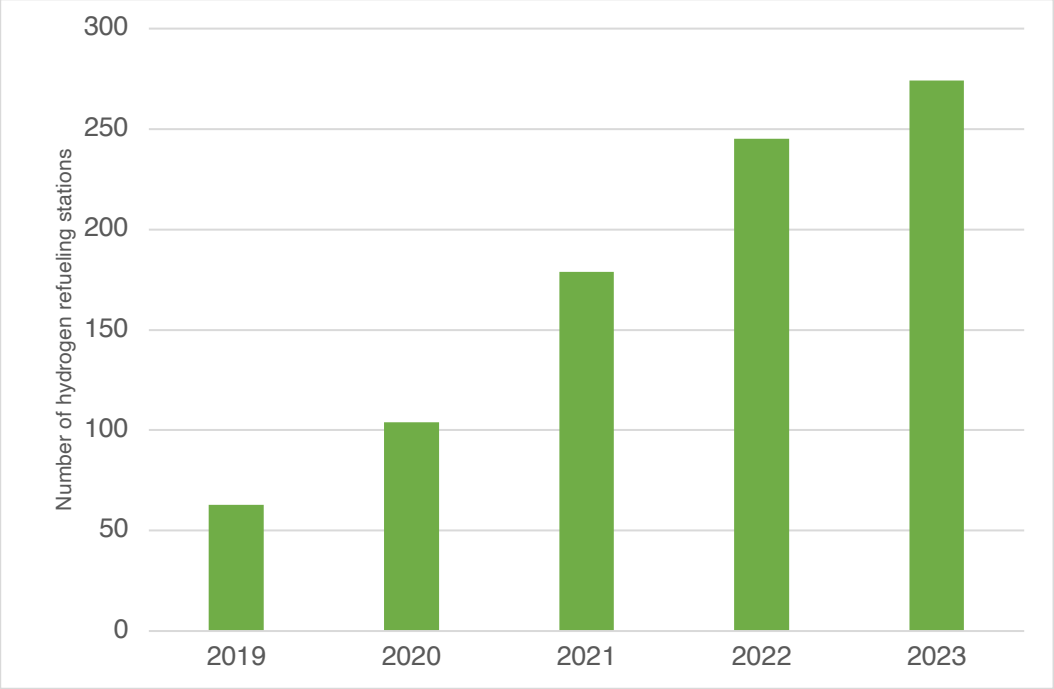

Figure 9: Number of Hydrogen Refuelling Stations in Operation (2019-2023) (China Hydrogen Alliance.2023).

7 Economic Assessment of Zero-Emission Trucks

There is no consensus on the cost parity timeline for pure electric heavy-duty trucks, necessitating further research based on real-world usage data. Key factors affecting cost parity include driving range and transport efficiency. Fiscal subsidy policies remain crucial in reducing the purchase cost of zero-emission heavy-duty trucks, while innovative financial instruments can also help logistics companies manage the financial burden of purchasing new vehicles.

7.1 Current Status of Total Cost of Ownership (TCO) Parity for Pure Electric Trucks

At present, there is no uniform conclusion on whether the total cost of ownership (TCO) of pure electric trucks has achieved parity with that of diesel trucks in practical applications. The time to TCO parity varies from project to project due to differences in the scope of calculation, parameter settings, and location. Based on recent studies[2,3,4,5,6] , expected dates of achieving TCO parity are as follow:

- Light-duty trucks used in urban logistics: 2020-2024
- Heavy-duty tractor trucks used in medium- to long-distance transport: 2022-2030
- Heavy-duty dump trucks used in medium- to short-distance transport: 2020-2030

7.2 Key Factors in Achieving Price Parity for Pure Electric Trucks

One of the critical factors determining when pure electric trucks can achieve TCO parity is their ability to leverage the price difference between electricity and diesel. The higher the usage intensity and the longer the driving distance, the more significant lower electricity costs become. Studies show that pure electric heavy-duty dump

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6. Shenzhen Xieli Innovation Center of New Energy and Intelligent Connected Vehicle
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trucks could achieve TCO parity with traditional diesel trucks at an annual milage of 45,000-52,000 kilometers, while heavy-duty tractor trucks would reach parity at 117,000 kilometers per annum. Additionally, trucks can further benefit from charging during off-peak hours at night, taking advantage of lower electricity rates and maximizing the cost differential between electricity and diesel.

7.3 Impact of Initial Purchase Cost on the Economics of Pure Electric Trucks

High initial purchase costs significantly affect the economic viability of pure electric trucks. The removal of national purchase subsidies for new energy trucks and the uncertainty about the continuation of purchase tax exemptions after 2027 pose challenges. Some study suggests that pure electric tractor trucks may not be able to achieve cost parity until 2029, with the assumption that after 2026, zero-emission trucks will no longer enjoy tax exemptions from the government[7].

In addition to government fiscal support, alternative financial mechanisms such as vehicle leasing, and battery leasing could help alleviate the financial burden of initial purchases on logistics companies and expand the application of zero-emission trucks.

7.4 Economic Challenges and Future Prospects for Hydrogen Fuel Cell Trucks

The purchase and refueling costs of hydrogen fuel cell trucks remain significantly higher than those of traditional diesel trucks. On one hand, hydrogen fuel cell vehicles are still in the small-scale demonstration phase, meaning that they have not yet achieved economies of scale in terms of unit cost. On the other hand, the reliance on imports for some key components makes it challenging to reduce costs.

Studies[8,9] estimate that the total cost of ownership (TCO) parity for hydrogen fuel cell trucks will be achieved by 2030 or shortly thereafter. With technological advancements and the increased scale of demonstration programs, hydrogen fuel cell trucks are expected to achieve cost parity before 2035 if the cost of hydrogen systems drops from RMB 2000/kW to RMB 500/kW and the price of hydrogen falls to RMB 25/kg.

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8 GHG Emission Reduction Benefits of Zero-Emission Trucks

Replacing traditional diesel trucks with zero-emission trucks is crucial for achieving zero emissions in freight transport. The report uses a logistics emissions accounting tool based on the GLEC (Global Logistics Emissions Council) framework with the default data for China[10] to evaluate the GHG emissions reduction effect of replacing traditional diesel trucks with zero-emission trucks. Below are the annual average Tank-to-Wheel (TTW) emission reductions for several popular models in typical application scenarios.

Vehicle Type	Gross Weight	Annual Mileage	Annual TTW Carbon Reduction Compared to Diesel	Equivalent Trees Planted
Pure Electric Light Box Truck	4.5 tons	30,000 km	10.42 ton CO2e	948 trees
Pure Electric Semi-Trailer Tractor	25 tons	100,000 km	93.85 ton CO2e	8,532 trees
Hydrogen Fuel Cell Semi-Trailer Tractor	25 tons	100,000 km	93.85 ton CO2e	8,532 trees
Pure Electric Dump Truck	31 tons	60,000 km	65.4 ton CO2e	5,946 trees
Hydrogen Fuel Cell Dump Truck	31 tons	60,000 km	65.4 ton CO2e	5,946 trees

The calculation shows that in 2022, the newly sold zero-emission trucks can reduce carbon emissions by nearly 2.9 million tons per year. This reduction represents a 154% increase compared to 2021. Based on these calculations, it is evident that zero-emission heavy-duty trucks offer more significant carbon reduction benefits compared to light-duty trucks. This is due to the longer average driving distances and higher energy consumption per unit of distance in heavy-duty trucks. Therefore, accelerating the adoption of zero-emission heavy trucks will play a critical role in the transition to zero-emission freight transport.

10 For further details on the GLEC framework and China Default GHG Emission Values, please visit: https://smartfreightcentre.org/en/our-programs/smart-freight-centre-china/glec-framework-adoption-in-china/.

9 Comparison of China and International Development of Zero-Emission Trucks

China leads the world in zero-emission truck sales and the number of refueling installations. In 2022, China sold 144,000 zero-emission trucks, ranking first globally. Over 85% of global zero-emission medium- and heavy-duty truck sales occurred in China. Furthermore, China installed 60% of the world's new public slow-charging stations and 90% of the fast-charging stations. The total number of public slow and fast charging stations in China is the highest in the world, reflecting the country's strong commitment to developing its electric vehicle infrastructure.

Despite these impressive achievements, there are still significant technological gaps between China and other leading countries in several specific areas. For instance, China's hydrogen fuel cell systems lag behind international standards in terms of lifespan, reliability, and low-temperature adaptability. Specifically, China primarily uses 35MPa Type III gaseous hydrogen storage tanks, while Type IV tanks are still in the development stage. In contrast, Japan and the United States have already achieved mass production of Type IV tanks, indicating a more advanced state of hydrogen storage technology.

The situation is similar regarding hydrogen refueling stations. Most operational hydrogen refueling stations in China operate at 35MPa, with only some operating at 70MPa. However, in countries like the United States and Japan, the majority of refueling stations have 70MPa hydrogen refueling capabilities, highlighting the technological gap in this area. This disparity underscores the need for China to further develop its hydrogen fuel cell technology and refueling infrastructure to match the capabilities seen in these leading nations.

China's dominance in zero-emission truck sales and charging infrastructure installations underscores its leading role in the global market. However, to maintain and enhance this leadership, China must address the existing technological gaps. By advancing its hydrogen fuel cell technology and refueling infrastructure, China can ensure it remains at the forefront of the zero-emission vehicle industry, continuing to set global standards in both sales and technology.

10 General Recommendations

To facilitate the transition to zero-emission trucks, it is essential to enhance research on the operational data of these vehicles to gain a deeper understanding of their performance. A thorough investigation into the total cost of ownership (TCO) for different types of zero-emission trucks is key to achieving this. This research should examine how costs are shared among stakeholders under various business models and explore potential cost reduction strategies and expected timelines for achieving cost parity. Such insights could provide technical support for the formulation of phased and differentiated national and local promotion and fiscal policies for pure electric and hydrogen fuel cell heavy-duty trucks. Currently, subsidies focus on the purchase phase, but as the market matures, these could be adjusted to increase support for the operational phase, including subsidies for vehicle operation, charging and swapping services, and hydrogen fuel.

In addition to research into different types of trucks, sustained support for the research and development of critical technologies for zero-emission trucks is crucial. While pure electric trucks have made progress in medium- and short-distance applications, there are still significant barriers to their adoption in long-distance scenarios, namely limited driving range and low energy replenishment efficiency. Hydrogen fuel cell trucks also face challenges, particularly in terms of the infrastructure related to hydrogen storage and transport as well as the reliability of battery systems, especially when compared to international standards. We recommend focusing on enhancing the energy density and lifespan of batteries for electric trucks, reducing energy consumption per kilometer, and achieving megawatt-level fast charging capabilities. At the same time, we recommend promptly initiating research on international experiences regarding the second-life battery market, and examine the conditions for its applicability in China. Additionally, efforts should be directed towards advancing key technologies for hydrogen fuel cells, promoting 70MPa high-pressure cylinders and liquid hydrogen technology, and domesticating core components. Continuous support in terms of talent, technical standards, and financial incentives is necessary to drive these advancements.

The development of high-power charging capabilities and incorporating it into relevant plans is equally important for the development of zero-emission trucks and increasing overall efficiency. Regions with suitable conditions should include high-power charging infrastructure in their development plans and promote the construction of high-power charging corridors along highways. In typical scenarios such as highway service areas, land and power resources should be reserved for high-power charging facilities, with careful consideration of the potential impact

on the power grid. Research on specific transportation scenarios and the needs of major transport companies will provide detailed guidance for the construction of public or dedicated energy replenishment infrastructure.

Finally, more emphasis should be put on analyzing and replicating successful zero-emission freight experiences to develop sustainable business models. This report highlights several practical cases where companies have successfully implemented business models such as operational leasing, accounts receivable pledges for financing, vehicle leasing with third-party operations, and battery leasing. These innovative "finance + operation" models have already demonstrated commercial viability in medium and short-distance transport scenarios and have been experimentally tested in long-distance transport scenarios. After analyzing the strengths and weaknesses of these cases, successful models can be replicated and promoted, paving the way for sustainable business development in the zero-emission freight sector.

ZERO EMISSION FREIGHT INITIATIVE

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