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Annual Report on the Big Data of New Energy Vehicle in China (2023)

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Foreword by Fengchun Sun

Since green and low-carbon development has become a major direction for international economic and social development, more than 133 countries and regions around the world have proposed or are preparing to propose carbon neutrality goals. Some typical countries and regions have adopted a series of policies and measures to accelerate the realization of such goals. For example, the European Union (EU) released the "Fit for 55" package aimed at amending EU legislation to ensure that the EU's goal of reducing net GHG emissions by at least 55% by 2030 compared to that in 1990 and achieving carbon neutrality by 2050. The United States, on the other hand, has launched the Net-Zero Government Initiative by organizing the Conference of the Parties (COP27) at the United Nations, calling for governments to lead by example to net-zero emissions by 2050 at the latest. China, with a responsible attitude, has been committed to accelerating the transformation of its energy structure, promoting green and low-carbon development, and actively contributing to global climate governance. General Secretary Xi Jinping made a solemn pledge of peaking carbon dioxide emission and carbon neutrality to the international community during the general debate of the 75th session of the UN General Assembly, which embodies our determination and commitment as a great power towards the goals under the *Paris Agreement*.

However, it is also learnt that political turmoil in some regions slowed down the progress of climate commitments to a certain extent, and some European countries also relaxed their climate efforts and suspended commitments to low-carbon economy. While climate policy faces the challenges of major geo-events, major countries and regions are taking policies and measures to reduce carbon emissions in key sectors for the transition to renewable energy. Since China is still in the process of industrialization and development, there is still large room for rigid growth in energy use and carbon emissions for the transportation sector, and the rooted, structural and tendency pressure on carbon emissions from the automotive industry have not yet been alleviated, meaning that China is in face of far greater stress on decarbonization transition than developed countries. Therefore, accelerating the sustainable low-carbon transformation of the energy structure and building energy-saving and efficiency upgrading of end-use sectors have become the key technical paths for achieving the goal of carbon neutrality.

I. **Accelerate the electrification of the public sector and enhance the contribution of road transportation to carbon emission reduction.** Given the great intensity of vehicles in the public sector and long average monthly mileage, promoting electrification in the public sector will help boost carbon emission reduction in segment of road transportation. According to the National Monitoring and Management in 2022, the average monthly mileage of new energy e-taxis, taxis, and cars for sharing was 4,309km, 4,282km, 2,893km, respectively; while that of logistics vehicles, buses, heavy-duty trucks was above 2,000km, indicating significant contributions to carbon emission reduction. In addition, as some new energy buses are to be decommissioned, a replacement in batch becomes necessary, in a bid to enhance the activity of buses. Therefore, efforts should be made to conduct pilot work of electrification in the public sector by exploring new technologies and new models, constantly optimize policies, standards, and regulations, apply pilot trials and implementation, thus effectively eliminating the pain points and obstacles in the development of NEV industry and improving the conditions for application.

II. **Continue the innovation of business model of "separation of vehicles and battery" and speed up the cleaning of the means of transportation with high emissions**. Heavy-duty trucks feature high fuel consumption, high intensity of use and high diesel emission factor. According to China Society of Automotive Society, in 2022, China's heavy-duty trucks accounted for about 4% of the total volume of vehicles nationwide, and the carbon emissions from operation therefrom reached 350 million tons, accounting for 33.4% of the total quantity of vehicles from operation. To speed up the electrification for heavy-duty trucks and other high-energy-consuming models is the major technical path to boost the cleaning of vehicle structure. New energy heavy-duty trucks are economically competitive compared to fuel heavy-duty trucks, while the battery-swapping heavy-duty trucks are advantageous in low cost for first purchase and high operational efficiency, making them an ideal choice for short-distance transportation and trunk line logistics. Therefore, it is important to encourage the enterprises to leverage superior resources in the region to explore the innovative model of "separation of vehicles and battery " and continue to further promote the pilot application of battery-swapping heavy-duty trucks in terms of policy support, technical standards, grid distribution coordination and management, and financial support and assurance, in order to drive industrial development through model innovation and to reinforce coordination of different sectors.

III. **Strengthen the coordination of upstream and downstream participants in the industry chain, and encourage and promote the integration of the transportation sector and the renewable energy sector in the carbon chain.** The NEV industry should establish a whole life cycle carbon emission system integrating parts production, equipment manufacturing, transportation and use, infrastructure construction and operation, and end-of-life recycling, develop a scientific and standardized carbon quota and measurement method, transform international standards into those suitable for local conditions in China, step up the formulation of China's carbon footprint accounting standards, and ensure products satisfy globally accepted low-carbon standards. the carbon chain of transportation and energy sources is the way to promote China's transportation industry to achieve carbon peak and carbon neutrality. The integrated development of transportation and energy is a necessary way to promote China's transportation industry to peak carbon dioxide emissions and achieve carbon neutrality. It is necessary to remove the constraints on the market consumption of new energy for the "space-time conversion" of new energy, thus promoting the consumption of renewable energy and boost large-scale and high-quality development.

IV. Establish a carbon asset management mechanism for road transportation and incorporate the NEV industry into the national carbon emissions trading market. Carbon market and carbon trading system are important initiatives for China to address climate changes and implement the "dual-carbon" strategy. On July 16, 2021, the national carbon emissions trading market was officially launched, and the cumulative turnover of carbon emission allowances reached 223 million tons with RMB10.121 billion in just 350 trading days. High-emission industries such as petrochemicals, chemicals, building materials, iron and steel, non-ferrous metals, paper-making, and aviation have been gradually incorporated into the carbon trading program, except for the automotive industry. The conditions for the road transportation industry to be included in the national carbon trading market have initially matured. By the end of July 2023, more than 14.92 million NEVs were accessed to the National Monitoring and Management Platform, which could provide important technical and data support for carbon trading of NEVs. To step up the establishment of the carbon management mechanism, it is recommended to initiate pilot programs in the field of NEVs to visually quantify and showcase the results of carbon emission reduction in China's transportation sector, and to support and promote the healthy and rapid development of the national strategic emerging industries on NEV.

Based on the real-time big data of NEV operations in China, the *Annual Report on the Big Data of New Energy Vehicle in China (2023)* presents readers with an overview of China's NEV industry in terms of technological advancement, industrial development, vehicle operation, and charging patterns. With various illustrations, informative data, and survey results, this Report aims to help readers understand the annual operation characteristics of NEVs in China and users' habits, proposes suggestions to guarantee the healthy and sustainable development of the NEV industry, and provides important references for governments to formulate policies and automotive enterprises to make strategic decisions. More importantly, this Report will also serve as a valuable reference to show the world the efforts made by the Chinese government in the promotion and application of NEVs and play an important role in boosting and facilitating the independent brands to go globe.

Beijing, China
August 2023

Fengchun Sun

Foreword by Xiangmu Zhang

The *Annual Report on the Big Data of New Energy Vehicle in China* (the "Annual Report") has been published for six consecutive years as an important tool for data evaluation of the NEV industry, and all editions are widely accepted and highly recognized by the industry. Towards the purpose of "serving the industry with data", the group of editors add latest contents on the hot spots of the industry and issues concerned by readers while leveraging the big data of NEV operation in depth, thus assessing the promotion and application of NEVs in multiple dimensions by means of big data.

I. Assess the operation characteristics of NEVs from various dimensions and in all scenarios by means of big data and summarize the user's habits of vehicle operation. NEV market, upon years of development, embodies its unique characteristics like abundant varieties, technological advancement, and increasing requirements of owners to new energy vehicles. For instance, the actual operation of NEVs in winter in low-temperature areas has been highly concerned by owners and enterprises. For the purpose of objective appraisal of compatibility of NEV technology to low-temperature environment, amid the compilation of this Annual Report, the group of editors conducted research on vehicle operation in low-temperature areas in winter. By the comparison of fuel consumption, mileage, and other indexes, objective results were acquired, which may serve as a useful guide for owners to use vehicles in winter. Meanwhile, relevant suggestions are also provided to vehicle enterprises for technological upgrading. The exploitation and utilization of big data on NEV operation are important and reliable means to evaluate the operation efficiency.

II. Objectively demonstrate the evolution of NEV technology and application achievements based on massive data and practice the proposals made by ministries and commissions to boost high-quality development of the industry. The National Monitoring and Management Platform has been moving deeper and deeper on data mining and utilization based on this Annual Report. Its researchers have provided efficient support to the research of national and industry-related policies on the data and first-hand information and successively put forward relevant recommendations for the national competent authorities in the areas like NEV safety system, energy storage platform, battery charging and swapping infrastructure, core technology breakthrough, and support policies for battery-swapping heavy-duty trucks, some of which were studied in a deeper sense for the purpose of high-quality development of NEV industry in China.

III. Build the NEV safety management system covering all elements by means of big data and enhance safety assurance of NEVs across the board. Safety operation is the bottom line of the sustainable development of NEV industry. Given the rapid growth in the NEV safety management system, enterprises attach higher importance to the safety system, keep enhancing product safety and quality management standards, continue to regulate vehicle operation data, and exert more efforts in emergency response. With the ongoing promotion of NEVs, the number of old vehicles is increasing, which result in varied quality. Therefore, it is crucial to give full play to the role of the National Monitoring and Management Platform for NEVs and the public management platform for setting up a big data-driven safety management system that covers various elements, including quality safety, operation safety, data safety, after-sales service, and accident response. We also suggest that enterprises should focus on the construction of the safety system and comprehensively and systematically plan and form a complete and practical structure in line with the *Guiding Opinions on Further Strengthening the Construction of the Safety System for New Energy Vehicle Enterprises*. Moreover, we also suggest in-depth internal review and self-examination, timely rectification of problems, and collaborative cooperation for building a strong safety fortress for the NEV industry.

Beijing, China
August 2023

Xiangmu Zhang

Preface

After years of industrial cultivation and development, the NEV industry has become an important driving force leading the growth of China's automotive market. In 2022 China's NEV market recorded a sales volume of 6,887,000 units, an increase of 93.4% year-on-year, while the market penetration rate reached 25.6%. The industry now serves as an important pillar to promote China's progress from a large country of automotive to a strong power thereof amid the transformation of the automotive industry.

China's NEV market is growing to a larger scale that align with international perspective, **with rising maturity of NEV industry**. From the perspective of market structure, the penetration rate is soaring in southeast coastal region; the share in the cities of new first-tier and below is gradually expanding, making them the major drives in the sales of new energy passenger cars; diversified technical paths and innovative operation modes support the expansion of NEV scenarios, for which a full coverage of the scenarios is achieved. Leading enterprises on NEVs, power batteries, and drive motors keep springing up and overseas supporting facilities and vehicle exports continue to improve, contributing to the constant enhancement of international competitiveness.

Despite of the remarkable achievements, NEV market is in face of several problems, such as uneven market penetration, slow electrification of commercial vehicles, charging inconvenience in old residential areas, and hidden safety hazards, which may hinder the high-quality development of the NEV industry. Annual Report on the Big Data of New Energy Vehicle in China (2023), in a global perspective, based on the real-time big data of more than 12.073 million NEVs accessed to the National Monitoring and Management Platform, summarizes the development outcome of China's NEV industry in the past three years, analyzes the contradictions and problems facing the industry, and puts forward pertinent suggestions in aspects of vehicle promotion and application, technological advancement, vehicle operation, battery charging and swapping, fuel cell vehicles, and plug-in hybrid electric vehicles, and other regular annual research contents, with an aim to provide support for the safe and steady development of the industry. This Report mainly offers the following views and understandings:

I. **Systematically analyze the NEV operation characteristics in various application scenarios**. This Report, based on the big data of more than ten million vehicles in operation, summarizes multiple application scenarios like private cars, online cars, taxis, cars for sharing, logistics vehicles, buses, and heavy-duty trucks by means of machine recognition and comprehensively and systematically analyzes vehicle activity, driving characteristics, charging characteristics, and other operation laws.

II. Analyze in-depth the key contents of popular models, **battery-swapping mode**, **carbon assets**, **and charging convenience from various angles.** This Report makes a comprehensive analysis on the operation and hydrogen refueling behaviors of hydrogen fuel cell electric vehicles and the operation characteristics of battery-swapping vehicles, which are highly concerned by the industry; and evaluates the process of carbon emission reduction in the vehicle operation, laying a solid foundation for the establishment of a mechanism in connection with the carbon trading market. In addition, this Report also proposes constructive suggestions for the charging facilities in the old residential areas upon comparison of the convenience of charging in old residential areas.

III. Appraise the technical evolution characteristics of NEVs from multiple dimensions with big data on yearly basis. This Report makes systematical analysis through the actual operation characteristics of NEVs and summarizes the curb weight, driving range, power battery energy density, mileage credibility, energy consumption level, fast charging efficiency, operation failures, safety accident rate, and other indicators over the years to comprehensively evaluate NEV quality, thereby providing references for the industry to follow the development trends and master latest technologies.

IV. Put forward constructive suggestions for industrial development. This Report gives targeted suggestions for industrial development by summarizing the achievements and emerging new issues of NEVs in the process of market-oriented promotion and application, vehicle operation and charging, fuel cell vehicles and demonstration and promotion of battery-swapping mode, with reference to the industrial development paths.

This is the sixth volume of Annual Report on the Big Data of New Energy Vehicle in China. We hope it could be a recorder and witness of the development of the NEV industry and also a promoter and leader of the healthy and sustainable development of the industry towards the future. We expect that this Report may provide fundamental information and valuable reference for government authorities, enterprises on upstream and downstream of NEV industry chain, industry research organization, scientific research institutes, and common readers, so that big data can truly serve the industry and promote industrial development.

This Report is successfully published with support of industry experts and partners. In the compilation, numerous managers, experts, and scholars from the National Big Data Alliance of New Energy Vehicles, National Monitoring and Management Platform for New Energy Vehicles, National Engineering Research Center of Electric Vehicles of the Beijing Institute of Technology, Beijing AUV Bus Branch of BAIC

Foton Motor Co., Ltd., CHINA FAW GROUP CO., LTD., and RA Market Research International Information and Consulting (Beijing) Co., Ltd., offered great support and aid. We would like to express our sincere gratitude for them!

Due to the limited competence of authors, this Report may be deficient in both depth and breadth. Your criticism and suggestions will be highly valued by us.

Zhenpo Wang
Professor at Beijing Institute
of Technology
Beijing, China

Acknowledgments

This book represents a collective effort, a journey undertaken by three passionate authors—Adebowale, Oluwaseun, and Abiodun—who are committed to exploring the transformative potential of generative AI in education. Our combined experiences, insights, and dedication have brought this work to life, and we are immensely grateful to the individuals and teams that have supported us along the way.

Adebowale extends his deepest gratitude to God, the giver of life! Special appreciation goes to his wife, Debbie, and their children, Divine, Fifi, and Zion, for their encouragement and for enduring the inevitable sacrifices. Your support has been invaluable. He also thanks his students and colleagues at De Montfort University, particularly the Centre for Computing and Social Responsibility (CCSR) and the Centre for Academic Innovation and Teaching Excellence (CAITE), for providing the opportunity to lead discussions that highlighted the importance of this book. Additionally, he expresses heartfelt gratitude to his family, friends and mentors who have steadfastly supported his pracademic and research career. To the Envoy Nation and Envoy Academic Expression, thank you for the privilege of influencing many through my diverse expressions.

Oluwaseun is grateful for his wife, Ore, and daughter, Demi, for their understanding and support, as he took time away to give attention to this book. He is also thankful for the various interactions that have shaped aspects of this work, including with students and colleagues from Sheffield Hallam University, colleagues from African Scholars' Forum, and participants in the British Council Research Connect workshops, among others. He also expresses his thanks to Olamide, of Enterprise Republic, for his admin support; and to all the family and friends who continue to encourage and support his research in the field of generative AI.

Abiodun thanks his wife, Oluwatosin, and children, Testimony, Oluwasemiloore and Barnabas, for their understanding and encouragement which have been a constant source of motivation. He is grateful for the intellectual stimulation and constructive feedback from students and colleagues at De Montfort University, National Centre for Technology Management, African Institute for Science Policy and Innovation, AfricaLICS and NigeriaLICS, among others. He also thanks the family, friends and mentors through whose support he has come this far.

Collectively, we thank the reviewers and all who took the time to endorse this book; you are much appreciated. To our commissioning editor, Alec and production manager, Supraja, your professionalism is unparalleled. You made the process seamless.

Finally, to our readers, thank you for your interest and engagement. It is our hope that this book will not only provide valuable insights but also inspire further discussion and innovation in responsible use of generative AI for teaching and learning in higher education. This book is as much yours as it is ours.

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About the Author

Zhenpo Wang is currently a professor in Beijing Institute of Technology. Professor Wang has long been engaged in theoretical research and key technical breakthrough related to new energy vehicles. Centering on the safe, efficient and reliable application of NEVs, he has made significant contributions to operation control, charging prevention, distributed driving, collaborative control and other aspects. Besides, professor Wang has headed over 10 government.sponsored researches such as key projects of National Natural Science Foundation of China (NSFC) and National Key Research & Development Program of China. He has published more than 80 SCI/EI papers and 11 monographs as the first author or corresponding author, and authorized 43 patented inventions as the first inventor. He is also a holder of 7 prizes of both national and provincial levels, and experts of general groups on national key research and development project "Integrated Transportation and Intelligent Transportation" for the 13th Five-Year Plan and "New Energy Vehicles" for the 14th Five-Year Plan.

Chapter 1
Overview of the Development of New Energy Vehicle Market in 2022

Thanks to years of industrial cultivation and development, China's new energy vehicle (NEV) industry system becomes increasingly complete and mature in both system and policies, with the growing strength of NEVs, especially in endurance ability and safety. With the climbing productivity and sales, the market demand sees significant rise in recent years. Based on the real-time operation data of 12.073 million new energy vehicles as of the end of December 2022 from the National Monitoring and Management Platform for New Energy Vehicles (hereinafter referred to as the "National Monitoring and Management Platform"), this Report objectively analyzes the hot spots of the NEV market, vehicle operation, vehicle charging, and other industrial concerns, summarizes the travel and charging patterns of NEVs, and puts forward relevant development suggestions, as a reference for the relevant government departments, scientific research institutes, colleges and universities, and enterprises of China's NEV industry.

1.1 Overview of the NEV Market

1.1.1 Overview of Global NEV Market

China's NEV industry has become the backbone in the automotive electrification transition worldwide. In 2022, the global NEV market continued its rapid growth, with sales volume of 10.55 million, up by 3.8 million over 2021 (Fig. 1.1). Such typical markets as China, Germany, the United States, the United Kingdom, and France, the sales volume exceeded 300,000 on annual average (Fig. 1.2). China's NEV market sales maintained its climbing momentum, with a sales volume of 6.887 million, accounting for 65.3% of the global market, and topping in the world for eight consecutive years.

Z. Wang, *Annual Report on the Big Data of New Energy Vehicle in China (2023)*,
https://doi.org/10.1007/978-981-97-4840-2_1

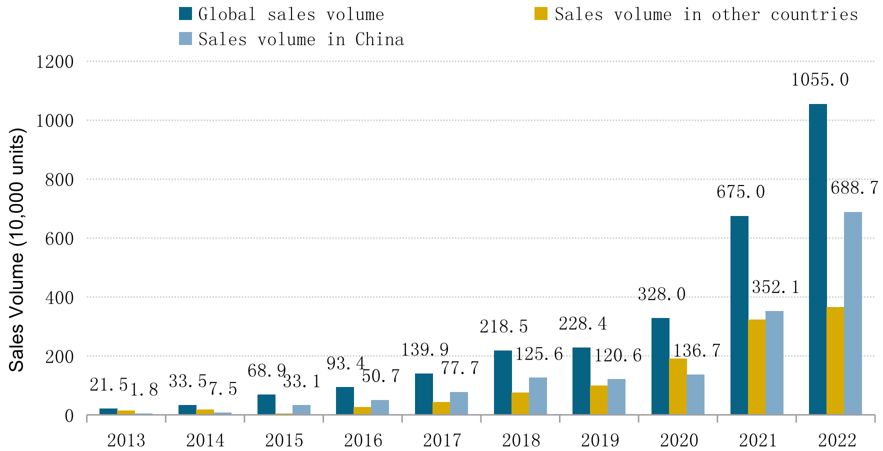


Fig. 1.1 Global NEV sales volume. *Source* China Association of Automobile Manufacturers (CAAM) for sales data of NEVs in China; EV-volumes (www.ev-volumes.com) for sales data of NEVs in countries other than China

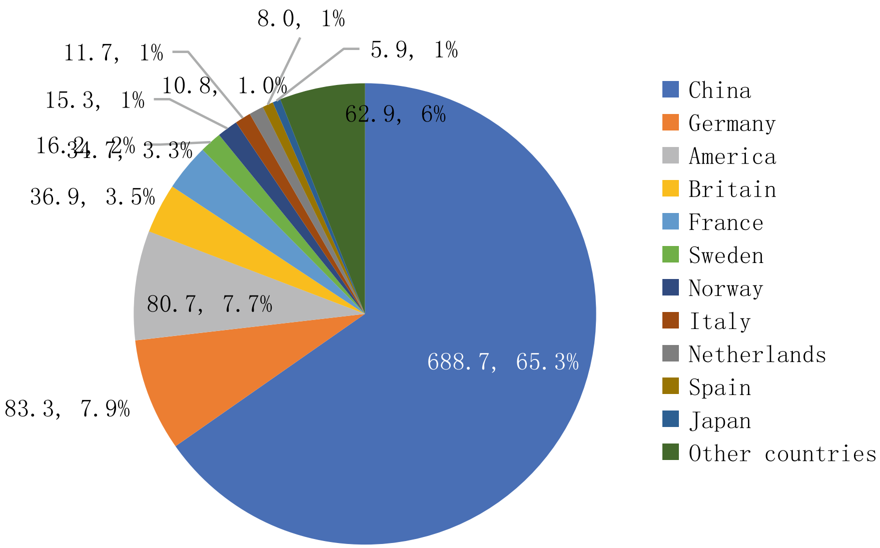


Fig. 1.2 NEV sales volume in typical countries in 2022 and proportion in global total (in 10,000, %). *Source* Sales of China is sourced from China Association of Automobile Manufacturers; while the sales of other countries is sourced from EV-volumes

1.1.2 *Current Marketing of NEVs in China*

(1) **Remarkable achievements of china in vehicle electrification, with rapid growth in NEV market in 2022**

China's NEV industry has ushered in an era of rapid development in large scale, proved by its soaring market penetration curve (Fig. 1.3). In 2022, China sold 6.887 million NEVs, an increase of 93.4% year on year, along with the explosive growth of market demand at this turning point of overall marketization. Also in 2022, NEV market penetration rate continued to rise to 25.6%, an increase of 12.2% points from 2021. The NEV access volume maintains a momentum of a rapid growth over the years (Fig. 1.4), of which that in 2021 and 2022 reached 2,732,000 and 5,418,000, respectively, with a year-on-year growth of 177.3 and 98.3% each.

The rapid expansion of NEV industry brings a swift increase in vehicle electrification. According to data from the Ministry of Public Security, by the end of 2022, China recorded 319 million vehicles registered, including 13.1 million NEVs, indicating a rapid growth (Fig. 1.5). Meanwhile, the proportion of NEVs in the total quantity of vehicles also manifests an upward momentum from 0.3% in 2015 to 4.1% in 2022, an increase of 3.8% points, along with the accelerating rise of automotive electrification curve.

With the rapid growth of the volume, the cumulative access rate of NEVs keeps rising year by year. By 2022, a total of 12.073 million NEVs accessed the platform (Fig. 1.6), with an access rate of 92.2%, indicating that 92.2% of NEVs in China are under monitoring for operation.

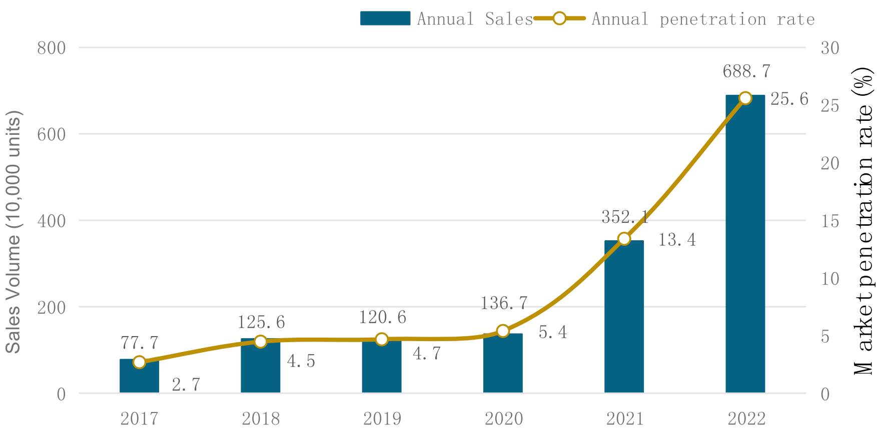


Fig. 1.3 NEV sales volume and growth in China over the years. *Note* Affected by the statistics of new enterprises in the previous year, the annual year-on-year growth rate was slightly adjusted. *Source* China Association of Automobile Manufacturers

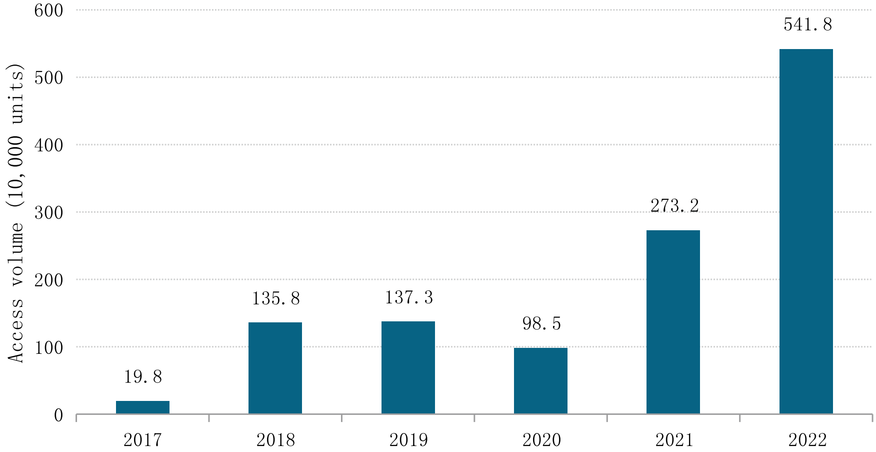


Fig. 1.4 NEV access amount over the years on national monitoring and management platform

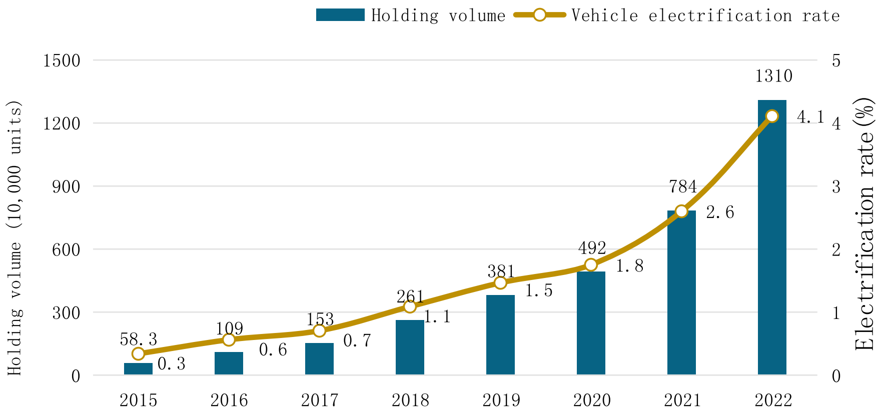


Fig. 1.5 Changes in NEV quantity and vehicle electrification in china over the years. *Remarks* Vehicle electrification rate = NEV holdings/Vehicle holdings in the same period. *Source* Ministry of Public Security

(2) High concentration of NEV promotion, with nearly 70% accessed in top10 provinces by the end of 2022

Guangdong Province and Zhejiang Province completed access of more than a million NEVs to the platform, accounting for more than 1/4 of the total in China. By the end of 2022, the TOP10 provinces with cumulative access volume of NEVs nationwide had a total of 8,337,000 NEVs accessed, with a national share of 69.0% (Fig. 1.7). Guangdong Province and Zhejiang Province completed the access for a total of more than one million NEVs, with a cumulative number of 1,867,000 and 1,220,000, respectively, each accounting for 15.5 and 10.1% of the total in China.

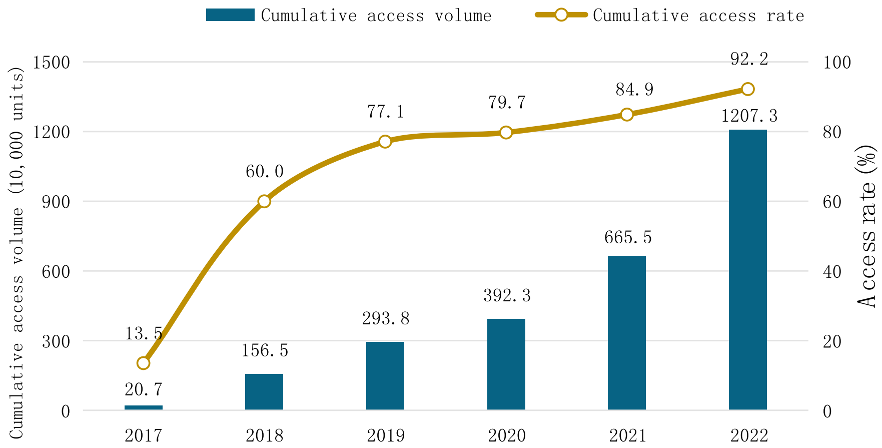


Fig. 1.6 Quantity of NEVs accessed the national monitoring platform over the years. *Remarks* Cumulative vehicle access rate = Cumulative NEV access rate/NEV holdings in the same period

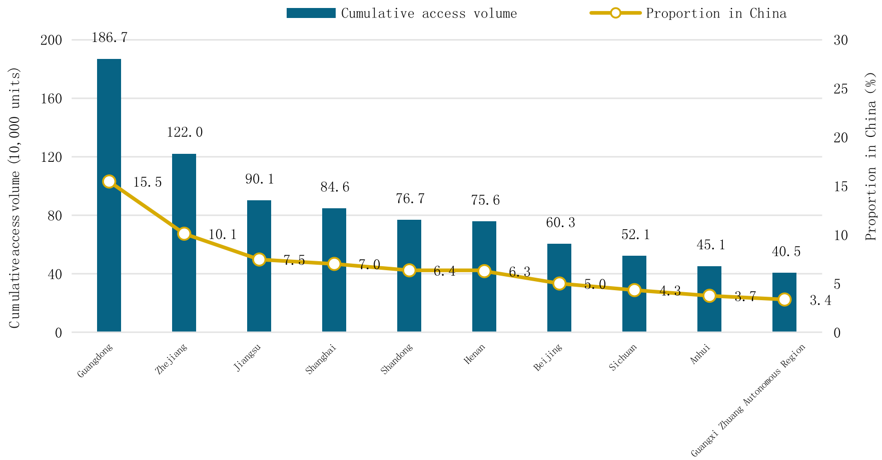


Fig. 1.7 Cumulative access and proportion of NEVs in the TOP10 provinces

The promotion of NEVs in first-tier cities has achieved remarkable results. In the ranking of cumulative NEV access among TOP20 cities (Fig. 1.8), by the end of 2022, such first-tier cities as Shanghai, Shenzhen, Beijing, and Guangzhou took the top four places, each with cumulative NEV access volume of more than 500,000, accounting for more than 4% of China. Among them, the cumulative access volume of NEVs in Shanghai was 846,000, accounting for 7.0% of the national total, topping the list.

Leading cities are holding over 400 new energy passenger cars per a thousand users, of which such number exceeds 200 in each of the TOP10 cities. The national

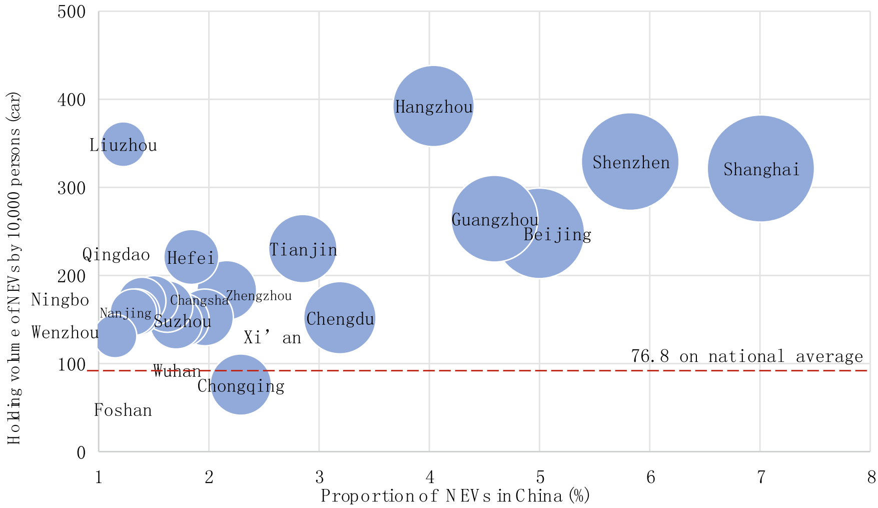


Fig. 1.8 Cumulative access and electrification rate of NEVs in the TOP20 cities. *Note* ① Bubble size indicates the cumulative access volume of NEVs in each city by the end of 2022; ② The Data of urban resident population originates from the Communiqué of the Seventh National Population Census in 2021 by the National Bureau of Statistics of China

average of new energy passenger car owned per 10,000 users was 76.8 in 2022 (Fig. 1.8). In terms of the cumulative NEV access in the TOP20 cities in 2022, Hangzhou and Liuzhou ranked in the top two in new energy passenger cars holdings per 10,000 users, with 392.5 and 349.1 respectively, ahead of such first-tier cities as Beijing (247.9), Shanghai (321.5), Guangzhou (264.5), and Shenzhen (329.4); and each of the rest cities recorded within 200 per 10,000 users.

(3) **Increasing number of new energy passenger cars over the years from 67.2% in 2017 to 94.8% in 2022**

New energy passenger cars dominate the NEV market, with the market share increasing yearly. In light of the changes in the access structure of various types of vehicles on the National Monitoring and Management Platform over the years, new energy passenger cars dominate the market and show a rapid expansion trend in their market share. In 2022, the access volume of new energy passenger cars took a proportion of 94.8%, of which BEV-passenger cars accounted for 72.9% with a dominance; PHEV-passenger cars witnessed a rapid growth in market share with the proportion of access volume exceeding 21.9%, an increase of 4.5% points over 2021 (Fig. 1.9).

Consumer demand in cities not subject to purchase restrictions is robust, and the market share of new energy passenger cars is increasing yearly. Under the stimulation of consumption promotion policies, diversification of product supplies, and increasing product quality, the awareness and recognition of NEVs by users in cities not subject to purchase restrictions have gradually increased, contributing to

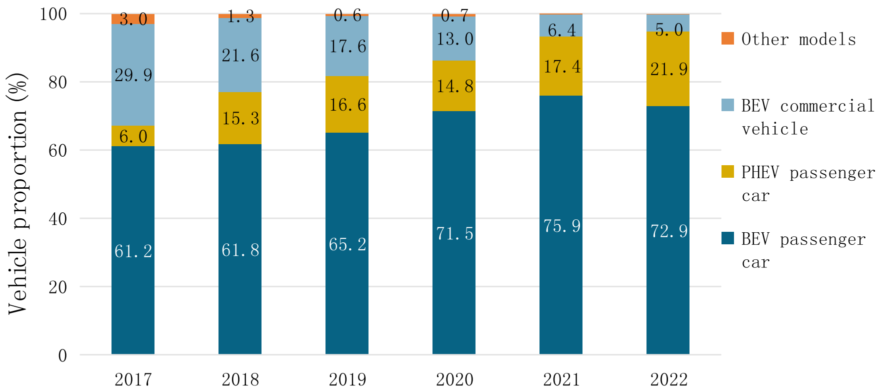


Fig. 1.9 Proportion of access volume of NEVs of different types over the years

the surge of consumer demand. According to the proportion of access volume of cities subject to purchase restrictions and not subject to purchase restrictions over the years, the market share of new energy passenger cars in cities not subject to purchase restrictions in 2022 was 74.1, 6.9% higher than that in 2021, showing an increasing trend in the market share (Fig. 1.10).

The NEV access volume in the TOP15 cities in 2022 is shown in Fig. 1.11, wherein Shanghai, Shenzhen, Hangzhou, Guangzhou, and other cities subject to purchase restrictions are at the forefront of the access volume, with robust consumer demand. The annual access volume in Shanghai reached 314,000, topping the list with an proportion of 5.8% of the total in China. In terms of the proportion of access volume of new energy passenger cars to local NEVs promoted in the TOP15 cities, the new energy passenger cars in the TOP15 cities accounted for 50% of the total

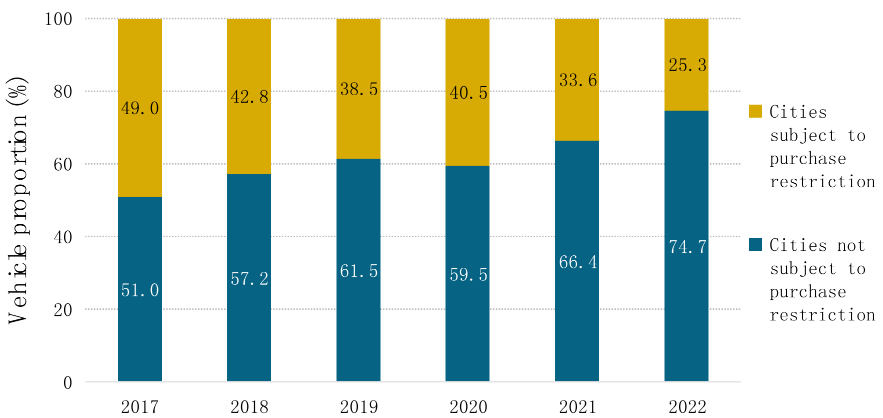


Fig. 1.10 Changes in the proportion of access volume of new energy passenger cars in cities subject to purchase restrictions and cities not subject to purchase restrictions

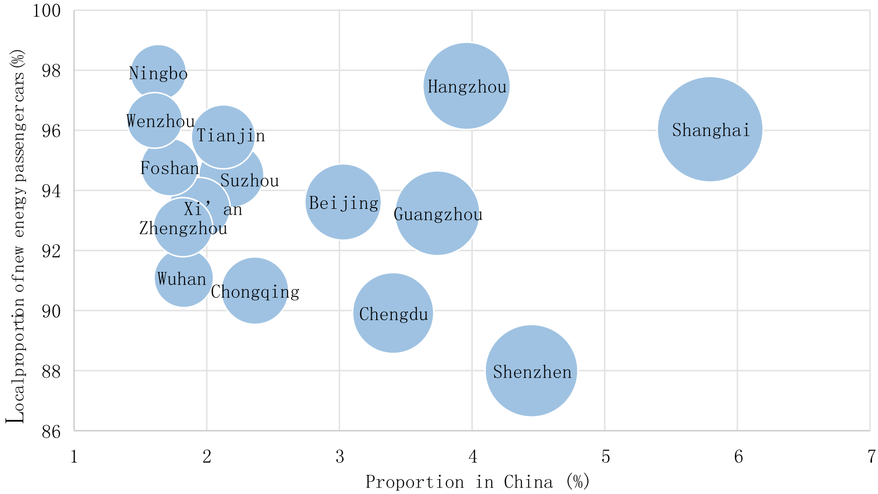


Fig. 1.11 NEV access and proportion of passenger cars in the TOP15 cities in 2022. *Note* ① Bubble size indicates the access volume of NEVs in each city to the National Monitoring and Management Platform in 2022; ② Proportion of new energy passenger cars = Annual access volume of new energy passenger cars in the city/Annual access volume of NEVs in the city

promotion in the TOP15 cities. Ningbo, Hangzhou, and Wenzhou ranked the top three in local access volume of new energy passenger cars, each exceeding 96%.

(4) **Pilot program for overall vehicle electrification in the public sector started, with expected development of new energy commercial vehicles**

***New Energy Vehicle Industry Development Plan (2021.2035)*, *Action Plan for Carbon Dioxide Peaking Before 2030*, and other related policies have provided arrangements and requirements for the electrification of vehicles in the public sector.** According to the data of the Ministry of Transport, by the end of 2021, the proportion of new energy buses in cities within China exceeded 66%, and more than 86,000 NEVs for urban logistics distribution were added in 46 green freight distribution demonstration cities, indicating gratifying progress in vehicle electrification in the public sector. For the purpose of further energy conservation and emission reduction in the automobile industry and faster development of green and low-carbon transportation systems, on February 3, 2023, the Ministry of Industry and Information Technology, the Ministry of Transportation, and other eight ministries jointly issued the *Notice on Organizing the Experimental Programs of Pilot Zones for the Comprehensive Electrification of Vehicles in the Public Sector* (hereinafter referred to as the "Notice"), planning to increase the ratio between the new public charging piles and the number of NEVs promoted in the public sector to 1:1 during the period of 2023–2025, thus significantly advancing the progress of vehicle electrification. The proportion of NEVs in the new and renewed vehicles in the pilot areas sees a significant increase, of which the proportion of urban buses, taxis, sanitation vehicles, postal courier carriers, urban logistics and distribution vehicles strives to reach 80%.

The frequent application in public sector with long operating hours per unit of time boosts the electrification of commercial vehicles, thus advancing the clean-up process in the road transport sector. The industry of China's new energy commercial vehicles lags behind the whole market of NEVs. Compared with the overall rapid growth of market penetration of NEVs, the market penetration of the public sector in China, especially new energy commercial vehicles, is low. In 2022, the overall market penetration of NEVs was 25.6%, while that of new energy commercial vehicles was only 10.2% (Fig. 1.12), and that of new energy trucks was merely 8.5% (Table 1.1). In respect of operation characteristics, NEVs in the public sector are more frequently in use with longer mileage on month average (over 2000 km per vehicle for public use in 2022 versus less than 1000 km per vehicle for private use in 2022). The vehicles in use have contributed substantial carbon emissions at the operational end, of vital importance for low-carbon development in the transportation sector.

(5) **Expediting cleaning process of trucks in the area of air pollution prevention and control, with remarkable contributions to keep the sky blue**

It is an inevitable trend for transformation from traditional technologies to zero emission technologies for trucks. To promote the process of freight cleaning, on October 29, 2021, the Ministry of Ecology and Environment, in conjunction with nine ministries and commissions and several local governments, issued the *Program for Comprehensive Prevention and Control of Atmospheric Pollution in Fall and Winter for 2021 and 2022* (H.D.Q [2021] No. 104), which lists Beijing, Tianjin, Hebei, neighboring "2+26" cities, and the cities in the Fenhe and Weihe plain, northern Hebei, northern Shanxi, eastern and southern Shandong, and southern Henan as key

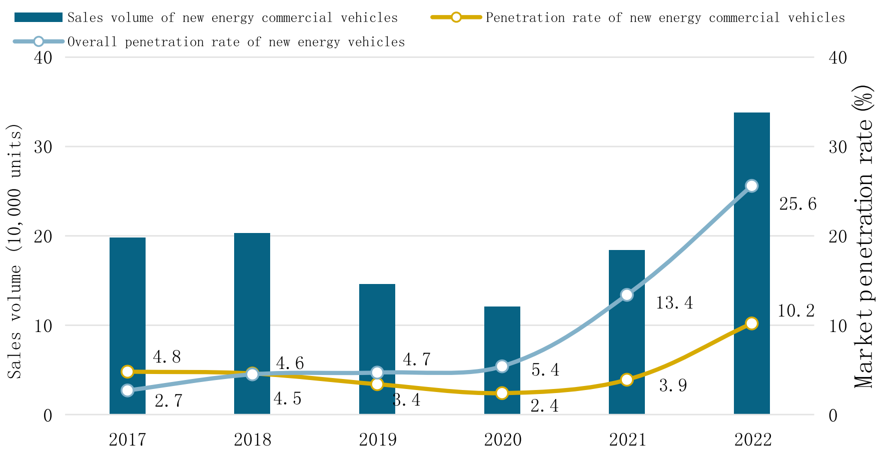


Fig. 1.12 Sales volume and market penetration of commercial vehicles in China over the years

Table 1.1 Sales volume and market penetration of NEVs in 2022

Vehicle type	Sales volume of fuel vehicles (in 10,000)	Sales volume of NEVs (in 10,000)	Market penetration rate (%)
Overall	2,686.4	688.7	99.98
Passenger car	2,356.3	654.8	99.98
Commercial vehicle	330.1	33.8	99.98
Including: passenger car	40.8	10.3	99.98
Trucks	289.3	23.5	99.98

Source China Association of Automobile Manufacturers

areas for air pollution prevention and control, making constant efforts to defend the blue sky by means of scientific and effective policies and initiatives. By the end of 2022, a total of more than 170,000 new energy trucks were accessed within Beijing-Tianjin-Hebei region and its surrounding areas, including 46,000 new energy trucks recorded in 2022, a year-on-year increase of 106.9%. The cumulative mileage of new energy trucks in the areas of air pollution prevention and control reached 6.166 billion kilometers, contributing to a cumulative reduction of 2.75 million tons of carbon emissions, which indicated an outstanding outcome to defend the blue sky.

Heavy-duty truck emissions plays a pivotal role in carbon emissions in the segment of road transportation, and accelerating the cleaning process of heavy-duty trucks is expected to propel the reduction of carbon emissions in the transportation sector. According to a study by the Chinese Academy of Engineering,[1] the carbon emissions from the road transportation accounted for 86.76% of the total emissions in the transportation sector, while that from heavy-duty trucks had a share of 54% of the total in the segment of road transportation. Promoting the electrification of heavy-duty trucks is the key orientation for reducing pollution and carbon emissions and the core approach to achieve the "dual carbon" goals in the transportation sector. Tangshan, in recent years, has been stepping up the application of hydrogen and electric new energy heavy-duty trucks in ports, steel mills, and mines for bulk commodity transportation. Over 7,000 new energy heavy-duty trucks have been put into operation, making it a significant and valuable case of low-carbon and zero-carbon development for regions with high carbon emissions from transportation.

(6) **Larger scope of application for the model of "separation of vehicle and battery" from successful promotions and applications of vehicles of battery swapping**

NEVs are the future of the automobile industry, while battery swapping serves as a key impetus to further enhance the penetration of NEVs. Battery swapping can effectively eliminate the dilemma of electric vehicles for power charging thanks to its edges, including less charging time, lower battery loss, secured driving, and

[1] Paths for Carbon Peak and Carbon Neutrality in Transport Sector in China, Strategic Study of CAE, [2021], Vol. 23, Issue 6.

less space occupation. There are abundant application scenarios for NEV battery swapping, such as private cars (consumer) and taxis or heavy-duty trucks (business). The mileage anxiety and strict requirements of power charging efficiency for NEVs can be effectively resolved under this mode. Some progress has been made in diversified application scenarios of battery-swapping vehicles. By the end of 2022, a total of more than 290,000 battery-swapping BEVs accessed the National Monitoring and Management Platform, including 279,000 battery-swapping passenger cars and 11,000 battery-swapping commercial vehicles. The application of battery-swapping passenger cars covers private cars and official passenger cars, and taxis, and NIO, Geely, BAIC and other vehicle companies have started its business efforts in battery swapping; in field of passenger car replacement. The application of battery-swapping commercial vehicles covers logistics vehicles, engineering vehicles, and sanitation vehicles, and Hanma Technology, XCMG, SAIC Hongyan, SANY Heavy Industry, and other enterprises are now engaged in battery-swapping for heavy-duty trucks.

The advantageous "separation of vehicles and battery" mode is expected to be further exerted in the segment of commercial vehicles for higher operational efficiency and less carbon emissions. In the segment of commercial vehicles, the mode can help significantly improve operational efficiency as it is commonly used in steel mills, coal workshops, and ports. The power charging efficiency for battery-swapping heavy-duty trucks rises significantly from one hour to only about five minutes, with an equivalent operational efficiency to traditional diesel vehicles. From the perspective of battery life cycle, the "separation of vehicles and battery" is conducive for the innovation of business modes for upstream and downstream participants on the industrial chain, such as developing the closed-loop asset circulation system in the whole life cycle of power batteries, tapping the commercial potential of battery banks, and innovating the upstream and downstream cooperation patterns on the industrial chain of power batteries.

(7) **Over 10,000 fuel cell electric vehicles (FCEVs) in China accessed the National Monitoring and Management Platform and better supporting systems in need for the healthy development of the industry**

Featuring a long industrial chain and massive participants from upstream and downstream, hydrogen energy and fuel cells have become a new engine for local governments to replace old growth drivers with new ones and speed up the high-quality development of green energy. In March 2022, the National Development and Reform Commission and the National Energy Administration jointly issued the *Medium- and Long-Term Strategy for the Development of the Hydrogen Energy Industry (2021–2035)*, which defined the top-level design and strategies for the hydrogen energy industry at the national level and highlighted the transportation sector as the focus for diversified applications at the downstream of the industrial chain. By the end of 2022, the cumulative access volume of FCEVs in China reached 10,564, mainly buses and special-purpose vehicles, of which bus promotion covers the fields of bus, highway, commuting, and tourism, while the promotion of special-purpose vehicles covers logistics, sanitation, engineering, and other fields. In the segment of vehicle operation, the cumulative mileage of FCEVs in China exceeded

300 million kilometers, and the driving time exceeded 12.519 million hours. As for fuel cell demonstration areas, Beijing 2022 and "3+2" demonstration city cluster and the demonstration technology demonstration projects of "Hydrogen into Ten Thousand Homes" and "Chengdu-Chongqing Hydrogen Corridor" have been running in full swing; the outcome of vehicle promotion has taken shape; and the upstream and downstream enterprises are gradually gathering into clusters, which played a demonstrative role to drive the development of FCEVs and hydrogen energy industry nationwide.

As indicated from the characteristics and problems in FCEV operation, there are still weak points on the industrial chain of hydrogen energy. The short mileage of special-purpose FCEVs in a single day is partly due to the imperfect hydrogen energy infrastructure and supply system and high hydrogen price in some areas, which affects the vehicle operation to some extent. For the long-term development of hydrogen energy and fuel cell industry, local governments need more efforts to promote FCEV demonstration and industrial cultivation, step up infrastructure construction, and deepen cooperation between upstream and downstream enterprises on the industrial chain based on regional superior resources and advantageous industries for the purpose of healthy and orderly development of FECV industry.

1.2 Characteristics of China's NEV Technology Evolution in 2022

1.2.1 Technical Progress of New Energy Passenger Cars

Battery technology advancement plus user consumption upgrading drive the growth of NEV average mileage on yearly basis. The average mileage of new energy passenger cars increased from 300.3 km in 2020 to 336.9 km in 2022. With regard to BEV passenger cars, the proportion of models with driving range below 200 km as a ride remained relatively stable, and their market share in 2021 and 2022 also exceeded 15%; the number of BEV passenger cars with high driving range grew rapidly, of which those with drive range exceeding 500 km accounting for 41.7%, an increase of 17% points over 2021.

Lithium iron phosphate batteries are superior in cost and security with constant innovation of battery system integration; the installed capacity of lithium iron phosphate batteries continued to expand. Since the power battery system is gradually transforming from the internal structural innovation and integration to the external innovative integration and in-depth integration of power batteries and vehicle components, the number of structural parts is declining with the constant system innovation, thus lowering the quality of vehicles and increasing the driving range. In addition, with the emerging advantages of lithium iron phosphate battery in cost and security, the installed capacity of such batteries on the market saw rapid increase in recent years, with year-on-year growth of market share. In 2022, the installed capacity of lithium iron phosphate battery reached 63.9%, with an increase of 27.4% points and 12.7% points over 2020 and 2021 respectively, indicating an absolute dominant position in the market.

Consumption upgrading drives the development of passenger cars towards larger size and higher driving range, and the average curb weight of new energy passenger cars showed an upward momentum. In 2022, the average curb weight of BEV passenger cars and PHEV passenger cars was 1,409.6 and 1,962.4 kg, respectively, each with an increase of 2.3 and 6.0% compared with 2021. MEV market shows a clear trend of consumption upgrade, which drives the rapid growth of the market share of mid-to-high-end priced passenger car models with high driving range.

1.2.2 Effects of Energy Conservation and Emission Reduction from NEVs

Compared with fuel vehicles, NEVs are superior in emission reduction effects in the whole life cycle. This Report, focusing on BEVs, has an in-depth analysis of the effects of energy conservation and emission reduction based on the operating data of NEVs. This Report makes comparisons among different types of NEVs in power consumption over the years in terms of energy conservation and highlights the reductions of pollutants from various types of NEVs within China in the light of emission reduction.

With regard to the actual energy consumption, the changes in energy consumption varied among different types of NEVs. The energy consumption of BEV passenger cars and logistics vehicles in 2022 increased over 2021 (Fig. 1.13), mainly due to the increasing size and curb weight of BEV passenger cars. On the other hand, given the rapid market expansion of the medium- and heavy-duty trucks, the energy consumption of logistics vehicles showed a rising tendency. The average energy consumption of BEV buses in 2022 was 65.4 kWh/100 km, with a slight decrease from 2021.

The power consumption of Class A cars and BEV SUVs remained stable as a whole. By model and class of BEV passenger cars, the average energy consumption of Class-A cars and BEV SUVs in 2022 was 16.1 kWh/100 km and 18.8 kWh/100 km, respectively, basically the same as that in 2021. As for A00+A0 cars and cars of Class B and above, the power consumption in 2022 increased over 2021 (Fig. 1.14).

With the rapid growth of vehicle holdings, the traffic-related air pollution (TRAP) has become a common problem in the process of urbanization, gradually becoming a public concern in the society. Vehicle electrification, as a key technical path to mitigate vehicle pollutions, features outstanding contributions to the reduction of pollutants such as O_X, CO, CO_2, and $PM_{2.5}$. This Report states a preliminary statistics of TRAP reductions from BEVs in each city of China in 2022, as shown Table 1.2, of

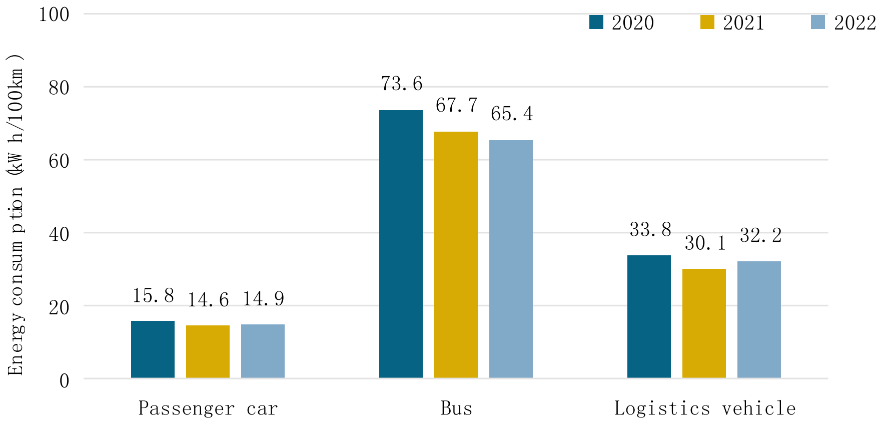


Fig. 1.13 Average energy consumption of different types of BEVs over the years

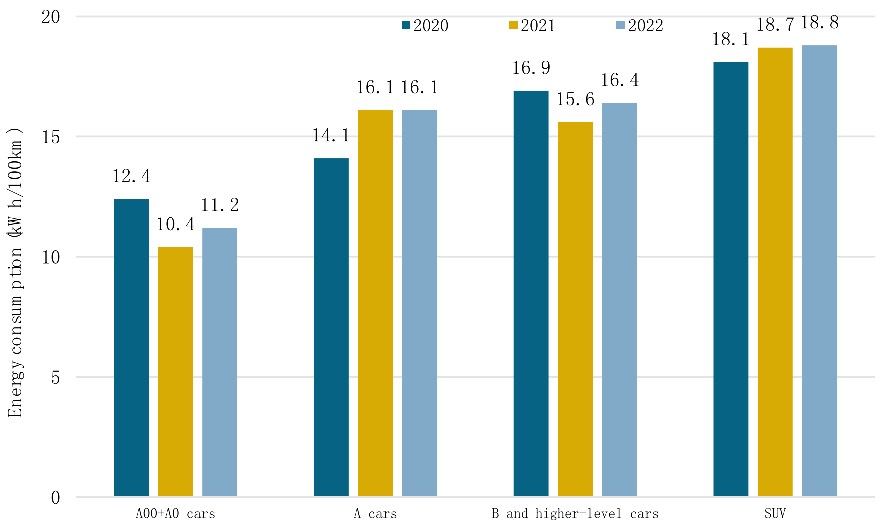


Fig. 1.14 Average energy consumption of BEV passenger cars of different classes over the years

which the first-tier and the emerging first-tier cities stayed in the forefront, showing significant outcome in pollutant reduction.

As for the effectiveness of carbon emission reduction from NEVs in operation, as of December 31, 2022, a total of 12.073 million NEVs have been connected to the National Monitoring and Management Platform, which contributed a total reduction of 147 million tons of carbon emissions. The carbon emission reduction of NEVs in 2019 increased significantly. In 2021 and 2022, such number reached 36.939 million tons and 61.442 million tons, respectively, which effectively boosted the reduction of carbon emissions in the sector of road traffic.

Table 1.2 Ranking of TRAP reduction from BEVs in TOP10 cities in 2022

Ranking	NO_x emission reduction	CO emission reduction	$PM_{2.5}$ emission reduction
1	Guangzhou	Shenzhen	Guangzhou
2	Beijing	Guangzhou	Beijing
3	Shanghai	Chengdu	Shenzhen
4	Shenzhen	Shanghai	Shanghai
5	Changsha	Beijing	Chengdu
6	Dongguan	Xi'an	Changsha
7	Chengdu	Hangzhou	Xi'an
8	Xi'an	Chongqing	Dongguan
9	Foshan	Changsha	Hangzhou
10	Harbin	Wuhan	Foshan

Remarks For the statistical results of annual mileage of vehicles in typical cities and the spatial distribution of TRAP emission reduction, please visit https://github.com/EVDataScience/EV-TRAP-emission-reduction

1.3 NEV Operation Characteristics of China in 2021

For this Report, an overall assessment is made from the operation characteristics, charging and swapping characteristics, vehicle energy conservation and emission reduction effects, failure and safety evaluation, vehicle evaluation index, hydrogen FCEVs, etc.

1.3.1 NEV Operation Characteristics

As of December 31, 2022, the cumulative mileage covered by NEVs was up to 362.22 billion kilometers.

According to the data of National Monitoring and Management Platform, as of December 31, 2022, the cumulative mileage covered by NEVs was 362.22 billion kilometers. By the power type of vehicles, the cumulative mileage covered by BEVs was up to 312.65 billion kilometers, accounting for 84.22%, including 229.86 billion kilometers (63.5%) covered by BEV-passenger cars, 49.29 billion kilometers (13.6%) covered by PHEVs, and 290 million kilometers (0.1%) covered by hydrogen FCEVs under demonstration and promotion in scale (Fig. 1.18).

Regarding application scenarios, the passenger cars are now leading the types of other application scenarios in the cumulative mileage due to scaled-up promotion. As of December 31, 2022, the cumulative mileage covered by private passenger cars was up to 1,212.3100 million kilometers, accounting for 33.5%; in the field of commercial vehicles, the cumulative mileage covered by buses and logistics vehicles stood out,

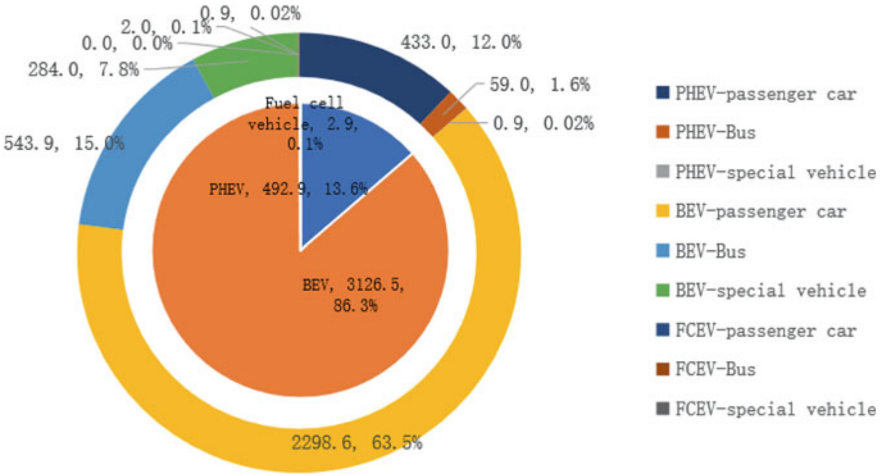


Fig. 1.18 Distribution of cumulative mileage of vehicles of different types (100,000,000 km, %)

554.7 billion kilometers and 27.61 billion kilometers respectively, accounting for 15.3% and 7.6% respectively (Fig. 1.19).

The average daily mileage in segments had somehow increased in 2022, with a significant increase in the average daily mileage of passenger cars.

The segments had been affected by the COVID-19 pandemic in the past three years, and the average daily mileage of vehicles had fluctuated to some extent. In 2022, the average daily mileage of private cars, taxis, cars for sharing, and buses decreased compared with 2021; while that of e-taxis, logistics vehicles and heavy-duty trucks increased over 2021 (Fig. 1.20).

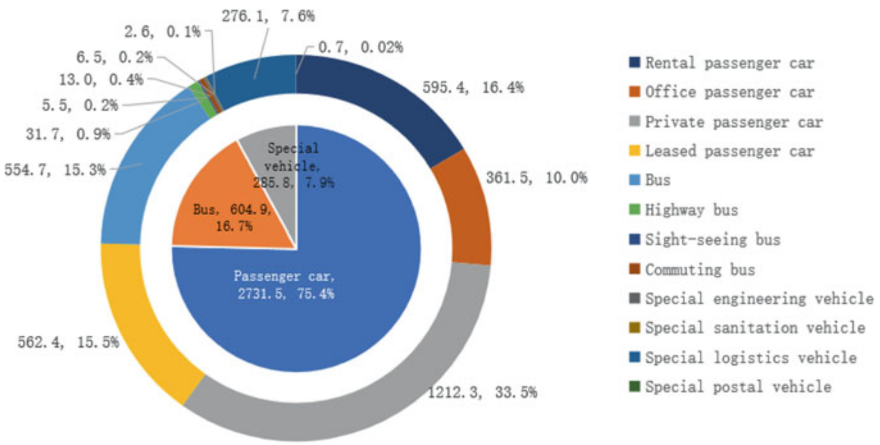


Fig. 1.19 Distribution of cumulative mileage of vehicles in different application scenarios (100,000,000 km, %)

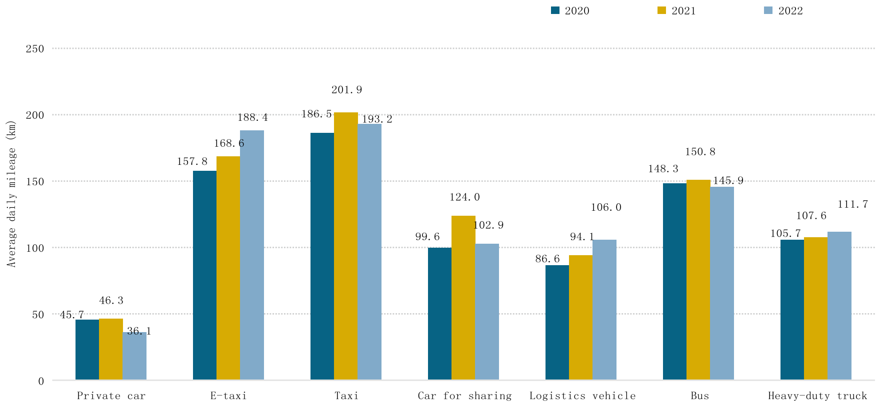


Fig. 1.20 Average daily mileage of NEVs in key segments over the years. *Remarks* Heavy-duty trucks: vehicles with an inherent label of "Vehicle for special purpose" in the National Monitoring and Management Platform, with total mass ≥12,000 kg according to the *Road Traffic Management—Types of Motor Vehicles* (GA801.2014) of the Ministry of Public Security, selected as the research object of the heavy-duty truck segment

The average monthly mileage of vehicles in segments had somehow decreased in 2022 over 2021, except e-taxis and heavy-duty trucks.

In 2022, the average monthly mileage of e-taxis and heavy-duty trucks increased year-on-year, reaching 4,309 and 2,473 km, respectively, up 1 and 2% year-on-year, respectively (Fig. 1.21). The average monthly mileage of other types decreased in 2022, mainly due to the COVID-19 that resulted in the decrease of frequencies and distances of travel. In the field of passenger cars, the average monthly mileage of private cars, taxis, and cars for sharing in 2022 was 731, 4,282, and 2,893 km, respectively, with a decrease of 20.7, 11.5, and 6.8%, respectively, compared with 2021; in the field of commercial vehicles, the average monthly mileage of NEV logistics vehicles and buses was 2,127 and 3,333 km, respectively, with an decrease of 6.3 and 10.2%, respectively, compared with 2021.

1.3.2 NEV Charging Characteristics

(1) **Characteristics of changes in vehicle charging methods**

The proportion of fast charging times in each segment is increasing greatly, except for private cars.

By charging methods (Fig. 1.22), fast charging is dominant in all key segments except private cars. In 2022, the proportion of fast charging times for e-taxis, taxis, shared rental vehicles, logistics vehicles, and heavy-duty trucks were all above 70%. Specifically, regarding the changes in fast charging times in each segment, the fast

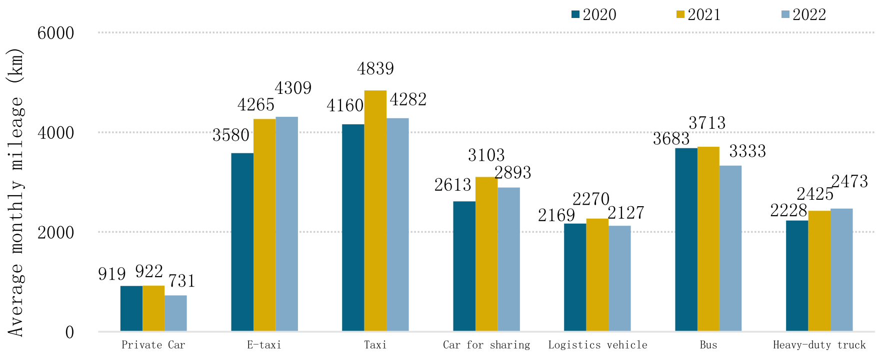


Fig. 1.21 Average monthly mileage of NEVs in key segments over the years

charging times for e-taxis, taxis, cars for sharing, logistics vehicles, buses, and heavy-duty trucks increases over 2021. Mainly on slow charging and supplemented by fast charging, the private cars also saw rapid growth in the proportion of public fast charging times from 15.6% in 2020 to 20.6% in 2022 thanks to the fast-growing holdings in the market.

(2) Characteristics of charging duration

The charging duration of operating vehicles in the public sector in 2022 was basically within two hours, of which that of private cars was significantly longer than that of operating vehicles.

Private cars were mainly applicable to slow charging mode with an average charging duration of 3.5 h in 2022. The other operating passenger vehicles as well as commercial vehicles were principally dependent on fast charging, with an average charging duration for a single time falling within two hours (Fig. 1.23). Given the changes in the average single-time charging duration for NEVs in key segments,

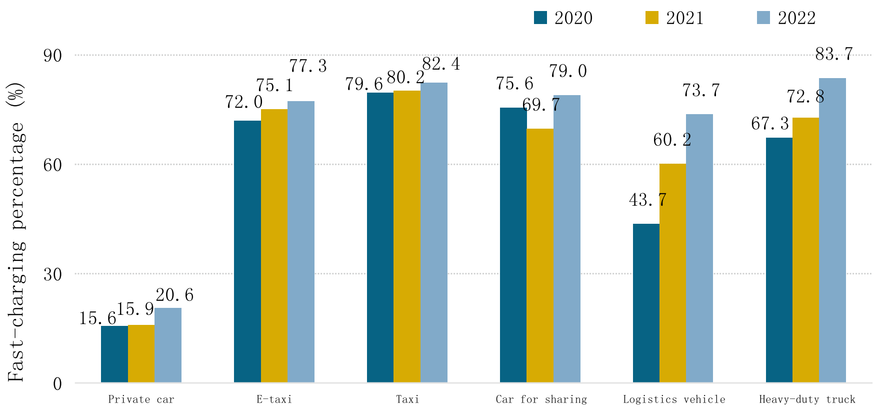


Fig. 1.22 Proportion of fast charging times in key segments over the years

in the past two years, the charging duration of private cars and logistics vehicles were on a downward trend, while that of taxis, cars for sharing, buses, and heavy-duty trucks were under fluctuation. The average single-time charging duration in key segments is closely related to the proportion of fast charging times. It can be found from Figs. 1.23 and 1.24 that the higher the proportion of fast charging times, the shorter the average single-time charging duration.

(3) **Characteristics of vehicle charging times**

Average monthly charging times of NEVs declined in 2022 in key segments, except for e-taxis and heavy-duty trucks.

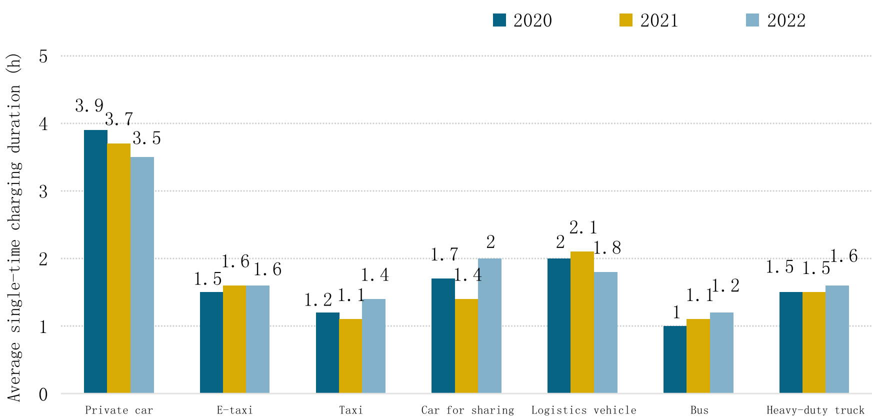


Fig. 1.23 Average single-time charging duration in key segments over the years

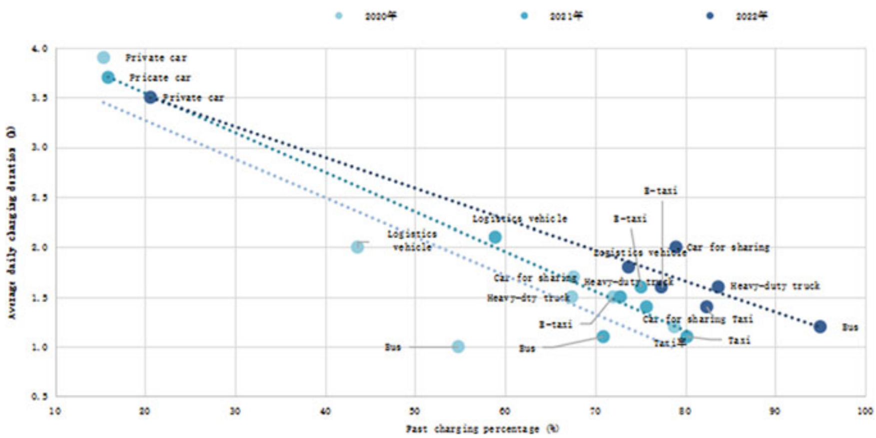


Fig. 1.24 Relationship between the average single-time charging duration and the proportion of fast charging times in key segments over the years

In 2022, the average monthly charging times of ride-hailing NEVs and heavy-duty trucks increased year by year, with fast charging as the key stimulator. Average monthly charging times of NEVs declined in 2022 in key segments, except for e-taxis and heavy-duty trucks (Fig. 1.25). The average monthly charging times of taxis, buses, and cars for sharing decreased greatly, each above 20%, which was mainly affected by the COVID-19 that affected the traveling frequencies. The average monthly charging times of e-taxis grew steadily, basically once a day in 2021. The monthly charging times were closely related to the monthly mileage (Fig. 1.26), that is the higher the average monthly mileage, the more the average monthly charging times.

(4) **Initial state-of-charge (SOC) Characteristics**

The average initial SOC of vehicle charging in all segments declined.

The average initial SOC of vehicle charging in all segments over the past three years stayed below 45%, while the charging initial SOC of new energy passenger cars by type fell year on year (Fig. 1.27), which indicated a significant consumption upgrade of new energy passenger cars, steady growth of driving range, and alleviating anxiety of users on power charging. In the field of commercial vehicles, the average initial SOC of logistics vehicles, buses, and heavy-duty trucks was far higher than that of passenger cars, which was closely related to the operation rules of commercial vehicles and the use of special charging piles.

(5) **Characteristics of typical cities in charging convenience**

According to the statistics, the percentage of charging times within 500 m of the resident of a private passenger car was lower than that of a taxi or a bus. The average percentage of vehicle charging within 500 m of a commonly parked location at night for private cars in Beijing was only 56%, while that for taxis and buses within the same distance was 70 and 79%, respectively. If the distance was extended

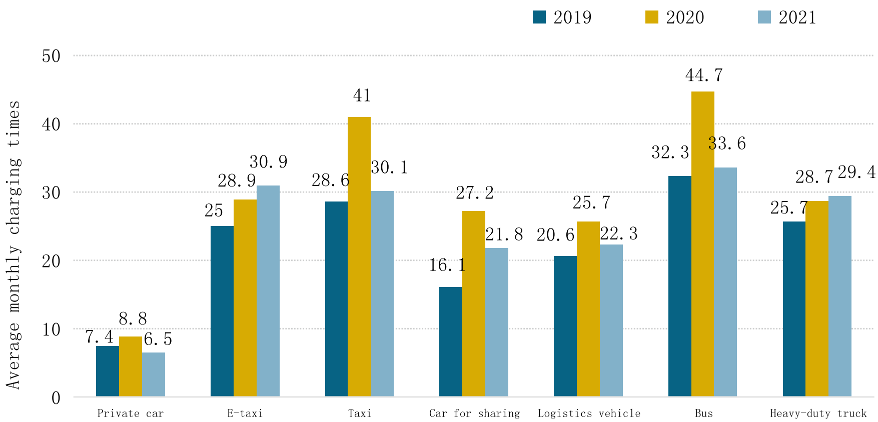


Fig. 1.25 Average monthly charging times in key segments over the years

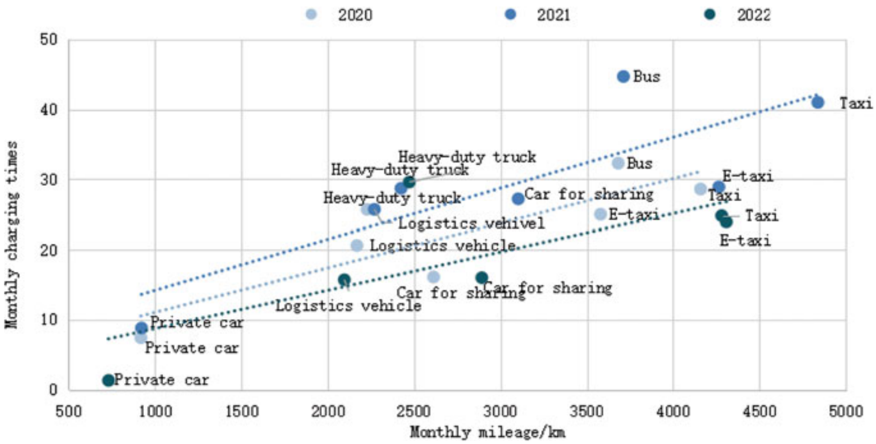


Fig. 1.26 Relationship between monthly charging times and monthly mileages in key segments over the years

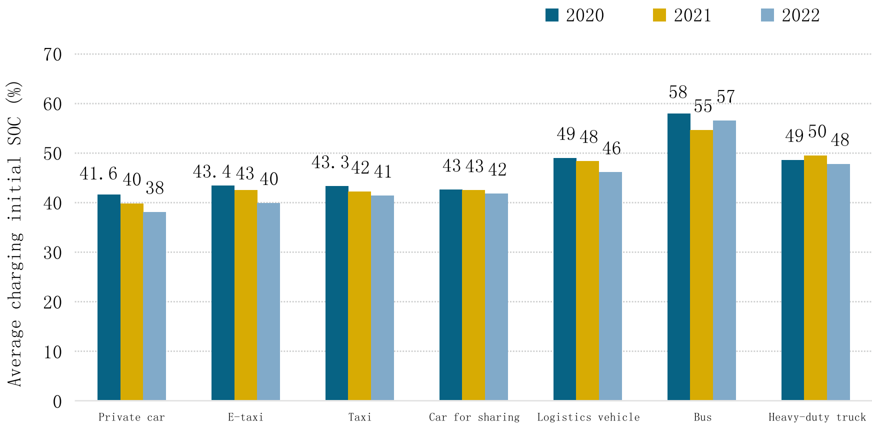


Fig. 1.27 Average initial SOC in key segments over the years

to within 1 km of a commonly parked location, the mean value of the percentage of charging times for private cars would soar to 70%. If the radius extended to 10 km, the mean value of the percentage of charging times for private passenger cars would reach 88%, surpassing that of taxis and buses, which was due to the wide range and type of charging piles available for private passenger cars, such as private and public piles near the usual place of residence (UPOR) and those in the second parking location (e.g., workplace). It was found from the statistics of charging convenience within a 500 m radius of the UPOR in different divisions of Beijing that the percentage of charging times of private passenger cars within such radius of UPOR in the core areas of Beijing was generally low, and the number of vehicles with charging operations accounted for 57.3%, while such percentage in Haidian District, Chaoyang District, Fengtai District, and Shijingshan District was slightly better, amounting to 65.8%. Compared with the aforesaid six districts, the charging times in suburban streets was generally higher than that in urban areas: The charging times of private passenger cars within a radius of 500 m of the UPOR reached 74.1%.

It is imperative to build more charging facilities in UPOR to improve the convenience of charging non-operating vehicles. Non-operating vehicles, represented by private passenger cars, took the dominant position among NEVs in China. In Beijing, compared with operating vehicles, non-operating vehicles feature a low demand for charging and replenishment and less charging times per month, making it more economical for "one pile for several vehicles while sharing". In addition, non-operating vehicles have a higher demand for charging at nighttime and for charging convenience in UPOR, making it necessary to set more charging infrastructure near the frequently parking locations. In 2022, China renovated 52,500 old residential areas, benefiting 8.76 million households. From January to May 2022, 8,940 charging piles were installed amid the renovation of old urban residential areas. Compared with the suburban townships, the downtown is the core area where residential areas gather and where problems like the difficulty in electricity expansion and limited construction space exist. Therefore, it is relatively difficult to allocate piles with vehicles or set public piles in the residential areas, weakening the charging convenience in UPOR. The existing "pile to vehicle" mode cannot be easily accomplished and may intensify the conflicts of vehicle purchasers in pile configuration. For the lack of safety supervision, the problem of resource shortage incurred from the establishment of private piles will become increasingly prominent with the explosive growth of NEVs.

1.3.3 Operation Characteristics of BEVs of Battery-Swapping Type

Battery swapping has been promoted and applied for private cars, taxis, and heavy-duty trucks for a period of time towards more diversified application scenarios. Given the similar duration between battery swapping and fuel refilling, users' anxiety in mileage and power replenishment can be effectively eliminated, making it in particular applicable to commercial vehicles in need of high operational efficiency. In 2022, the initial SOC of more than 50% of heavy-duty trucks was 20–30%, while the battery-swapping end SOC of more than 80% of BEV-heavy-duty trucks was above 90%. With a single-time battery swapping, the battery capacity would rise rapidly, and the mileage would be longer, which would help alleviate the mileage-related anxiety.

The heavy-duty trucks of battery-swapping type are mainly used for short and medium haul and closed transportation scenarios, hence a great potential for line haul to be tapped. By the average daily mileage, the average daily mileage of battery-swapping heavy-duty trucks mainly focuses on short haul or fixed-route transportation, while that of battery-swapping tractors and dump trucks was 208.9 and 183.7 km, respectively, lagging behind that of fuel heavy-duty trucks. In the medium and long run, the medium- and long-haul logistics on mainline are expected to be the next development scenario for battery-swapping heavy-duty trucks, which will further break down the barrier for the electrification of heavy-duty trucks. However, the mainline logistics relies on a sound network of battery-swapping facilities, which is expected to be a focus of the cities featuring batter-swapping facilities in the next step.

The improvement and standardization of battery-swapping infrastructure are of vital importance for the operational efficiency of battery-swapping vehicles. According to the operation characteristics of battery-swapping vehicles accessed the National Monitoring and Management Platform, following the continuous improvement of the battery-swapping infrastructure, the proportion of battery-swapping vehicles with actual swapping operation grows rapidly. In 2022, the actual battery-swapping rate of private cars, taxis, and cars for sharing exceeded 90%, and that of heavy-duty trucks was above 50%. According to the actual operation of such vehicles, there are still some problems to be solved urgently for the operation of battery-swapping stations and NEVs. For example, it is difficult to operate models of different brands in battery-swapping stations; a unified standard is in urgent need for battery packs and charging interfaces; and no unified management standards are available for the construction and operation of battery-swapping stations. It is, therefore, crucial to enhance the interchangeability of battery-swapping facilities in stations and on vehicles, which becomes the key for the operational efficiency of battery-swapping stations. At the window period for battery-swapping heavy-duty trucks, it is imperative to speed up the formulation and revision of standards to adapt to the rapid development of the battery-swapping industry. In addition, given the high cost in building battery-swapping stations, it is of great significance to make constant investment in the establishment and operation of the stations by means of finance or subsidy and further improve the operation management system for the purpose of reinforcing the operational efficiency of the battery swapping in the public sector.

1.3.4 Operation Characteristics of Plug-in Hybrid Electric Vehicles (PHEVs)

The market demand of PHEVs underwent rapid growth. A total of 2.298 million PHEVs had accessed the National Monitoring and Management Platform as of December 31, 2021, including 1.191 million PHEVs recorded throughout 2021, with a year-on-year growth of 147.8% Private purchase was the major source for such growth. PHEV-private cars accounted for 93.2% of the national total in 2022. From the perspective of the promotion structure at city level, the access proportion of PHEVs in first-tier cities keeps shrinking year by year, from 47.5% in 2019 to

21.5% in 2022. The market demand of new first-tier cities and below was rapidly released, with the access proportion expanding over the years. In 2022, the access volume of PHEV-private cars below first-tier cities accounted for 78.5% in 2022, with an increase of 26% points compared with 2019.

The proportion of mileage from PHEV in EV Mode kept expanding. From the perspective the operation mode of PHEVs in the past two years, the proportion of mileage from PHEVs in EV Mode kept increasing in 2022. In 2022, the mileage of private cars in EV Mode accounted for 47.7% of the total, up by 2.7 percentage points over 2021. With the increasing average driving range of PHEVs in EV Mode, users prefer the EV Mode for daily travel due to economic considerations.

1.4 Summary and Prospect

This Report, based on the real-time operation data of over 12.073 million NEVs on the National Monitoring and Management Platform, proposes relevant suggestions for the high-quality development of China's NEV industry upon in-depth analysis of the characteristics of the industrial development, the achievements of technological advancement, the operation of vehicles and charging characteristics and with regard to the current outcomes and problems of the industry, with an aim to provide reference for the policy-making authorities and relevant enterprises.

(1) **Give full play to the role of big data in NEV monitoring backed up by the National Monitoring and Management Platform to enhance NEV safety and security across the board.**

China has built and been running a National Monitoring and Management Platform for NEVs and achieved initial results in quality management, safety control, and after-sales service on NEVs. The construction of safety management system for NEVs has been greatly accelerated, characterized by greater emphasis among all the enterprises concerned on the safety system by further optimizing the organization and management of the safety system, increasingly standardized product and quality management for NEVs, more systematic regulation over vehicle operation data, further improved safety risk prevention and control measures, and more targeted emergency and response mechanism against problems and accidents. With the rapid growth of the NEV holdings and the number of old NEVs, there are still some problems facing the NEV safety system construction, such as the lack of systematic planning, the imperfect specifications on battery, motor, and electronic control systems, the urgent need to improve the monitoring techniques and efficiency of platforms, the shortage of proactive investigation in after-sales services, and the incomplete mechanism of accident emergency response. Therefore, the industry is in urgent need to establish a new NEV safety management system covering all factors such as quality safety, operation safety, data safety, after-sales service, and accident handling for the purpose of overall reinforcement of NEV safety and high-quality development of the industry.

(2) **Accelerate the electrification of commercial vehicles by means of technological innovation and business model innovation**

Electrification of commercial vehicles is of great significance, and the increase of penetration of vehicle electrification contributes more to carbon emission reduction. From the perspective of ministries and commissions, such pilot programs as cities with batter-swapping facilities and fuel cell demonstration city clusters will help advance the electrification in the public sector. From the perspective of local governments, it is necessary to combine technological innovation and business model innovation based on the top-level design and prospective strategies. For example, in the field of battery-swapping heavy-duty trucks, thanks to the constant innovation in intelligent battery swap, battery-swapping safety, battery storage, and energy management, the battery-swapping heavy-duty trucks are rapidly replacing the fuel cell heavy-duty trucks in the featured cities and those with steel mills, mines, and ports. The upstream and downstream participants on the industrial chain of battery-swapping heavy-duty trucks are now stepping up the businesses including battery asset management, battery safety supervision, and battery life assessment.

It is necessary to regularly monitor the health of power storage batteries based on the activity of commercial vehicles and upgrade new energy commercial vehicles in batches. In terms of buses, some of the new energy buses currently are close to or fall out of the warranty period, which impact the activity to some extent. According to the National Monitoring and Management Platform, the bus activity dropped from 89.6% in 2020 to 86.2% in 2022 due to the pandemic and the expiration of warranty period that resulted in the withdrawal. Considering the economic factors, local businesses should maintain effective monitoring of the health of power batteries in operating vehicles, including battery discharge capacity retention rate, energy efficiency retention rate, peak power retention rate, DC internal resistance change rate, and other aspects, in a bid to save financial funds, revitalize the operation of NEVs, and boost the upgrading and iteration of NEVs.

(3) **Step up the classification and guidance of charging infrastructure and strive to eradicate the contradiction between the rapid growth of NEVs and the sluggish development of charging convenience.**

Compared with the rapid growth of NEV market demand, charging infrastructure construction still lags behind. Operating vehicles, including rental passenger cars, leased passenger cars, buses, and logistics vehicles featured longer average monthly mileage, frequent replenishment, high proportion of DC fast charging, and great demand for charging, making them the key segment for the promotion of electrification in the transportation sector. In early 2023, China launched a pilot program for full electrification of the public sector, further highlighting the importance of charging security. For buses, highway buses, and other vehicles subject to fixed routes, points, and stations, it is recommended that the proportion of DC fast charging piles be satisfied as per the planning of vehicle stations and the monthly charging demand of vehicles and other data; for rental passenger cars, leased passenger cars, logistics vehicles, and other vehicles not subject to fixed points and routes, it is recommended that, considering the charging demands in time and space, more piles be erected in the downtown areas, such as transportation hubs, business centers and other areas. Charging pile construction enterprises and power grid enterprises are advised to commence grid renovation projects (e.g., capacity expansion and line upgrading) in the aforesaid areas in advance as a support for the large-scale construction of public DC fast charging piles, thus boosting comprehensive electrification in the public sector. In the field of private cars, non-operating vehicles represented by private passenger cars takes the dominant position among NEVs in China. Efforts should be made to further improve charging infrastructure in UPOR to enhance the charging convenience of non-operating vehicles. For the old residential areas in cities, it is suggested to apply the mode of "sharing one pile for more cars adjacent" for pile establishment. With the rapid growth in the penetration rate of NEVs in rural areas, the adaptive transformation of the local power grid and the configuration and renovation of charging piles in rural areas are both expediting.

(4) **Speed up the construction of a new energy infrastructure system, continue to promote intelligent and orderly charging models, and strengthen energy interaction and vehicle-network collaboration.**

Following the boosting traffic electrification, vehicles in the sector such as taxis and logistic vehicles are expected to see vigorous growth. Since such vehicles are more inclined to DC fast charging, and the power grid faces greater challenges on the load. For the special logistics vehicles with larger proportion among DC fast charging vehicles, the time of charging mainly starts from 16:00 to early morning (less at night), which fails to fully exert the effect of peak cut. For this purpose, it is suggested to promote the smart charging piles with intelligent and orderly charging mode, apply intelligent power regulation by the grid load in different regions and periods, reasonably increase the charging power at night, guide special logistics vehicles to charge at night, and lead more private passenger cars to charge at night via remote and scheduled charging, thus giving full play to the role of peak cut for NEVs. It is recommended to apply vehicle-station-network interaction demonstration project and business model, aggregate battery-swapping, energy storage, and adjustable heavy-duty truck power battery resources, consume energies locally, and advance the integrated development of energy, power, and transportation networks. In the effective application of peak cut, it is necessary to regulates power balance, reduce the pressure on the power grid, and drive market-oriented participation in regional power support.

Chapter 2
Promotion and Application of New Energy Vehicles

NEVs have entered into a stage of overall market expansion featuring a world-leading position in market scale and constant enhancement of product competitiveness. This Report, based on the NEV access data on the National Monitoring and Management Platform, concludes China's promotion experience in the NEV industry from vehicle access characteristics, which provides reference for us to predict the industrial development trend and promote the stable development of the NEV industry.

2.1 Development Status of China's New Energy Vehicle (NEV) Industry

Market demand for NEVs is exuberant, and the monthly market sales have hit a record high.

According to China Association of Automobile Manufacturers, China sold a total of 6.887 million NEV in 2022, up by 93.4% year on year. The monthly sales volume of NEVs reached a record high of 814,000 in December 2022. Product supply and quality were both improved; consumer recognition was enhanced year by year; market demand for NEVs remained robust; and market penetration curve accelerating went up at a great lick (Fig. 2.1). The monthly market penetration rate of NEVs has remained above 20% since March 2022, during which the rate hit the highest record in November 2022, reaching 33.8% (Fig. 2.2).

The monthly access volume of NEVs was growing rapidly. A total of 5.418 million NEVs accessed the National Monitoring and Management Platform throughout 2022. According to the trend of the monthly access volume of NEVs to National Monitoring and Management Platform (Fig. 2.3), the monthly access volume of NEVs in 2022 was far higher than that in 2021. With the expanding NEV market, the access volume of NEVs grew rapidly. With regard to the changes of monthly access rate, in January and February 2022, the access rate of NEVs was 118.9% and 102.1% respectively,

Z. Wang, *Annual Report on the Big Data of New Energy Vehicle in China (2023)*,
https://doi.org/10.1007/978-981-97-4840-2_2

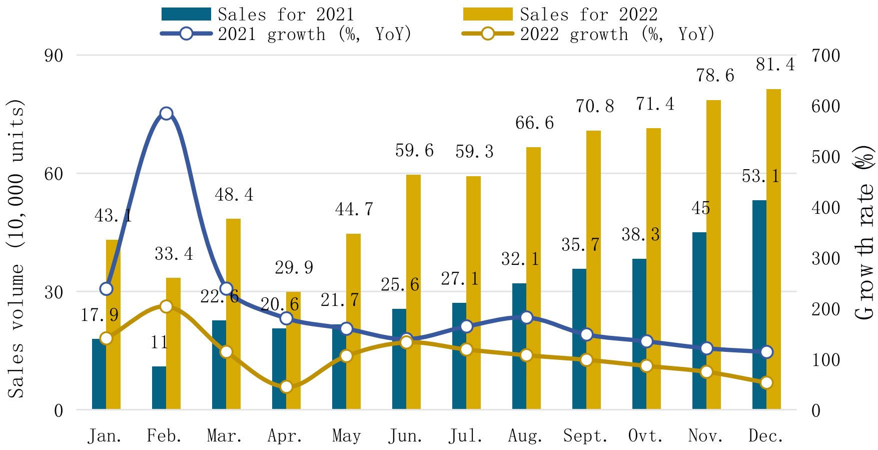


Fig. 2.1 Monthly sales growth of NEVs in China. *Source* China Association of Automobile Manufacturers

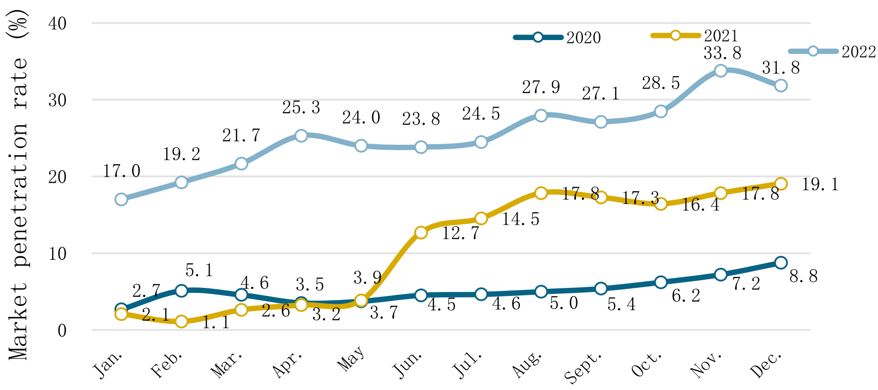


Fig. 2.2 Monthly market penetration rate of NEVs in China over the years. *Source* China Association of Automobile Manufacturers

and the access volume was significantly higher than the sales volume, indicating a period of access concentration.

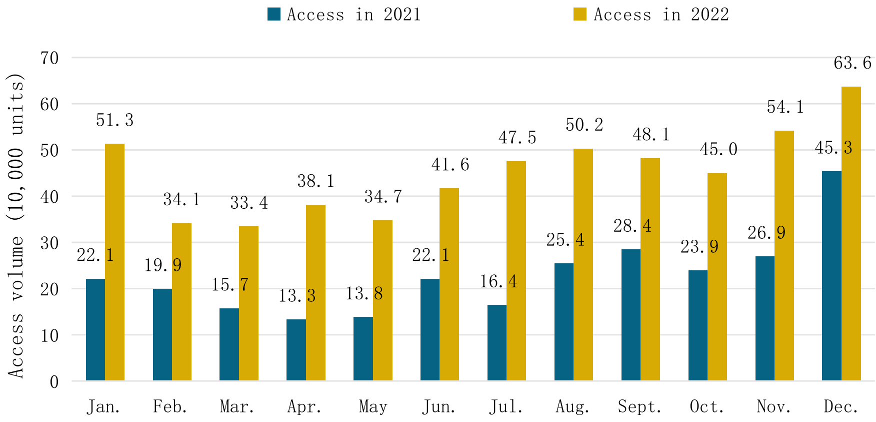


Fig. 2.3 Monthly access volume of NEVs in China over the years

2.2 Characteristics of Vehicle Access to National Monitoring and Management Platform

This Report, from the perspective of the characteristics on cumulative access and yearly access of NEVs to National Monitoring and Management Platform over the years, makes in-depth analysis of market concentration, production concentration, regional concentration, and other dimensions, which is of great significance for drawing the experience of NEV industry and promoting the high-quality development of the industry.

2.2.1 Overall Access Characteristics of Vehicles

(1) **Overview in access**

As of December 31, 2022, 12.073 million NEVs had been accessed to the National Monitoring and Management Platform, including 5,863 models accessed by 306 enterprises. From different vehicle types (Fig. 2.4), the access volume of passenger cars, buses, and Vehicle for special purposes was 10.846 million, 0.496 million, and 0.731 million, respectively, accounting for 89.8%, 4.1%, and 6.1%, respectively, with passenger cars dominating the proportion.

According to the cumulative access characteristics of vehicles in application scenarios, the cumulative access volume of private passenger cars accounted for more than half. As of December 31, 2021, the cumulative access volume of private passenger cars reached 8.321 million, accounting for 68.9% of the total access volume

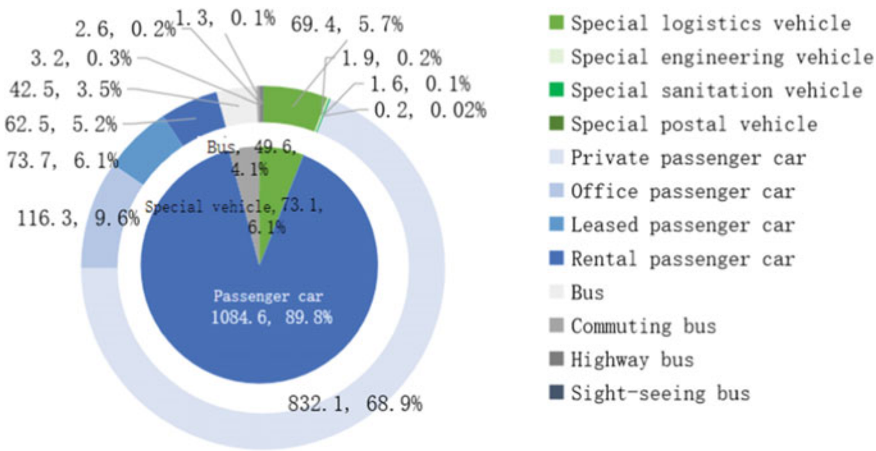


Fig. 2.4 Cumulative access and proportion of NEVs for different purposes (vehicle, %)

of vehicles to the National Monitoring and Management Platform, followed by official vehicles, rental passenger cars, special logistics vehicles, and buses, with cumulative access volume of 1.163 million, 0.737 million, 0.649 million, 0.25 million, and 0.425 million, respectively, accounting for 9.6%, 6.1%, 5.7%, 5.2%, and 3.5% each.

(2) **Characteristics of vehicle promotion concentration by province**

The number and access share of provinces with cumulative access exceeding 500,000 vehicles increased significantly in 2022 compared with the previous two years.

Judging from the cumulative access volume of NEVs in provinces (autonomous regions and municipalities directly under the Central Government (Table 2.1) on the National Monitoring and Management Platform, eight provinces with cumulative access exceeded 300,000 vehicles, namely Guangdong, Zhejiang, Jiangsu, Shanghai, Henan, Shandong, Beijing, and Sichuan. The cumulative access volume of vehicles in the above provinces/cities were 7.481 million, accounting for 62% of the total access volume in China.

The increment of NEVs in each of the TOP10 provinces in 2022 was more than 150,000.

In the past three years, the promotion of NEVs in all provinces of China has achieved remarkable results (Fig. 2.5), and, by the end of 2021, a total of 8.338 million NEVs had been accessed in the TOP10 provinces, accounting for 69.1% of the access volume in China. The increment of NEVs in each of the TOP10 provinces in 2022 was more than 150,000. Guangdong, Zhejiang, and Jiangsu ranked among the top three, and by the end of 2022, 3.987 million NEVs had been accessed in the three provinces, accounting for 33.0% of the total access volume in China.

According to the proportion of NEV promotion-type structures in each province (Fig. 2.6), the cumulative access proportion of new energy passenger cars in Guangxi,

Table 2.1 Number of provinces with different promotion levels of NEVs and their proportion of access

Cumulative access level (10,000)	2020		2021		2022	
	Number of provinces (Nr.)	Cumulative access volume proportion (%)	Number of provinces (Nr.)	Cumulative access volume proportion (%)	Number of provinces (Nr.)	Cumulative access volume proportion (%)
0–5	11	4.6	9	2.5	6	1.3
5–10	5	10.6	3	3.8	2	0.9
10–20	8	27.8	7	17.3	3	3.6
20–30	4	23.6	5	18.1	5	10.2
30–50	2	16.7	4	25.4	7	22.0
>50	1	16.7	3	32.9	8	62.0

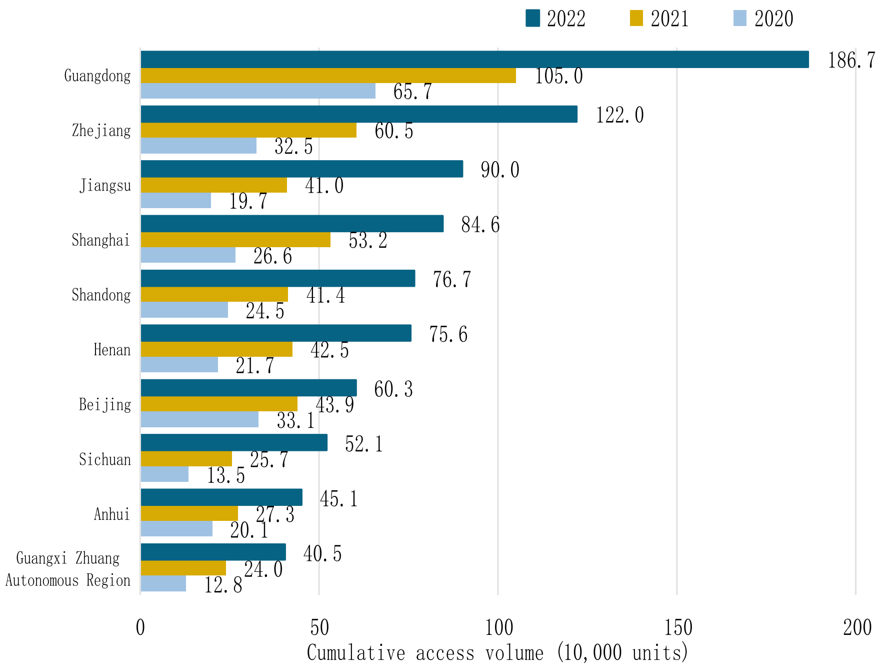


Fig. 2.5 Cumulative access volume of NEVs in the TOP10 provinces over the years. *Remarks* The cumulative access volume of each province in 2022 is taken as the ranking standard

Zhejiang, Shanghai, Shandong, Henan, and Jiangsu was over 90%, among which Guangxi was dominated by the promotion of BEV-small passenger cars, with the cumulative access accounting for 96%.

The access volume of new energy passenger cars grew steadily, and the Vehicle for special purposes among the commercial vehicles featured outstanding performance, with increasingly electrification in the past two years.

The market demand for passenger cars has been gradually released, and the access volume of new energy passenger cars in each province increased steadily. According to the cumulative access characteristics of vehicles by type over the years (Table 2.2), new energy passenger cars' cumulative access volume was obviously higher than that of buses and logistics vehicles. According to the changes in the cumulative access volume of new energy passenger cars over the years, the cumulative access volume of new energy passenger cars in the TOP5 provinces increased from 1.536 million in 2020 to 5.127 million in 2022, and that in the TOP10 provinces increased from 2.28 million in 2020 to 7.6 million in 2022.

New energy buses were generally slow in growth of access volume in recent years. According to the changes in the cumulative access characteristics of new energy buses over the years, the cumulative access volume of new energy buses in Guangdong, Jiangsu, Shandong, Zhejiang, Hunan, and Beijing ranked in the forefront, and the cumulative access volume of new energy buses in the TOP5 provinces increased from 144,000 in 2020 to 181,000 in 2022, and that in the TOP10 provinces increased from 233,000 in 2020 to 296,000 in 2022. The growth rate of access volume in the market of new energy buses slowed down in the past two years, mainly due to the rapid penetration of the market of NEV buses in the early stage, the limited capacity of new energy buses in large cities and insufficient demand on terminals. Meanwhile, the rapid development of rail transit and e-taxis has squeezed the market demand of new energy buses to a certain extent. In addition, due to financial constraints and shrinking purchasing power in several cities, the purchase plan of new energy buses were canceled or delayed in some regions. As the new energy buses entering the post-subsidy era, it is necessary for bus companies to further reduce cost and enhance intelligence with an aim to vitalize the bus market.

Affected by increasingly strict control over road traffic emissions, the electrification for Vehicle for special purposes has been accelerating. According to the changes in the cumulative access characteristics of new energy Vehicle for special purposes over the years, the cumulative access volume of new energy Vehicle for special purposes in the TOP5 provinces increased from 211,000 in 2020 to 357,000 in 2022, and that in the TOP10 provinces increased from 292,000 in 2020 to 518,000 in 2022.

The regional concentration of NEVs by type showed an overall downward trend.

According to the access concentration of vehicles by type over the years (Table 2.3), the cumulative access concentration of various types of NEVs in the TOP3, TOP5, and TOP10 provinces showed an overall downward trend yearly. Among them, the proportion of cumulative access volume of new energy passenger cars in the TOP10 provinces decreased from 72.2% in 2020 to 70.1% in 2022, that of

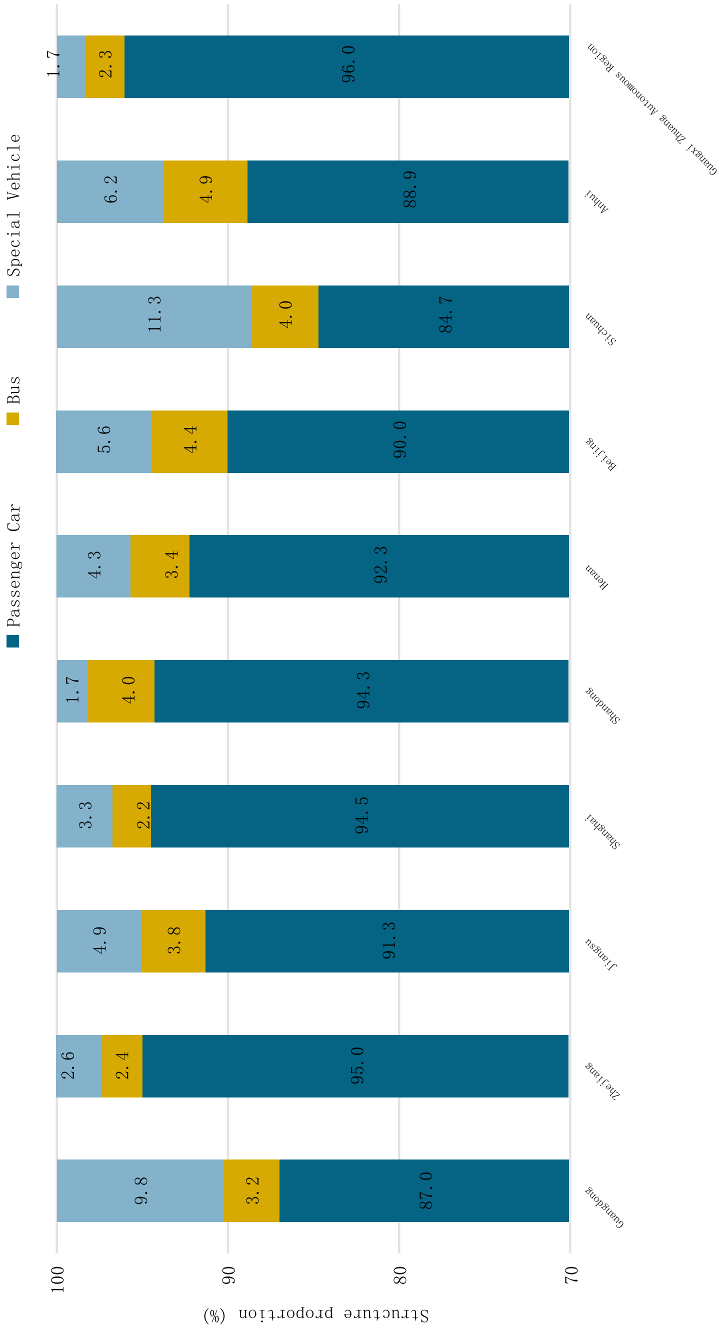
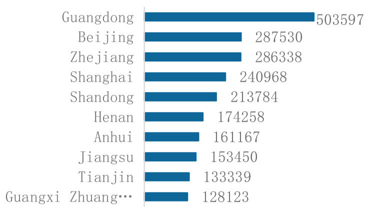
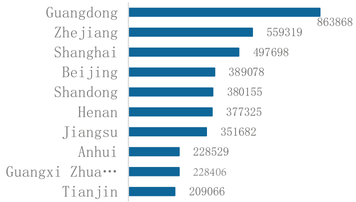
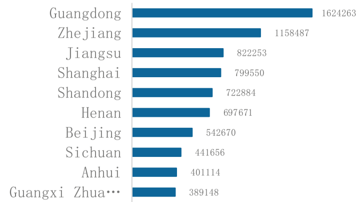
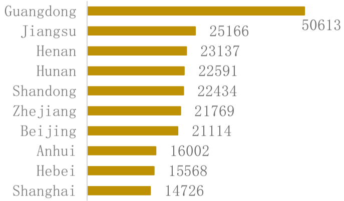
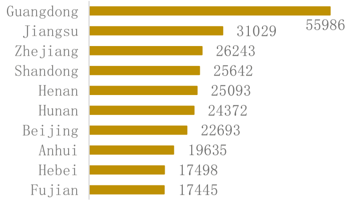
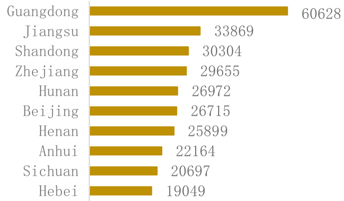
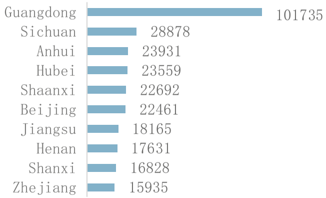
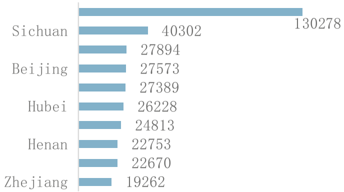
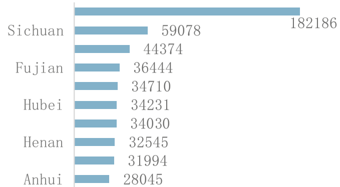


Fig. 2.6 Proportion of cumulative access structures of NEVs by type in the TOP10 provinces

Table 2.2 Cumulative access volume of NEVs by type in difference provinces (autonomous regions/municipalities directly under the Central Government)

Type of vehicle	Cumulative access volume in 2020 (vehicle)	Cumulative access volume in 2021 (vehicle)	Cumulative access volume in 2022 (vehicle)
Passenger Car			
Bus			
Vehicle for special purpose			

new energy buses in the TOP10 provinces decreased from 61.2% in 2020 to 59.8%, and that of new energy Vehicle for special purposes in the TOP10 provinces decreased from 76.3% in 2020 to 70.9% in 2022. The regional concentration of new energy Vehicle for special purposes was relatively higher than that of new energy passenger cars and buses.

(3) **Characteristics of vehicle promotion concentration by city**

In 2022, the promotion scale of NEVs in the TOP10 cities had increased rapidly, and the promotion effect in first-tier cities was significant.

In the past three years, the promotion scale of NEVs in the TOP10 cities had increased rapidly (Fig. 2.7). By the end of 2022, 4.697 million NEVs had been accessed in the TOP10 cities, accounting for 38.9% of the access volume in China. Shanghai, Shenzhen, Beijing, and Guangzhou ranked at the forefront regarding cumulative access volume of NEVs, and by the end of 2022, 2.707 million NEVs had been accessed, accounting for 22.4% of the total access volume in China.

According to the proportion of NEV promotion-type structures in the TOP10 cities (Fig. 2.8), the cumulative access proportion of new energy passenger cars in Hangzhou, Shanghai, and Tianjin was over 90%; the cumulative access proportion of new energy commercial vehicles in Shenzhen, Chengdu, and Xi'an accounted for more than 15%, and the new energy Vehicle for special purpose was the primary type promoted.

By the vehicle type, the promotion of NEVs in each city has its own characteristics.

According to the cumulative access volume of new energy passenger cars in the TOP10 cities (Fig. 2.9), by the end of 2022, the cumulative access volume of new energy passenger cars in Shanghai, Shenzhen, and Beijing ranked among the forefront, with 00,000, 578,000, and 543,000 respectively, accounting for 7.4%, 5.3%, and 5.0%, respectively of the total access volume in China. According to the year-on-year growth rate of new energy passenger car access in each city (Fig. 2.10), the new energy passenger car market in Foshan and Wuhan proliferated in 2022. Among them, in 2022, the access volume of NEVs in Foshan had the highest year-on-year growth rate, up to 303%.

According to the cumulative access characteristics of the TOP10 cities in the field of new energy buses (Fig. 2.11), by the end of 2022, Beijing, Shanghai, and Guangzhou ranked the top three in China, with a cumulative access volume of 27,000, 19,000 and 17,000 vehicles respectively, accounting for 5.4%, 3.8%, and 3.5% respectively of the total access volume in China.

According to the year-on-year growth rate of new energy bus access in the TOP15 cities in China in 2021 (Fig. 2.12), the annual growth rate of new energy bus access in Shenzhen, Yinchuan, and Shijiazhuang in 2022 was faster, with a year-on-year growth rate of more than 15 times.

According to the cumulative access characteristics of the TOP15 cities in the field of new energy Vehicle for special purposes (Fig. 2.13), by the end of 2022, the cumulative access volume of new energy Vehicle for special purposes in Shenzhen

Table 2.3 Cumulative access and proportion of nevs of different types in each province

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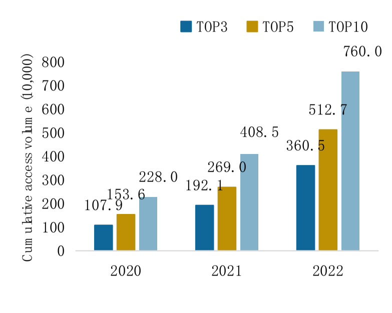
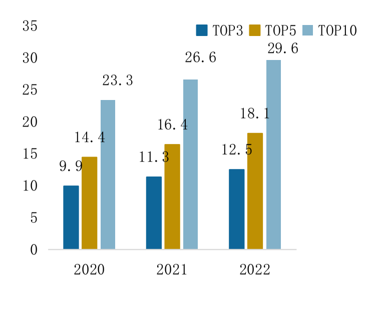
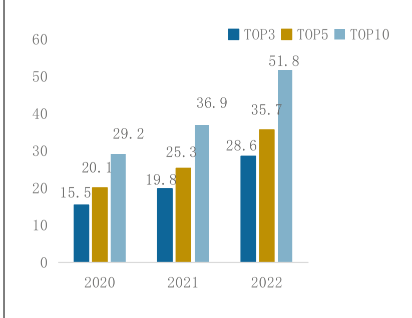
<tr><td>Cumulative access volume</td><td>
</td><td>
</td><td>
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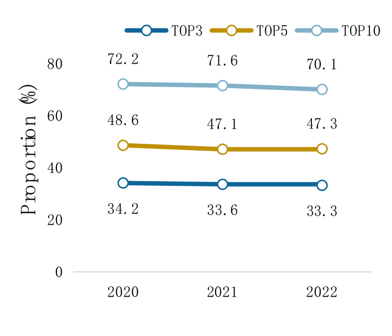
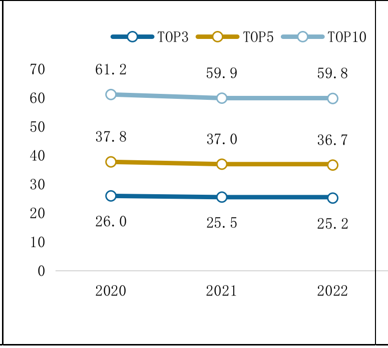
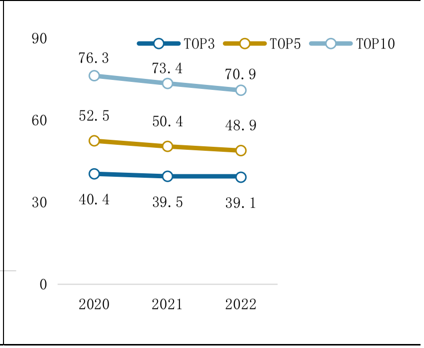
<tr><td>Cumulative access volume percentage</td><td>
</td><td>
</td><td>
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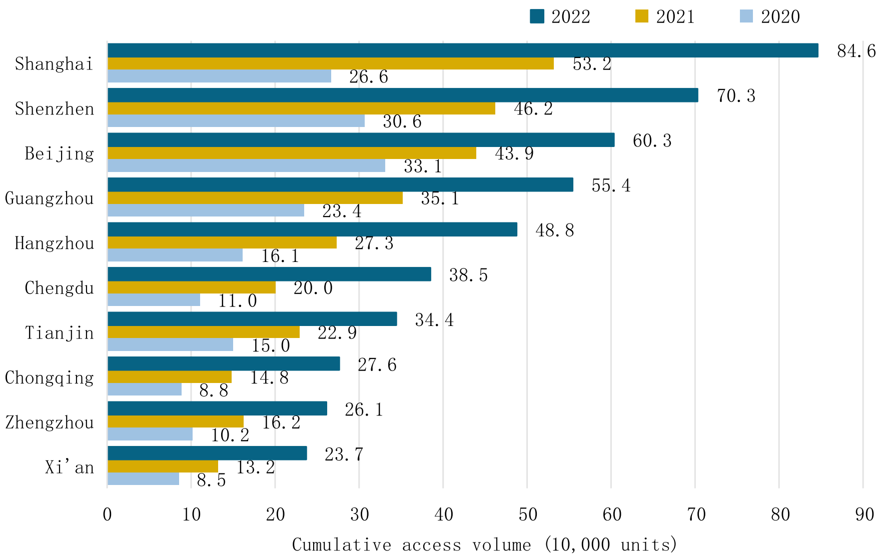


Fig. 2.7 Cumulative access volume of NEVs in the TOP10 cities over the years. *Remarks* The cumulative access volume of each city in 2022 is taken as the ranking standard

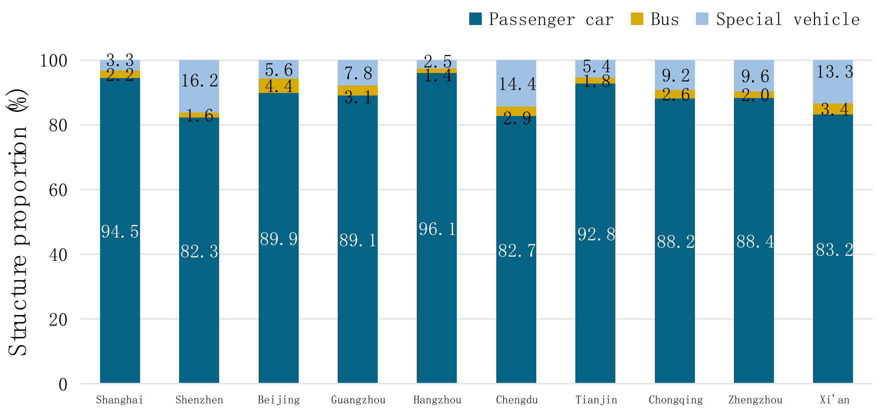


Fig. 2.8 Proportion of cumulative access structures of NEVs by type in the TOP10 cities

was significantly higher than that in other cities, up to 114,000 vehicles, accounting for 15.6% of the total access volume in China.

In 2022, the annual access volume of new energy Vehicle for special purposes in the TOP15 cities in China increased year-on-year (Fig. 2.14). The access growth rate of new energy Vehicle for special purposes in Hangzhou, Tangshan, and Wuhan in 2022 was significantly higher than that in other cities, with a year-on-year growth rate of more than 1.5 times.

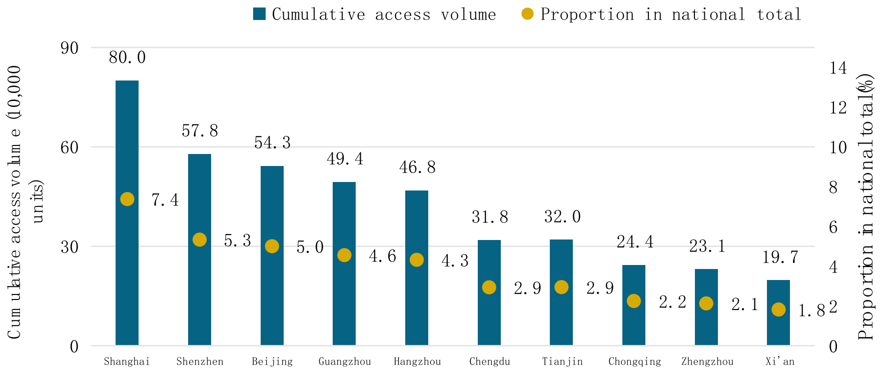


Fig. 2.9 Cumulative access and proportion of new energy passenger cars in the TOP10 cities

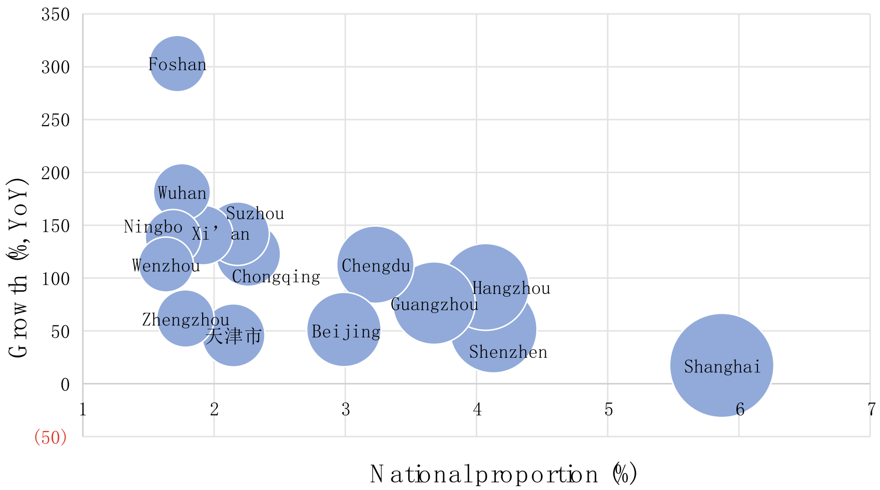


Fig. 2.10 Access volume and growth rate of new energy passenger cars in the TOP15 cities in 2022. *Remarks* Bubble size indicates a city's annual access volume of new energy passenger cars in 2022

(4) Characteristics of market concentration

In the past three years, the concentration of NEV access characteristics of the TOP10 enterprises by field had shown an overall downward trend, and the access volume of typical enterprises was outstanding.

From the cumulative access characteristics of different types of vehicles, in the field of passenger cars, the cumulative access volume of the TOP10 enterprises increased from 1.943 million in 2020 to 7.056 million in 2022, and the market concentration increased from 61.5% in 2020 to 65.1% in 2022. Among them, BYD performed noticeably well. By 2022, BYD had 2.583 million new energy passenger

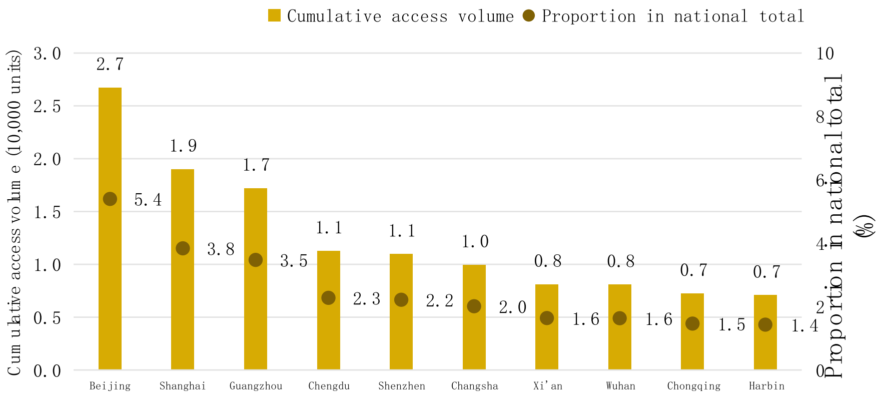


Fig. 2.11 Cumulative access volume and proportion of new energy buses in the TOP10 cities

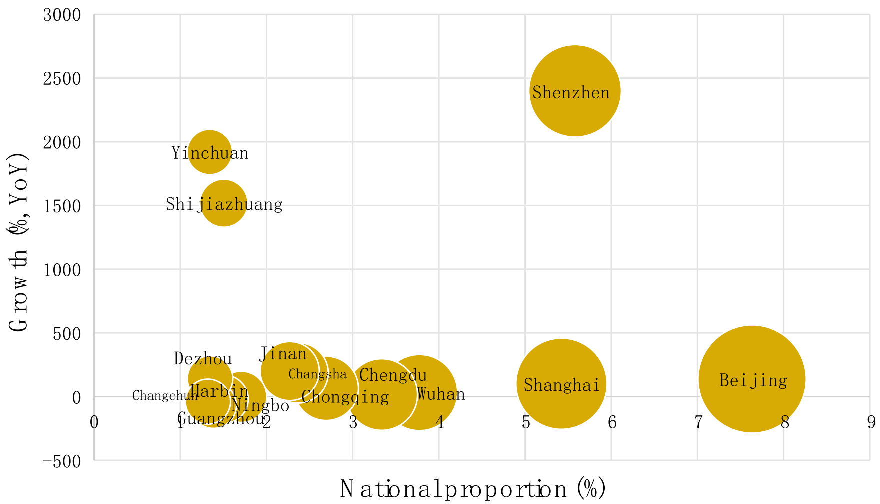


Fig. 2.12 Access and growth rate of new energy buses in the TOP15 Cities in 2022. *Remarks* Bubble size indicates the number of new energy buses accessed by the National Monitoring and Management Platform in 2022

cars accessed, accounting for 23.8% of the cumulative access volume of new energy passenger cars in China (Table 2.4).

In the field of new energy buses, the cumulative access characteristics of the TOP10 enterprises increased from 265,000 in 2020 to 346,000 in 2022, and the market concentration increased from 69.6% in 2020 to 69.7% in 2022 (Table 2.5). Yutong Bus ranked first Regarding promotion volume. As of December 31, 2022, Yutong Bus had 117,000 new energy buses accessed, accounting for 23.6% of the cumulative access volume of new energy buses in China.

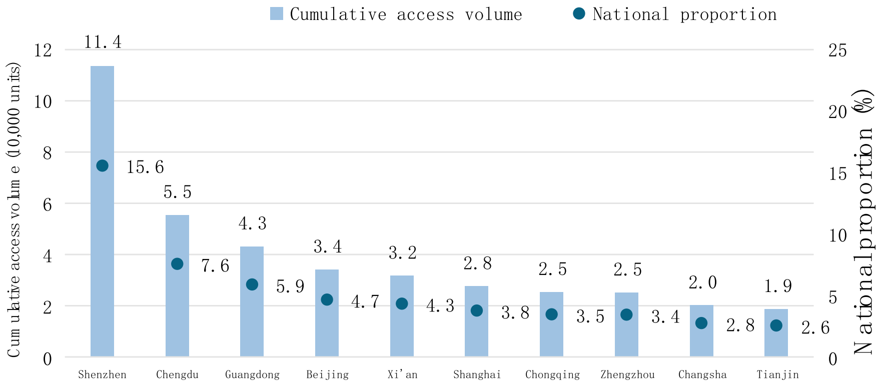


Fig. 2.13 Cumulative access and proportion of NEVs for special purposes in the TOP10 cities

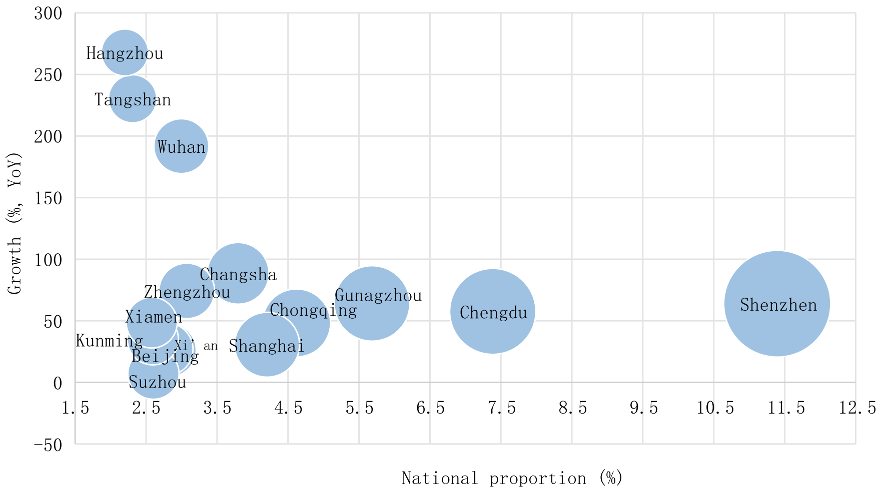
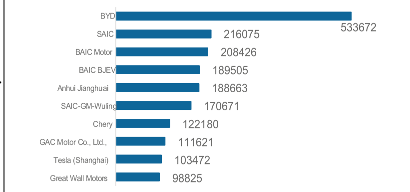
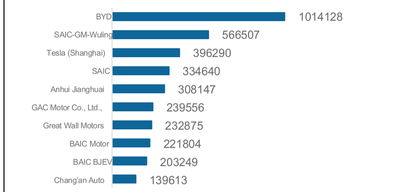
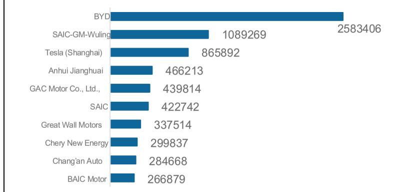


Fig. 2.14 Access and growth rate of new energy Vehicle for special purposes in the TOP15 cities in 2022. *Note* Bubble size indicates the number of new energy Vehicle for special purposes accessed by the National Monitoring and Management Platform in 2022

In the field of new energy Vehicle for special purposes, the cumulative access characteristics of the TOP10 enterprises increased from 216,000 in 2020 to 392,000 in 2022, and the market concentration decreased from 56.5% in 2020 to 53.7% in 2022. Dongfeng Motor had 82,000 new energy Vehicle for special purposes accessed, accounting for 11.2% of the cumulative access volume of new energy Vehicle for special purposes in China.

From the change in the concentration of access volume of different types of vehicles in each enterprise (Table 2.5), the concentration of vehicle access volume of bus enterprises and Vehicle for special purpose enterprises in the TOP5 and TOP10

Table 2.4 Cumulative access of NEVs of the TOP10 enterprises—by type

<table>
<tr><th>Type of vehicle</th><th>Cumulative access volume in 2020 (vehicles)</th><th>Cumulative access volume in 2021 (vehicles)</th><th>Cumulative access volume in 2022 (vehicles)</th></tr>
<tr><td>Passenger Car</td><td>
</td><td>
</td><td>
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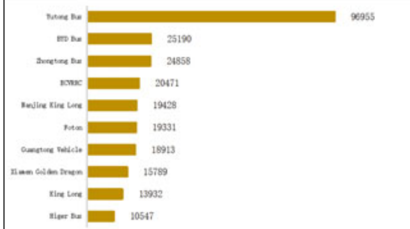
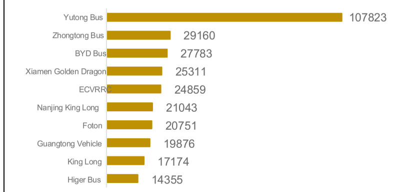
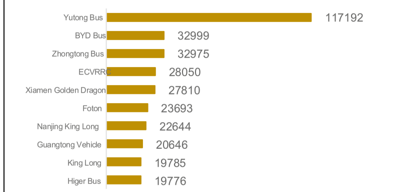
<tr><td>Coaches</td><td>
</td><td>
</td><td>
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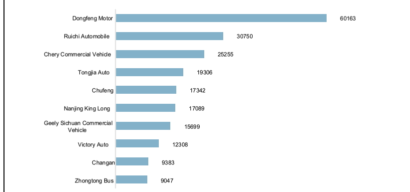
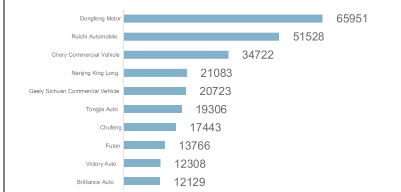
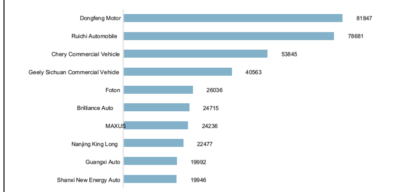
<tr><td>Vehicle for special purpose</td><td>
</td><td>
</td><td>
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Table 2.5 Cumulative access and proportion of NEVs of different types of each enterprise

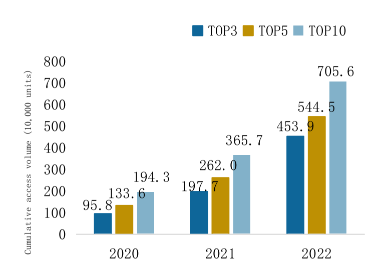
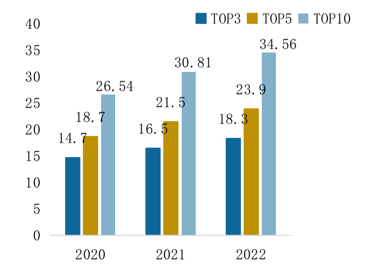
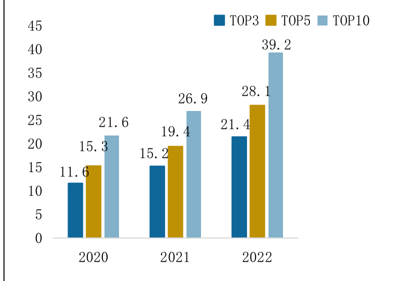
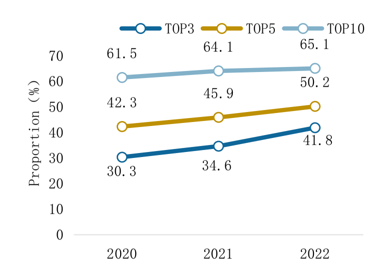
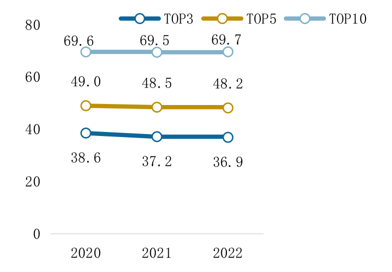
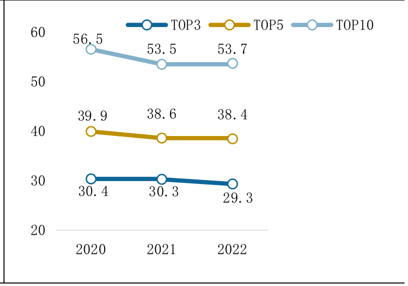
	Passenger car	Coaches	Vehicle for special purpose
Calendar year Cumulative Access Volume			
Cumulative Access Volume Percentage			

Table 2.6 Access of NEVs in China over the years

Year	In 2020	2021	2022
Vehicle access volume (10,000)	98.5	273.2	541.8

sub-fields showed an overall downward trend; in the field of passenger cars, due to the strong sales growth of Tesla, SGMW, BYD, and other star models, the concentration of enterprises in 2022 increased compared with that in the previous years.

2.2.2 Historical Access Characteristics of NEVs

(1) **Access to the National Monitoring and Management Platform over the years**

A total of 5.418 million NEVs were accessed to the National Monitoring and Management Platform in 2022, with a substantial YoY increase.

From Table 2.6, 5.418 million NEVs accessed the National Monitoring and Management Platform in 2022, an increase of 98.3% compared with 2021. According to the comparison between the annual access volume of NEVs and the annual sales of NEVs on the National Monitoring and Management Platform (Table 2.7), the access volume of NEVs in January 2022 and January 2023 was significantly higher than the sales of NEVs due to the appropriate delay in the time of NEV access to the National Monitoring and Management Platform, indicating that some NEVs were sold at the end of 2022. However, such vehicles' access to the National Monitoring and Management Platform was in January 2023.

(2) **Access volume of NEVs in China in 2021 by driving type**

The access characteristics of NEVs in all regions of China showed a steady growth trend in the past two years, with outstanding performance in East China.

Table 2.7 Comparison between access and sales of NEVs in January of each year

Type	January 2022	January 2023
Sales volume (10,000)	**43.1**	**40.80**
BEVs	34.6	28.7
PHEVs	8.5	12.1
Access volume (10,000)	**51.2**	**43.5**
BEVs	40.9	32.0
PHEVs	10.3	11.4

Note Due to the supplementary access characteristics of NEVs to the National Monitoring and Management Platform, this Report will continuously update the access data of NEVs over the years
Source The sales data is from the China Association of Automobile Manufacturers (CAAM), and the access data is from the National Monitoring and Management Platform

As shown in Table 2.8, 4.224 million BEVs were accessed in 2022, accounting for 78%; the access volume of PHEVs and FCEVs was 1.191 million and 0.3 million, respectively, accounting for 22% and 0.05%, respectively. According to the distribution of monthly access throughout 2021 (Fig. 2.15), BEVs' access volume per month in 2022 was over 250,000. The access volume of BEVs in June 2022 reached and stayed afterwards at 300,000 and then reached 480,000 in December to the highest level of the year.

(3) **Access characteristics of NEVs over the years by region**

The access characteristics of NEVs in all regions of China showed a steady growth trend in the past two years, with outstanding performance in East China.

East China ranks first regarding NEV access over the years. According to the access in different regions (Fig. 2.16), in 2022, East China boasts the highest access with a volume of 2.105 million, accounting for 38.9%, followed by South China and Central China with a volume of 1.079 million and 0.741 million, respectively, accounting for 19.9% and 13.7%.

NEV promotion was unbalanced in China, of which the proportion of access in East China exceeded 1/3 over the years, while that of Northwest and Northeast China was relatively lower.

According to the proportion of NEVs in different regions over the years (Fig. 2.17), the proportion of NEVs in East China remained above 30% over the years, which is significantly higher than that in other regions. According to the changes in the proportion of access volume over the years, the proportion in East China, South China, Southwest China, Northwest China and Northeast China expanded in 2022

Table 2.8 Access volume of NEVs in China in 2022—by power type

Driving type	BEVs	PHEVs	FCEVs
Access volume of NEVs in China (10,000)	422.4	119.1	0.3

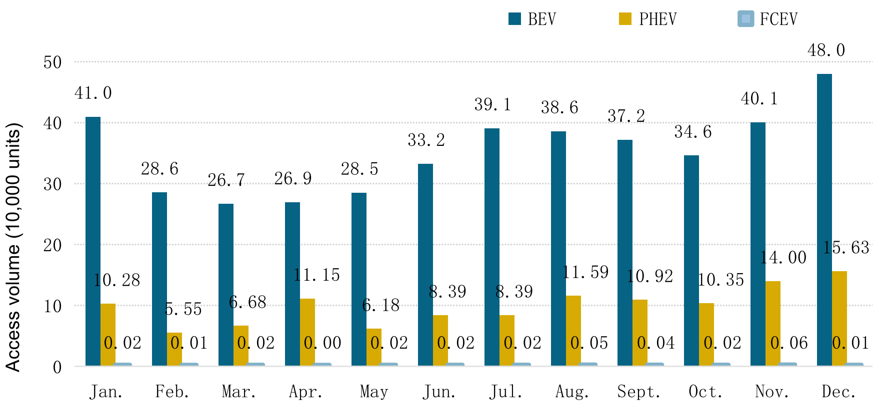


Fig. 2.15 Monthly access volume of NEVs in China in 2021—by driving type

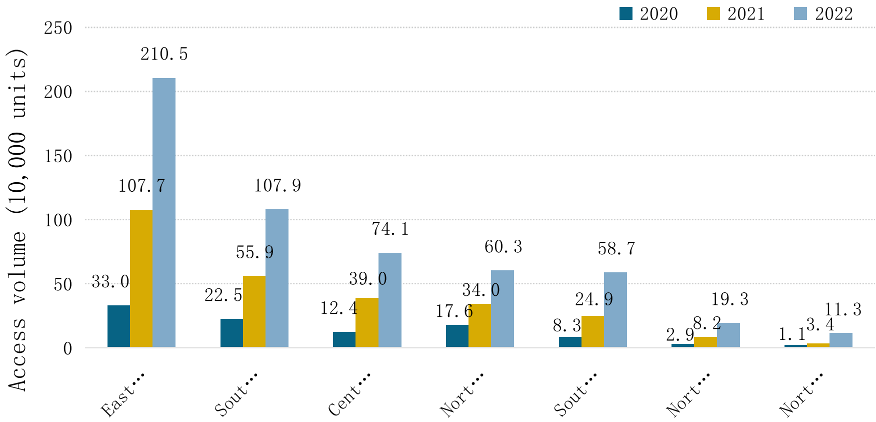


Fig. 2.16 Access of NEVs in different regions of China over the years

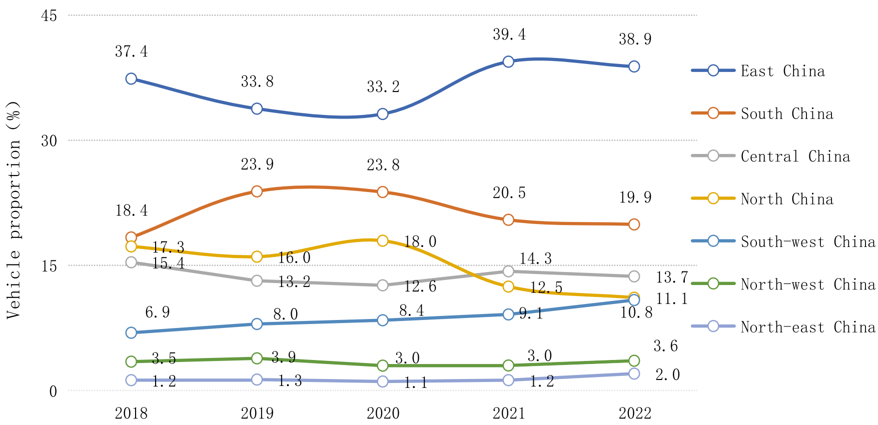


Fig. 2.17 Proportion of access volume of NEVs in different regions over the years

compared with 2018. Due to the early application of NEVs in North China and favorable policies that stimulated market demand, the proportion of access volume in North China decreased in 2021 compared with 2018. With the rapid promotion of NEVs nationwide, the market demand in other regions is expected to be released soon.

(4) **Access of NEVs in cities of each tier in China over the years**

The consumer demand in cities of each tier is robust, and the access volume of NEVs in cities of different tiers grew rapidly in 2022; and the access structures in new first-tier cities and below took a larger proportion.[1]

[1] Reference to city tiers: 2022 Rankings of Cities in Business Charm released by YICAI and THE RISING LAB, https://www.yicai.com/topic/101425010/.

According to the access volume of cities of different tiers over the years (Fig. 2.18), the consumer demand for cities of each tier had recovered steadily, which boosted the increase of NEV access volume in different tiers of cities in varying degree in 2022. In 2022, the access volume of NEVs in first-tier cities was the highest, reaching 1.553 million, up 1.4 times year-on-year; the access volume of NEVs in the second-tier to fifth-tier cities increased by 136.0%, 100.2%, 108.5% and 119.8%, respectively, compared with 2021, with growth rate doubled.

From the proportion of access in cities of each tier over the years (Fig. 2.19), the market promotion of NEVs grew rapidly from first-tier cities to new first-tier cities and below. The proportion of access volume of NEVs in first-tier cities dropped from 29.2% in 2020 to 17.0% in 2022; that in new first-line cities and below climbed from 70.8% in 2020 to 83.0% in 2022, indicating a rapid release of endogenous market demand and constant improvement of users' recognition of NEVs.

(5) **Access of NEVs by key enterprises over the years**

From the perspective of enterprise access volume (Fig. 2.20), the access volume of NEVs by the Top 3 enterprises in 2022 were BYD, SAIC-GM-Wuling, and Tesla (Shanghai), registering 1.575 million, 0.525 million, and 0.47 million, respectively, accounting for 29.1%, 9.7%, and 8.7% of the total access volume in China, respectively.

(6) **Access characteristics of NEVs over the years by application scenario**

In order to better study the characteristics of vehicle behaviors in key segments, seven segments, including private cars, e-taxis, taxis, cars for sharing, logistics vehicles, buses, and heavy-duty trucks, are selected with the support of the big data intelligent analysis technology from the National Monitoring and Management Platform as the key application scenarios for research. The vehicles in the main application scenarios are defined as follows:

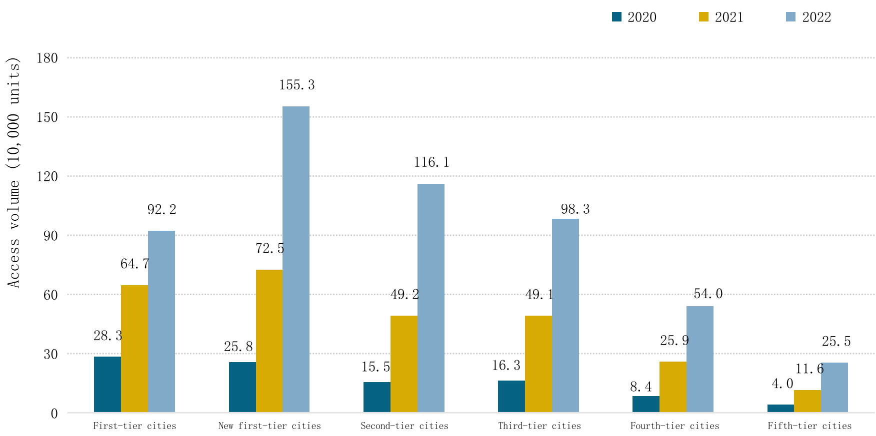


Fig. 2.18 Access of NEVs in cities of each tier in China over the years

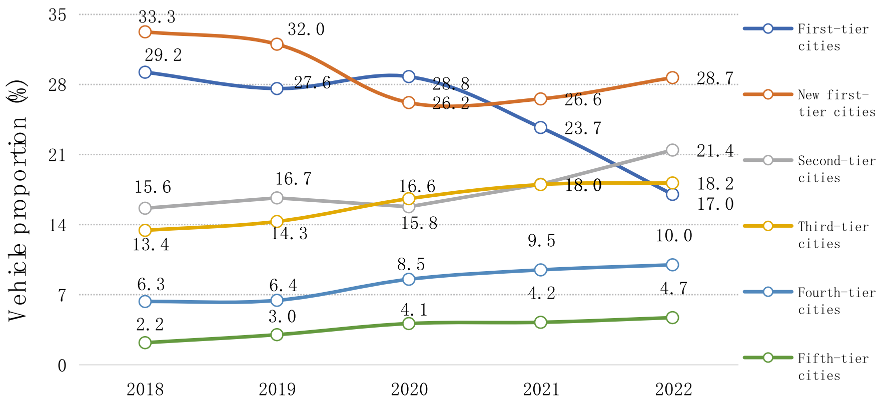


Fig. 2.19 Proportion of access volume of NEVs in cities of different tiers over the years

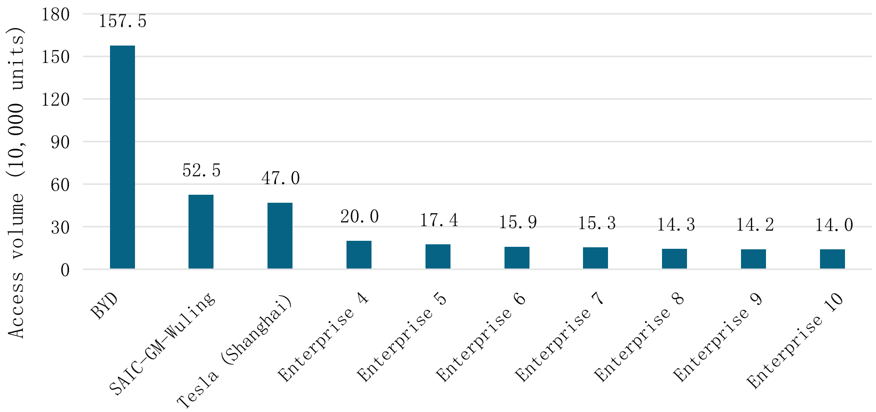


Fig. 2.20 Access of NEVs by TOP10 enterprise over the years

- **Private car:** A vehicle not for online ride-hailing service selected from vehicles with an inherent "private car" label in the National Monitoring and Management Platform as the research object for the private car segment.
- **E-taxi:** A vehicle for online ride-hailing service selected from vehicles with an inherent label of "private car," "official car," and "rental car" in the National Monitoring and Management Platform as the research object for the e-taxis segment.
- **Car for sharing:** A vehicle for time-based rental service and long/short-term rental service filtered from vehicles with an inherent label of "rental car" in the National Monitoring and Management Platform as the research object for a segment of cars for sharing.
- **Taxi:** A vehicle with an inherent label of "taxi car" in the National Monitoring and Management Platform selected as the research object of the taxi segment.

- **Logistics vehicle:** A vehicle with an inherent label of "logistics vehicle" in the National Monitoring and Management Platform selected as the research object of the logistics vehicle segment.
- **Bus:** A vehicle with an inherent label of "bus" in the National Monitoring and Management Platform selected as the research object of the logistics vehicle segment.

From Table 2.9, in 2022, the access volume of private cars was 4.015 million, up 1 time year-on-year; that of e-taxis was 247,000; that of taxis was 276,000; that of cars for sharing was 91,000; that of logistics vehicles was 214,000, up 87.7% year-on-year; and that of buses was 47,000, down 13.% year-on-year.

Private purchase has become the main driver for market growth, and the market share of new energy private cars has reached a new high.

According to the National Monitoring and Management Platform data (Fig. 2.21), the proportion of access volume of new energy private cars showed a rapid growth trend. In 2022, the annual access volume of private cars accounted for more than 70% of NEVs; private purchase has become the main driver for market growth; and new energy private cars have been gradually become the major vehicles for family use. In terms of operation, the access share of e-taxis, taxis, and logistics vehicles increased slightly, while that of cars for sharing and buses declined from 2021.

Stimulated by the user recognition improvement and diversified product supply, the market share of new energy private cars in cities of new first-tier or below increased rapidly.

According to data on the National Monitoring and Management Platform (Fig. 2.22), the proportion of access volume of new energy private cars in cities of new first tier and below increased rapidly the past three years. The proportion of access volume of new energy private cars increased from 63.9% in 2018 to 82.9% in 2022, an increase of 19 percentage points. Due to the increasing user recognition

Table 2.9 Vehicle access volume of key segments

Key segment	Access in 2020 (10,000)	Access in 2021 (10,000)	Access in 2022 (10,000)	2022 YoY change (%)
Private car	59.9	200.0	401.5	100.8
E-taxi	3.5	8.9	24.7	177.5
Taxi	7.3	12.4	27.6	122.6
Car for sharing (time-based renting and long/short-term renting)	5.0	8.9	9.1	2.2
Logistics vehicle	6.5	11.4	21.4	87.7
Bus	6.1	5.4	4.7	−13.0
Other types	10.4	26.2	52.8	101.5
Total	98.5	273.2	541.8	98.3

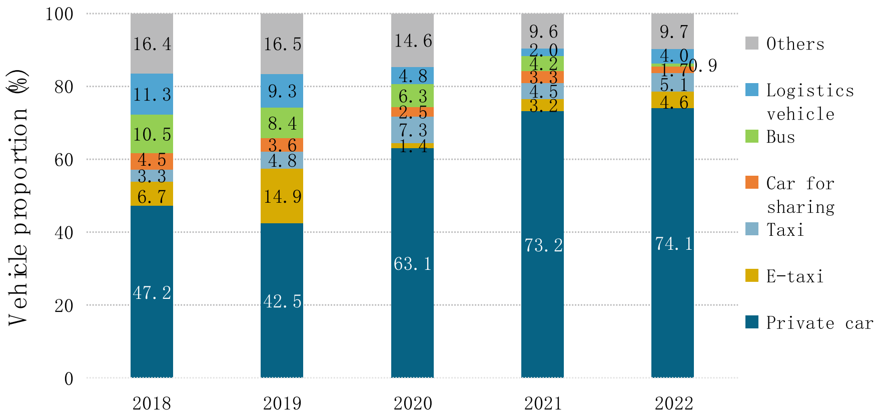


Fig. 2.21 Proportion of access volume of NEVs in segments over the years

of the NEV market and the rapid release of market demand, compared to the rapid growth in the market share of NEV access in cities of other tiers, the market share of NEV access in first-tier cities decreased from 36.1% in 2018 to 17.1% in 2022.

From the proportion of access volume of new energy private cars in cities subject to purchase restrictions and cities not subject to purchase restrictions (Fig. 2.23), the market share of cities not subject to purchase restrictions increased significantly, accounting for 74.2%, with an increase of 8% compared with 2021.

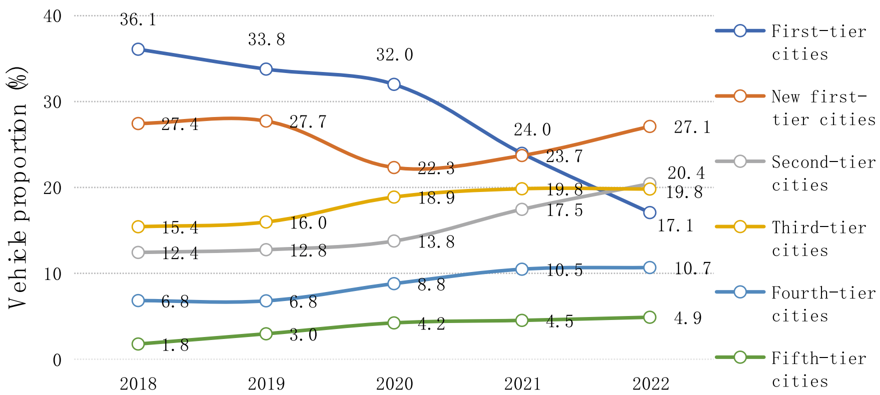


Fig. 2.22 Proportion of access volume of new energy private cars in cities of different tiers

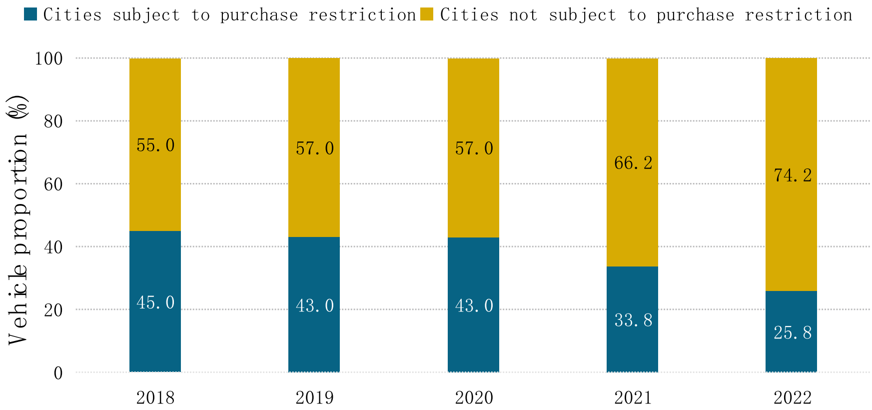


Fig. 2.23 Proportion of access volume of new energy private cars in cities subject to purchase restrictions and cities not subject to purchase restrictions

2.3 Summary

By summarizing the access characteristics of NEVs on the National Monitoring and Management Platform over the years, this Report concludes the development characteristics of NEVs in the field of vehicle promotion and application in China:

The regional concentration of NEV promotion is decreasing yearly, and the market share of cities of new first tier and below is expanding rapidly. In the past three years, the cumulative access proportion of new energy passenger cars, buses, and Vehicle for special purposes in TOP10 provinces showed a downward trend, and the concentration of NEV promotion in provinces declined significantly. In respect of the concentration of NEV promotion in different cities, the proportion of vehicle access in cities of new firs tier and below rose sharply from 70.8% in 2020 to 83.0% in 2022, and the market demand was rapidly released. In contrast, the proportion of NEV access in first-tier cities fell from 29.2% in 2020 to 17.0% in 2022, along with the shrinking market share.

The market demand for NEVs is robust, and market share of new energy private cars increases fleetly. As of December 31, 2022, 12.073 million NEVs had been accessed to the National Monitoring and Management Platform, including 5,863 models accessed by 306 enterprises. In 2022, the access volume of NEVs totaled 5.418 million. In terms of application scenarios, the access volume of new energy private cars reached 4.015 million in 2022, accounting for 74.1% of the national total, indicating that private purchase has become the main driver for market growth, and the market share of new energy private cars steadily increased year by year.

The proportion of NEV in cities not subject to purchase restrictions increased steadily, showing the features of "market dominance". According to the data of the National Monitoring and Management Platform in the past five years, the proportion of NEVs in cities not subject to purchase restrictions in China witnessed stable increase from 55.0% in 2018 to 74.2% in 2022. The "policy-driven" effects of the

NEV market continued to degrade, and the impact of purchase restriction on the sales volume of NEVs also declined. The NEV industry is shifting from "policy-driven" development to "market-oriented" growth, with the market demand for NEVs being released.

Chapter 3
Technical Progress of New Energy Vehicles

Based on the access characteristics of NEVs on the National Monitoring and Management Platform, this Report analyzes from the perspectives of driving range progress, power battery technology progress, lightweight reform, and energy consumption characteristics, and summarizes the characteristics of key NEV technologies amid evolution in China over the years, so as to provide valuable reference for enterprises in the industry to satisfy the market demand following the trend of product development.

3.1 Technical Progress in Driving Range of NEVs

(1) **Overall change of the driving range**

The driving range of NEVs is increasing yearly on the whole.

According to the changes in the average range of new energy passenger cars in China over the years (Fig. 3.1), the average driving range of NEVs of different types is increasing yearly. In the past three years, the average range of new energy passenger cars has increased from 300.3 km in 2020 to 336.9 km in 2022. By segment, the driving range of BEV-passenger cars and PHEVs was increasing year by year. In 2022, the average driving range of BEV-passenger cars was 403.9 km, up 2.3% year-on-year. PHEVs (including extended-range NEVs) saw rapid improvement of driving range driven by hot-selling models like Li Auto One.

(2) **Changes in driving range of BEV-passenger cars by model**

User consumption keeps upgrading, and the market share of BEV-passenger cars with a driving range exceeding 500 km is on the rise.

From the changes in the average driving range of BEV-passenger cars (Fig. 3.2), the BEV-passenger cars with a high driving range exceeding 500 km still dominate

Z. Wang, *Annual Report on the Big Data of New Energy Vehicle in China (2023)*,
https://doi.org/10.1007/978-981-97-4840-2_3

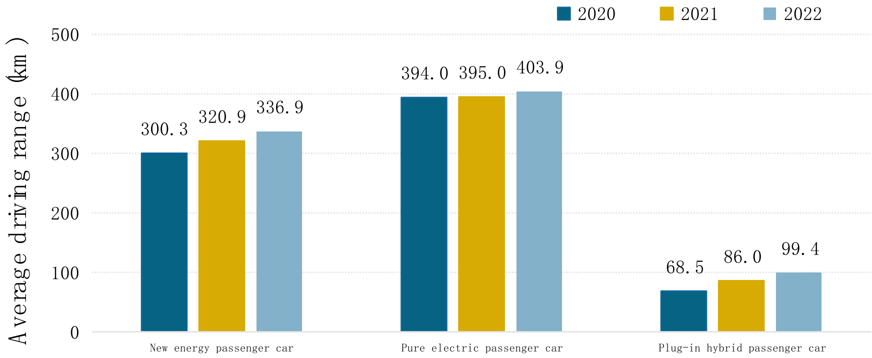


Fig. 3.1 Changes in the average range of NEVs of different types over the years. *Note* PHEV-passenger cars include PHEVs and extended-range electric vehicles

the market with the share rapidly rising from 12.9% in 2020 to 41.7% in 2022. The market share of the BEV-passenger cars with low driving range of below 200 km for short-distance transportation has been remaining stable in recent two years, with the market share of 20.4% in 2021 and 15.1% in 2022. Generally speaking, in the market of BEV-passenger cars, the proportion of those with high driving range is rising, while the proportion of those with medium driving range (200 km–500 km) remains low, since the structural proportion of driving range reshapes from spindle to dumbbell.

BEV-passenger cars in different application scenarios vary in distribution of driving range.

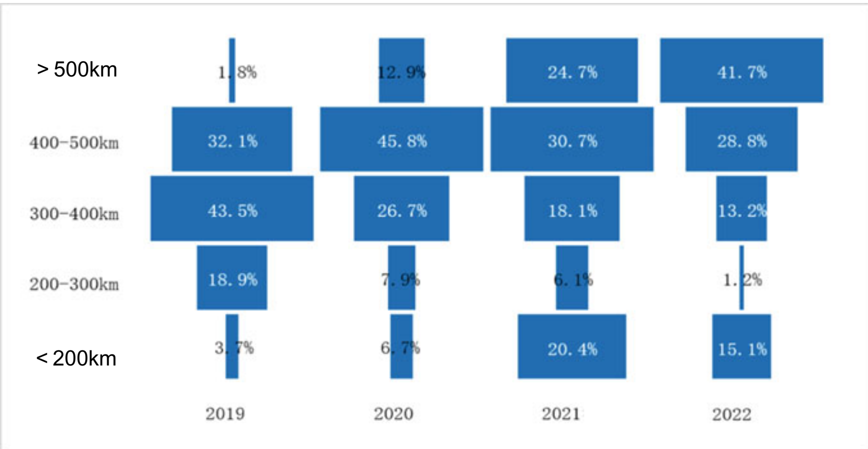


Fig. 3.2 Distribution of BEV-passenger cars in different range sections. *Note* The sum of the proportion of vehicles in different range sections of each year equals 100%, the same as below

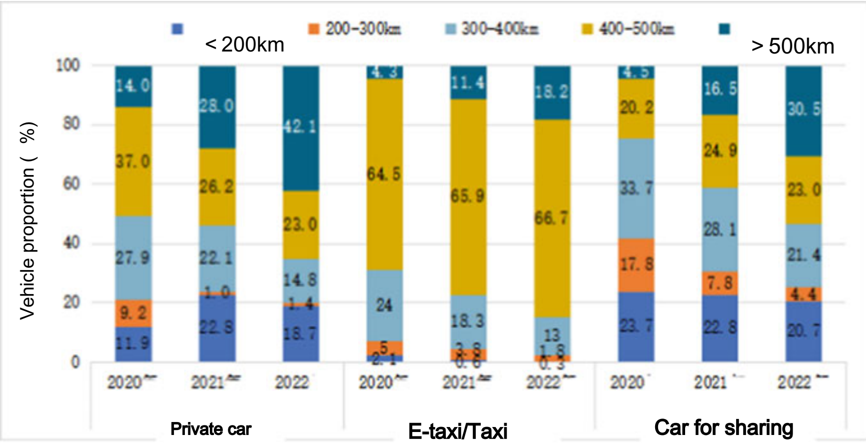


Fig. 3.3 Distribution of BEV-passenger cars in different range sections by application scenario

By the application scenario (Fig. 3.3), in the segment of passenger cars, the proportion of those with high driving range was increasing sharply. In 2022, the proportion of BEV-private cars with high driving range of above 500 km reached 42.1%, an increase of 14.1 percentage points compared with 2021. In the segment of operating passenger vehicles, the e-taxis/taxis with 400 km–500 km range account for a major market share, over 60% from 2020 to 2022; while the market share of e-taxis/taxis with a range of less than 300 km gradually decreased. In the segment of cars for sharing, the proportion of those with high driving range gradually increased, while those with a driving range of over 400 km gradually dominated the market.

The driving range of Class A and above cars and BEV SUVs has increased rapidly.

According to the changes in the average range of BEV-passenger cars of different classes (Fig. 3.4), the range of the cars of Class A and above and BEV SUVs has increased rapidly year by year. The average driving range of the cars of Class B and above in 2022 reached 578.5 km, significantly higher than other models; A0+A00 cars recorded basically stable average range as they were used for daily travel. In 2021 and 2022, the average driving range of A0+A00 cars was 245.1 km and244.8 km, respectively.

3.2 Annual Technical Characteristics of Power Batteries

(1) **Development of power battery industry**

By the end of 2022, the installed capacity of power batteries on the National Traceability Platform was 708.5 GWh.

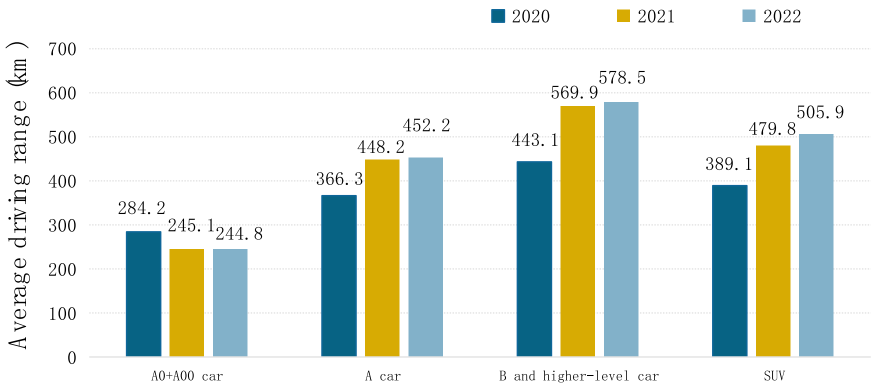


Fig. 3.4 Distribution of average range of BEV passenger cars of different classes

The National Monitoring and Power Battery Recycling and Utilization Traceability Integrated Management Platform for New Energy Vehicles (hereinafter referred to as "National Traceability Platform") takes new energy vehicles as the reporting subject under the traceability rules of information of NEV power battery, and the management links involved include production (vehicle production, i.e., battery installation stage), sales, maintenance, and out-of-service. Each link records the complete lifecycle traceability information of power batteries from installation and use to out-of-service and recycling.

According to the data collected on the National Traceability Platform and based on vehicle production time statistics, as of December 31, 2022, a total of 14.603 million NEVs have been accessed, with 18.625 million supporting battery packs and over 708.5Wh supporting battery capacity (Fig. 3.5). By annual statistics, the installed capacity of power batteries maintained an upward momentum. Throughout 2022, the installed capacity of NEVs totaled 5.888 million, a year-on-year increase of 85.9%; the installed power reached 288.8 GWh, up 102.4% year-on-year; and the quantity of supporting battery packs was 6.224 million, up by 77.8% year-on-year.

As of December 31, 2022, the TOP10 vehicle production enterprises with battery access to the National Traceability Platform recorded an installed capacity of 375.8GWh, accounting for 53.0% of China's installed capacity (Fig. 3.6). Among them, BYD Auto (including BYD Automobile Industry Co., Ltd. and BYD Auto Co., Ltd.), Tesla (Shanghai) Co., Ltd. SAIC-GM-Wuling Automobile, GAC Motor Co., Ltd., and Geely Automobile Holdings Limited (Zhejiang Geely Holding Group Company Ltd. and Zhejiang Haoqing Automotive Manufacturing Co., Ltd.) rank the top five regarding the battery access, of which BYD, topping the list, has a battery access proportion of up to 21.6%, with a high market concentration.

According to the battery installation enterprises corresponding to the vehicle manufacturers on the National Traceability Platform, BYD Auto mainly relies on

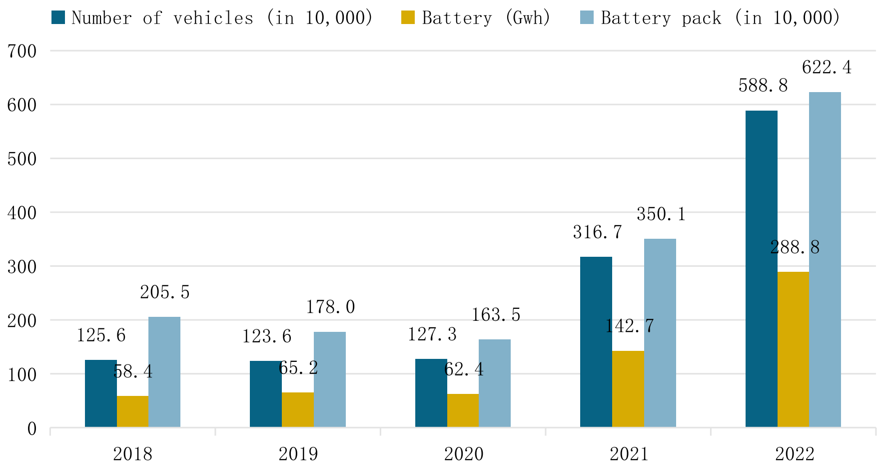


Fig. 3.5 Installed capacity of NEVs and power batteries accessed to the National Traceability Platform over the years. *Note* There is a time lag in the access volume of NEVs on the National Traceability Platform, and the installed capacity data over the years has been updated

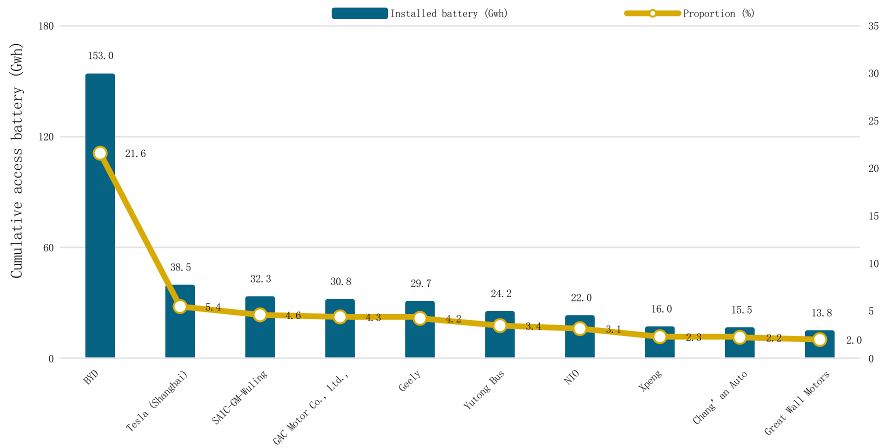


Fig. 3.6 Cumulative installed capacity of the TOP10 vehicle manufacturers with battery access

its battery supply; other vehicle manufacturers take CATL as the leading battery supplier, and there is a trend of supplier diversification.

The leading manufacturers of power battery are growing rapidly, forming a pattern of one superpower followed by giants.

From the perspective of battery manufacturers, as of December 31, 2022, the cumulative installed capacity of the TOP10 battery suppliers in China was 546.5 GWh, accounting for 72.2% of the total cumulative power capacity in China, with CATL and BYD firmly occupying the top two taking the first two places (Fig. 3.7).

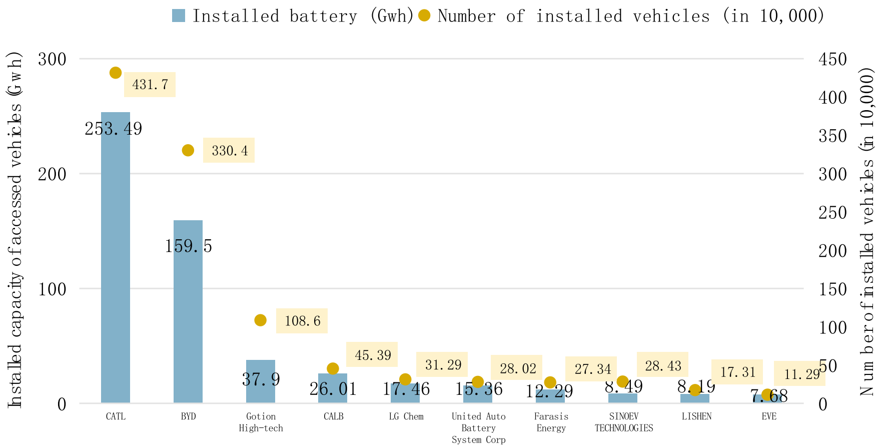


Fig. 3.7 Cumulative installed capacity of the TOP10 battery manufacturers

Among them, CATL has the largest cumulative installed battery power capacity, accounting for 35.8% of the total in China. The number of installed vehicles reached 4.317 million. CATL continued to explore the international market with market competitiveness increasing constantly. BYD achieved rapid sales growth of NVEs and steadily ranked second in installed capacity thanks to its blade battery technology and integration of upstream and downstream industrial chains, taking the second place in terms of installed capacity of battery. Gotion High-tech, CALB, and other power battery manufacturers also enlarged its installed capacity steadily in 2022.

In terms of the TOP10 suppliers of vehicle battery manufacturers in the past three years, CATL, as the leading manufacturer, has provided products for more than 120 vehicle manufacturers for the past three years, and its power batteries were used by most of the vehicle manufacturers in China. Gotion High-tech, with years of experience in battery manufacturing, provides supporting services to nearly 40 vehicle manufacturers. BYD, specialized in the technologies of lithium iron phosphate battery, offers products and services for nearly 20 vehicle manufacturers thanks to its superior safety performance, most of which are associated with BYD Auto. Other suppliers, such as CALB, Lishen Battery, EVE, and Farasis Energy, also provide batteries for a number of NEV manufacturers (Fig. 3.8).

(2) **Installation structure change by material type**

As NEV industry enters the post-subsidy era, lithium ferro-phosphate (LFP) batteries dominate the market based on its advantages in economy and safety.

Since NEV industry enters the post-subsidy era, LFP batteries came to the fore in respect of cost, safety, and other aspects, with its cumulative installed capacity surpassing ternary batteries. As indicated from the cumulative installed capacity of power batteries on National Traceability Platform (Fig. 3.9), LFP battery has gradually become the mainstream battery type. By the end of 2022, the cumulative

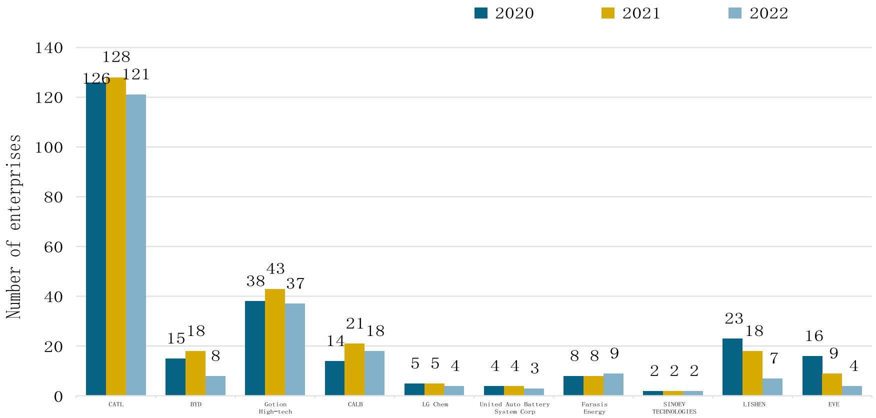


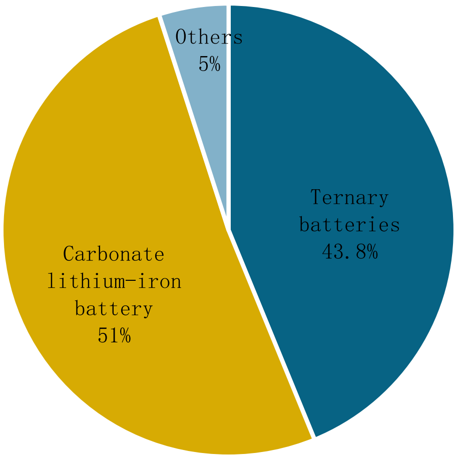
Fig. 3.8 Supply of TOP10 battery manufacturers for vehicle manufacturers in the past three years

installed capacity of LFP batteries accounted for51.2%, followed by ternary batteries with a proportion of 43.8%.

The statistics on the National Traceability Platform showed that the installed capacity of LFP batteries increased rapidly over the years, with its market share increasing yearly. In 2022, LFP batteries maintained its dominant position on the market, with installed capacity accounting for 63.9%. In comparison, the market share of ternary batteries was 35.1%, down 13.6 percentage points from 2021 (Fig. 3.10).

In the field of passenger cars, the installed capacity of LFP batteries has proliferated in market share; in the field of commercial vehicles, the installed power capacity of LFP batteries is dominant.

Fig. 3.9 Proportion of cumulative installed capacity of different types of power batteries



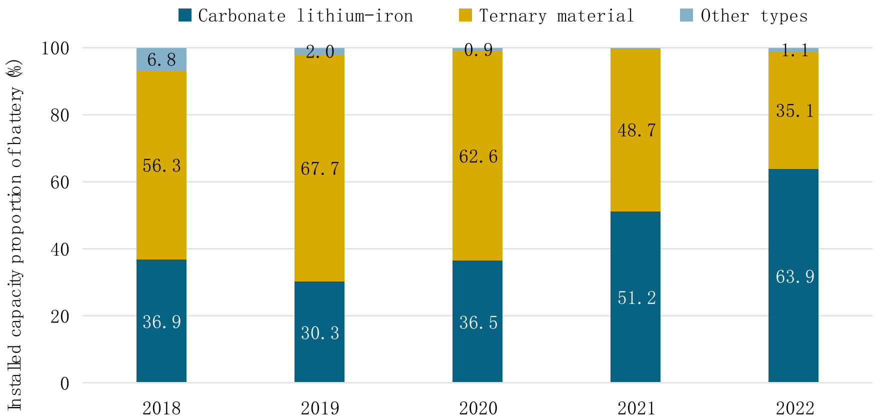


Fig. 3.10 Changes in the proportion of installed capacity of different types of power batteries over the years

The application scenarios vary due to the difference in energy density, safety, and price of batteries made of different materials. **According to the data on the proportion of installed capacity of power batteries by type of vehicle on the National Traceability Platform** (Fig. 3.11)**, in the field of passenger cars, in 2022, the installed capacity of LFP batteries reached 60.4%, with an increase of 15 percentage points over 2021.** Featuring lost cost, LFP batteries gain great popularity in the low-end passenger car market. Meanwhile, LFP batteries, superior in economy and safety, have been basically covered by various types of commercial vehicles.

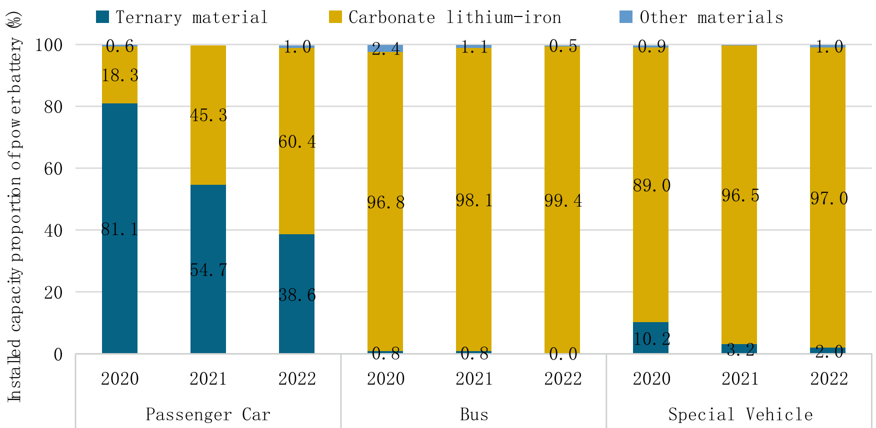


Fig. 3.11 Structural changes in installed power capacity of power batteries for different types of vehicles

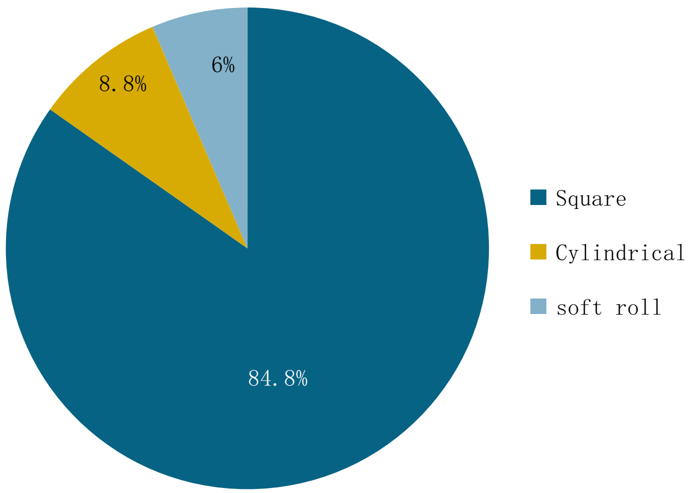


Fig. 3.12 Proportion of cumulative power capacity accessed of different forms of batteries

(3) **Change of installed structure by form type**

Power battery manufacturers in China mainly produce square batteries, with a small share of pouch and cylindrical batteries.

As of December 31, 2022, the cumulative access volume of square batteries on the National Traceability Platform was the largest, with a total power of 600.7 GWh, accounting for 84.8% of the total access volume of power batteries in China (Fig. 3.12)**.** The square battery has a high grouping rate and energy density, making it more suitable for the current market demand, followed by cylindrical batteries with relatively mature development technology. The data of National Traceability Platform indicated that the cumulative access volume of cylindrical batteries reached 62.3 GWh, accounting for 8.8%.

According to the changes of access structure of different types of batteries over the years, the access volume of square batteries in recent three years accounted for more than 80%, the highest market share. **With regard to the installed capacity of different forms of batteries installed in different types of vehicles** (Fig. 3.13)**, due to the higher requirements of the grouping efficiency and safety for the batteries of passenger cars and special-purpose vehicles, in the relevant areas, square batteries are more advantageous and have maintained a market share of more than 95% for the past three years.**

(4) **Change in energy density of power batteries**

In the field of power batteries, the proportion of high energy density LFP batteries and ternary batteries further increased among NEVs.

China takes a leading position in key power battery technologies characterized by constant improvement of the technical capabilities of electric core design and

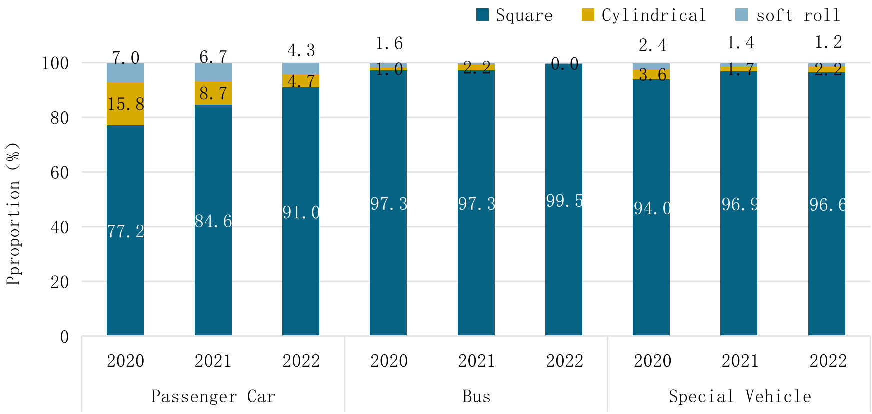


Fig. 3.13 Proportion of power capacity accessed of different forms of power batteries over the years. *Note* There is a time lag in the access volume of NEVs on the National Traceability Platform, and the installed capacity data over the years has been updated

system integration and further increase of high energy density power batteries. In 2022, among the BEV-passenger cars with ternary batteries, models with the battery energy density of more than 160Wh/kg accounted for 77.5%, nearly 10 percentage points higher than that in 2021; while among the those with LFP batteries, models with energy density exceeding 140Wh/kg accounted for 50.3%, nearly 12 percentage points higher over 2021 (Fig. 3.14).

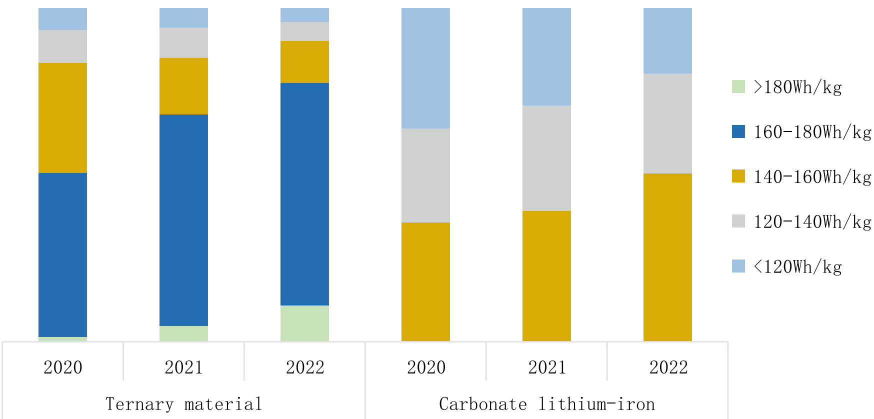


Fig. 3.14 Changes in energy density of power batteries installed on BEV-passenger cars by type from 2020 to 2022. *Source* Annual Report on the Implementation of Parallel Management of Average Fuel Consumption of Passenger Car Enterprises and Credits for New Energy Vehicles (2023)

3.3 Changes in the NEV Curb Weight Over the Years

(1) Changes in curb weight of vehicles over the years

Given the hot sale of models with high driving range and other stimulants, the curb weight of BEV-passenger cars in 2022 increased over 2021.

As concerns the average curb weight of NEVs in China over the years (Table 3.1), the average curb weight of new energy passenger cars in 2022 was 1,491.0 kg, a slight increase compared to 2021. The high battery load mass of some popular models with high driving range was the major impetus to such changes.

The BEV-passenger cars kept growing in scale, along with significant upgrade of user consumption.

According to the changes in the average curb weight of passenger cars by type over the years (Fig. 3.15), the average curb weight of both BEV-passenger cars and PHEV-passenger cars increased to 1,409.6 kg and 1,962.4 kg in 2022, respectively, with an increase of 2.3% and 6.0%, respectively, over 2021. The average driving range of passenger cars also increased, mainly due to the constant user consumption upgrade; and the proportion of BEV-passenger cars and PHEV-passenger cars in high driving range rose sharply, lifting the average driving range of passenger cars as a whole.

(2) Changes in curb weight of BEV-passenger cars by type over the years

As regards the distribution of the average curb weight of BEV-passenger cars of different classes (Fig. 3.16), in 2022, except for those of Class B and above,

Table 3.1 Changes in average curb weight of new energy passenger cars over the years

Year	In 2020	2021	2022
New energy passenger car Average curb weight (kg)	1,486.3	1,471.1	1,491.0

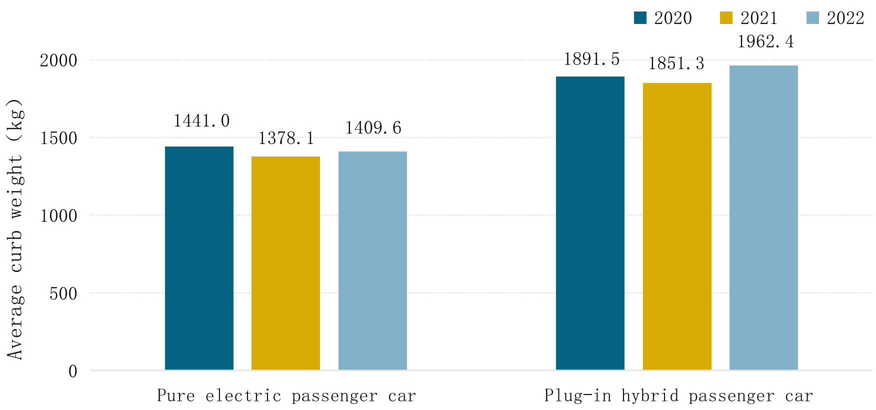


Fig. 3.15 Changes in average curb weight of different types of passenger cars over the years

the average curb weight of those of Class A00+A0, Class A, and SUVs, slightly increased.

Referring to the distribution of the average curb weight of PHEV-passenger cars of different classes (Fig. 3.17), in 2022, the average curb weight of cars of Class B and above decreased, while that of Class A00+A0 and SUVs grew by 1.5% and 5.9%, respectively. The average curb weight of SUVs grew faster in 2022 due to the high curb weight of some hot-selling extended-range electric vehicles in the same year.

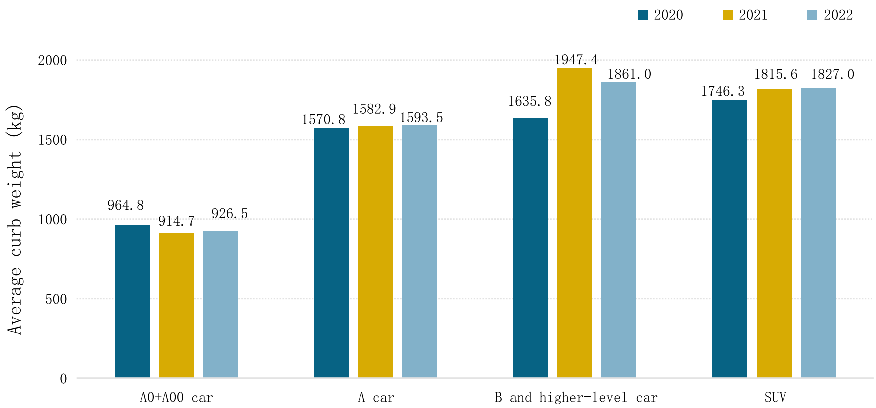


Fig. 3.16 Changes in average curb weight of different lasses of BEV-passenger cars over the years

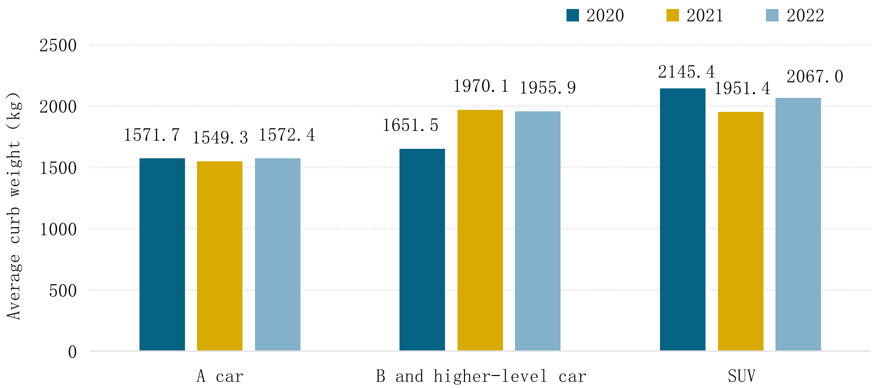


Fig. 3.17 Changes in average curb weight of different lasses of PHEV-passenger cars over the years

3.4 Changes in Energy Consumption Over the Years

The energy consumption level refers to the average energy consumption of BEVs every 100 km in the operating environment, expressed in kWh/100 km. The calculation formula for the energy consumption for a single vehicle[i] per 100 km is as follows:

$$\beta BEV,\ i = \frac{Qi}{Li} \times 100 \quad (3.1)$$

where,

βBEV, [i]Table 示 is the energy consumption per 100 km (kWh/100 km) of a BEV in the actual operating environment;

Li is the mileage (km) driving by a single vehicle [i]in a certain period of time;

Qi Is the energy consumption (kWh) of a single vehicle[i], by Amp-hours calculation.

Calculate the energy consumption level of the model *j* for each 100 km, which is expressed as the mean value of the actual 100 km electricity consumption of all BEVs of that type in each month.

The energy consumption level evaluated in this Report is mainly for and from BEVs. Where the effective samples are selected by enterprise or region, the number of operating vehicle samples is not less than 100; where they are selected within the whole country, that number is not less than 1,000.

3.4.1 Energy Consumption Evaluation of BEV Passenger Cars by Region

The average energy consumption of passenger cars in 2022 was 14.9kWh/100 km, up 2.1% over the previous year (Table 3.2).

SGMW, Chery, Dongfeng Forthing, and other enterprises mainly engaged in manufacturing small passenger cars had the lowest energy consumption level. The average energy consumption of SGMW passenger cars in 2022 was 9.7kWh/100 km, significantly lower than that of other enterprises (Fig. 3.18).

According to the comparison of the average energy consumption of BEV passenger cars in different regions (Fig. 3.19), in 2022, the energy consumption level in South China, Northwest China, and Southwest China declined, while that in other regions went up slightly.

Table 3.2 Average energy consumption of passenger cars over the years

Year	In 2020	2021	2022
Average energy consumption of passenger cars (kWh/100 km)	15.8	14.6	14.9

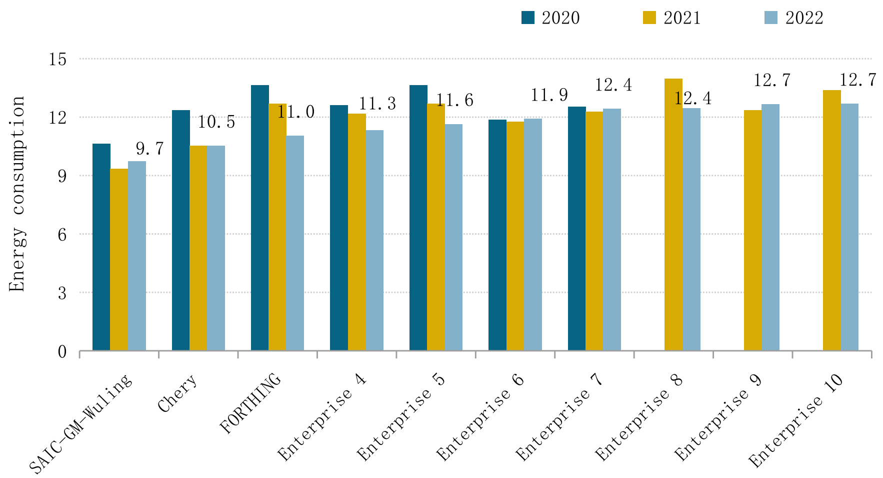


Fig. 3.18 Average energy consumption of key passenger car enterprises

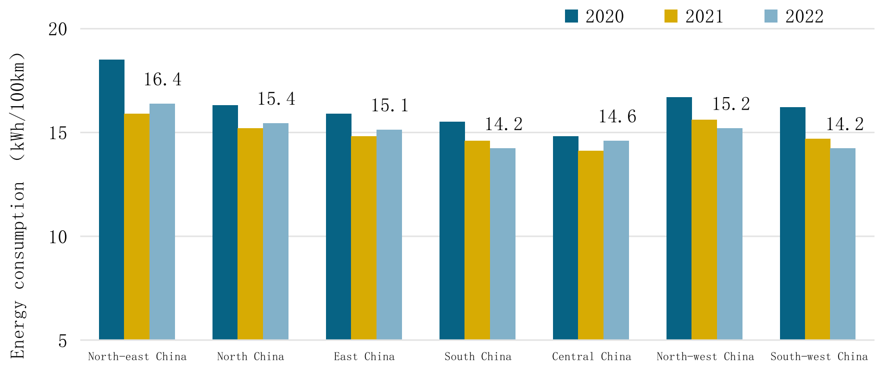


Fig. 3.19 Average energy consumption of BEV passenger cars in various regions of China in 2021

(1) Northeast China

In 2022, the energy consumption level of BEV passenger cars of all classes in Northeast China showed an upward trend over 2021.

The average energy consumption of passenger cars in Northeast China in 2021 was 16.4kWh/100 km, with an increase of 3% compared with the previous year (Table 3.3). As regards to the energy consumption level of passenger cars of different classes in Northeast China, the energy consumption level of passenger cars of different classes showed an upward trend to different extent (Fig. 3.20).

(2) North China

The average energy consumption level of vehicles, other than SUVs, in North China increased slightly in 2022 from 2021.

Table 3.3 Average energy consumption of passenger cars in Northeast China over the years

Year	In 2020	2021	2022
Average energy consumption of passenger cars (kWh/100 km)	18.5	15.9	16.4

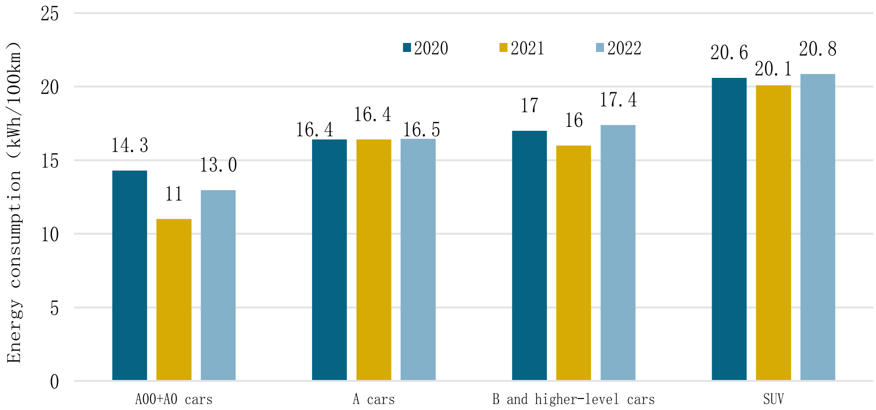


Fig. 3.20 Average energy consumption of passenger cars of different classes in Northeast China

The average energy consumption of passenger cars in North China in 2022 was 15.4kWh/100 km, an increase of 1.6% compared with that in 2021 (Table 3.4). According to the average energy consumption of passenger cars of different classes in North China (Fig. 3.21), in 2022, the average energy consumption of BEV SUVs was 18.3kWh/100 km, with a slight decrease year on year, while that of other models increased.

(3) **East China**

In 2022, the energy consumption of cars of Class A in East China stood out, with a slight decrease from 2021.

In 2022, the average energy consumption of BEV-passenger cars in East China was 15.1kWh/100 km, up 2.2% year on year (Table 3.5). According to the average energy consumption of passenger cars by class (Fig. 3.22), the energy consumption level of Class A cars in East China outperformed at 16kWh/100 km, down 1.2% year on year, while that of models recorded a slight increase over 2021.

(4) **South China**

The energy consumption level of BEV-passenger cars in South China dropped year by year.

Table 3.4 Average energy consumption of passenger cars in North China

Year	In 2020	2021	2022
Average energy consumption of passenger cars (kWh/100 km)	16.3	15.2	15.4

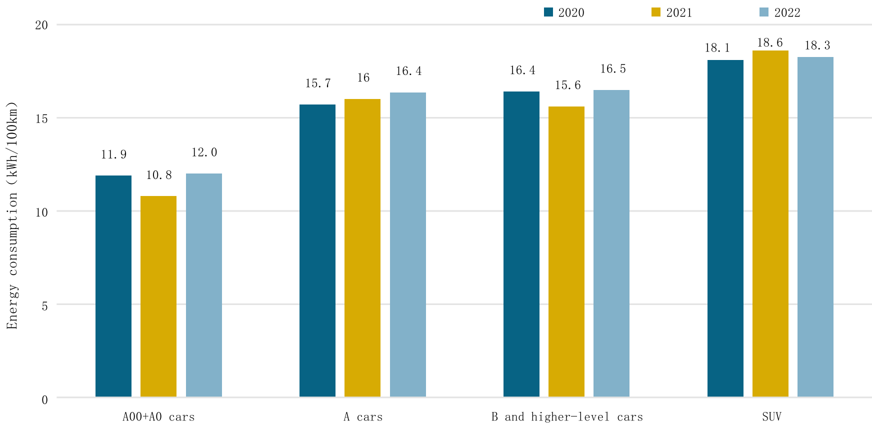


Fig. 3.21 Average energy consumption of passenger cars of different classes in North China

Table 3.5 Average energy consumption of passenger cars in East China

Year	In 2020	2021	2022
Average energy consumption of passenger cars (kWh/100 km)	15.9	14.8	15.1

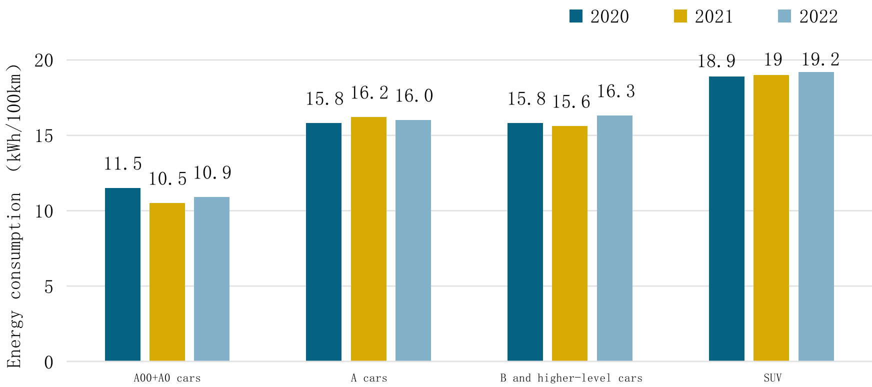


Fig. 3.22 Average energy consumption of passenger cars of different classes in East China

The average energy consumption of passenger cars in South China in 2022 was 14.2kWh/100 km, with a decrease of 2.5% over 2021 (Table 3.6). By class and model (Fig. 3.23), the energy consumption level of all models of all classes, except Class B cars, decreased on the whole in 2022.

(5) **Central China**

In 2022, the energy consumption level of BEV passenger cars of all classes in Central China showed an upward trend over 2021.

Table 3.6 Average energy consumption of passenger cars in South China

Year	In 2020	2021	2022
Average energy consumption of passenger cars (kWh/100 km)	15.5	14.6	14.2

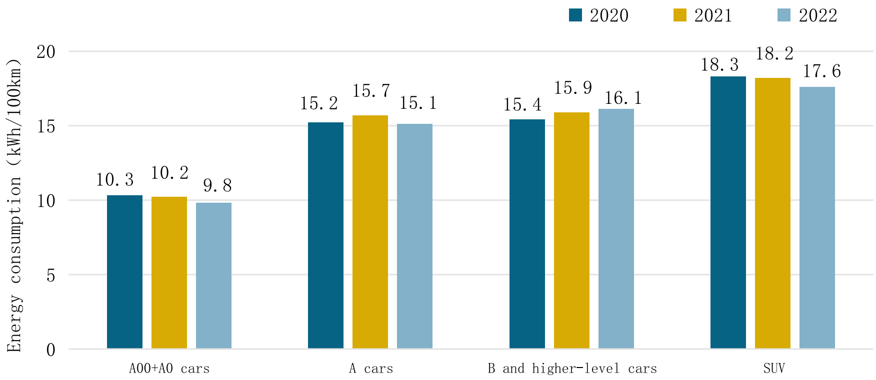


Fig. 3.23 Average energy consumption of passenger cars of different classes in South China

The average energy consumption of passenger cars in Central China in 2022 was 14.6kWh/100 km, a slight increase from 2021 (Table 3.7). The average energy consumption of passenger cars of different classes rose by varying degrees in 2022 (Fig. 3.24). In 2022, the energy consumption level of Class A cars and SUVs remained relatively stable, whilst that of the cars of Class A00+A0, Class B increased significantly.

(6) **Northwest China**

In 2022, the energy consumption of BEV-passenger cars in Northwest China showed a downward trend.

The average energy consumption of passenger cars in the Northwest in 2022 was 15.2kWh/100 km, a slight decrease compared to 2021 (Table 3.8). Regarding the average energy consumption of passenger cars by class (Fig. 3.25), all the classes, except Class A00+A0, showed a steady downward trend year by year.

(7) **Southwest China**

The energy consumption level of BEVs in Southwest China dropped year by year.

Table 3.7 Average energy consumption of passenger cars in Central China

Year	In 2020	2021	2022
Average energy consumption of passenger cars (kWh/100 km)	14.8	14.1	14.6

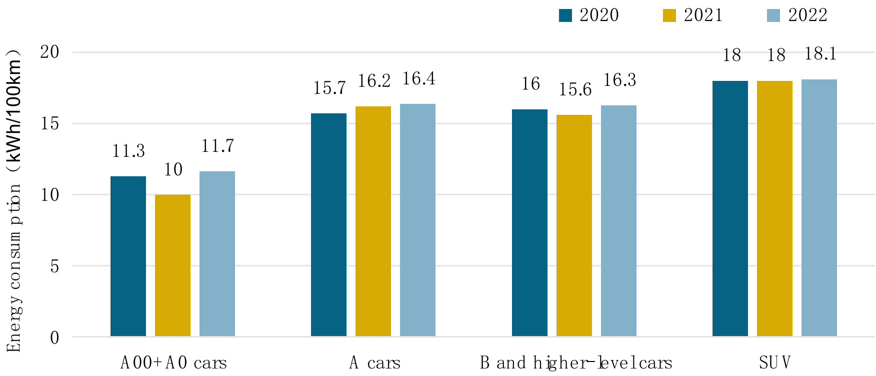


Fig. 3.24 Average energy consumption of passenger cars of different classes in Central China

Table 3.8 Average energy consumption of passenger cars in Northwest China

Year	In 2020	2021	2022
Average energy consumption of passenger cars (kWh/100 km)	16.7	15.6	15.2

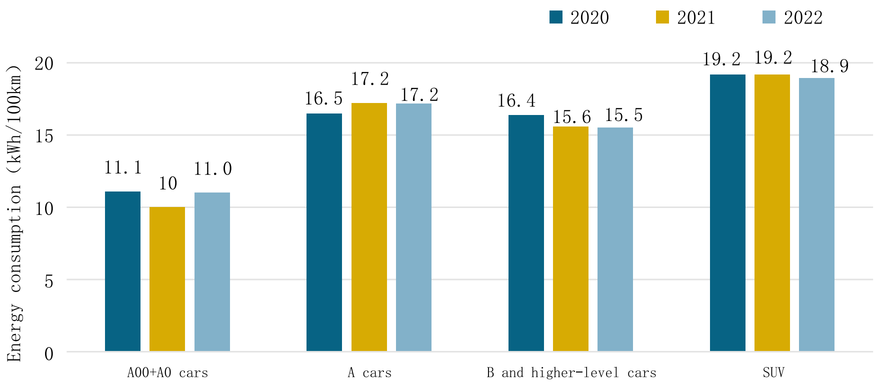


Fig. 3.25 Average energy consumption of passenger cars of different classes in Northwest China

The average energy consumption of passenger cars in the Southwest region was 14.2kWh/100 km in 2022, a slight decrease compared to 2021 (Table 3.9). Regarding the average energy consumption of passenger cars by class (Fig. 3.26), the energy consumption level of Class A00+A0 cars, Class A cars, and SUVs showed a downward trend year by year.

Table 3.9 Average energy consumption of passenger cars in Southwest China

Year	In 2020	2021	2022
Average energy consumption of passenger cars (kWh/100 km)	16.2	14.7	14.2

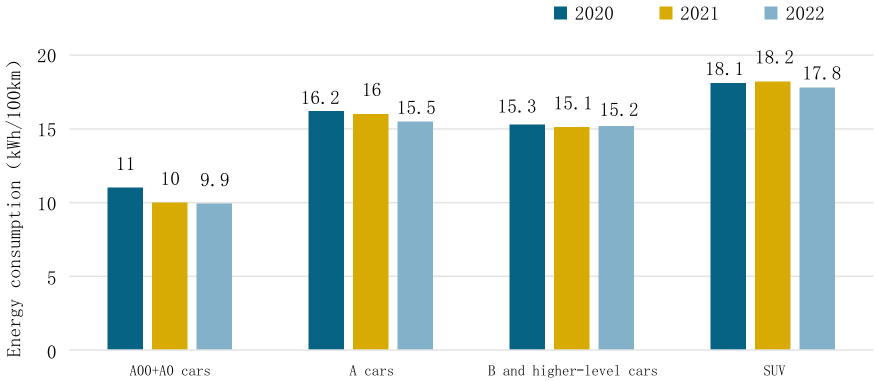


Fig. 3.26 Average energy consumption of passenger cars of different classes in Southwest China

3.4.2 Energy Consumption Evaluation of BEV-Passenger Cars of Different Classes

(1) **Vehicles by class and model**

In 2022, the energy consumption of Class A00+A0 cars was 11.2kWh/100 km, up 7.7% over 2021.

The average energy consumption of Class A00+A0 cars in 2022 was 11.2kWh/ 100 km, 7.7% higher than that in 2021, but 9.7% lower compared to that in 2020 (Table 3.10); in terms of key models, the energy consumption level of Class A00+A0 Wuling Hongguang Mini EV, Chang'an LUMIN, and Dongfeng FENGON MINI in 2022 was lower at 9.2kWh/ 100 km, 9.3kWh/100 km, and 9.9kWh/100 km respectively (Fig. 3.27).

The average energy consumption of Class A cars in 2022 was 16.1kWh/ 100 km, basically the same as that in 2021.

The average energy consumption of Class A cars in 2022 was 16.1kWh/100 km, basically the same as that in 2021 (Table 3.11); from the perspective of key models, the energy consumption level of Class A cars like BYD e2, Geometry A, and Kia

Table 3.10 Average energy consumption of Class A00+A0 cars over the years

Year	In 2020	2021	2022
Average energy consumption of Class A00+A0 cars (kWh/100 km)	12.4	10.4	11.2

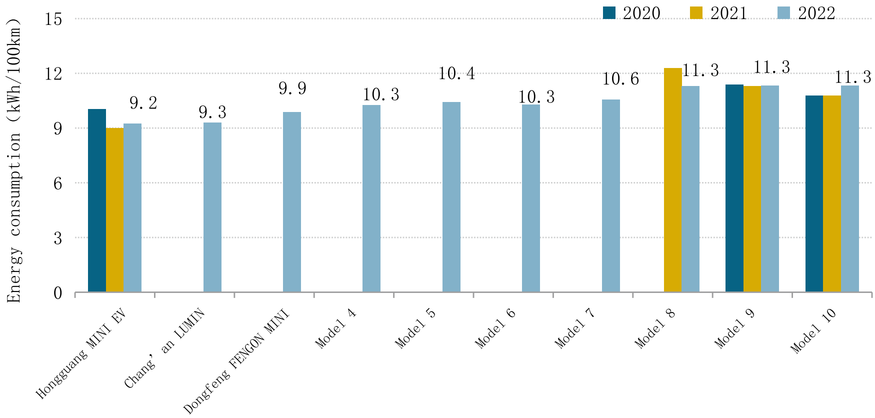


Fig. 3.27 Average energy consumption of key models of Class A00+A0 cars

K3 EV in 2022 was lower at 13.7kWh/100 km, 13.8kWh/100 km, and 13.8kWh/100 km, respectively (Fig. 3.28).

Energy consumption of BEVs of Class B and above was 16.4kWh/100 km in 2022, up 5.1% compared to 2021.

Regarding the distribution of energy consumption of vehicles over the years, the average energy consumption of cars of Class B and above in 2022 was 16.4kWh/100 km, up by 5.1% compared with that in 2021 but lower than that in 2020 (Table 3.12); in view of key models, the average energy consumption of MODEL 3,

Table 3.11 Average energy consumption of Class A cars over the years

Year	In 2020	2021	2022
Average energy consumption of Class A cars (kWh/100 km)	14.1	16.1	16.1

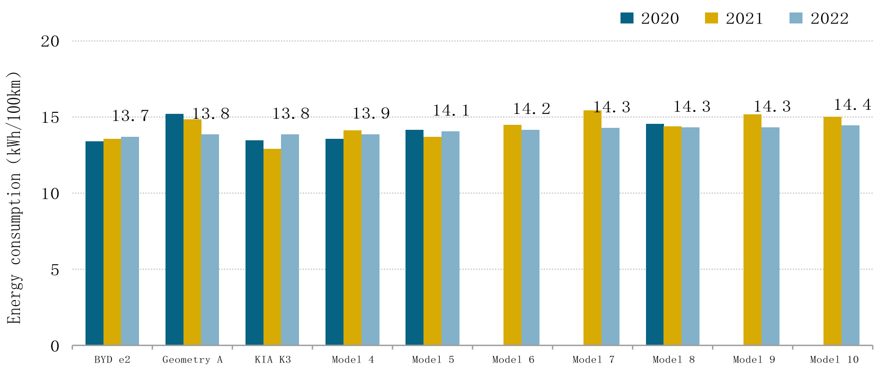


Fig. 3.28 Average energy consumption of key models of Class A cars

HONGQI E-QM5, and BYD Han EV lowered in 2022 to 15kWh/ 100 km, 16.6kWh/ 100 km, and 16.8kWh/100 km, respectively (Fig. 3.29).

The energy consumption of BEV SUVs in 2022 was 18.8kWh/100 km, a slight increase from 2021.

The average energy consumption of BEV SUVs in 2022 was 18.8kWh/100 km, slightly higher than that in 2021 (Table 3.13); in terms of key SUV models (Fig. 3.30), the energy consumption level of the Forthing T1 EV, Neta V, and Forthing E1 in 2022 lowered to 10.5kWh/100 km, 11.2kWh/100 km, and 11.6kWh/100 km, respectively.

(2) **Vehicles by field of operation**

By the field of BEV passenger cars, the energy consumption level of operating vehicles was generally higher than that of non-operating vehicles.

In 2021, the energy consumption level of operating BE-passenger cars at different speeds was generally higher than that of non-operating BEV-passenger cars, especially in the lower and higher speed ranges. There is a significant difference in energy consumption levels between operating and non-operating vehicles at the same speed (Fig. 3.31). The vehicle power consumption curve shows an apparent U-curve from the energy consumption distribution of vehicles in various fields at different speed ranges. Among them, the economic speed range was between 68 km/h and 80 km/

Table 3.12 Average energy consumption of key models of Class B and above cars

Year	In 2020	2021	2022
Average energy consumption of Class B and above cars (kWh/100 km)	16.9	15.6	16.4

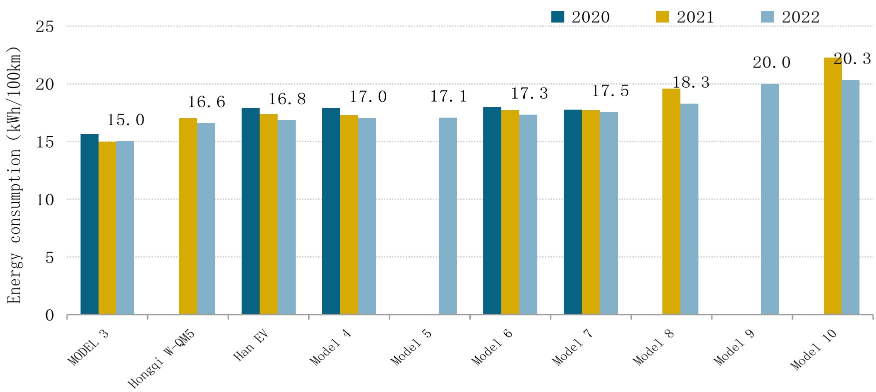


Fig. 3.29 Average energy consumption of key models of Class B and above cars

Table 3.13 Average energy consumption of SUVs over the years

Year	In 2020	2021	2022
Average energy consumption of SUVs (kWh/100 km)	18.1	18.7	18.8

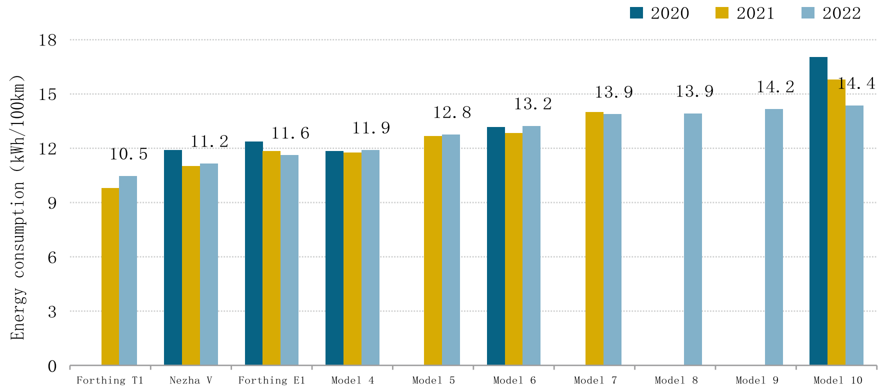


Fig. 3.30 Average energy consumption of key models of SUVs

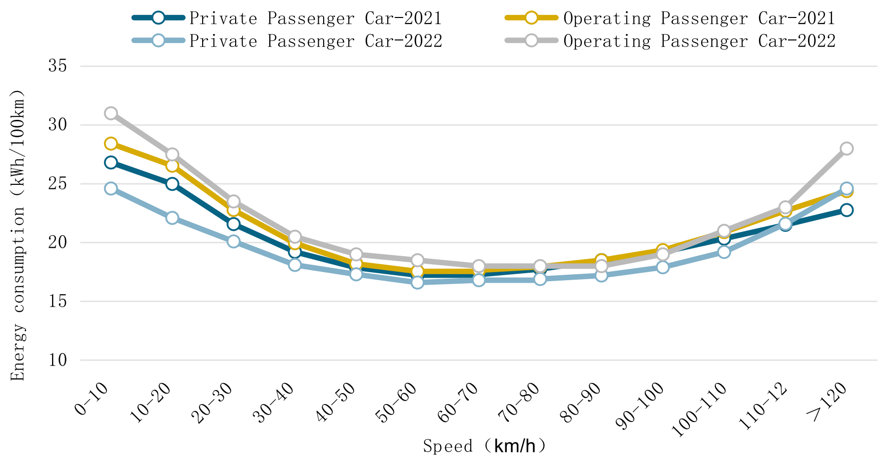


Fig. 3.31 Distribution of energy consumption of passenger cars in different operating scenarios in 2022

h, and the energy consumption level of vehicles in this speed range was relatively low. In terms of the distribution of energy consumption over the years, the energy consumption level of private cars in 2022 was relatively lower than that in 2021.

3.4.3 Energy Consumption Evaluation of BEV Buses

In 2022, the energy consumption of buses was 58.9kWh/100 km, with a decrease of 0.8% compared with 2021.

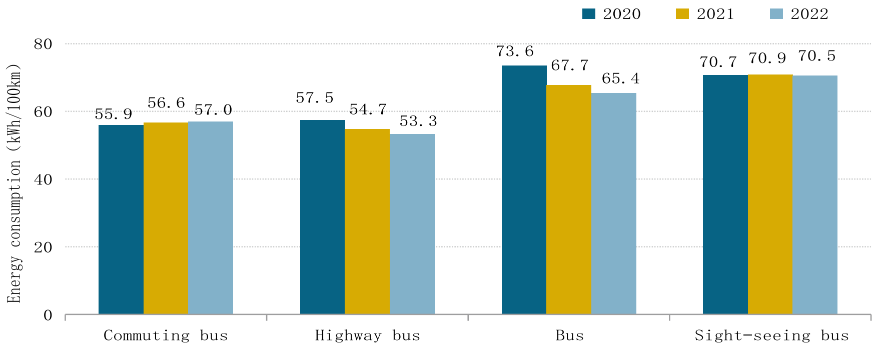


Fig. 3.32 Average energy consumption of BEV buses in different scenarios

The average energy consumption of buses in 2022 was 58.4kWh/100 km, a decrease of 3.3% and 0.8% compared with 2020 and 2021, respectively (Table 3.14). From the perspective of application scenario, the energy consumption level of road buses in 2022 was lower than that of other types of buses (Fig. 3.32). From the changes in energy consumption of various models over the years, the energy consumption level of all types of buses, other than urban commuting buses, in 2022 decreased compared to 2021 (Fig. 3.32).

The energy consumption of BEV buses with different lengths varied greatly, and in 2022, the energy consumption of buses with different lengths increased from 2021.

By different types of BEV buses with different lengths (Fig. 3.33), the longer the length, the higher the energy consumption level. The overall energy consumption level of BEV buses below 8 m in length remained above 50kWh/100 km, while that of BEV buses over 8 m in length was about 150kWh/100 km. The energy consumption of BEV buses over 12 m long was about 100kWh/100 km. According to the changes in the energy consumption level of buses in different years, in 2022, the energy consumption level of BEV buses below 12 m in length decreased by varying degrees compared with that of 2021, while that of BEV buses over 12 m in length showed undulatory growth.

By region, the energy consumption level of BEV buses in Southwest China was generally lower than that of other regions.

According to energy consumption level of BEV buses in different regions (Fig. 3.34), the energy consumption level of BEV buses in northern China (including Northeast, North, and Northwest China) was generally higher than that in other regions. The average energy consumption of BEV buses in Northeast China was

Table 3.14 Average energy consumption of buses over the years

Year	In 2020	2021	2022
Average energy consumption of buses (kWh/100 km)	60.4	58.9	58.4

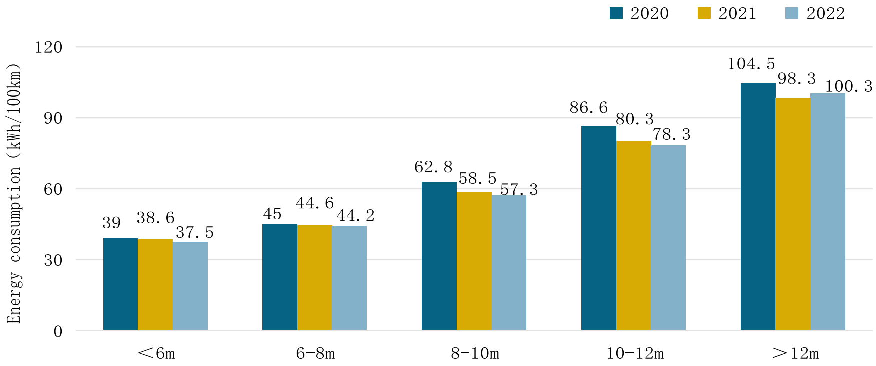


Fig. 3.33 Average energy consumption of BEV buses with different lengths

75.7kWh/100 km, with a decrease of 2.4% compared with the previous year and maintaining a downward trend despite the higher value than other regions. In other regions, the energy consumption level of BEV buses in Southwest China and South China was slightly lower than other regions.

The economical speed of BEV buses was mainly at 50 km/h–70 km/h, basically the same as previous years.

In comparison with the data in 2021 and 2022, the distribution of energy consumption of BEV buses at different economical speeds was basically the same (Fig. 3.35). There was little difference in the distribution of energy consumption of BEV buses at speed above 10 km/h. The energy consumption of vehicles at lower speed and higher speed stayed at a high level, while that of BEV buses was relatively lower at the range from 50 km/h to 70 km/h, namely the economical speed.

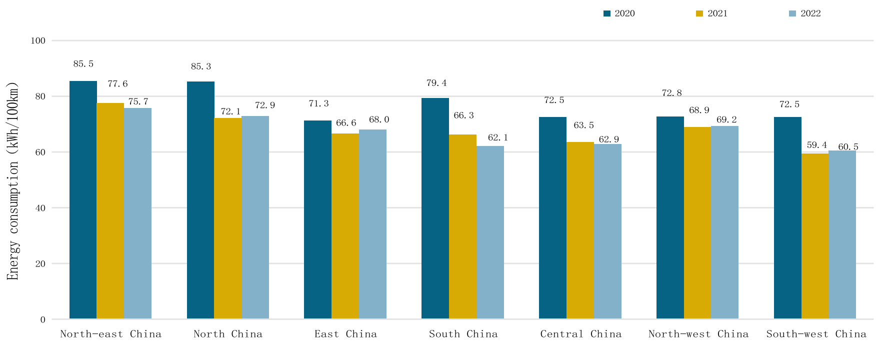


Fig. 3.34 Average energy consumption of BEV buses in different regions

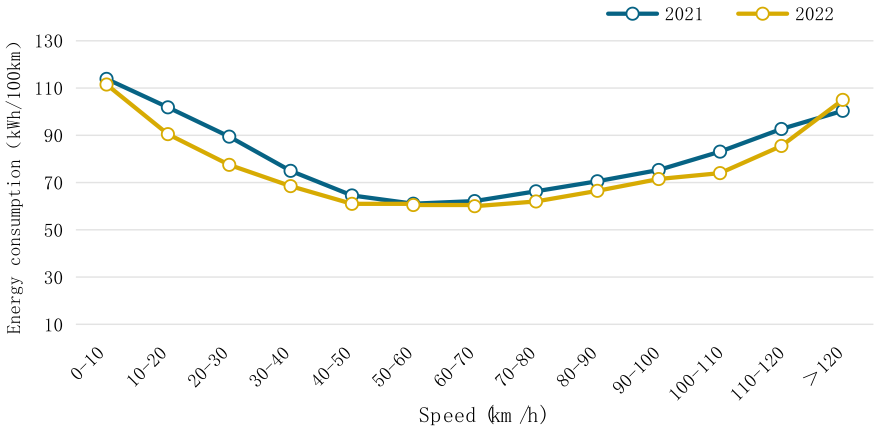


Fig. 3.35 Energy consumption distribution of BEV buses in different speed ranges in 2021

3.4.4 Energy Consumption Evaluation of BEV Logistics Vehicles

In 2022, the average energy consumption of BEV logistics vehicles was 32.2kWh/100 km, with an increase of 7% from 2021.

This Report selected 59 companies with an annual sales volume of over 100 logistics vehicles. The calculation results showed that the average energy consumption of BEV logistics vehicles in 2022 was 32.2kWh/100 km, with an increase of 7% from 2020 (Fig. 3.35). From the distribution of key logistics vehicle enterprises (Fig. 3.36), the energy consumption of such enterprises as Changhe Automobile, Keyton Motor, and Ruichi Automobile was low in 2022 (Table 3.15).

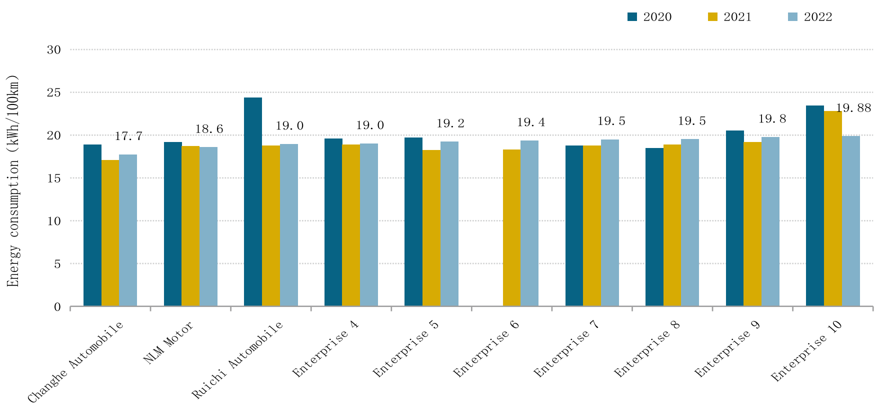


Fig. 3.36 Average energy consumption of key logistics vehicle enterprises

Table 3.15 Average energy consumption of logistics vehicles over the years

Year	In 2020	2021	2022
Average energy consumption of logistics vehicles (kWh/100 km)	33.8	30.1	32.2

The heavier the total mass of the vehicle, the higher the energy consumption of the vehicle.

From the average energy consumption of BEV logistics vehicles in different tonnage ranges over the years (Fig. 3.37), the higher the vehicle's total mass, the higher its energy consumption. The average energy consumption of BEV logistics vehicles with a capacity of over 12t was significantly higher than those in other ranges. As regards the changes in the energy consumption of vehicles in different tonnage ranges over the years, the energy consumption of vehicles in each range showed varied changes in 2022. In 2022, the average energy consumption of BEV logistics vehicles below 4.5t was 25.0kWh/100 km, indicating downward trend year by year, and that of BEV logistics vehicles above 4.5t increased over 2021. In addition, the energy consumption of BEV logistics vehicles over 12t showed a rapid increment.

The overall energy consumption of BEV vehicles in Northeast China was significantly higher than that in other regions.

According to the energy consumption of BEV logistics vehicles in different regions (Fig. 3.38), the average energy consumption of BEV logistics vehicles in Northeast China and North China in 2022 was higher than that in other regions (below 30kWh/100 km on average). In 2022, the energy consumption level of BEV logistics vehicles in North China rose sharply, mainly due to the rapid growth of heavy-duty BEV logistics vehicles promoted in North China, which on the whole lifted the energy consumption level of logistics vehicles in North China. Regarding the changes in vehicle energy consumption in different regions over the years, the average energy consumption of BEV logistics vehicles in East China, South China, Central China, Northwest China, and Southwest China in 2022 decreased from 2021.

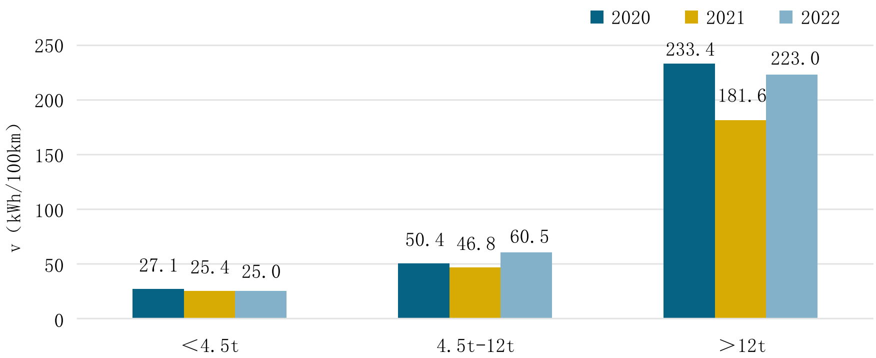


Fig. 3.37 Average energy consumption of BEV logistics vehicles in different tonnage ranges

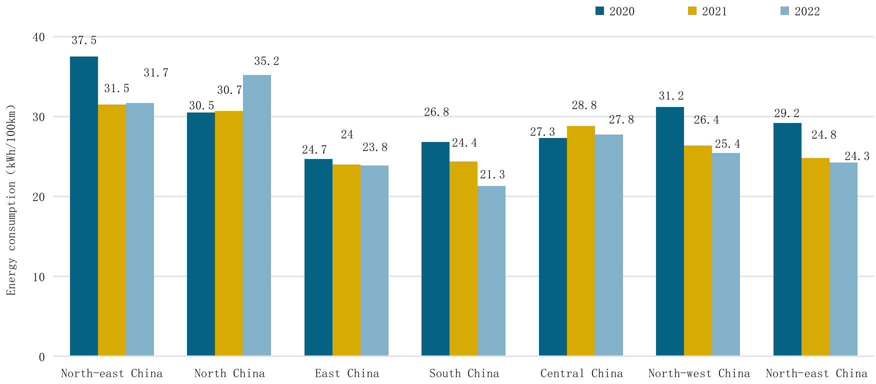


Fig. 3.38 Average energy consumption of BEV logistics vehicles in different regions

In 2022, the energy consumption level of BEV logistics vehicles was lower in the range of 30 km/h to 90 km/h.

In 2022, BEV logistics vehicles had higher energy consumption in low-speed ranges below 30 km/h and high-speed ranges above 90 km/h, both above 30kWh/100 km (Fig. 3.39). Based on the distribution of energy consumption of vehicles in different ranges over the years, the distribution of energy consumption of BEV logistics vehicles in different speeds over the years was basically the same, and energy consumption level of vehicles in the high-speed ranges in 2022 was relatively higher.

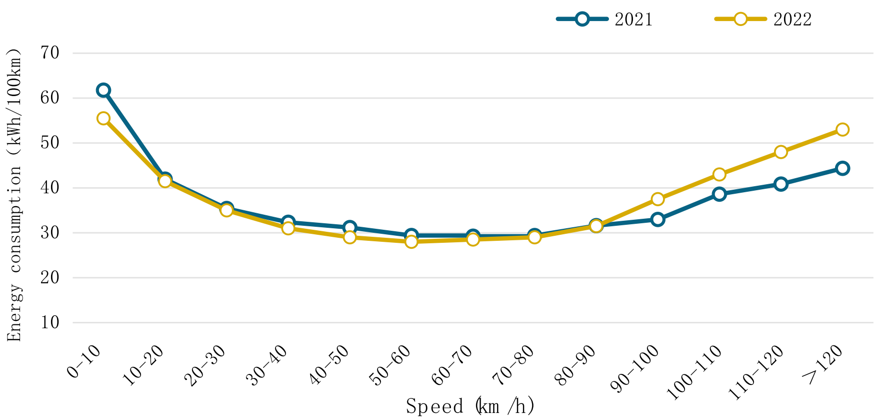


Fig. 3.39 Energy consumption distribution of BEV logistics vehicles in different speed ranges in 2022

3.5 Summary

By summarizing the changes of driving mileage of NEVs over the years on the National Monitoring and Management Platform, the characteristics of technological advancement of power storage batteries on yearly basis, and the curb weight and energy consumption over the years, this Section concludes the following development features of China's NEVs in the technological advancement:

NEV consumption kept upgrading, while the market share of medium and large-sized vehicles was on the rise. The average driving range of new energy passenger cars increased steadily from 300.3 km in 2020 to 336.9 km in 2022. Throughout 2022, the market share of small-sized BEV passenger cars below 200 km was basically stable, while that of BEV passenger cars in speed ranges exceeding 500 km saw a rapid rise from 1.8% in 2019 to 41.7% in 2022, along with the constantly upgrading consumption in NEVs.

LFP battery held market dominance thanks to such advantages as battery structure innovation and superior performance in safety and economy. According to the data of cumulative installed capacity of power batteries and proportion of installed capacity over the years on the National Traceability Platform, the installed capacity of LFP batteries rose rapidly with its market share increasing year on year, making it a leading role in the market. The advantages of LFP batteries in safety and cost effectiveness were further highlighted.

In terms of energy consumption, user consumption upgrading and enlarging vehicle size drove the energy consumption of vehicles upwards. Considering the actual operation of various types of vehicles, the average energy consumption of BEV passenger cars in 2022 was 14.9kWh/100 km, up 2.1% over 2021. The energy consumption level of Class A cars and SUVs remained basically stable. In the field of commercial vehicles, the energy consumption level of BEV buses showed a downward trend in the past two years, from 60.4kWh/100 km in 2020 to 58.4kWh/100 km in 2022. According to the changes of energy consumption level of BEV buses with different lengths over the years, the energy consumption level of BEV buses below 12 m in length declined; the average energy consumption of BEV logistics vehicles in 2022 was 32.2kWh/100 km, with a slight increase over 2021. The energy consumption level of lightweight BEV vehicles below 4.5tons showed a downward trend year by year, from 27.1kWh/100 km in 2020 to 25kWh/100 km in 2022; that of medium- and heavy-duty BEV logistics vehicles above 4.5 tons rose amid fluctuations, mainly due to the accelerated pollution and carbon emission reduction for freight vehicles in recent years and the rapid growth of sales volume of medium- and heavy-duty new energy freight trucks.

Chapter 4
Operation of New Energy Vehicles

This chapter, based on the real-time operation data of millions of NEVs on the National Monitoring and Management Platform, analyzes the operation characteristics of vehicles in the seven major segments, including private cars, e-taxis, taxis, cars for sharing and rental service, logistics vehicles, buses, and heavy-duty trucks, providing important bases and references for the study and evaluation of the operation rules of NEVs and the establishment of an intelligent low-carbon traffic system.

4.1 NEV Online Rate in 2022

Vehicle online rate refers to the ratio of the number of vehicles running in the current period to the cumulative vehicle access, which reflects the use of vehicles in the current period. The higher the online rate of the vehicle, the higher the demand for the use of the vehicle and the higher the utilization rate of the vehicle. On the contrary, it means there is a certain idle situation of vehicles in the current period. Through an analysis of the overall online rate of BEVs on the National Monitoring and Management Platform and the vehicle online rate in key markets in the past three years, this Section summarizes the current utilization rate of NEVs in China's NEV market.

4.1.1 Vehicle Online Rate in China

The average monthly online rate of NEVs in 2022 was 84.8%, with a constant increase for two years straight.

The average monthly online rate of NEVs in China was gradually stabilized. According to the data from the past three years, the average monthly online rate in

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https://doi.org/10.1007/978-981-97-4840-2_4

Table 4.1 Average monthly online rate in China

Year	In 2020	2021	2022
Average online rate in China (%)	81.1	81.8	84.8

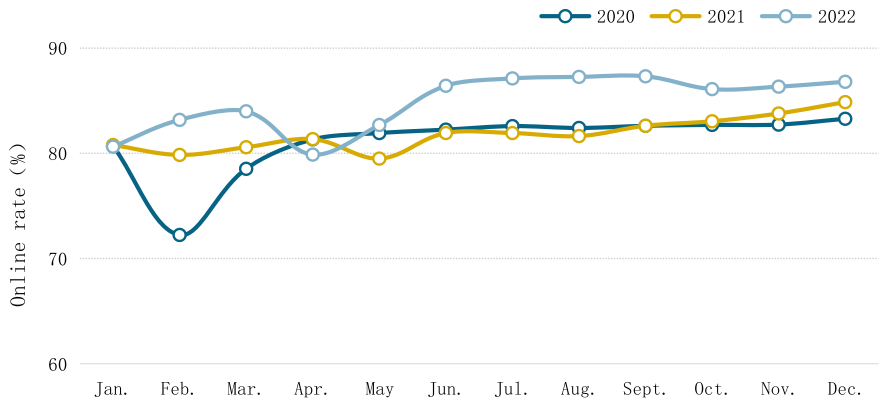


Fig. 4.1 Monthly online rate of NEVs in China

Table 4.2 Average online rate of China in 2022—by driving type

Driving type	BEV	PHEV	FCEV
Average online rate in China (%)	83.7	90.4	48.5

2020 increased to 84.8% by 3.7 percentage points from 2020 and 3 percentage points from 2021 (Table 4.1).

According to the monthly online rate distribution of vehicles over the years (Fig. 4.1), the online rate was low in April due to the pandemic and then returned to stable entering June 2022, indicating a stabilized use rate of vehicles.

By driving type, PHEVs had a higher online rate than BEVs and FCEVs.

As seen from Table 4.2, the average online rate of PHEVs in 2022 was significantly higher than that of BEVs and FCEVs, indicating a higher use rate of PHEVs, followed by BEVs with the average monthly online rate of 83.7% and FCEVs at 48.5%.

4.1.2 Online Rate in Each Region of China

The online rate in all the regions of China increased compared to 2021, of which the average monthly online rate in South China was the highest.

In terms of the average monthly online rate across all regions of China (Fig. 4.2), the average monthly online rate of NEVs across all regions of China in 2022 increased slightly over 2021. In 2022, the average monthly online rate of NEVs in South China and Northeast China was 88% and 86.8% respectively, higher than that in other

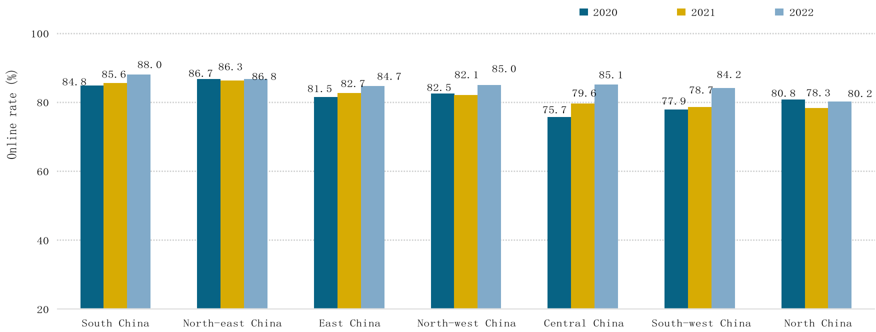


Fig. 4.2 Average monthly online rate of new energy vehicles in various regions of China

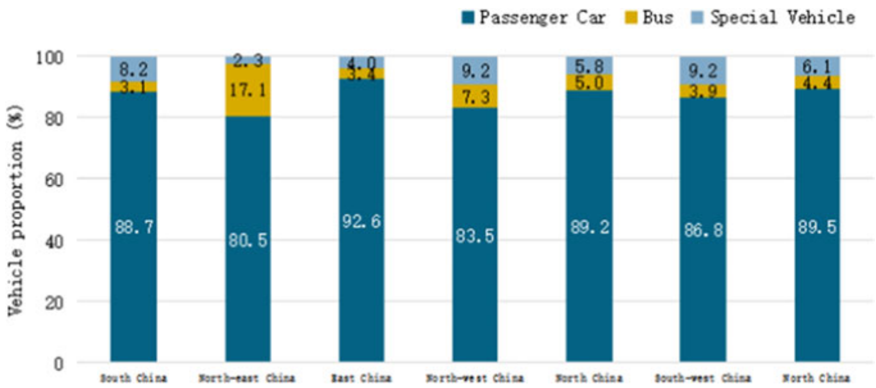


Fig. 4.3 Proportion of cumulative access volume of new energy vehicles of different types in China

regions. South China featured a high online rate of NEVs, with higher frequency of vehicle attendance and intensity of operation. The high online rate in Northeast China was partly due to the higher proportion of new energy commercial vehicles accessed and the regular operations, which increased vehicle attendance to a certain extent (Fig. 4.3).

4.1.3 Online Rate in Cities at All Tiers in China

NEVs were more active in low-tier cities, significantly higher than first-and second-tier cities.

Judging from the average monthly online rate of vehicles in cities at all tiers in China, the average monthly online rate of vehicles in cities at all tiers kept increasing yearly. Compared with other triers, the difference in the average monthly online rate of NEVs in first-tier cities over the years gradually stabilized (Fig. 4.4). The

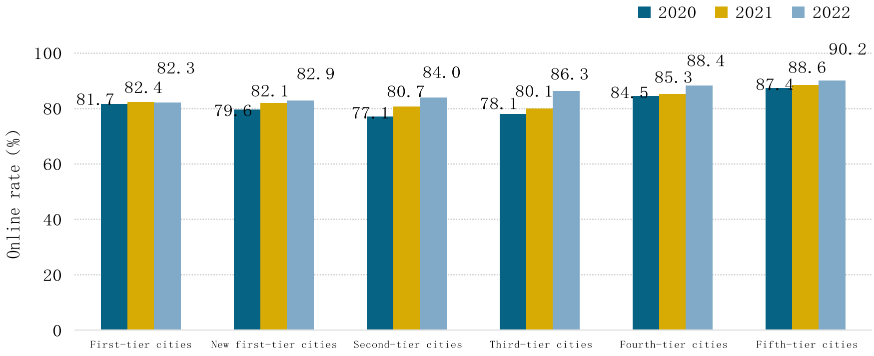


Fig. 4.4 Average monthly online rate of new energy vehicles in cities at all tiers in China over the years

online rate of fourth- and fifth-tier cities was significantly higher than that of the first- and second-tier cities, indicating a higher demand of travel with NEVs since the promotion of NEVs in the fourth- and fifth-tier cities was mainly affected by the internal driving force of the market. Meanwhile, the base of NEV holdings in fourth- and fifth-tier cities was relatively small, making it an essential area for future promotion of NEVs.

4.1.4 Online Rate of Vehicles in Each Segment

In 2022, the average monthly online rate of e-taxis remained high, and that of private cars and heavy-duty trucks grew steadily with high activity.

In terms of online rate for key segments (Fig. 4.5), e-taxis recorded the highest average monthly online rate for the second consecutive year, exceeding 95% in both 2021 and 2022. The annual changes in online rate indicated a year-on-year increase of average monthly online rates for private cars and heavy-duty trucks. New energy private cars have basically met the needs of users for traveling, with the online getting stabilized over the years. Heavy-duty trucks became more active due to the rapid market promotion and increase in number of new vehicles in the past two years. The online rate may truthfully reflect the user's actual demand for vehicles. As for buses, due to the rapid introduction of NEV buses, some of them were close to decommissioning, which resulted in a smaller number of operating buses. In the market of the cars for sharing, due to the impact of the pandemic, the user demand declined, which impacted the activity to some extent.

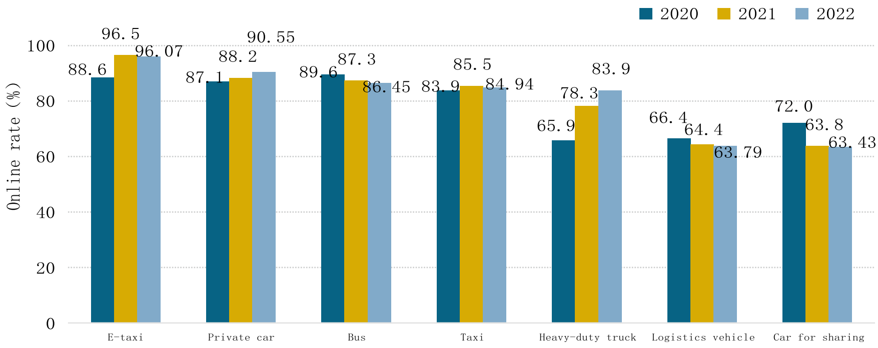


Fig. 4.5 Average monthly online rate of new energy vehicles in key segments

4.2 Operation Characteristics of Vehicles in Key Segments

This Section studies the operation characteristics of vehicles in key segments and summarizes the features of users' traveling, with an aim to provide an essential basis for the transition of the NEV industry from the policy-driven mode to the market-driven mode. In this Section, NEV market is divided into seven segments for further analysis, namely private cars, e-taxis, taxis, cars for sharing, logistics vehicles, buses, and heavy-duty trucks. It summarizes the average single-trip travel characteristics, average daily travel characteristics, and average monthly travel characteristics of vehicles in those segments to obtain the operation characteristics of different segments, with the specific indicators and the descriptions as shown in Table 4.3.

Table 4.3 Indicators of NEV market operation characteristics

Analysis dimension	Analysis indicator	Definition
Average single-trip travel characteristics	Average single-trip travel duration	Average travel duration of a single trip
	Average single-trip mileage	Average mileage of a single trip
Average daily travel characteristics	Average daily travel duration	Average travel duration in a single day
	Average daily mileage	Average mileage in a single day
	Driving time	Distribution of driving time in a single day (24 h) Cumulative number of vehicles accessed to National Monitoring and Management Platform
Average monthly travel characteristics	Average monthly travel days	Average travel days in a single month
	Average monthly mileage	Average mileage in a single month

4.2.1 Operation Characteristics of Private Cars

(1) **Average single-trip travel characteristics of private cars**

The average single-trip travel duration of private cars in 2022 was 0.55 h, less than that recorded in 2021.

According to the data over the years, in 2021, the average single-trip travel duration of private cars was 0.55 h, with a decrease of 0.8 h from 2021 and an increase of 0.13 h over 2020 (Table 4.4).

The average single-trip travel duration of private cars was mainly within 1 h, and the proportion of vehicles with an average single-trip travel duration of more than 1 h increased.

In terms of the distribution of average single-trip travel durations (Fig. 4.6), the proportion of vehicles with average single-trip travel duration of 1 h or less has been higher than 80% since 2020. In terms of the distribution of average single-trip driving durations of private cars over the years, the proportion of those exceeding 1 h was 15.5%, with a significant increase over 2021.

The average single-trip driving duration of private cars in the first-tier cities was mainly between 0.5 h and 1 h, while that in other tiers was basically within 0.5 h.

Based on the distribution of the average single-trip driving durations of private cars at all tiers of cities (Fig. 4.7), the average single-trip driving duration of private cars in the first-tier cities was mainly between 0.5 h and 1 h, holding a proportion of 57.4%, while that in other tiers was basically within 0.5 h in a proportion of more than 40%.

Table 4.4 Average single-trip travel duration of private cars over the years

Year	In 2020	2021	2022
Average single-trip travel duration (h)	0.42	0.63	0.55

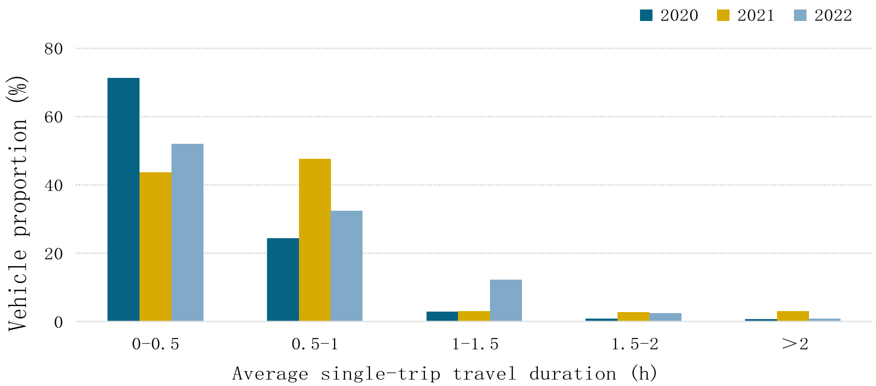


Fig. 4.6 Distribution of private cars of different average single-trip travel durations—by year

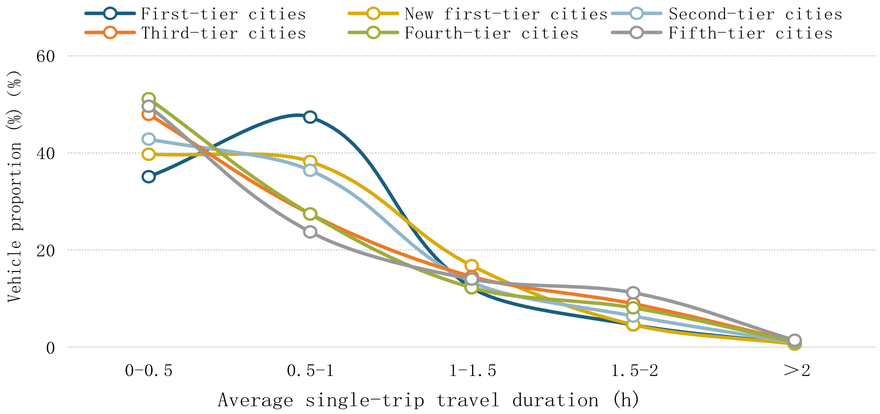


Fig. 4.7 Distribution of private cars of average single-trip travel durations in 2022—by city tier

The average single-trip mileage of private cars in 2022 was basically the same as that in 2021.

According to the average single-trip mileage of private cars over the years (Table 4.5), such value in 2021 was 14.39 km, basically the same as that in 2021. By the proportion of vehicles with an average single-trip mileage (Fig. 4.8), the single-trip mileage of private cars was mainly within 20 km, holding a proportion of 80% for years.

As per the distribution of average single-trip mileage of private cars in different tiers of cities (Fig. 4.9), the average single-trip mileage in major cities fell within 20 km. By city, the distribution of average single-trip mileage of private cars in

Table 4.5 Average single-trip mileage of private cars over the years

Year	In 2020	2021	2022
Average single-trip mileage (km)	11.44	14.43	14.39

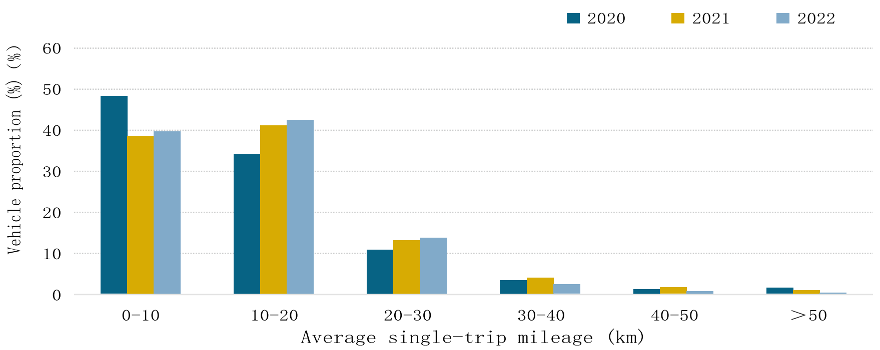


Fig. 4.8 Distribution of private cars of different average single-trip mileages—by year

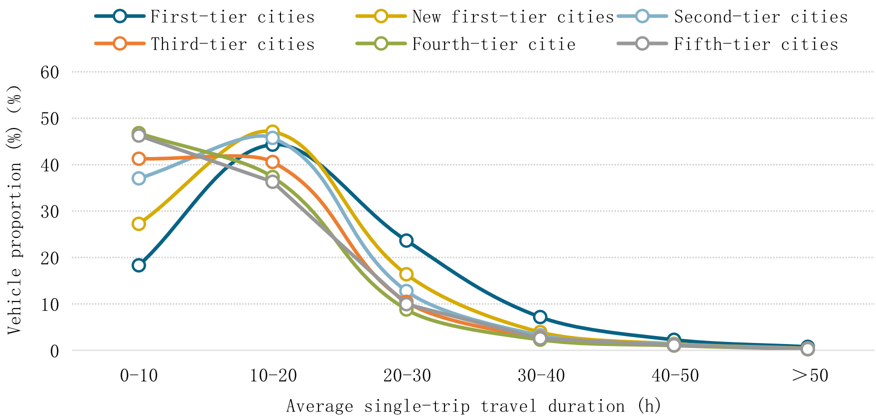


Fig. 4.9 Distribution of private cars of different average single-trip mileages in 2022—by city tier

the first-tier cities was different from that of other cities. In 2022, the private cars with higher average single-trip mileage in the firs-tier cities held larger proportion, of which those with average single-trip mileage exceeding 20 km accounting for 33.87%, which is significantly higher than that in other tiers of cities.

(2) Average daily travel characteristics of private cars

The average daily travel duration of private cars in 2022 was 1.64 h, basically the same as that in 2020 and 2021.

The average daily travel duration of private cars in 2022 was 1.64 h, basically the same as that in 2020 and 2021 (Table 4.6). Form the average daily travel duration of private cars in each month of 2022 (Fig. 4.10), the lowest record was logged in April; and after May, such value became and maintained stable.

The average daily travel duration of private cars mainly fell into the range of 1–2 h, during which the proportion of vehicles remained above 45% over the years. In terms of annual changes (Fig. 4.11), the percentage of private cars with average daily travel duration within 2 h to 3 h in 2022 was 67.47%, with a stable increase from 2020 and 2021.

The average daily mileage of private cars in 2022 was 36.07 km, showing a decrease from 2020 and 2021.

The average daily mileage of private cars in a single trip in 2022 was 34.07 km, showing a significant downward trend from 2020 and 2021 (Table 4.7). Upon comparison with the average daily mileage of private cars over the years (Fig. 4.12), it can be concluded that the average daily mileage of private cars was mainly in the range of 10–40 km, of which the percentage of those with average daily mileage in the

Table 4.6 Average daily travel duration of private cars-average

Year	2020	2021	2022
Average daily travel duration (h)	1.58	1.66	1.64

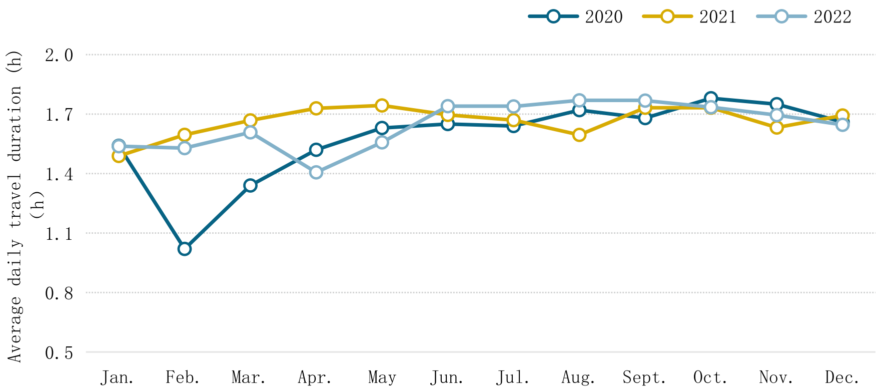


Fig. 4.10 Monthly average of average daily travel duration of private cars over the years

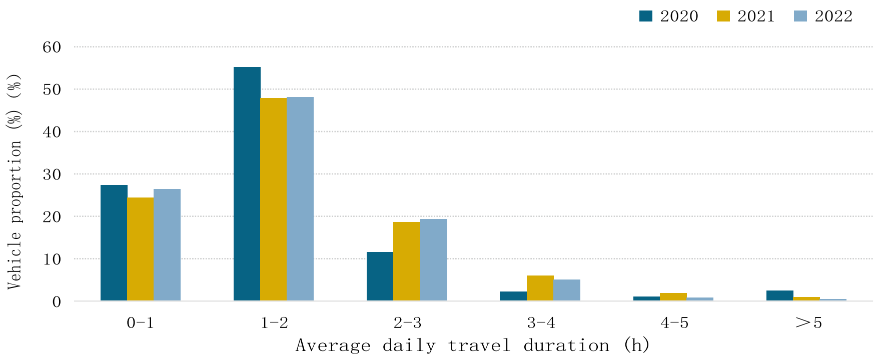


Fig. 4.11 Distribution of private cars of different average daily travel durations—by year

range of 10–40 km in 2022 reached 60.04%. In addition, the distribution of vehicles with an average daily mileage of 40 km or more showed a significant long-tail effect, suggesting that private cars for long-distance trips accounted for a high proportion.

By city (Fig. 4.13), there were more private cars of medium and high average daily mileages in first-tier, new first-tier, and second-tier cities than other tiers of cities. The proportion of private cars with average daily mileage of 30 km or more in first-tier, new first-tier and second-tier cities was over 50%, versus 40% recorded in other tiers of cities, which indicated that size and traffic congestion of cities had a certain impact on the average daily mileage of private cars.

The driving time of private cars exhibited a "double-peak" characteristic, and the primary use was still commuting.

Table 4.7 Average daily mileage of private cars

Year	2020	2021	2022
Average daily mileage (km)	45.73	46.25	36.07

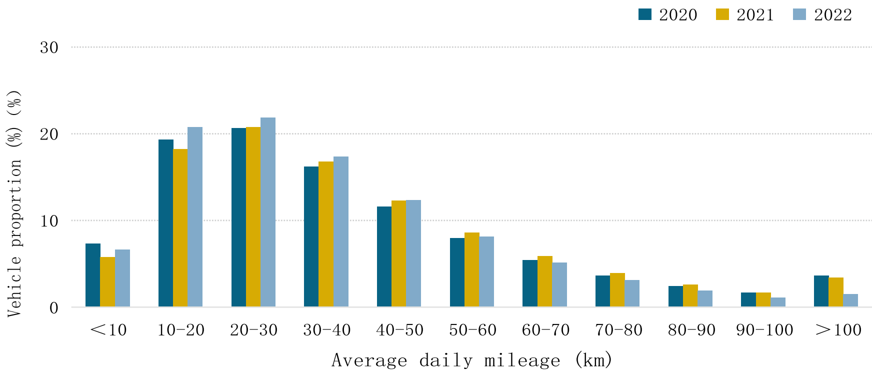


Fig. 4.12 Distribution of private cars of average daily mileage—by year

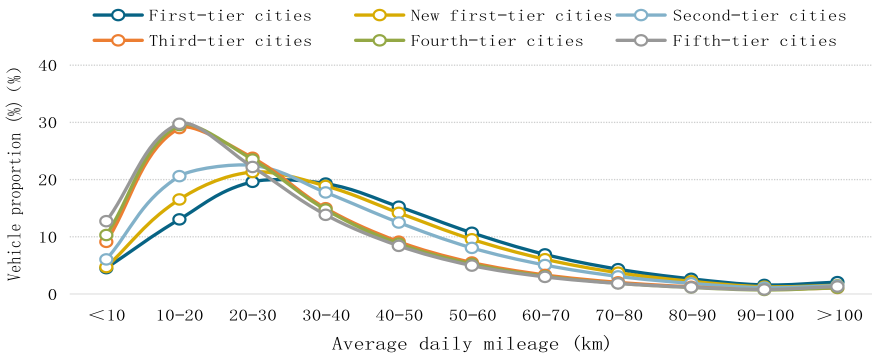


Fig. 4.13 Distribution of private cars of average daily mileage in 2022—by city tier

As the distribution shows (Fig. 4.14), the traffic of private cars mainly peaks at two periods, namely 07:00–09:00 and 17:00–18:00. During the morning rush hours, the traffic of private cars climbed rapidly after 7:00, especially from 7:00 to 9:00 when over 20% private cars were driving on the road. During the evening rush hour, the traffic of private cars was mainly between 17:00 and 18:00 when over 30% private cars were on the road. The distribution of private cars driving within the whole day over the years showed a higher percentage of private cars driving during the daytime in 2022 over the last three years.

According to the distribution of private cars driving on the road in different periods of time of a day in cities of all tiers (Fig. 4.15), the proportion of those driving during the daytime in first-tier cities was significantly lower than that in cities of other tier; the proportion of those driving during the daytime in second-tier cities was significantly higher than that in cities of other tiers; and the proportion of those driving during the morning rush hours in the new first-tier cities and second-tier cities was higher.

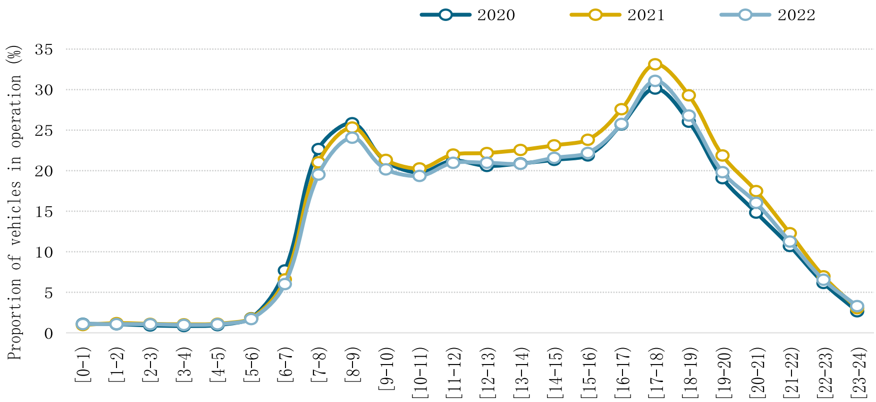


Fig. 4.14 Distribution of NEV private cars in different periods of time of the day over the years

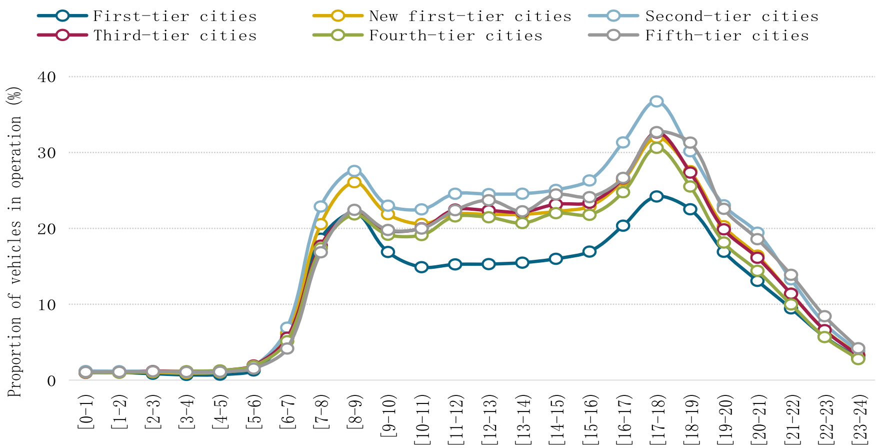


Fig. 4.15 Distribution of NEV private cars in different periods of time of the day in 2022

(3) Average monthly travel characteristics of private cars

The average number of travel days for private cars basically remained at around 18 days.

The data shows that the average number of monthly travel days for private cars in 2022 was 18.06, a slight decrease from 2020 and 2021 (Table 4.8). According to the distribution of the average monthly travel days of private cars over the years (Fig. 4.16), such number in 2022 mainly ranged from 10 to 25 days, with the proportion of private cars involved reaching 70.84%. Compared to 2020 and 2021, the percentage of private cars with average monthly travel days of more than 25 days lowered in 2022.

In 2021, the average monthly mileage of private cars was 730.9 km, showing a decrease from 2020 and 2021 (Table 4.9).

Table 4.8 Average monthly travel days of private cars-average

Year	2020	2021	2022
Average monthly travel days (day)	18.68	19.42	18.06

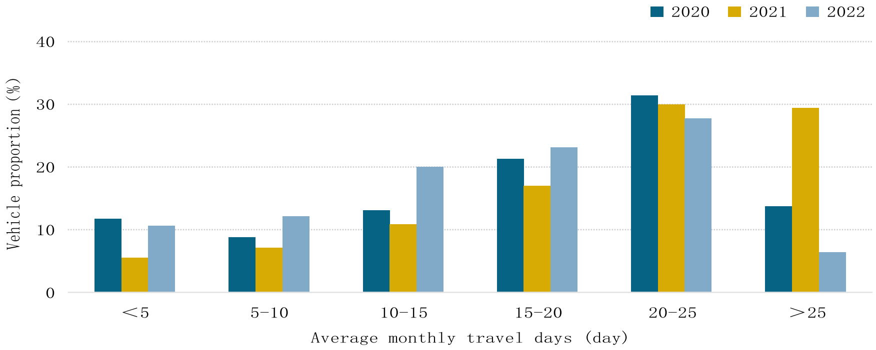


Fig. 4.16 Distribution of private cars of different average monthly travel days—by year

Table 4.9 Average monthly mileage of private cars-average

Year	2020	2021	2022
Average monthly mileage (km)	918.54	921.70	730.9

As a result of the pandemic, the average monthly mileage of private cars in 2022 was 730.9 km, a slight decrease from the past two years. According to the distribution of the average monthly mileage of private cars (Fig. 4.17), the average monthly mileage of private cars over the years was mainly within 1000 km, with the proportion of private cars involved exceeding 60%.

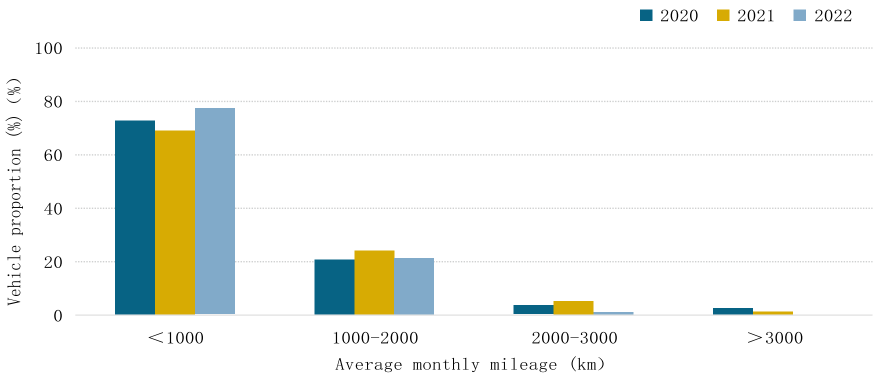


Fig. 4.17 Distribution of private cars of different average monthly mileages—by year

4.2.2 Operation Characteristics of E-taxis

(1) **Average daily travel characteristics of e-taxis**

The daily travel duration of e-taxis in 2022 was 6.48 h, with a slight increase over 2020 and 2021.

In 2022, the average daily travel duration of e-taxis was 6.48 h (Table 4.10), an increase of 6.2% and 2.2% from 2020 and 2021, respectively. In terms of the distribution of average daily travel duration (Fig. 4.18), the proportion of e-taxis with average daily travel duration between 4 and 6 h in 2022 increased significantly over 2020 and 2021.

As shown in Fig. 4.19, the percentage of e-taxis with average daily travel duration exceeding 6 h in first-tier and new first-tier cities was lower than that in other tiers of cities.

The average daily mileage of e-taxis was mainly 150–250 km.

According to the data over the years, the average daily mileage of e-taxis was 188.39 km in 2022, with an increase of 19.4% and 11.8% from 2019 and 2020, respectively (Table 4.11). According to changes of average daily mileage over the years (Fig. 4.20), the average daily mileage of e-taxis remained stable following May 2022, showing a significant increase in users' willingness and demand for travel.

From the distribution of the average daily mileage of e-taxis over the years (Fig. 4.21), the average daily mileage of e-taxis was within 150–200 km, with the proportion exceeding 43.5%. By the tier of cities (Fig. 4.22), the e-taxis in low mileage ranges of first-tier, new first-tier, and second-tier cities held a higher proportion, while the proportion of e-taxis in high mileage ranges was higher in the other tiers of cities.

Table 4.10 Average daily travel duration of e-taxis-average

Year	In 2020	2021	2022
Average daily travel duration (h)	6.10	6.34	6.48

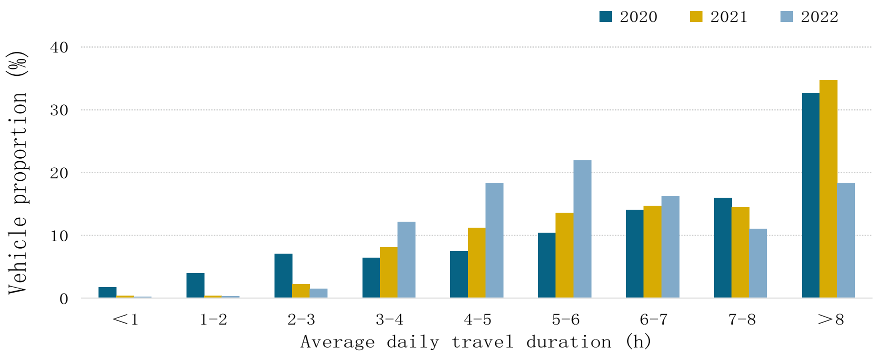


Fig. 4.18 Distribution of e-taxis of different average daily travel durations—by year

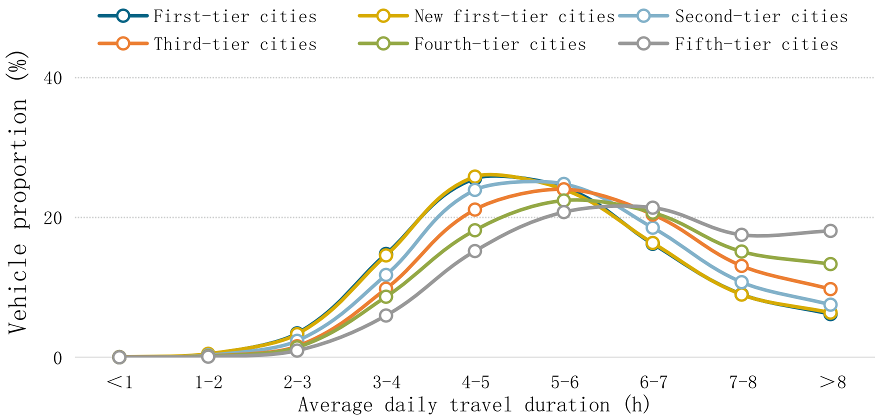


Fig. 4.19 Distribution of e-taxis of different average daily travel durations in 2022—by city tier

Table 4.11 Average daily mileage of e-taxis-average

Year	2020	2021	2022
Average daily mileage (km)	157.81	168.56	188.39

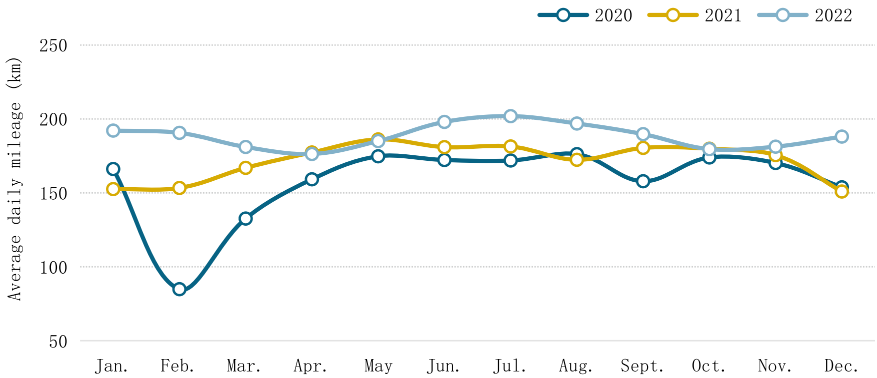


Fig. 4.20 Monthly average of average daily mileage of e-taxis over the years

The driving time of e-taxis was mainly between 7:00 and 21:00, during which the proportion of vehicles in operation was over 40% in each period of time. According to the distribution of vehicles operating at different periods of time within a day (Fig. 4.23), the period for e-taxis in operation during the day were mainly from 07:00 to 21:00, without any significant peak. The number of e-taxis on the road at different periods accounted for more than 40%. By the changes over the years, the proportion of vehicles in operation in 2021 and 2022 was significantly higher than that in 2020.

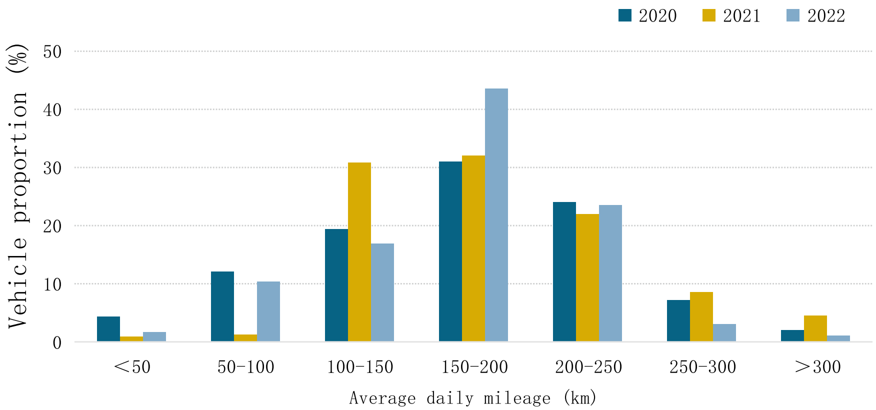


Fig. 4.21 Distribution of e-taxis of different average daily mileages—by year

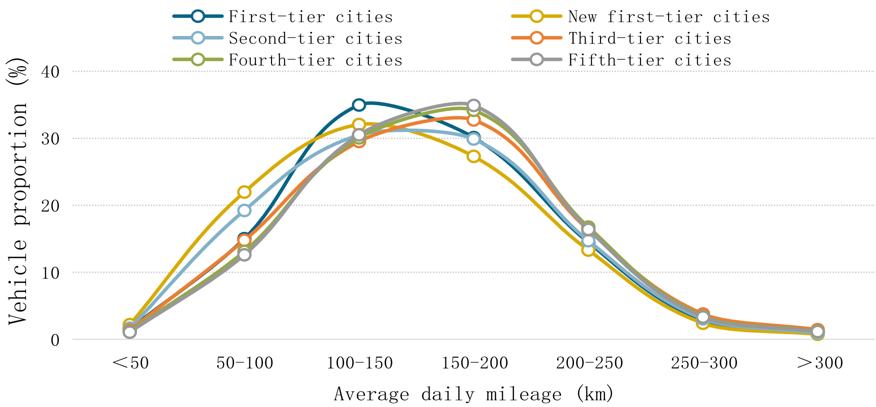


Fig. 4.22 Distribution of e-taxis of different average daily mileages in 2022—by city tier

In lower-tier cities, e-taxis highlighted more on economic operation with a higher number in operation.

There is a significant difference in the proportion of the number of new energy e-taxis running during the daytime in different tiers of cities (Fig. 4.24). The proportion of e-taxis traveling during all the periods of time during the day in the second-tier to fifth-tier cities was significantly higher than that in the first-tier and new first-tier cities, and owners of new energy e-taxis in lower tiers of cities stressed more on economy with a higher number of e-taxis in operation.

(2) **Average monthly travel characteristics of e-taxis**

The average monthly travel days of the e-taxis increased steadily over the previous two years to 24.76 days.

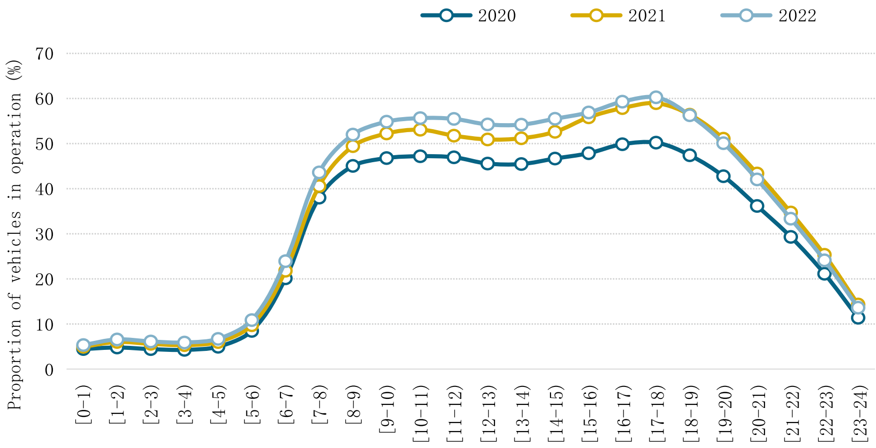


Fig. 4.23 Distribution of new energy e-taxis of different driving times within the day—by year

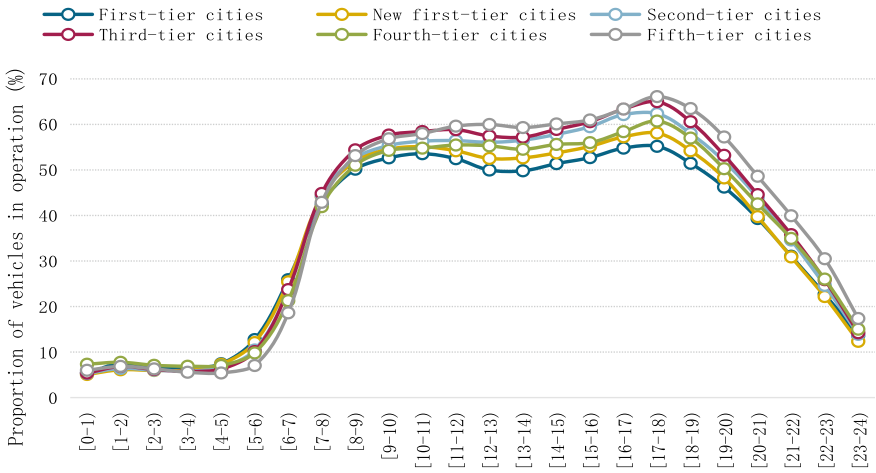


Fig. 4.24 Distribution of new energy e-taxis of different driving times within the day in 2022

In 2022, the average monthly travel days of e-taxis was 24.76 days, with a steady increase over 2020 and 2021 (Table 4.12). From the distribution of average monthly travel days over the years (Fig. 4.25), such number of e-taxis was mostly higher than 20 days, of which the proportion of e-taxis all exceeded 60%. By city tier (Fig. 4.26), the average monthly travel days of e-taxis in first-tier cities fell in the range of 20 days to 25 days, with the percentage reaching 34.24%,; while the number in other tiers of cities was basically the same.

In 2022, the average monthly mileage of e-taxis was 4308.68 km, basically the same as that in 2021.

Table 4.12 Average monthly travel days of e-taxis-average

Year	2020	2021	2022
Average monthly travel days (day)	21.6	24.60	24.76

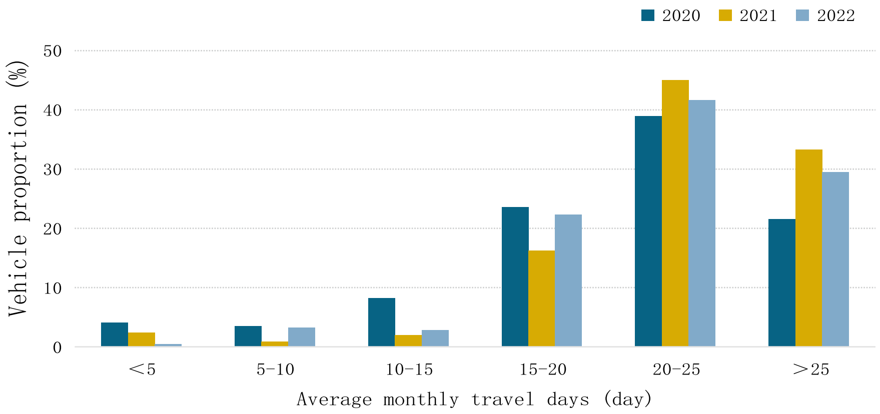


Fig. 4.25 Distribution of e-taxis of different average monthly travel days—by year

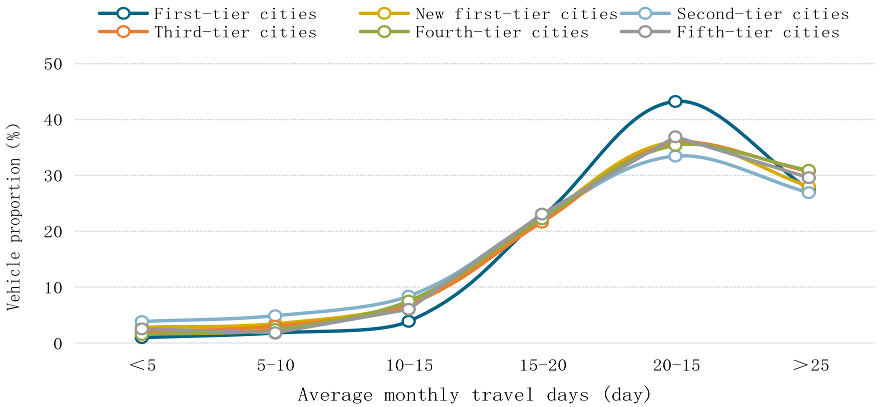


Fig. 4.26 Distribution of e-taxis of different average monthly travel days in 2022—by city tier

According to the average monthly mileage over the years (Table 4.13), the average monthly mileage of e-taxis in 2022 was 4308.68 km, basically the same as that in 2021.

Table 4.13 Average monthly mileage of e-taxis-average

Year	2020	2021	2022
Average monthly mileage (km)	3580.24	4265.16	4308.68

As the distribution indicates (Fig. 4.27), the average monthly mileage of e-taxis was mainly over 3000 km, with a proportion exceeding 60% over the years. Among them, the e-taxis with an average monthly mileage exceeding 3000 km accounted for 77.6% in 2022, up by 14.7 percentage points and 4.9 percentage points over 2020 and 2021, respectively. In terms of city tier (Fig. 4.28), the average monthly mileage of e-taxis in first-tier cities was mainly from 3000 to 5000 km, with the proportion of 55.9%, which is significantly higher than that of other tiers of cities.

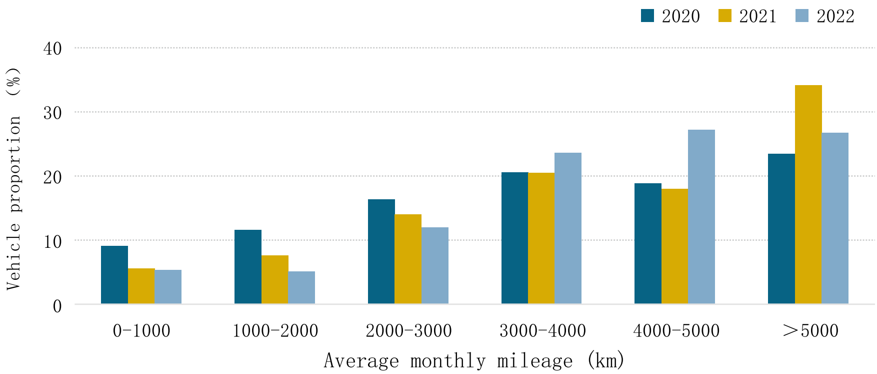


Fig. 4.27 Distribution of e-taxis of different average monthly mileages—by year

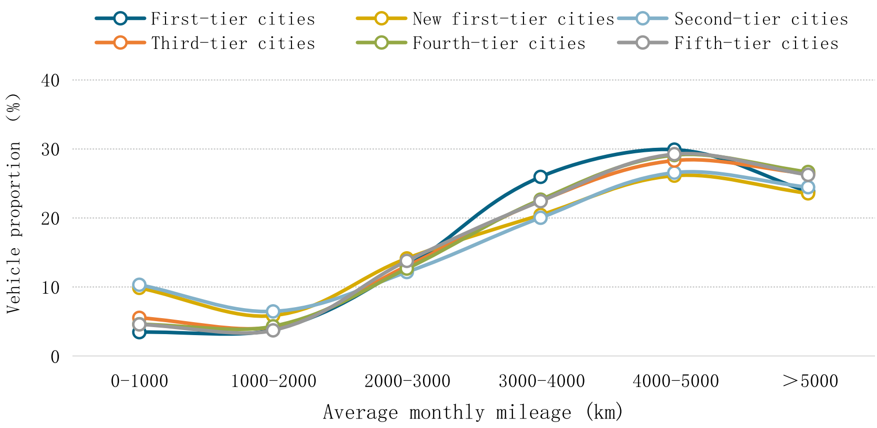


Fig. 4.28 Distribution of e-taxis of different average monthly mileages in 2022

4.2.3 Operation Characteristics of Taxis

(1) **Average daily travel characteristics of taxis**

The average daily travel duration of taxis in 2022 was 7.02 h, with a slight decrease from 2021.

In 2022, the average daily travel duration of taxis in 2022 was 7.02 h, a decrease of 4.6% and 14.1% compared to 2020 and 2021, respectively (Table 4.14). From the distribution of average daily travel duration of taxis (Fig. 4.29), the proportion of taxis with average daily travel duration of at least 8 h was 37.67% in 2022, a decrease from 2020 and 2021.

Average daily mileage of taxis in 2022 went down compared to 2021.

As per average daily travel mileage of taxis over the years, such mileage of taxis in 2022 was 193.24 km, slightly lower than the average mileage in 2021, but 3.6% higher than that in 2020 (Table 4.15). According to the monthly changes in average daily mileage over the years (Fig. 4.30), the average monthly mileage was relatively low around in April 2022 due to the recurrence of pandemic events, and taxi operation slowly recovered from May.

From the distribution of the average daily mileage of taxis over the years (Fig. 4.31), the average daily mileage of taxis in 2022 mainly fell in the range of

Table 4.14 Average daily travel duration of taxis-average

Year	2020	2021	2022
Average daily travel duration (h)	7.36	8.17	7.02

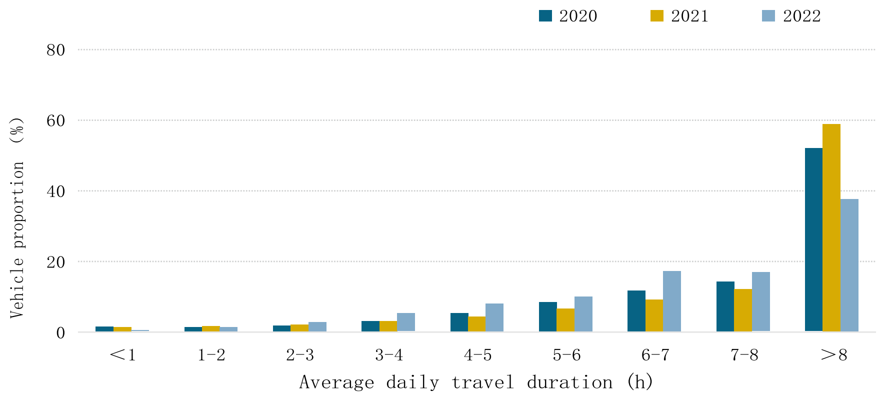


Fig. 4.29 Distribution of taxis of different average daily travel durations—by year

Table 4.15 Average daily mileage of taxis-average

Year	2020	2021	2022
Average daily mileage (km)	186.46	201.88	193.24

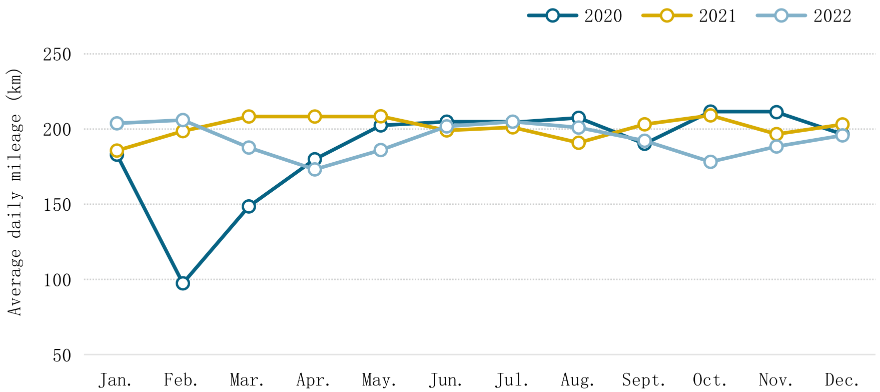


Fig. 4.30 Monthly average of average daily mileage of taxis over the years

100–250 km, with the proportion of more than half of the total over the years. By the city tier (Fig. 4.32), in 2022, the average daily mileage of taxis in first-tier cities was mainly from 150 to 200 km, accounting for 27.47% of the total; while that in fourth-tier and fifth-tier cities mainly centered on high mileages, with the proportion of taxis with average daily mileage exceeding 200 km at 56.44% and 59.93%, respectively, which is significantly higher than that in other tiers of cities.

Taxis were mainly running in the period from 07:00 to 21:00 throughout the day, with more than 40% of the vehicles traveling in each of the hours within such period.

According to the distribution of taxis running at all times of the day (Fig. 4.33), most of the such taxis were mainly in operation from 07:00 to 21:00. In 2021, the proportion of taxis running at all times of the day was relatively high, and that of taxis running in the peak hours in the afternoon was close to 60%. In respect of the

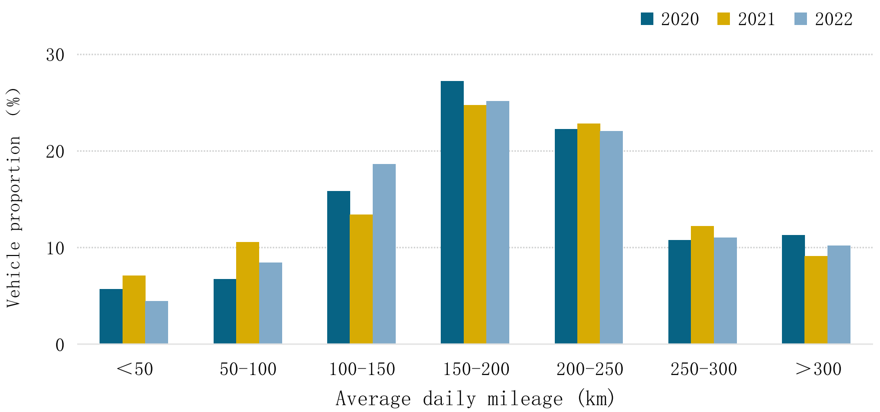


Fig. 4.31 Distribution of taxis of different average daily mileages—by year

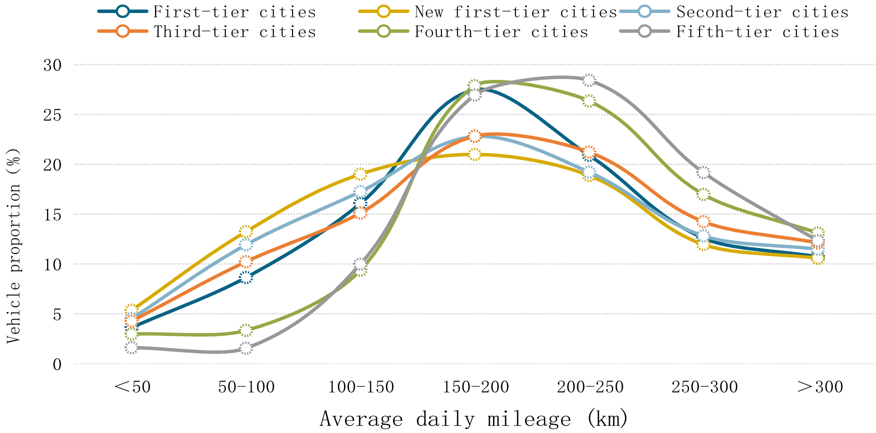


Fig. 4.32 Distribution of taxis of different average daily mileages in 2020—by city tier

distribution of taxis running in the nighttime, the proportion of taxis driving in the early morning remained essentially at about 10%, higher than other driving at the same time of day.

The proportion of new energy taxis running in cities of the second tier or lower was significantly higher than that in first-tier and new first-tier cities.

The proportion of new energy taxis running in different tiers of cities varied significantly (Fig. 4.34). The proportion of new energy taxis running in cities of the second tier or lower was significantly higher than that in first-tier and new first-tier

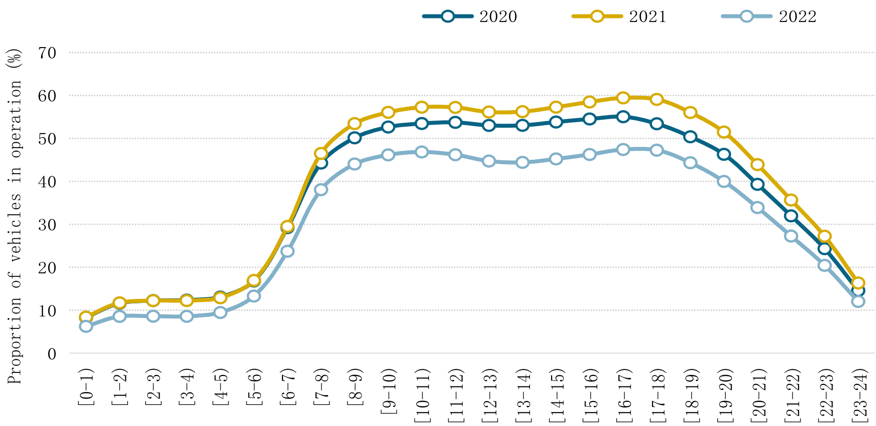


Fig. 4.33 Distribution of new energy taxis of different driving times—by year

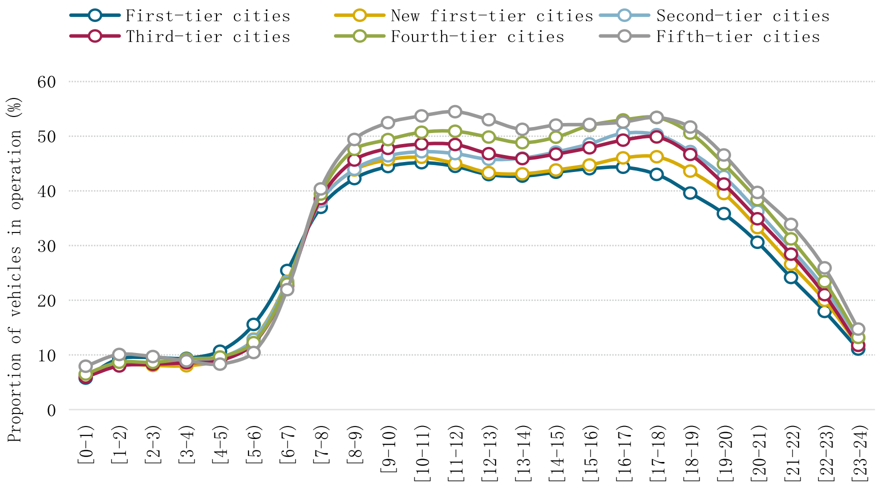


Fig. 4.34 Distribution of new energy taxis of different driving times in 2022

cities. The proportion of taxis running during the daytime in the fifth-tier cities was basically above 50%, while that in first-tier cities was basically around 45%.

(2) **Average monthly travel characteristics of taxis**

The average monthly travel days of taxis in 2022 totaled 21.41, a slight decrease from 2020 and 2021.

In terms of the average monthly travel days of taxis over the years, the average monthly travel days of taxis in 2022 totaled 21.41 days, indicating a slight decrease from 2020 and 2021 (Table 4.16). Taxi operation was affected to some extent due to the pandemic. The data (Fig. 4.35) shows that the average monthly travel days of taxis in 2022 was dispersed in distribution, with a higher proportion of the taxis running less than 10 days per month compared to the previous two years.

The average monthly mileage of taxis in 2022 was 4281.64 km, a decrease year on year (Table 4.17).

From the distribution of average monthly mileage (Fig. 4.36), the distribution of taxis in each mileage was relatively even in 2022. The proportion of taxis with an average monthly mileage of more than 3000 km decreased compared to 2020 and 2021, while that with an average monthly mileage in the 2000–5000 km was 69.8%, up by 16.2 percentage points and 29.1 percentage points compared to 2020 and 2021, respectively.

Table 4.16 Average monthly travel days of taxis-average

Year	2020	2021	2022
Average monthly travel days (day)	22.28	24.91	21.41

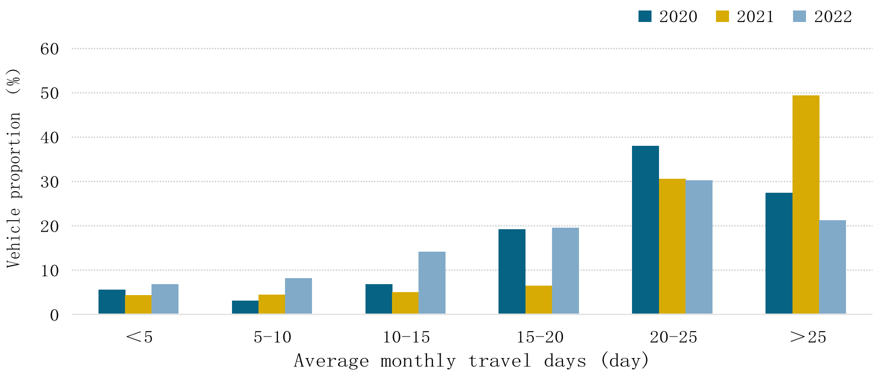


Fig. 4.35 Distribution of taxis of different average monthly travel days-by year

Table 4.17 Average monthly mileage of taxis over the years

Year	2020	2021	2022
Average monthly mileage (km)	4159.89	4838.73	4281.64

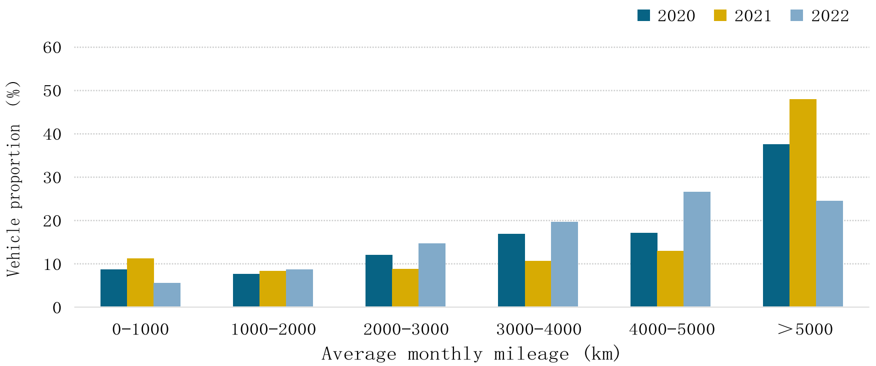


Fig. 4.36 Distribution of taxis of different monthly mileages-by year

4.2.4 Operation Characteristics of Cars for Sharing

(1) **Average single-trip travel characteristics of cars for sharing**

In 2022, the average single-trip travel duration of cars for sharing was 0.81 h showing a decrease from 2021.

The average single-trip travel duration of cars for sharing was 0.81 h in 2022, down 39.7% from 2021, but up 39.7% over 2020 (Table 4.18). The cars for sharing held a relatively higher proportion among the vehicles for medium- and long-distance trips (Fig. 4.37). The proportion of cars for sharing with average driving duration

Table 4.18 Average single-trip travel duration of cars for sharing-average

Year	2020	2021	2022
Average single-trip travel duration (h)	0.58	0.92	0.81

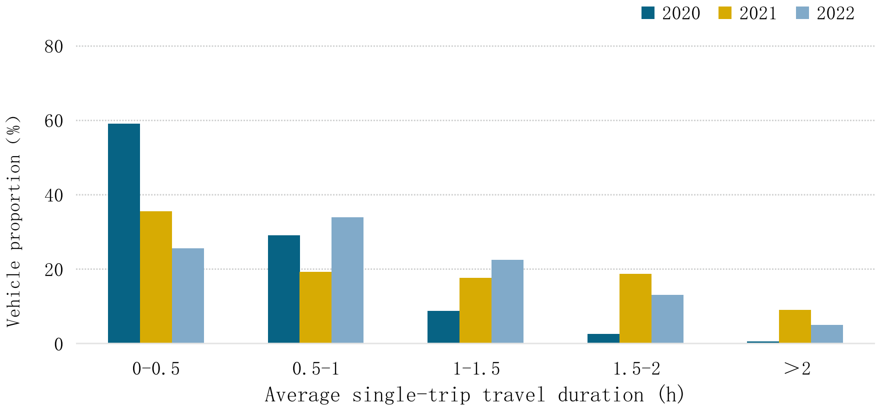


Fig. 4.37 Distribution of cars for sharing of different average single-trip travel durations—by year

of 0.5–1.5 h was 56.46% in 2022, up 18.58 percentage points and 19.64 percentage points compared to 2020 and 2021, respectively.

By city tier, the proportion of cars for sharing with an average single-trip travel duration of 1–1.5 h in first-tier cities was significantly higher than that in other tiers of cities; the average single-trip travel duration of the cars for sharing in new first-tier, second-tier, and third-tier cities was mainly concentrated in 0.5–1 h; and the proportion of cars for sharing with single-trip travel duration exceeding 1.5 h was higher in fourth-tier and fifth-tier cities (Fig. 4.38).

In 2022, the average single-trip mileage of cars for sharing was 24.74 km, showing a decrease from 2021.

In terms of the average single-trip mileage over the years, that of cars for sharing in 2022 was 24.74 km, with a slight decrease from 2021, but an increase of 18.7% over 2020 (Table 4.19). Over the past three years, the average single-trip mileage of cars for sharing had been shifting the mileages of 20 km or more as a whole. In 2022, the proportion of the cars with average single-trip mileage in 20–50 km reached 61.29%, with a significant increase from the previous two years (Fig. 4.39).

By city tier (Fig. 4.40), the proportion of cars for sharing with average single-trip mileage in 20–30 km was far higher in first-tier, new first-tier, and second-tier cities than in other tiers; while the cars for sharing in the fourth-tier and fifth-tier cities mainly fell within the range of 30–40 km.

(2) **Average daily travel characteristics of cars for sharing**

In 2022, the average daily travel duration of cars for sharing was 4.45 h, with a slight decrease compared with that in 2021.

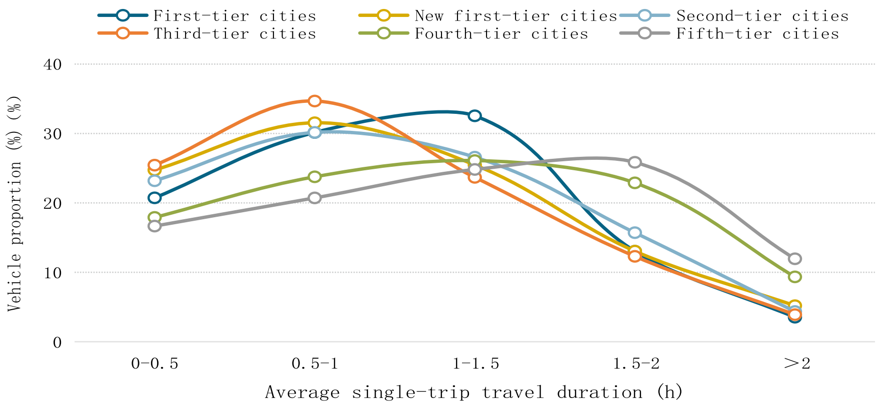


Fig. 4.38 Distribution of cars for sharing of different average single-trip travel durations in 2022—by city tier

Table 4.19 Average single-trip mileage of cars for sharing-average

Year	2020	2021	2022
Average single-trip mileage (km)	20.85	29.07	24.74

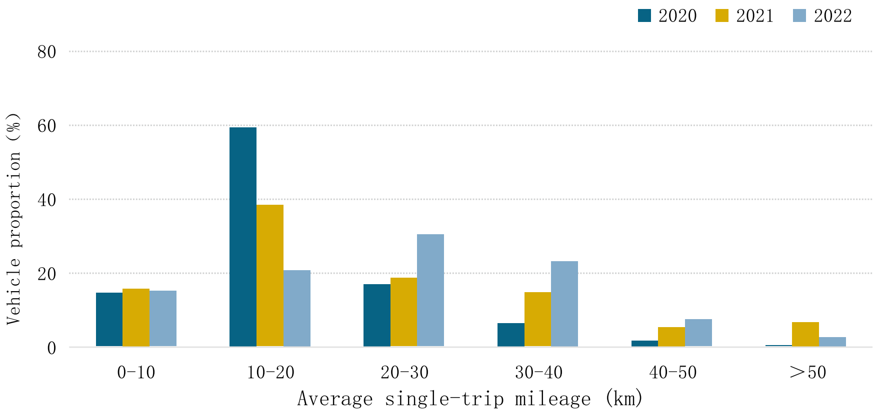


Fig. 4.39 Distribution of cars for sharing of different average single-trip mileages—by year

The market of cars for sharing started to recover in 2021, with average daily travel duration reaching 5.06 h, a significant increase over 2020. In 2022, the average daily travel duration of cars for sharing declined by 12.06% year-on-year due to the pandemic, but still recorded a significant growth from 2020 (Table 4.20).

With respect to the average daily travel duration per month over the years (Fig. 4.41), the distribution of average daily travel durations of cars for sharing was relevant stable by month in 2021 and 2022. The average daily travel duration of cars for sharing in each month of 2022 was higher than 4 h. However, the average

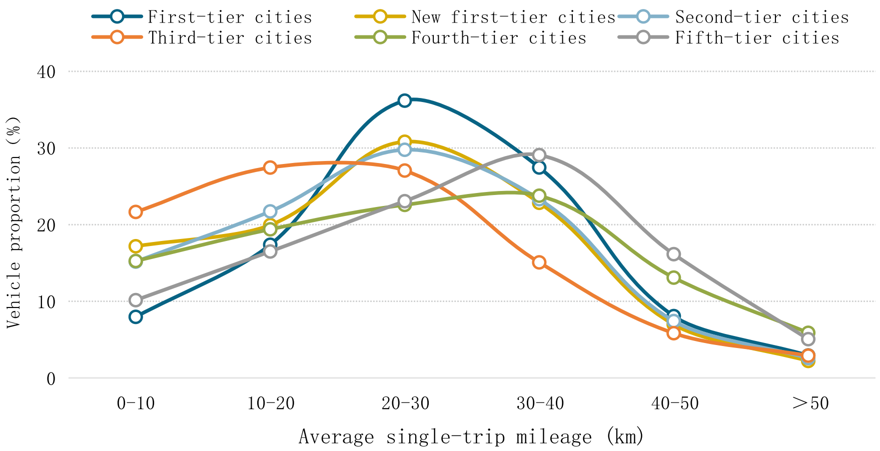


Fig. 4.40 Distribution of cars for sharing of different average single-trip mileages in 2022—by city tier

Table 4.20 Average daily travel duration of cars for sharing-average

Year	In 2020	2021	2022
Average daily travel duration (h)	2.74	5.06	4.45

daily travel duration of cars for sharing was relatively low in winter due to battery performance degradation.

The average daily travel duration of cars for sharing was evenly distributed in 2022 (Fig. 4.42). The proportion of cars for sharing with an average daily travel duration of less than 2 h decreased over previous years, while that of an average daily travel duration of 2–7 h significantly increased over previous years, indicating

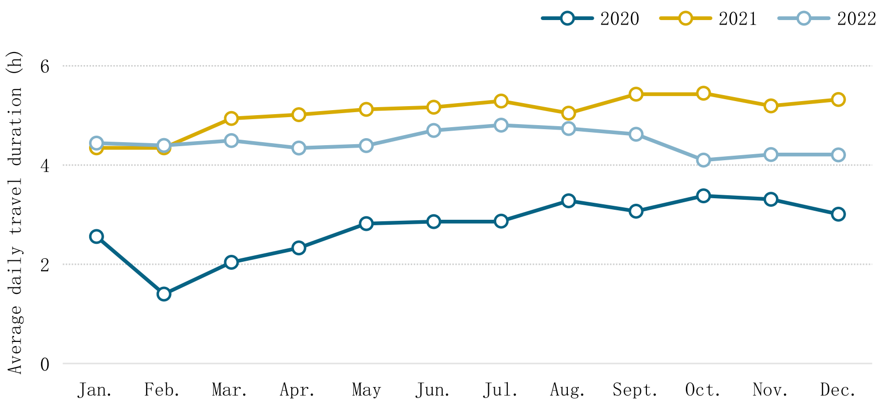


Fig. 4.41 Monthly average of average daily travel duration of cars for sharing over the years

a great improvement of turnover and utilization of the market of cars for sharing in 2022.

Regarding the distribution of average daily travel duration of cars for sharing by city tier (Fig. 4.43), there were more cars for sharing in third-tier cities in 2022 with average daily travel duration within 4 h and more in fifth-tier cities within 6 h, indicating that more users of cars for sharing have demands for medium- and long-distance travel.

In 2022, the average daily mileage of cars for sharing was 102.85 km, and most of the cars for sharing are used long-distance travel.

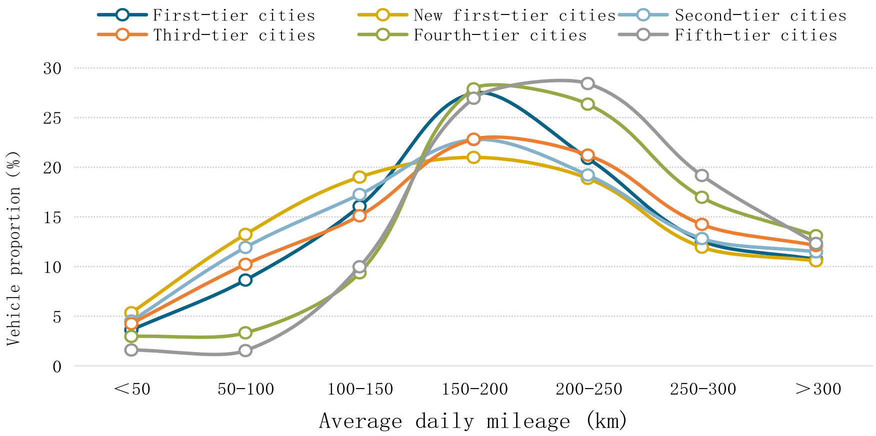


Fig. 4.42 Distribution of cars for sharing of different average daily travel durations—by year

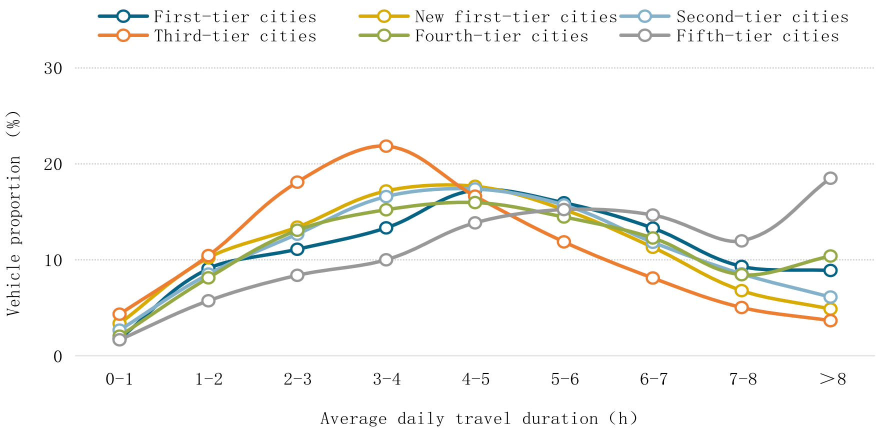


Fig. 4.43 Distribution of cars for sharing of different average daily travel durations in 2022—by city tier

Table 4.21 Average daily mileage of cars for sharing

Year	2020	2021	2022
Average daily mileage (km)	99.63	123.96	102.85

The market of cars for sharing witnessed a resurgence in average daily mileage. The average daily mileage of cars for sharing in 2022 was 102.85 km, an increase of 3.2% (Table 4.21) compared to 2020, but lower than the data for taxis and e-taxis in the same period (188.39 km and 193.24 km). Unlike taxis and e-taxis, no empty load was found in the cars for sharing. If the average daily mileage of cars for sharing reaches the level of e-taxis, it could be assumed that the cars for sharing are more efficient in operation and more profitable under the same conditions.

In the light of the distribution of average daily mileage (Fig. 4.44), the proportion of cars for sharing with average daily mileage in the range of 50–150 km was 60.11% in 2022, up by 12.43 percentage points and 30.06 percentage points compared with 2020 and 2021, respectively. By city tier, the distribution of average daily mileages of cars for sharing in first-tier and fifth-tier cities differed significantly from that in other tiers of cities (Fig. 4.45).

Cars for sharing were mainly running in the period from 8:00 to 20:00 throughout the day Point, with more than 30% of the vehicles traveling in each of the hours within such period.

According to the distribution of cars for sharing running in each hour throughout the day (Fig. 4.46), most of the cars were running in the period from 8:00 to 20:00, and the percentage of the number of vehicles running after 7:00 each day in 2021 was significantly higher than that in the same period in 2020 and 2022, showing a higher attendance.

(3) **Average monthly travel characteristics of cars for sharing**

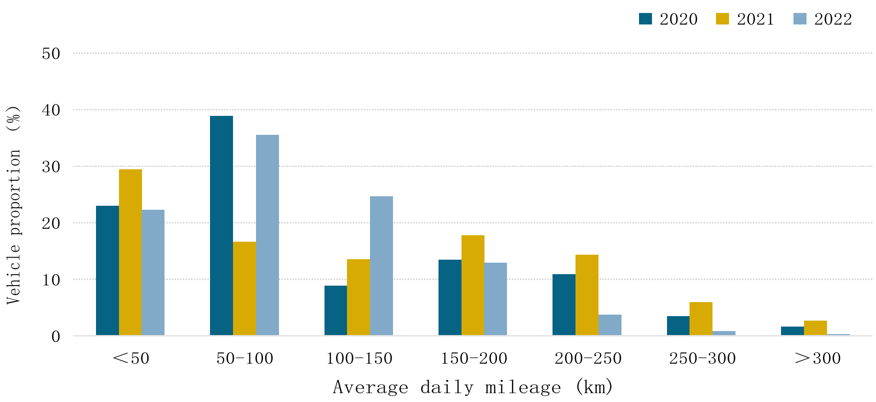


Fig. 4.44 Distribution of cars for sharing of different average daily mileages—by year

Fig. 4.45 Distribution cars for sharing of different average daily mileages in 2022—by city tier

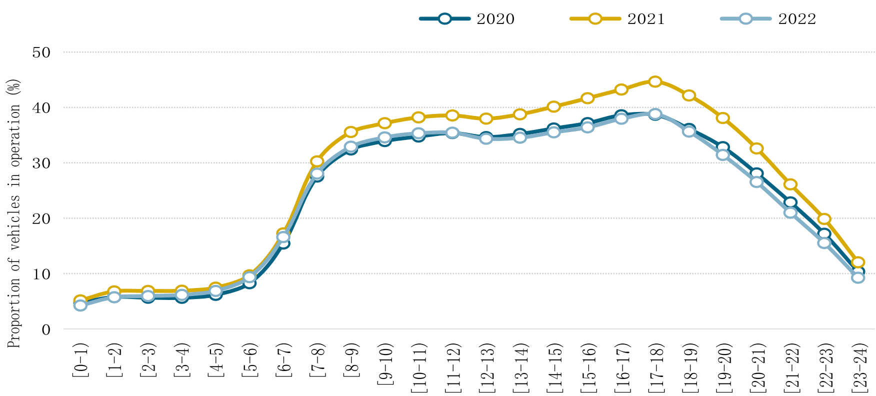


Fig. 4.46 Distribution of cars for sharing of different driving times—by year

In 2022, the average monthly travel days of cars for sharing was 19.61, a slight increase compared with 2020 (Table 4.22).

According to the data over the years (Fig. 4.47), the average monthly travel days of cars for sharing in January to September 2021 exceeded that recorded in 2020; while that in other months of 2022 dropped due to the pandemic.

As the distribution shows (Fig. 4.48), the proportion of monthly travel days of the cars for sharing was scattered, wherein a certain proportion of cars for sharing was logged for running less than 15 days.

Table 4.22 Average monthly travel days of cars for sharing-average

Year	2020	2021	2022
Average monthly travel days (day)	18.43	21.74	19.61

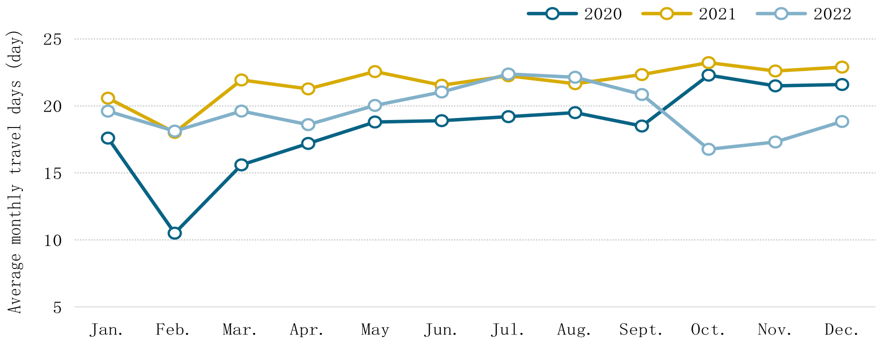


Fig. 4.47 Average monthly travel days of cars for sharing over the years

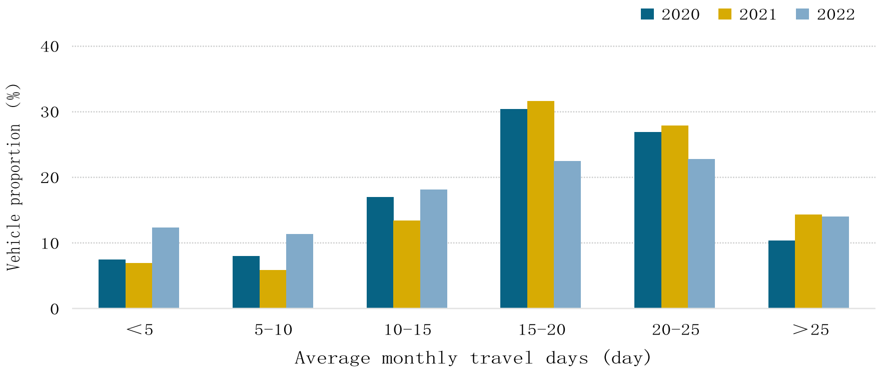


Fig. 4.48 Distribution of cars for sharing of different average monthly travel days—by year

In 2022, the average monthly mileage of cars for sharing was 2892.75 km, with a slight increase over 2020.

In 2022, the average monthly mileage of cars for sharing was 2892.75 km, an increase of 10.7% compared with 2020, but a decrease compared with 2021 (Table 4.23). According to the distribution of average monthly mileage (Fig. 4.49), in 2022, the proportion of cars for sharing with an average monthly mileage of 2000–4000 km increased compared with previous years.

Table 4.23 Average monthly mileage of cars for sharing over the years

Year	2020	2021	2022
Average monthly mileage (km)	2612.85	3103.41	2892.75

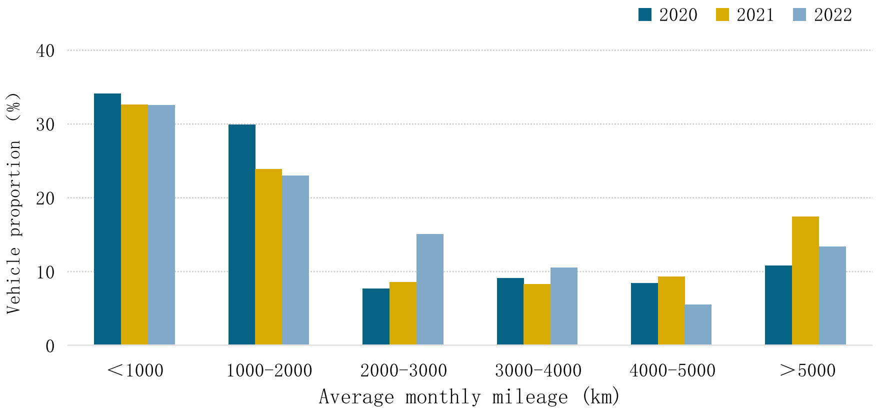


Fig. 4.49 Distribution of cars for sharing over the years based on average monthly mileage

4.2.5 Operation Characteristics of Logistics Vehicles

(1) **Average single-trip travel characteristics of logistics trains**

The average single-trip travel duration of logistics vehicles in 2021 was 1.05 h, a slight increase compared with that in 2020 and 2021.

In 2022, the average single-trip travel duration of logistics vehicles in 2022 was 1.05 h, a decrease of 128.3% and 20.7% compared to 2020 and 2021, respectively (Table 4.24). From the distribution of average single-trip travel duration of logistics vehicles (Fig. 4.50), the duration for logistics vehicles for a single trip was mainly between 0.5 and 1.5 h, with over 70% vehicles within such period, indicating an increasingly sound operation of new energy logistics vehicles.

The average single-trip mileage of logistics vehicles in 2022 was 22.28 h, with a slight increase over 2020 and 2021.

The average single-trip mileage of logistics vehicles increased substantially compared to the past two years (Table 4.25). The average monthly single-trip mileage of logistics vehicles in 2022 was 22.28 km, an increase of 97.3% and 17.5% compared to 2020 and 2021, respectively.

As indicated from the distribution of the average single-trip mileage (Fig. 4.51), the percentage of logistics trips with an average single-trip mileage exceeding 20 km in 2022 was 53.0%, up by 42.4 percentage points and 12.9 percentage points compared with 2020 and 2021, respectively. In terms of city tier, the percentage of logistics vehicles with single-trip mileage of 20–40 km in first-tier cities reached 49.1%, which was significantly higher than that in other tiers of cities, indicating a

Table 4.24 Average single-trip travel duration of logistics vehicles over the years

Year	2020	2021	2022
Average single-trip travel duration (h)	0.46	0.87	1.05

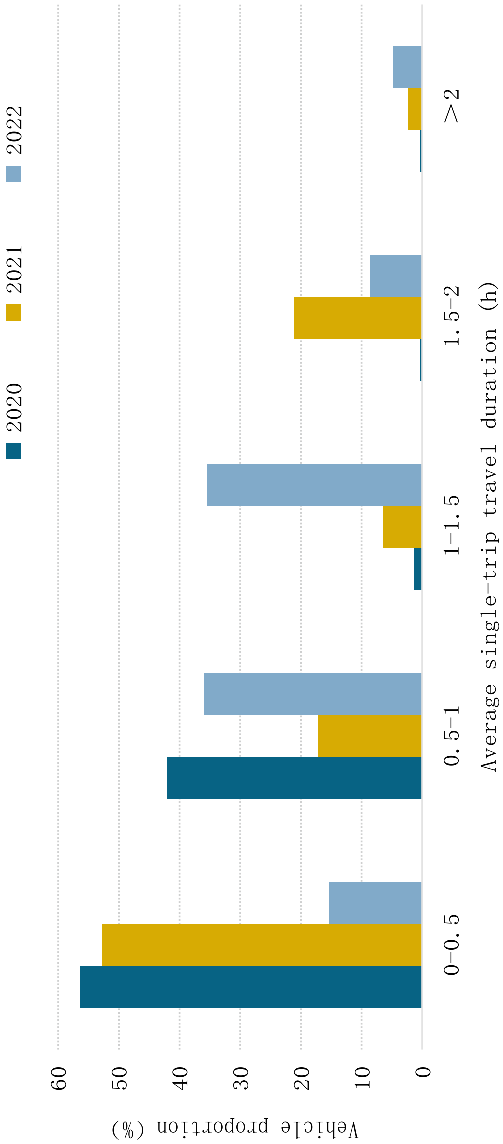


Fig. 4.50 Distribution of logistics vehicles of different average single-trip travel durations—by year

Table 4.25 Average single-trip mileage of logistics vehicles-average

Year	2020	2021	2022
Average single-trip mileage (km)	11.29	18.96	22.28

longer distance of distribution and transportation of logistics vehicles in the first-tier cities (Fig. 4.52).

(2) **Average daily travel characteristics of logistics vehicles**

The average daily travel duration of logistics vehicles kept increasing yearly.

In the past three years, the average daily travel duration of logistics vehicles in China was increasing yearly. In 2022, it reached 4.8 h, an increase of 48.1% and

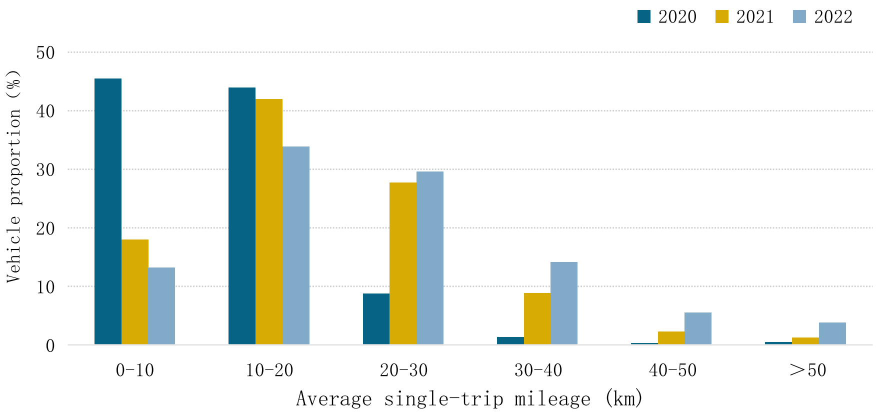


Fig. 4.51 Distribution of logistics vehicles of different average single-trip mileages—by year

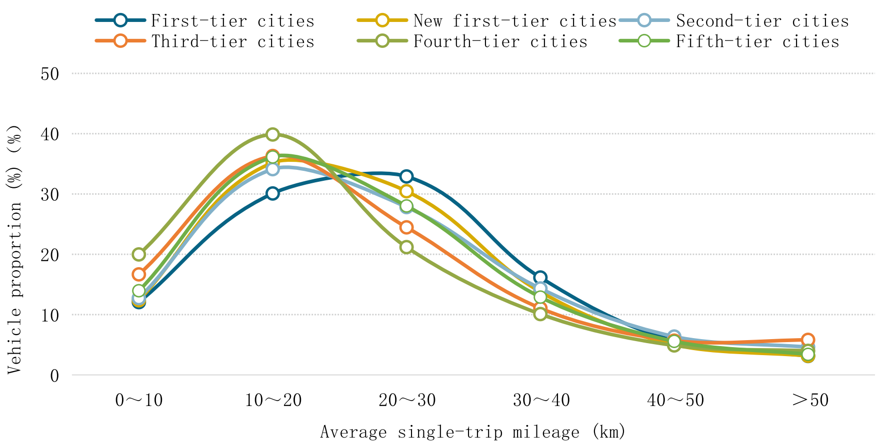


Fig. 4.52 Distribution of logistics vehicles of different average single-trip mileages in 2022—by city tier

Table 4.26 Average daily travel duration of logistics vehicles-Average

Year	2020	2021	2022
Average daily travel duration (h)	3.24	4.12	4.8

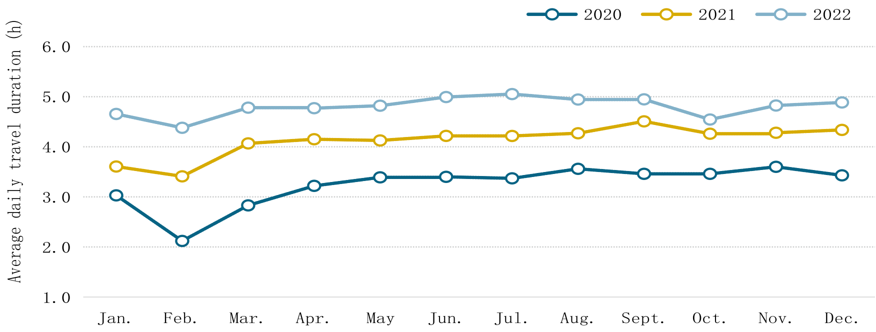


Fig. 4.53 Monthly average of average daily travel duration of logistics vehicles—by year

16.5% over 2020 and 2021, respectively (Table 4.26). In terms of monthly average daily travel duration per month (Fig. 4.53), the duration recorded by logistics vehicles remained essentially even and stable throughout the year except October, November, and December.

From the distribution of average daily travel durations (Fig. 4.54), the proportion of logistics vehicles with average daily travel duration of more than 4 h gradually increased in 2022. In 2022, the proportion of vehicles with an average daily travel duration of more than 4 h was 68.37%, 34.6 percentage points and 18.2 percentage points higher than that in 2020 and 2021, respectively, indicating a significant increase in average daily travel duration. By city tier (Fig. 4.55), the proportion of vehicles with average daily travel duration of 6–8 h in first-tier cities was 24.62%, significantly larger than that in other tiers of cities. The average daily travel duration of logistics vehicles in fourth- and fifth-tier cities mainly ranged from 2 to 4 h.

The average daily mileage of logistics vehicles grew steadily in the past three years.

From the perspective of the average daily mileage of logistics vehicles by year (Table 4.27), the average daily mileage of logistics vehicles in 2022 was 105.97 km, an increase of 22.3% and 12.6% compared with 2019 and 2020, respectively, and the annual average daily mileage of logistics vehicles maintained a steady growth momentum.

In regard to the distribution of average daily mileage (Fig. 4.56), that of logistics vehicles mainly stayed between 50 to 150 km, with a proportion accounting for more than a half in such period. According to the changes in the distribution of vehicles over the years, the proportion of vehicles with average daily mileage in the range of 50–250 km in 2022 increased significantly from 2021, indicating that some logistics vehicles were gradually transitioning to higher average daily mileage. By city tier

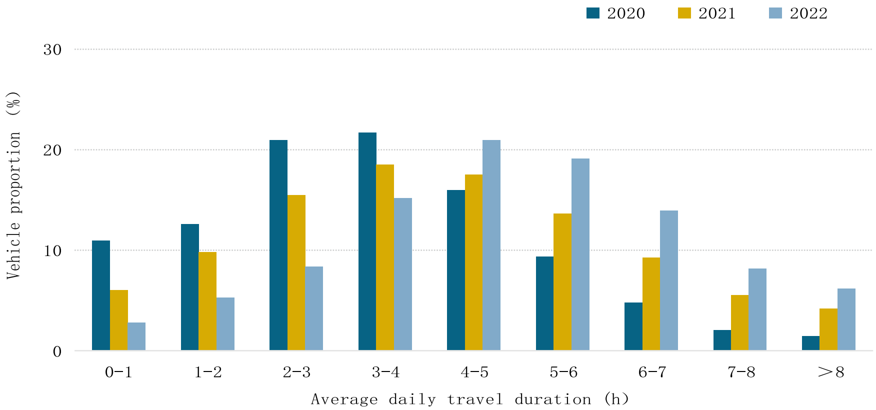


Fig. 4.54 Distribution of logistics vehicles of different average daily travel durations—by year

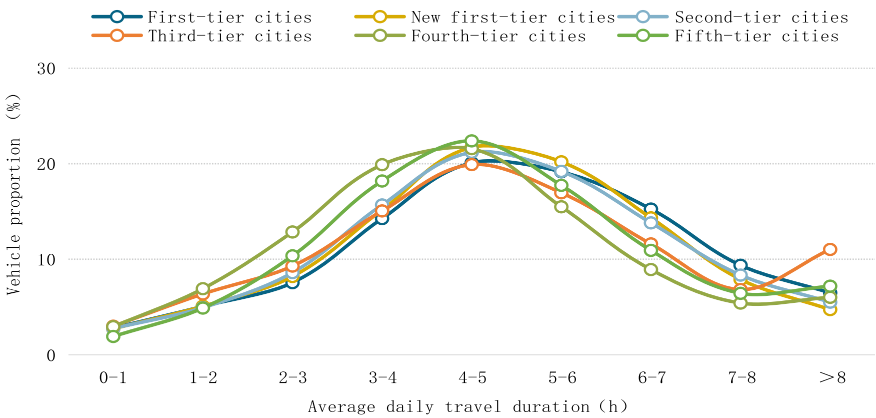


Fig. 4.55 Distribution of logistics vehicles of different average daily travel durations in 2022—by city tier

Table 4.27 Average daily mileage of logistics vehicles-average

Year	2020	2021	2022
Average daily mileage (km)	86.62	94.12	105.97

(Fig. 4.57), the proportion of vehicles with average daily mileage ranging from 100 to 200 km in first-tier cities was higher than that in other tiers of cities.

Logistics vehicles were mainly running in the period from 8:00 to 18:00 throughout the day, with more than 40% of the vehicles traveling in each of the hours within such period.

In can be concluded from the distribution of logistics vehicles of different driving times (Fig. 4.58) that most of the logistics vehicles were running from 8:00 to 18:00,

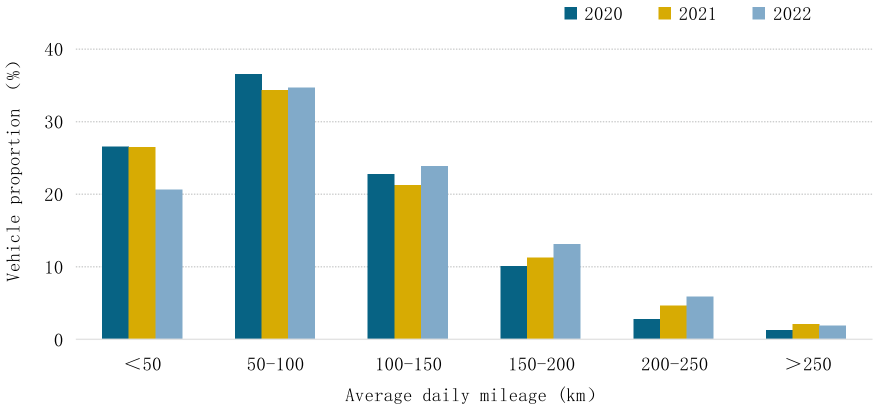


Fig. 4.56 Distribution of logistics vehicles of different average daily mileages—by year

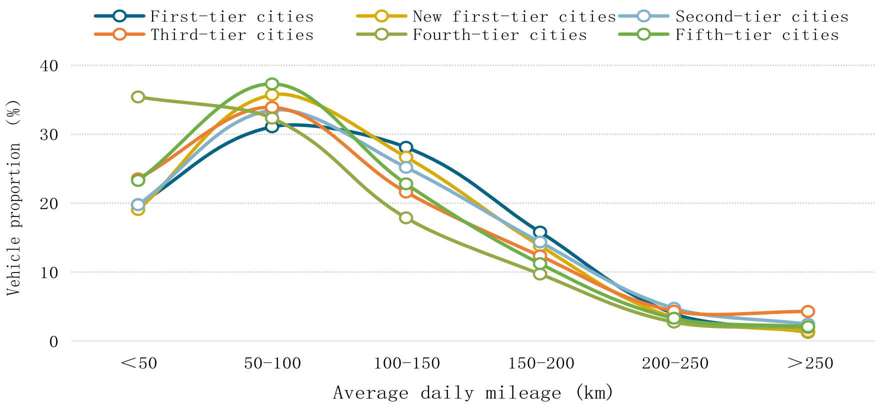


Fig. 4.57 Distribution of logistics vehicles of different average daily mileages in 2022—by city tier

with a lesser number of logistics vehicles than private cars, taxis, and e-taxis in the morning rush hours. According to the changes in the distribution of logistics vehicles over the years, the proportion of logistics vehicles running in the daytime in 2022 stayed at about 45%, slightly lower than the same period in 2021.

The proportion of new energy logistics vehicles running from 17:00 to 24:00 in first-tier cities was significantly higher than that of vehicles running in the same period in other tiers of cities.

As indicated in Fig. 4.59 on the proportion of new energy logistics vehicles running in different tiers of cities in 2022, most of the vehicles were mainly operating in the daytime, during which the morning rush hours were avoided. In the eyes of the difference in the proportion of new energy logistics vehicles under operation in different tiers of cities, the proportion of those in operation from 17:00 to 24:00 in

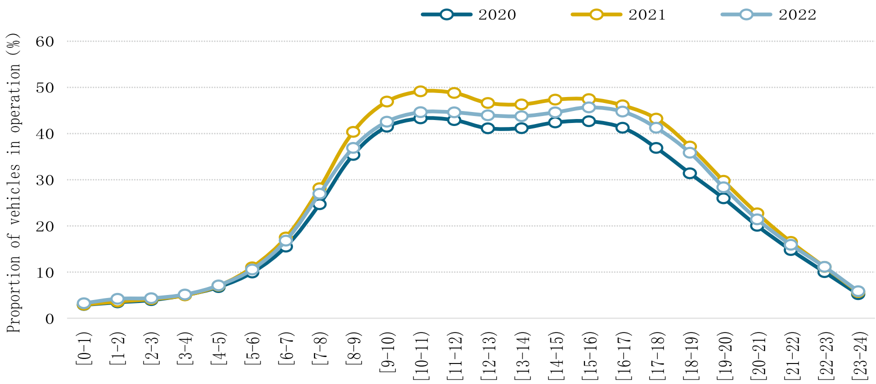


Fig. 4.58 Distribution of new energy logistics vehicles of different driving times—by year

first-tier cities was significantly higher than that in the same period in other tiers of cities, indicating a higher volume of freight and activity in the first-tier cities.

(3) **Average monthly travel characteristics of logistics vehicles**

The average monthly travel days of logistics vehicles in 2022 totaled 18.28, a slight decrease from 2020 and 2021.

The average monthly travel days for logistics vehicles in 2022 totaled 18.28, with a decrease from 2020 and 2021 (Table 4.28). Affected by the pandemic and other factors, despite the significant increase in daily average travel mileage, the average travel days decreased,

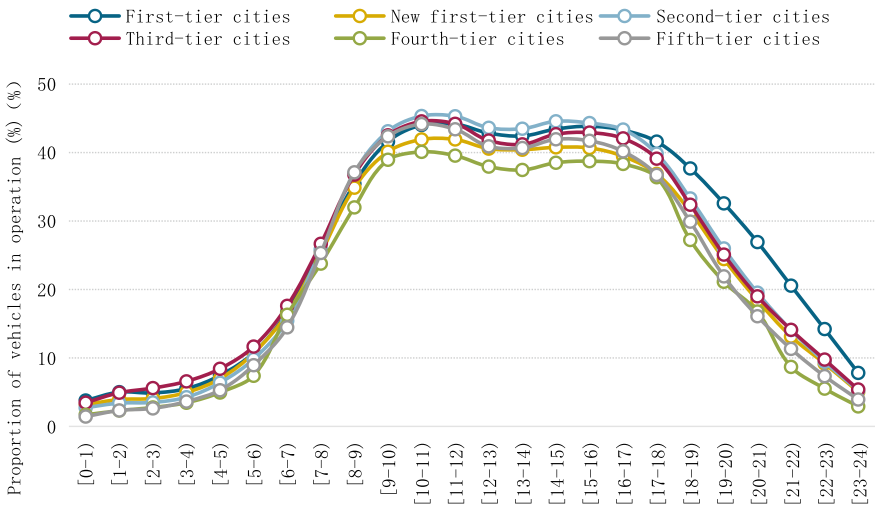


Fig. 4.59 Distribution of new energy logistics vehicles of different driving times in 2022

Table 4.28 Average monthly travel days of logistics vehicles-average

Year	2020	2021	2022
Average monthly travel days (day)	19.65	21.94	18.28

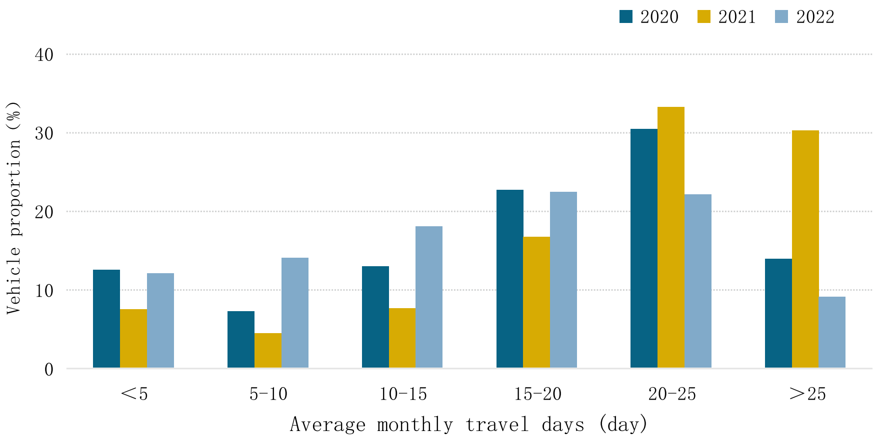


Fig. 4.60 Distribution of logistics vehicles of different average monthly travel days—by year

It can be seen from the distribution of average monthly travel days (Fig. 4.60) that more than 60% of logistics vehicles in 2021 ran over 20 days per month, indicating a normal operation status. Affected by epidemic situation and other factors, the average monthly travel days of some logistics vehicles in 2022 was similar to that in 2020.

In 2022, the average monthly mileage of logistics vehicles decreased from 2020 and 2021.

In 2022, the average monthly mileage of logistics vehicles was 2127.15 km, showing a decrease from 2020 and 2021 (Table 4.29). With respect to the distribution of average monthly mileage (Fig. 4.61), the proportion of logistics vehicles with average monthly mileage of 2000–5000 km in 2022 increased from 2020 and 2021, and new energy logistics vehicles were operating towards higher efficiency and normalization. By city tier (Fig. 4.62), those with average monthly mileage exceeding 3000 km in the first-tier cities held a proportion of 39.9%, and the proportion of those with longer mileages in first-tier cities increased faster than that in other tiers of cities.

Table 4.29 Average monthly mileage of logistics vehicles

Year	2020	2021	2022
Average monthly mileage (km)	2169.17	2270.33	2127.15

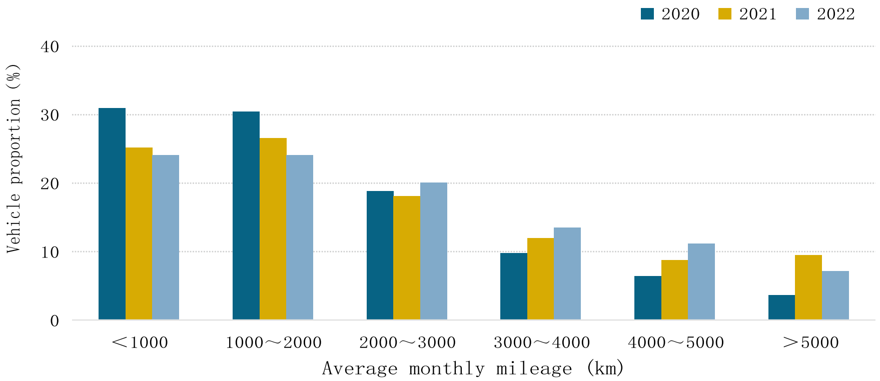


Fig. 4.61 Distribution of average monthly mileage of logistics vehicles—by year

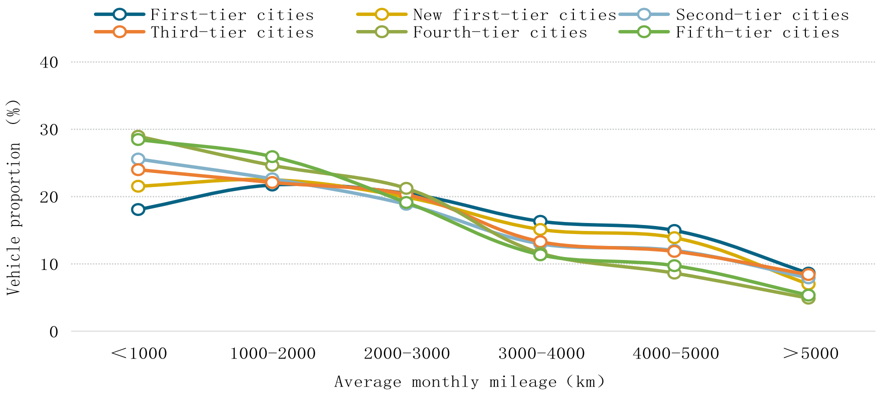


Fig. 4.62 Distribution of logistics vehicles of different average monthly mileages in 2021—by city tier

4.2.6 Operation Characteristics of Buses

(1) **Average single-trip travel characteristics of buses**

In 2022, the single-trip travel duration of buses ranged from 0.5 to 1.5 h, with 1.26 h on average.

The operating route and single-trip travel duration of buses were longer. In 2022, the single-trip travel duration of buses was 1.26 h, higher than that in 2020 (Table 4.30). From the distribution of single-trip travel duration (Fig. 4.63), the proportion of buses with single-trip travel duration of more than 1.0 h increased from 39.93% in 2020 to 57.89% in 2022; in terms of city tier (Fig. 4.64), the proportion of buses with single-trip travel duration of more than 1.5 h in first-tier and new first-tier cities was significantly higher than that in other tiers of cities.

Table 4.30 Average single-trip travel duration of buses—average

Year	2020	2021	2022
Average single-trip travel duration (h)	0.98	1.39	1.26

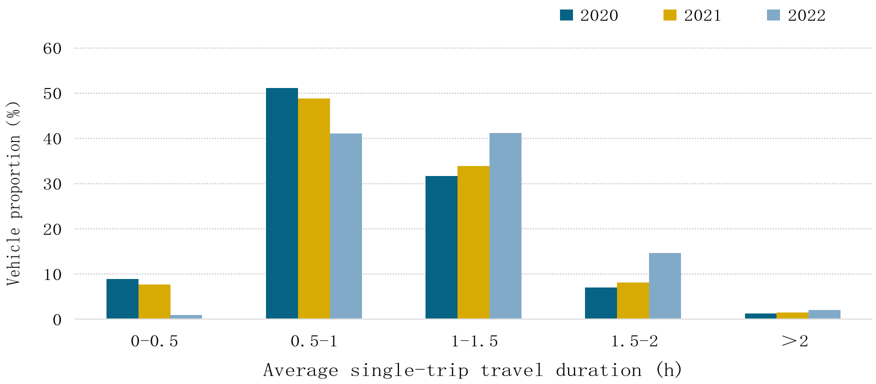


Fig. 4.63 Distribution of buses of different average single-trip travel durations—by year

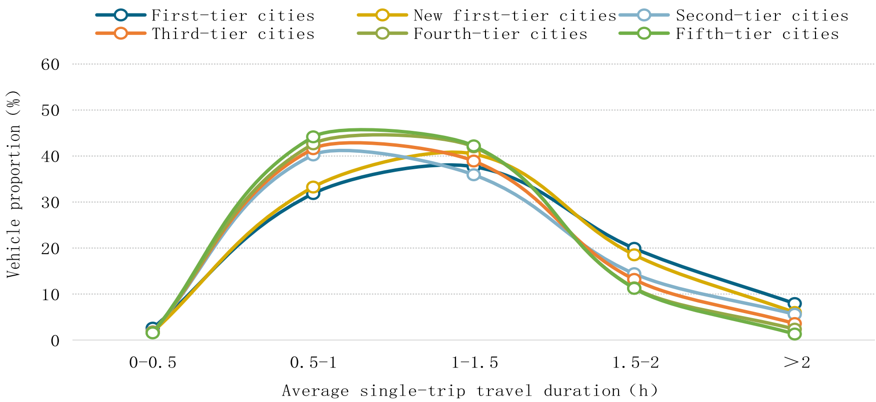


Fig. 4.64 Distribution of buses of different average single-trip travel durations in 2022—by city tier

In 2022, the average single-trip mileage of buses was 25.01 km, basically the same as that in 2021.

In 2022, the average single-trip mileage of buses was 25.01 km basically the same as that in 2021 (Table 4.31). The buses with an average single-trip mileage exceeding 20 km accounted for 60.33% in 2022, up by 10.0 percentage points and 0.6 percentage points over 2020 and 2021, respectively (Fig. 4.65).

(2) **Average daily travel characteristics of buses**

Table 4.31 Average single-trip mileage of buses-average

Year	2020	2021	2022
Average single-trip mileage (km)	19.44	25.10	25.01

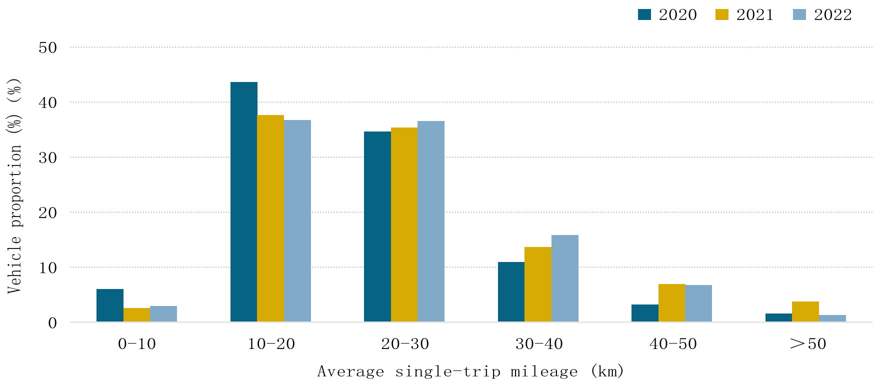


Fig. 4.65 Distribution of buses of different average single-trip mileages—by year

The daily operation of buses featured strong regularity, and the average daily travel duration of buses remained stable at around 6–7 h.

The average daily travel duration of buses remained relatively stable over the years, with an average daily travel duration of 6.65 h in 2022, which is mostly consistent with that in previous years (Table 4.32); the proportion of vehicles with an average daily travel duration of more than 8 h accounted for the majority, reading over 25% (Fig. 4.66). By city tier (Fig. 4.67), the proportion of buses with high daily travel durations in first-tier cities topped the list, and those with an average daily travel duration exceeding 8 h accounted for 35.2%, significantly higher than that in cities of other tiers.

The average daily mileage of buses was 145.85 km in 2022, basically the same as that in 2021.

The average daily mileage in 2022 was 145.85 km, which mainly remained unchanged compared with previous years (Table 4.33). The average daily mileage of buses concentrated at 100–200 km (Fig. 4.68). By city tier (Fig. 4.69), due to the relatively low average speed, the proportion of buses with average daily mileage within 150 km in first-tier and new first-tier cities was slightly higher than that in cities of other tiers.

Table 4.32 Average daily travel duration of buses-average

Year	2020	2021	2022
Average daily travel duration (h)	6.75	6.85	6.65

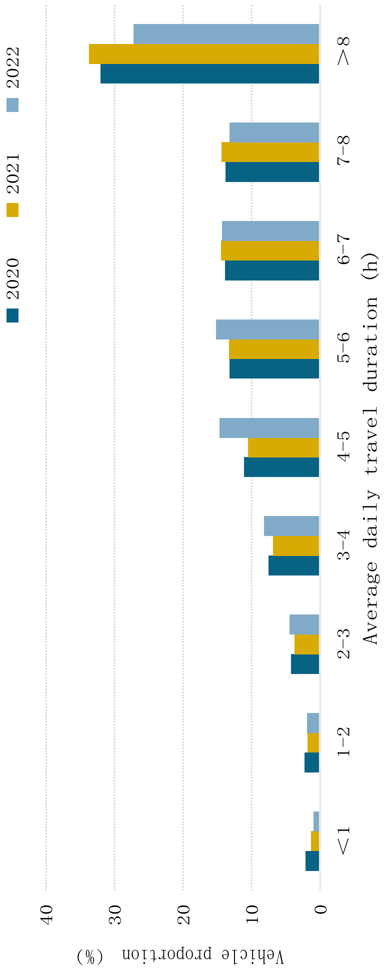


Fig. 4.66 Distribution of buses of different average daily travel durations—by year

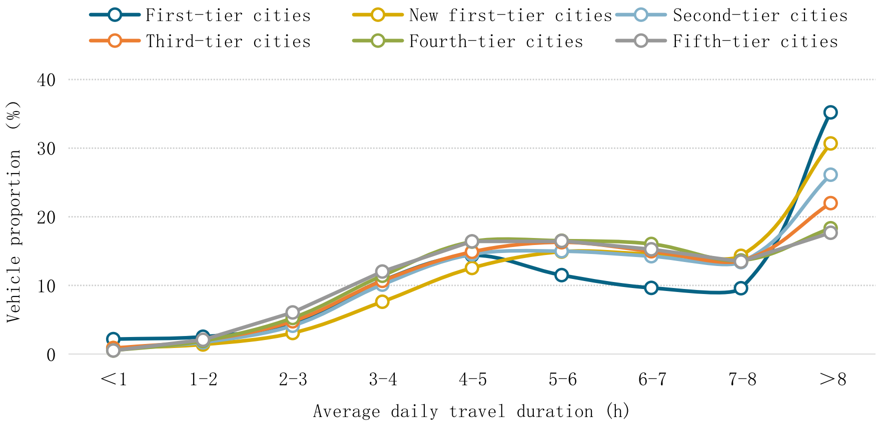


Fig. 4.67 Distribution of buses of different average daily travel durations in 2022—by city tier

Table 4.33 Average daily mileage of buses-average

Year	2020	2021	2022
Average daily mileage (km)	148.29	150.78	145.85

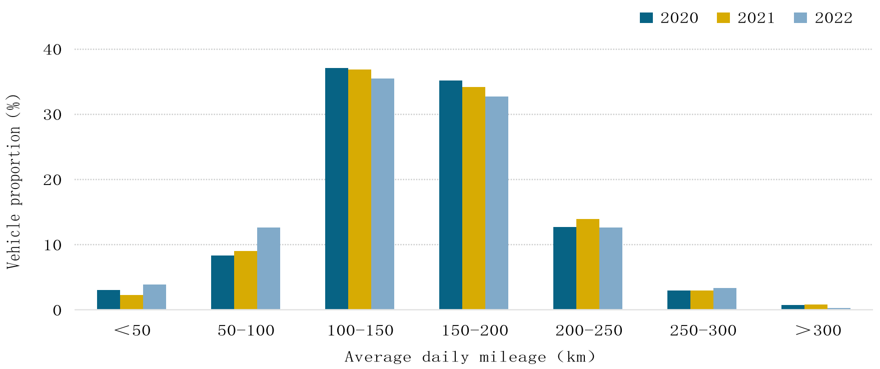


Fig. 4.68 Distribution of buses of different average daily mileages—by year

Buses were mainly running in the period from 6:00 to 20:00 throughout the day, with more than 50% of the vehicles traveling in each of the hours within such period on the whole.

From the distribution of driving times of buses (Fig. 4.70), the proportion of buses traveling between 6:00 and 20:00 was the highest, indicating a relatively high proportion of vehicles in operation, fixed operation routes, and regular operation schedule. The proportion of buses running in daytime in 2022 was lower than that in 2020 and 2021, in part due to a decline in the attendance affected by the pandemic.

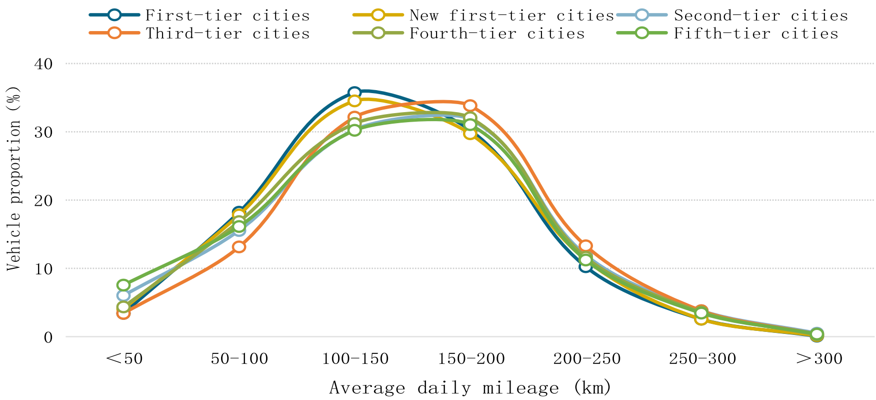


Fig. 4.69 Distribution of buses of different average daily travel mileages in 2022—by city tier

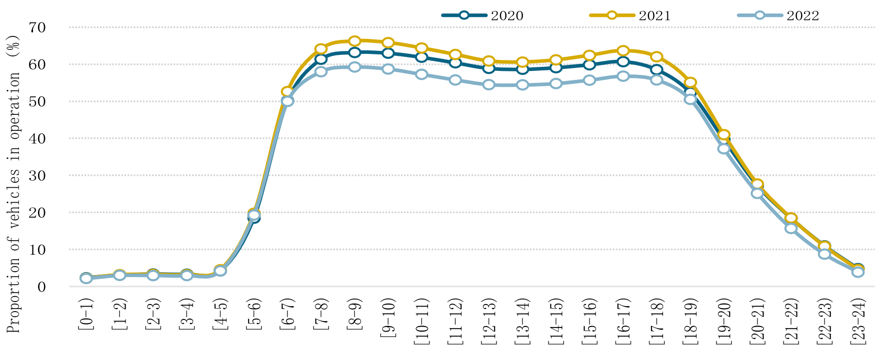


Fig. 4.70 Distribution of buses of different driving times—by year

The proportion of new energy buses in operation in first-tier, new first-tier and second-tier cities was significantly higher than that in cities of lower tiers. New energy buses in cities of all tiers were mainly operating in the daytime, and new energy buses in first-tier, new first-tier, and second-tier cities accounted for more than 50% of the total (Fig. 4.71). From 7:00 to 10:00 in the morning, the proportion of new energy buses in operation in the new first-tier cities exceeded 60%. From 19:00 to 24:00 at night, the proportion of new energy buses in operation in first-tier and new first-tier cities was larger, with higher dispatching frequency.

(3) **Average monthly travel characteristics of buses**

In 2022, more than 70% of buses operated at least 20 days on average per month. The average monthly travel days for buses in 2022 was 21.33, and the such average remained above 20 days for years (Table 4.34). The operation of new energy buses was increasingly regular. From the distribution of average monthly travel days of

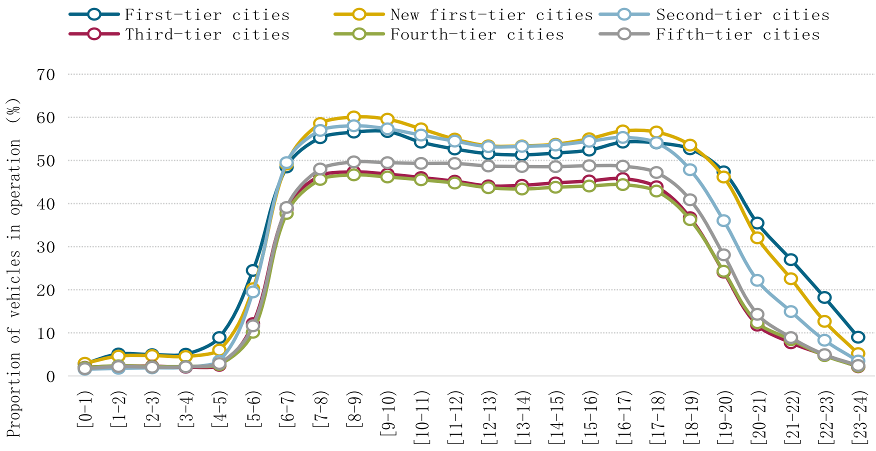


Fig. 4.71 Distribution of new energy buses of different driving times in 2022

buses over the years (Fig. 4.72), the proportion of buses with an average of more than 20 days of operation per month stayed above 65% for the last three years.

The average monthly mileage of buses was 3332.94 km in 2022, showing a decline from 2020 and 2021.

In 2022, the average monthly mileage of buses in 2022 was 3332.94 km, a decrease of 9.5% and 10.2% compared to 2020 and 2021, respectively (Table 4.35). From the distribution of the average monthly mileage of buses over the years (Fig. 4.73), it can be seen that the proportion of vehicles with a monthly mileage of more than

Table 4.34 Average monthly travel days of buses-average

Year	2020	2021	2022
Average monthly travel days (day)	22.55	23.44	21.33

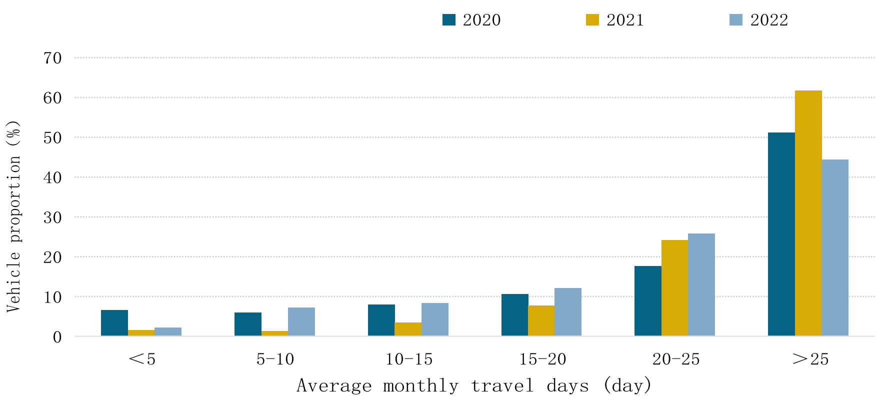


Fig. 4.72 Distribution of buses of different average monthly travel days—by year

3000 km was above 60%, indicating favorable operation effects (Fig. 4.74). By city tier, the vehicles with average monthly mileage of 1000–3000 km took the highest proportion.

Table 4.35 Average monthly mileage of buses-average

Year	2020	2021	2022
Average monthly mileage (km)	3682.57	3712.63	3332.94

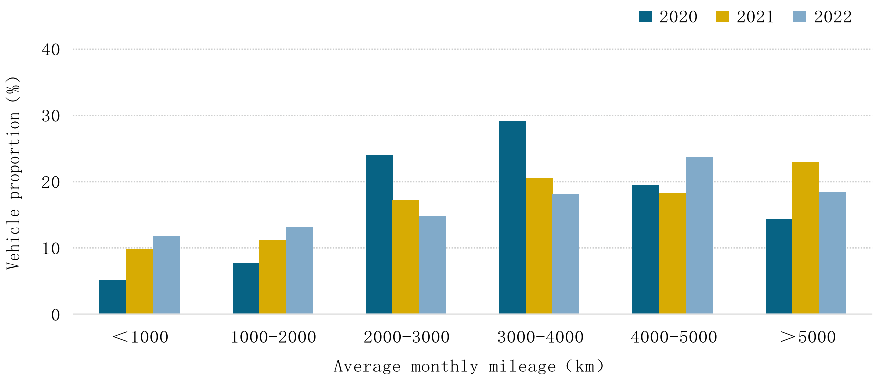


Fig. 4.73 Distribution of buses of different average monthly mileages—by year

Fig. 4.74 Distribution of buses of different average monthly mileages in 2022—by city tier

Table 4.36 Average single-trip travel duration of heavy-duty trucks-average

Year	2020	2021	2022
Average single-trip travel duration (h)	1.11	1.10	1.2

4.2.7 Operation Characteristics of Heavy-Duty Trucks

(1) **Average single-trip travel characteristics of heavy-duty trucks**

The average single-trip travel duration of heavy-duty trucks maintained stably at over 1 h.

In the past three years, the single-trip travel duration of heavy-duty trucks maintained at above 1 h. In specific, the duration in 2022 was 1.2 h, with an increase compared with the previous two years (Table 4.36). In view of the distribution (Fig. 4.75), the single-trip travel duration of heavy-duty trucks in 2022 was from 1 to 2 h, with the proportion of vehicles accounting for 73.56%, which saw significantly increase from 2020 and 2021, indicating that heavy-duty trucks played an increasingly important role in medium- and long-distance transportation.

The average single-trip mileage of heavy-duty trucks in 2022 was 23.44 km, basically the same as that in 2020 and 2021.

In view of the average single-trip mileage of heavy-duty trucks, such average in 2022 was 23.44 km, which is slightly higher than that in 2020 and 2021 (Table 4.37).

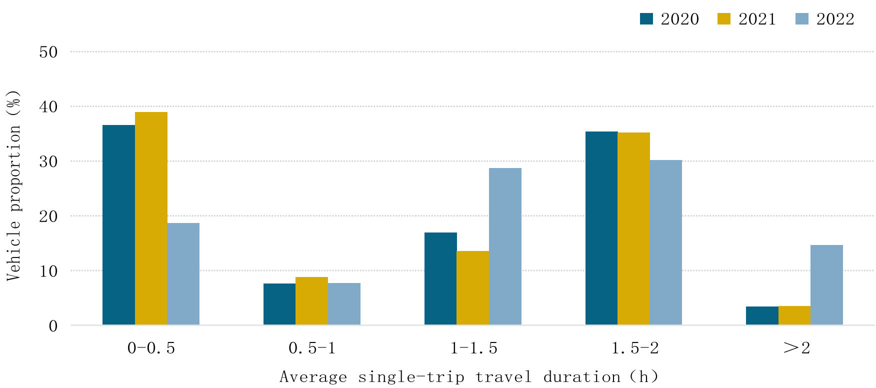


Fig. 4.75 Distribution of heavy-duty trucks of different average single-trip travel durations—by year

Table 4.37 Average single-trip mileage of heavy-duty trucks-average

Year	2020	2021	2022
Average single-trip mileage (km)	22.98	22.97	23.44

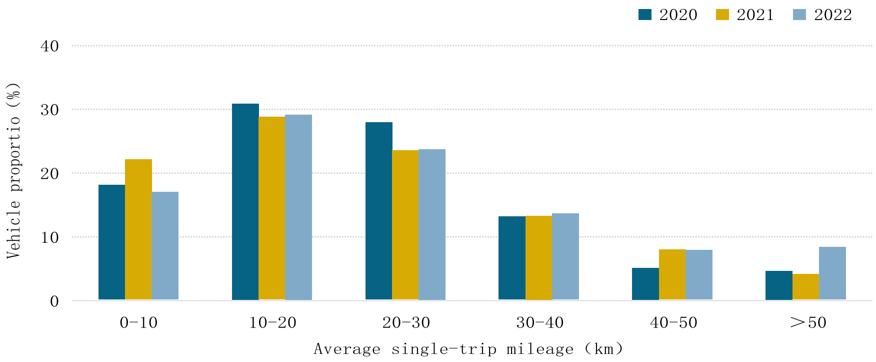


Fig. 4.76 Distribution of heavy-duty trucks of different average single-trip mileages—by year

With regard to the distribution of average daily mileage (Fig. 4.76), that of logistics vehicles mainly stayed between 50 and 30 km, with a proportion accounting for more than a half in such period. The proportion of vehicles with a single-trip mileage exceeding 50 km increased from 4.66% in 2020 to 8.40% in 2022.

(2) **Average daily travel characteristics of heavy-duty trucks**

The average daily travel duration of heavy-duty trucks increased over years.

The average daily travel duration of heavy-duty trucks remained relatively stable over the past two years, reading 5.91 h in 2022, with an increase compared to 2020 and 2021 (Table 4.38). From the monthly average daily travel duration of heavy-duty trucks over the years (Fig. 4.77), the figure in 2022 was basically stable at around 6 h. After August, the monthly average daily travel duration of heavy-duty trucks remained above 6 h.

As per the distribution of average daily travel durations over the years (Fig. 4.78), the distribution in different hours throughout the day was uneven. There was a significant increase in the proportion of heavy-duty trucks with average daily travel duration of more than 8 h in 2022 and a significant decrease in the proportion of those with average daily travel duration of less than 3 h, which indicated the increasing daily operation intensity of new energy heavy trucks. This might be related to the penetration of battery-swapping technologies and the continuous improvement of charging infrastructure. In addition, the improvement of operating efficiency of heavy-duty trucks also promoted the growth of average daily mileage.

The average daily mileage of heavy-duty trucks maintained at above 100 km with favorable operating efficiency.

The average daily mileage of heavy-duty trucks in 2022 was 111.74 km, showing a steady growth (Table 4.39). In view of the distribution of monthly average daily

Table 4.38 Average daily travel duration of heavy-duty trucks-average

Year	2020	2021	2022
Average daily travel duration (h)	5.12	5.21	5.91

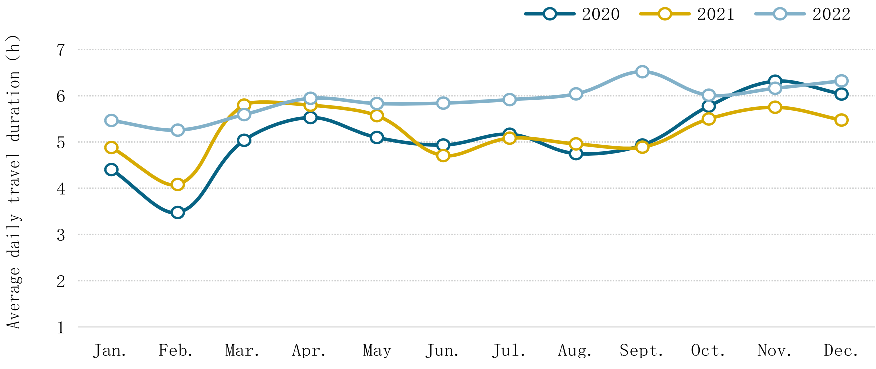


Fig. 4.77 Monthly average of average daily travel duration of heavy-duty trucks—by year

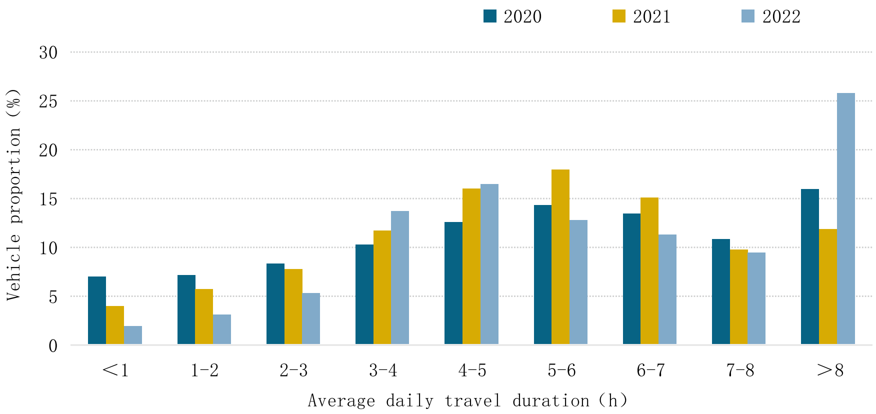


Fig. 4.78 Distribution of heavy-duty trucks of different average daily travel durations—by year

mileage of heavy-duty trucks over the last three years (Fig. 4.79), the average daily mileage of heavy-duty trucks in the second half of 2022 was higher, showing a favorable operating efficiency. According to the distribution of average daily mileage over the years (Fig. 4.80), the percentage of heavy-duty trucks with mileage of more than 100 km in 2022 was 61.63%, up by 12.9 percentage points and 12.3 percentage points compared to 2020 and 2021 respectively.

The heavy-duty trucks were mainly running in the period from 10:00 to 18:00 throughout the day, with a higher proportion than other types of vehicles at night.

Table 4.39 Average daily mileage of heavy-duty trucks-average

Year	2020	2021	2022
Average daily mileage (km)	105.73	107.57	111.74

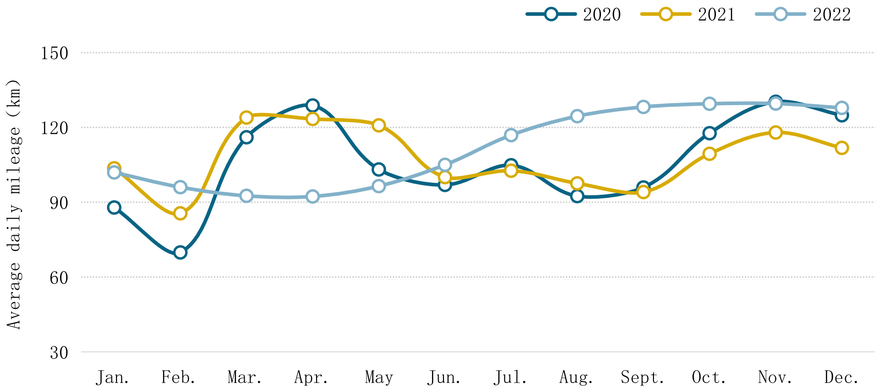


Fig. 4.79 Monthly average of average daily mileage of heavy-duty trucks—by year

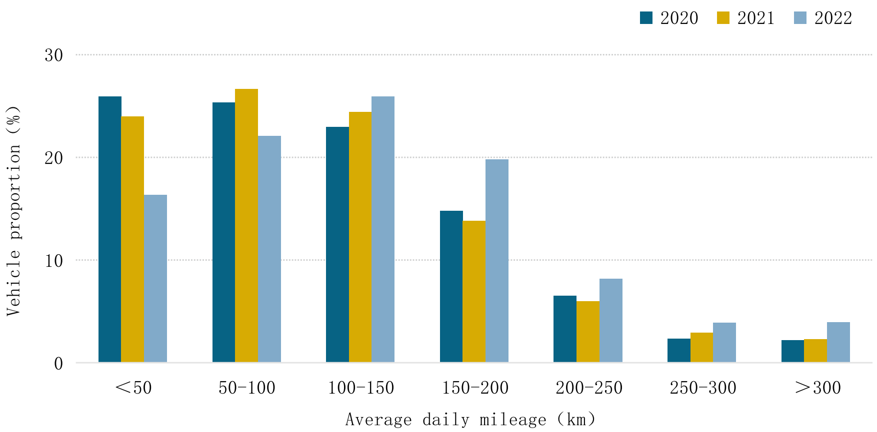


Fig. 4.80 Distribution of heavy-duty trucks of different average daily mileages—by year

The heavy-duty trucks were mainly running in the period from 10:00 to 18:00 throughout the day (Fig. 4.81), with a high proportion in each period of time. The proportion of heavy-duty trucks operating at night was higher than other operating vehicles; the proportion of heavy-duty trucks operating in the early morning in 2022 was significantly higher than that in 2020 and 2021. Due to traffic control and other factors, some heavy-duty trucks operated at night.

The proportion of heavy-duty trucks in operation throughout the day in third-tier cities was significantly higher than that in cities of lower tiers.

New energy heavy-duty trucks in cities of all tiers mainly operated in the daytime. The proportion of heavy-duty trucks in operation in third- and fifth-tier cities was

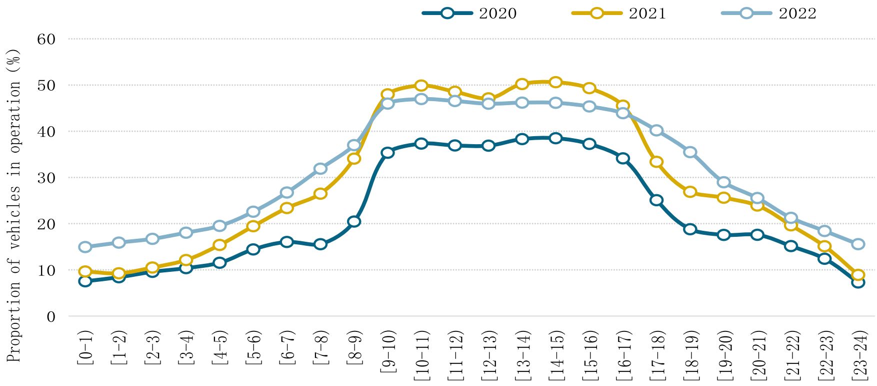


Fig. 4.81 Distribution of heavy-duty trucks of different driving times—by year

around 50%, while that in other tiers of cities was 40% (Fig. 4.82). In third-tier cities, the proportion of heavy-duty trucks running was higher in the nighttime.

(3) **Average monthly travel characteristics of heavy-duty trucks**

The average monthly travel days for heavy-duty trucks has been increasing over the past three years.

Over the past three years, the average monthly travel days for heavy-duty trucks kept increasing, with the average in 2022 reading 21.78, with an increase of 4.9% over 2021 (Table 4.40). In respect of the average monthly travel days for heavy-duty trucks over the years (Fig. 4.83), the heavy-duty trucks operated over 20 days per month on average, except January, February, and March.

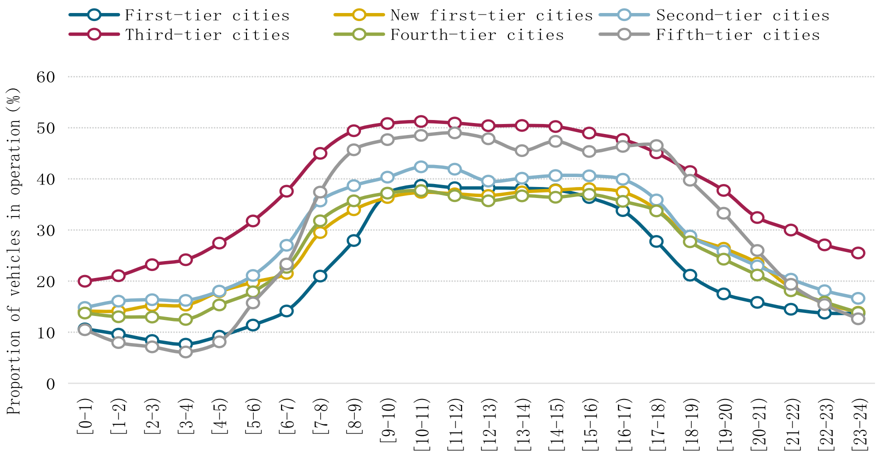


Fig. 4.82 Distribution of new energy heavy-duty trucks of different driving times in 2022

Table 4.40 Average monthly travel days of heavy-duty trucks

Year	2020	2021	2022
Average monthly travel days (day)	18.28	20.77	21.78

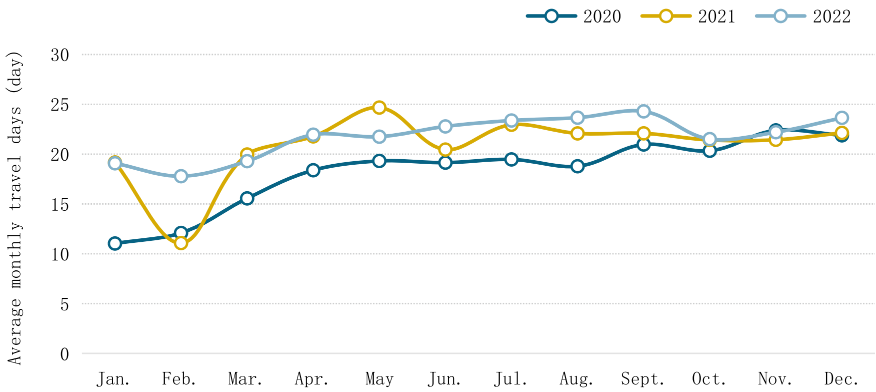


Fig. 4.83 Average monthly travel days of heavy-duty trucks over the years

It can be concluded from the distribution of average monthly travel days of heavy-duty trucks (Fig. 4.84), the proportion of those with average monthly travel days under 5 days in 2022 significantly declined, and more than 60% of the heavy-duty trucks operated more than 20 day per month on average, showing good operation effects.

The average monthly mileage of heavy-duty trucks has been increasing yearly, and that in 2022 reached 2472.64 km.

The average monthly mileage of heavy-duty trucks in 2022 was 2472.64 km, an increase of 11.0% and 2.0% compared with 2020 and 2021, respectively (Table 4.41). According to the average monthly mileage over the years (Fig. 4.85), the average

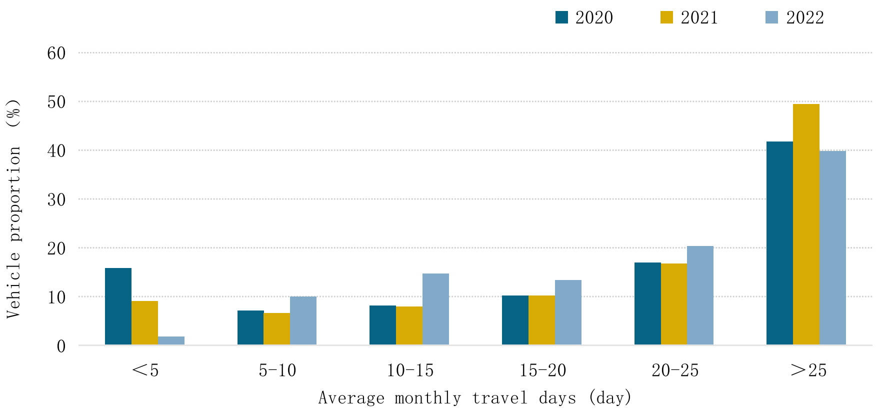


Fig. 4.84 Distribution of heavy-duty trucks of different average monthly travel days—by year

monthly mileage of heavy-duty trucks was relevant distributed throughout 2022: The average monthly mileage in the first and second half of 2022 was 2180.0 km and 2765.23 km, respectively, indicating an increasingly normal operation.

Regarding the distribution of average monthly mileage (Fig. 4.86), the proportion of heavy-duty trucks with average monthly mileage of more than 4000 km in 2022 increased over the previous two years from 20% in 2020 to 25.43% in 2022, indicating an increasingly important role of heavy-duty trucks in the long haul.

Table 4.41 Average monthly mileage of heavy-duty trucks-average

Year	2020	2021	2022
Average monthly mileage (km)	2228.24	2424.87	2472.64

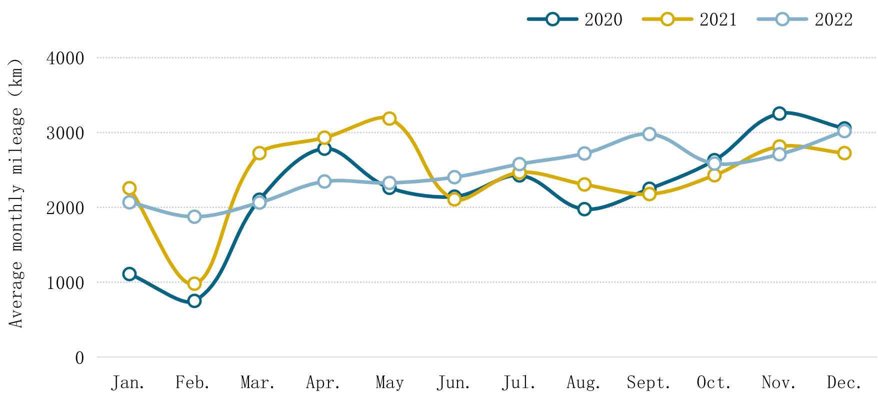


Fig. 4.85 Average monthly mileage of heavy-duty trucks over the years

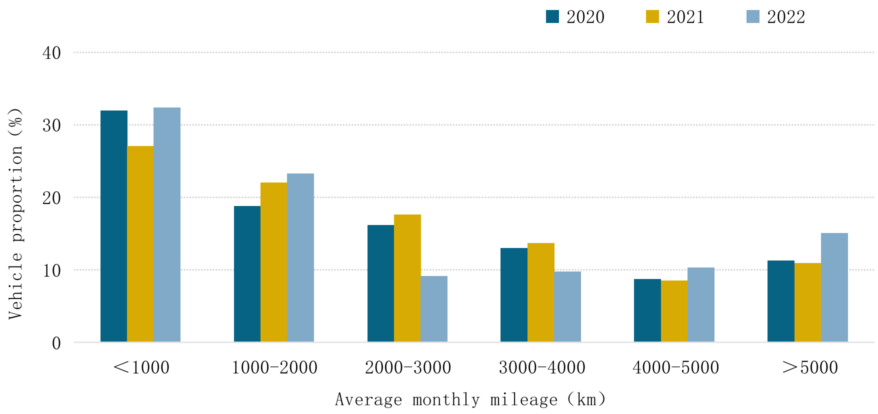


Fig. 4.86 Distribution of heavy-duty trucks of different average monthly mileages—by year

4.3 Summary

(1) **The online rate of NEVs in China grew steadily with the user stickiness.**

The online rate of NEVs in China continued to grow in the past three years. The average online rate of NEVs in 2022 was 84.8%, a steady increase compared to 2020 and 2021. By power type, PHEVs still recorded a higher online rate than BEVs and FCEVs.

The average online rate of NEVs in low-tier cities was far higher. The fourth- and fifth-tier cities lagged behind the first-tier cities in vehicle electrification with higher dependence on internal force to drive the promotion of NEVs. In addition, due to impacts of public transportation system and parking accessibility, users in first-tier cities used NEVs less frequently than users in fourth- and fifth-tier cities.

The online rate of e-taxis and private cars was far higher than that of other types of vehicles. In 2022, the online rate of e-taxis and private cars was significantly higher than that of other types of vehicles. E-taxis, an ecology of shared mobility, keeps growing steadily, characterized by a high online rate of more than 95% in both 2021 and 2022. The online rate of private cars maintained a steady growth, and new energy private cars have met the daily travel needs of users. In the field of commercial vehicles, due to the rapid growth of the market for new energy heavy-duty trucks in the past two years and a large base of new heavy trucks, the online rate showed rose sharply from 65.9% in 2020 to 83.9% in 2022.

(2) **New energy private cars have met the daily demands of users for traveling.**

New energy private cars have met the daily demands of users for traveling with higher user stickiness. Entering 2020, the online rate of NEVs in China steadily increased, from 87.1% in 2020 to 96.1% in 2022. The average daily travel time and mileage of private cars grew steadily. By comparison of different tiers of cities, most of the NEVs in first-tier cities featured high average daily mileage with a relatively larger travel radius, which is mainly due to such factors as city size and traffic congestion. In terms of the links for use, NEVs for now are able to satisfy the demands of users for satisfactory product quality, design, and driving range, and the user's experience of NEVs continued to improve. From the perspective of users, the key problems to be solved in the next step are infrastructure construction and supporting power grid transformation. The transformation of power grid in old residential areas, the allocation and construction of charging piles, and the high-power fast charging and replenishment for long-distance travel for NEVs, for instance, are also the problems to be solved urgently in the rapid development of NEV industry.

(3) **New energy passenger cars have basically met the travel characteristics of vehicles for commercial purpose, and the e-taxis and taxis are more effective in operation.**

As for the operating passenger cars, the average daily mileage of taxis and e-taxis was about 200 km, and the average daily driving time was about 7 h, which basically met the travel characteristics of vehicles for commercial purpose. In 2022, the average monthly travel days of both taxis and e-taxis were higher than 20, and the monthly mileage was more 4000 km. Compared with taxis and e-taxis, the cars for sharing had less average daily travel time and mileage, which was 4.45 h and 102.9 km respectively. However, no empty load was found in the cars for sharing.

On February 3, 2023, the Ministry of Industry and Information Technology, the Ministry of Transportation and other six departments jointly issued the *Notice on the Organization of the Pilot Work of the Pilot Zone for the Full Electrification of Vehicles in Public Sector* (hereinafter referred to as the Notice), proposing that during the pilot period of 2023 to 2025, the proportion of urban buses, taxis, sanitation vehicles, postal courier carriers, urban logistics and distribution vehicles strives to reach 80%. The average daily mileage of new energy operating passenger cars now basically caters to the operation of taxis. With the launch of the pilot work on the full electrification of vehicles in the public sector, the market of operating passenger cars will see a new growth point.

(4) **The operation of new energy buses becomes stable, but the first batch of new energy buses are about to be decommissioned, which makes it necessary to continue the monitoring of power batteries.**

The electrification has its own advantages thanks to the fixed travel routes, regular operation, and accessible charging infrastructure. The average daily travel duration of buses remained stable at about 7 h, basically the same as that in previous years, mainly ranging from 100 to 200 km. In terms of monthly travel characteristics, the buses with average monthly travel days of new energy buses in the last three years accounted for more than 65% of the total with an average monthly mileage exceeding 3500 km. New energy buses entered the stage of normal operation and gradually replace fuel buses for longer routes.

After the subsidy recedes, the new energy buses will be driven by marketization, which makes it a challenge facing bus companies to seek "hematopoiesis" in the coming days. For the purpose of new energy bus operation, it is necessary to resolve the problem of decommissioning of the first batch of new energy buses. The first batch of new energy buses are about to decommission due to the uneven quality or the excess of warranty period. In the past three years, the online rate of new energy buses nationwide showed a downward trend from 89.6% in 2020 to 86.4% in 2022, indicating that some new energy buses are already not in service. Therefore, in view of the development, public transport companies should properly deal with the testing of battery health for the first batch of new energy buses to be decommissioned and solve any problems detected in a timely manner to avoid the safety hazards. In the meantime, such companies should also consider "hematopoiesis" for market-oriented operations by exploring innovative business models to prevent long-term dependence on government subsidies.

(5) **The regular operation of new energy road freight vehicles is of key significance in promoting the transformation of traditional trucks to zero-emission vehicles and an important path towards green and low-carbon transportation.**

Logistics vehicles are now mainly used for intra-city distribution, and medium- and long-distance transportation across cities requires improvement of vehicle performance and supporting facilities. Logistics vehicles are mainly used as a means of production for daily transportation, while the vehicle distribution capacity and efficiency and other performance indicators are the key to defining transportation revenue and cost. China started early in the promotion of new energy logistics vehicles, which brought in abundant experience in vehicle operation. The average daily mileage of new energy logistics vehicles was around 100 km in the past three years. The new energy logistics vehicles are now mainly used to satisfy the demands for logistics distribution in cities. For the long-distance intra-city transportation, due to the high loading rate, large capacity, and long mileage, more breakthroughs should be made in terms of technology and product performance and the charging infrastructure along the highway should be further improved.

As to heavy-duty trucks, there lies a contradiction between load efficiency and transportation radius, and medium- and long-distance transportation depends more on battery swapping facilities. Thanks to the national and local policy support, the operational efficiency of heavy-duty trucks in China has been steadily growing in the past three years, along with the monthly average travel days and mileage. The average daily mileage of BEV heavy-duty trucks in China was mainly within 150 km. Battery electric (BV), as a matured clean technology in the field of heavy-duty trucks, is mainly applied in short- and medium-distance transportation and enclosed transportation scenarios. Heavy-duty trucks pose high requirements for load efficiency and economic performance. However, subject to battery energy density and energy consumption for single vehicles, there lies a contradiction between the BEV heavy-duty trucks load efficiency and transportation radius, and BEV heavy-duty trucks are in face of technical restrictions on distance of transportation. To achieve the economic performance of green and low-carbon medium- and long-distance transportation, efforts should be made to constantly improve the battery swapping infrastructure and technical breakthroughs in hydrogen fuel cells.

Chapter 5
Charging of New Energy Vehicles

Charging infrastructure is a great assurance for BEV users towards green travel and an important pillar to boost the development of the industry of new energy vehicles, the construction of new electric power system, and the achievement of "dual-carbon" goals. On January 10, 2022, the National Development and Reform Commission (NDRC), the National Energy Administration (NEA) and other departments jointly issued the *Implementation Opinions of the National Development and Reform Commission and Other Departments on Further Enhancing the Service Guarantee of Electric Vehicle Charging Infrastructure* (F.G.N.Y.G. [2022] No. 53) (hereinafter referred to as the "Implementation Opinions"), which specified the target plans and guidelines for the establishment of charging infrastructure system featuring moderate advance of time, balanced in layout, and intelligent and efficient for the "14th Five-Year Plan" period. This Section analyzes the charging characteristics of vehicles in different application scenarios, charging behaviors in different cases, and operation characteristics under battery swapping mode to summarize the charging rules of BEV users, thus providing reference for the further improvement of the charging infrastructure in planning and distribution in China.

5.1 Construction Situation of Charging Infrastructures

5.1.1 Industry Policies for Charging Infrastructure

Public charging piles are growing towards DC and high-power transition with optimized top-level design and detailed targets with policy.

On February 3, 2023, the Ministry of Industry and Information Technology (MIIT) and other seven departments issued the *Notice on the Organization of the Pilot Work of the Pilot Zone for the Full Electrification of Vehicles in Public Sector*

Z. Wang, *Annual Report on the Big Data of New Energy Vehicle in China (2023)*,
https://doi.org/10.1007/978-981-97-4840-2_5

(G.X.B.L.T.Z.H. [2023] No.23) (hereinafter referred to as "Notice"), which highlighted the goal to increase the proportion of NEVs in the new and renewed vehicles in the pilot areas to 80% and strive to achieve a ratio between the number of standard piles in the public sector and that of NEVs promoted (standard vehicles) in the public sector to 1:1. Such initiatives are conducive to the construction of DC charging piles in the public sector in the pursuit of full DC operation for new charging piles. The Notice adjusts the conversion of charging piles above 180 kW by a factor of 1.1 to encourage the development of charging piles towards a higher power.

Under the support of local subsidy policies with the amount of subsidy close to the cost of equipment, the establishment of charging facilities are stepping up in the public sector. Subsidies for charging facilities are mainly granted in two forms, namely one-time construction subsidy and operation subsidy per kWh. According to the local subsidy policy (Table 5.1), the one-time subsidy is usually RMB200/kW-RMB300/kW for AC piles and RMB300/kW-RMB500/kW for DC piles or 30% of the total investment cost; the subsidy per kWh usually starts from RMB0.1/kWh and is then adjusted based on the regional economic performance and other factors. Given the equipment price of RMB300/kW for AC piles and about RMB500/kW for DC piles, the current subsidy is relatively high, which can basically cover the cost of equipment purchase. In particular, as the power of charging piles increases, the cost per kW would be diluted. Therefore, the subsidy per kWh may boost the building of high-power fast charging piles. As encouraged by policies and driven by current demands, the construction of high-power charging piles will speed up.

Table 5.1 Subsidy policies for charging facilities in some cities or regions in China in 2022

City or Region	Contents
Shanghai	AC: RMB300/pile, smart: RMB500/pile; DC subsidy cap: RMB600/kW, AC subsidy cap: RMB300/kW; 30% of the total investment by municipal platform; public charging pile: RMB0.2/kWh-RMB0.8/kWh, special charging piles: RMB0.1/kWh-RMB0.3/kWh
Chongqing	RMB300/kW for new DC piles in high-speed service areas
Fujian	RMB0.2/kWh
Guangxi Zhuang Autonomous Region	AC piles: RMB150/kW, DC piles: RMB 300/kW; RMB0.14/kWh
Harbin	A single project of no less than 180 kW; RMB300/kW for charging piles
Chengdu	RMB200/kW for the public sector
Changzhou	AC pile: no more than RMB200/kW, DC pile: no more than RMB500/kW; no more than RMB0.1/kWh

Source Local development and reform commissions and energy administrations; CSI

5.1.2 *Progress in Charging Infrastructure Construction*

The construction scale of charging facilities continued rapid growth thanks to the accelerating vehicle electrification.

China's NEV market has been expanding in full swing. The rapid growth of marker demands of NEVs resulted in the constant release of users' charging demands and high-rate increase of the holding volume of charging infrastructure in China. According to the statistics of China Electric Vehicle Charging Infrastructure Promotion Alliance (hereinafter referred to as "EVCIPA") (Fig. 5.1), by the end of 2022, the number of charging infrastructure in China reached 5.209 million. Stimulated by the NEV market, the market demand for charging piles also kept growing swiftly.

In the field of battery swapping infrastructure, by the end of 2022, a total of 1,973 battery swapping stations have been built across China, of which 289 stations were established in Beijing, accounting for 14.6% of national total, ranking first in China.

The number of newly-built charging infrastructure in China maintained a rapid growth trend over the years.

In 2022, a total of 2.451 million new charging infrastructures (public charging piles + private charging piles) were built within China, with a YOY increase of 142.7% (Fig. 5.2). With the rapid growth of NEV sales, the number of new private charging piles also increased significantly. In 2022, a total of 1.942 million private charging piles were built over China, an increase of 2.3 times year-on-year. According to the statistics of the ECVIPA, the major causes that affected the installation of private charging piles were the lack of fixed parking spaces, less support by property companies, and insufficient power capacity. Since an increasing number of users prefer electric vehicles, it requires great concerned and support for the successful installation of private charging piles.

Vehicle-to-pile ratio in China was optimized constantly.

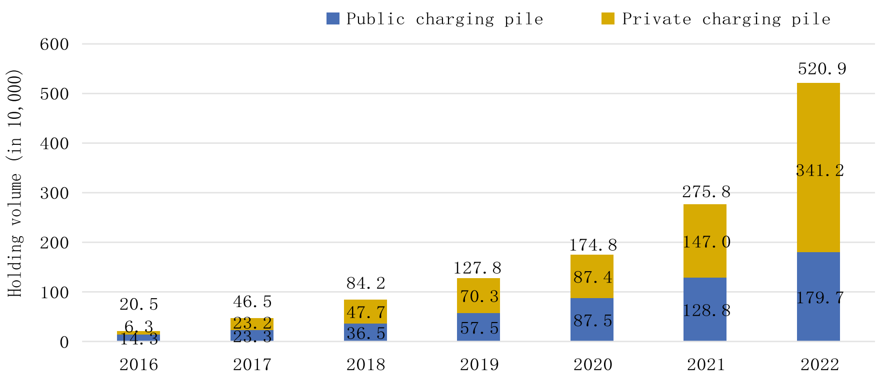


Fig. 5.1 Holding volume of charging infrastructures in China over the years. Remark Data of charging infrastructure was properly rectified by the ECVIPA. *Source* Annual Report on Charging Infrastructure of Electric Vehicles in China from 2021 to 2022 EVCIPA

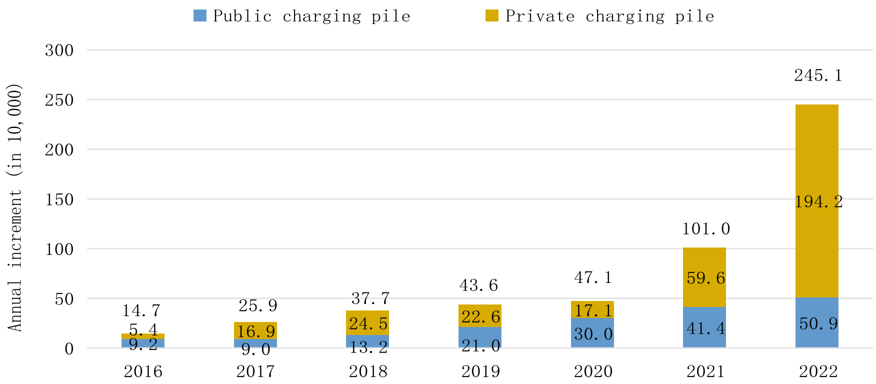


Fig. 5.2 Increment of charging infrastructures in China over the years. *Source* Annual Report on Charging Infrastructure of Electric Vehicles in China from 2021 to 2022—EVCIPA

China's vehicle-to-pile ratio constantly decreased from 4.43:1 in 2016 to 2.51:1 in 2022 (Fig. 5.3). According to the changes in vehicle-to-pile incremental ratio over the years, China's vehicle-to-pile incremental ratio read 3.34:1 in 2016, ranged from 2 to 3 between 2017 and 2022, and reached 2.89 in 2021, close to the holding ratio of piles.

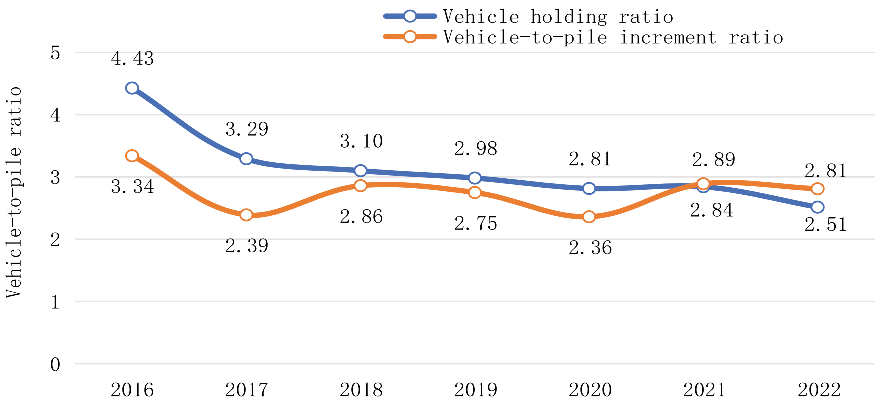


Fig. 5.3 Changes of vehicle-to-pile ratio in China's charging infrastructure over the years. *Source* Annual Report on Charging Infrastructure of Electric Vehicles in China from 2021 to 2022—EVCIPA

5.1.3 Progress in Charging Technology

The charging technology continued to improve, and the average charging power of the public DC charging piles increased steadily.

As shown in Fig. 5.4 the average charging power of the public AC charging piles mostly remained stable at about 9 kW since 2016; the charging power of public AC charging piles decreased slightly from 2017. The charging power of public DC charging piles rose sharply. The average power of public DC charging piles exceeded 100 kW after 2019 and reached 123.3 kW in 2022, with a YOY growth of 2.8%.

The trend of high power in the field of public charging facilities gradually emerged.

According to the changes in average power of new public DC charging piles over the years (Fig. 5.5), the high-power charging piles with 120 kW and above was proliferating, with a proportion of 24.4%, up 4.7 percentage points over 2017, indicating a momentum towards higher power.

Fast charging pile construction quickened, forming a synergy with private charging piles.

Based on the bidding data of charging facilities along the Electricity Super Highway of the State Grid (Fig. 5.6), in 2021, State Grid organized three public bidding activities for charging and battery facilities, of which 63% were those rated 1000 V and 80 kW. As of October 2022, of the bidding structure of charging and swapping facilities under the State Grid, 60% facilities were rated above 160 kW and another 6% had a power of 240 kW and above.

Several brands started deployment with 880v fast charging solutions, showing a trend towards higher voltage.

High-power charging can significantly improve the charging capacity, making it a major orientation in charging infrastructure construction. Although China's NEV market has been expanding in full swing, the time-consuming vehicle replenishment remains an obstacle in BEV development. In general, BEV passenger cars may take

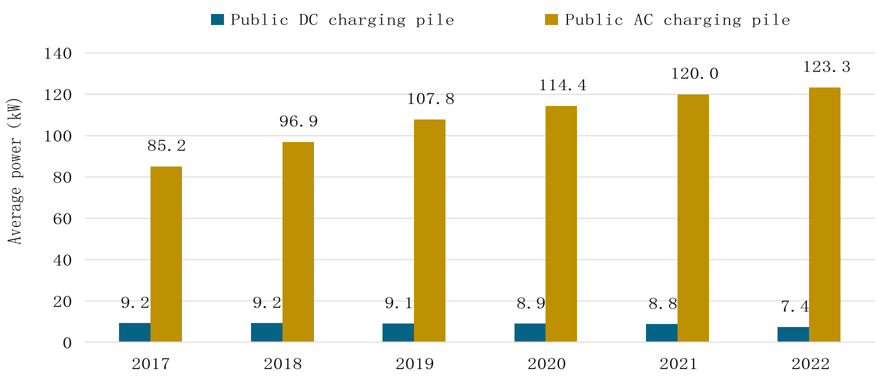


Fig. 5.4 Average power change of charging piles in the public sector over the years. *Source* China Electric Vehicle Charging Infrastructure Promotion Alliance (EVCIPA)

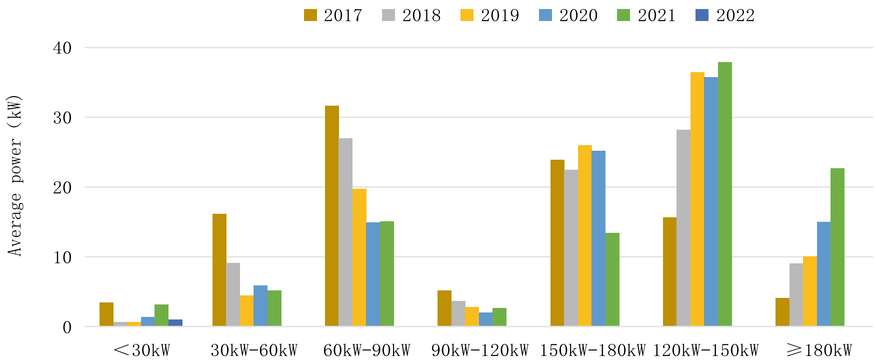
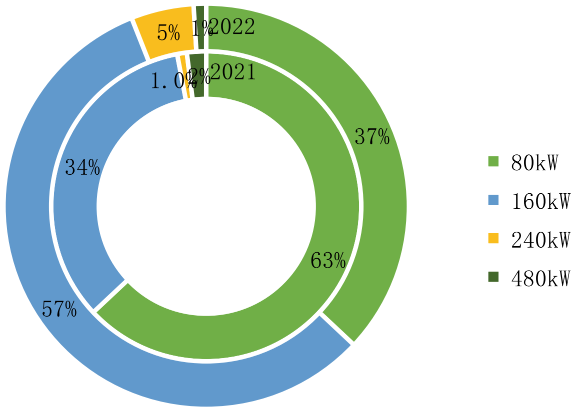


Fig. 5.5 Average power change of new public DC charging piles over the years in China. *Source* China Electric Vehicle Charging Infrastructure Promotion Alliance (EVCIPA)

Fig. 5.6 Proportion of bidding structure of charging and swapping facilities of State Grid in 2021 and 2022. *Source* State Grid, CSI



one hour to fill up with 60 kW-80 kW DC public fast charging facilities. Considering the waiting time for piles, the duration for power replenishment further prolongs.

For the purpose of fast charging, Porsche launched the world's first model Taycan with 800 V high-voltage electrical architecture in 2019, upon which the 800 V fast charging solution gained an increasing popularity by vehicle manufacturers. By the end of 2022, following Porsche, BYD, Xpeng, and other brands also released and sold 800 V high-voltage charging models. BYD Seal, BAIC ArcFox Alpha S HI, Xpeng G9, Avatr 11, and other models were released, with the highest charging power of 480 kW. Other independent brands also launched their own high-voltage fast charging programs. For instance, Li Auto launched 800 V models in 2023, NIO is expected to launch 800 V fast charging battery packs in 2024, and SAIC released its Modular Scalable Platform for high-voltage fast charging. High-voltage and high-power charging becomes a major solution to ease the anxiety of replenishment and promote NEV development.

5.2 Charging Characteristics of Vehicles in Key Segments

Through analysis of vehicles in seven segments, including new energy private cars, BEV e-taxis, BEV taxis, BEV cars for sharing, BEV logistics vehicles, BEV buses, and heavy-duty trucks, this Section analyzes and summarizes the charging characteristics of vehicles at different periods with the average single-time charging characteristics, average daily charging characteristics, and average monthly charging characteristics as focuses (Table 5.2), and draws a conclusion on the vehicle charging laws, with an aim to provide references and support for the improvement of charging facility policies and the reasonable layout of charging facilities by operators. The specific indicators under analysis are as follows:

5.2.1 Charging Characteristics of New Energy Private Cars

1. **Average single-time charging characteristics of new energy private cars**

The average single-time charging duration of new energy private cars concentrated at 2h–5h, and the proportion of new energy private cars with an average single-time charging duration of more than 5h in 2022.

In 2022, the average single-time charging duration of new energy private cars was 3.5 h, 0.2 h shorter than that in 2020 (Table 5.3). The proportion of those with

Table 5.2 Analysis indicators for NEV segments

Analysis dimension	Analysis indicator	Definition
Average single-time charging characteristics	Average single-time charging duration	Average charging duration of single charging
	Average single-time charging initial SOC	Average initial SOC of single charging
Average daily charging characteristics	Charging time	Distribution of charging time in a single day (24 h) / Cumulative number of vehicles accessed to National Monitoring and Management Platform
Average monthly charging characteristics	Average monthly charging times	Average charging times in a single month
	Average monthly fast charging times	Average times of fast charging in a single month
	Average monthly slow charging times	Average times of slow charging in a single month
	Average monthly charge	Average charges in a single month

Table 5.3 Average single-time charging duration of new energy private cars over the years

Year	2020	2021	2022
Average single-time charging duration (h)	3.9	3.7	3.5

average single-time charging duration of more than 5 h in 2022 increased year on year (Fig. 5.7).

By distribution in weekdays and weekends, the proportion of BEVs and PHEVs with single-trip charging duration within 1 h in weekends was significantly higher than that in weekdays (Figs. 5.8, 5.9).

In terms of the charging mode (Fig. 5.10), the fast charging duration of new energy private cars mainly fell in 1 h, with a proportion of 86.7%; the slow-charging distributions were distributed unevenly, with a proportion of 67.1% for a slow-charging duration in 2 h-6 h.

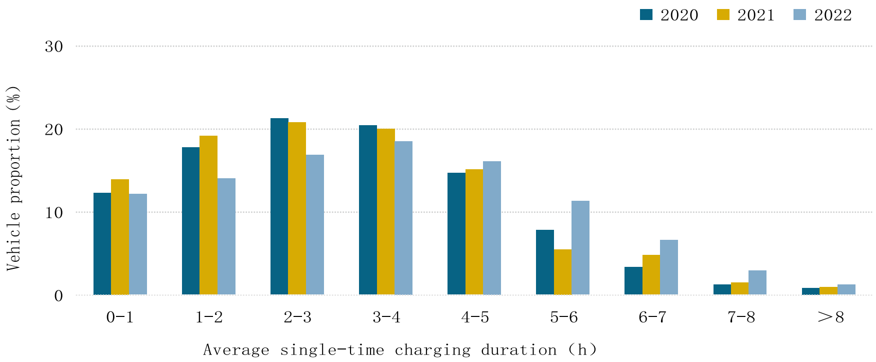


Fig. 5.7 Distribution of average single-time charging duration of new energy private cars—by year

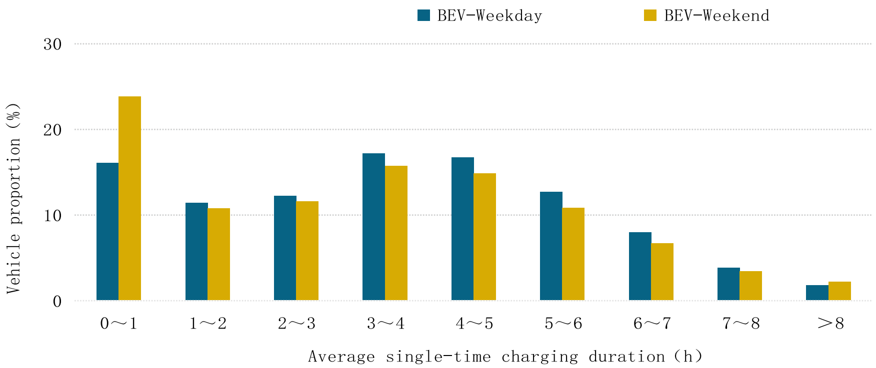


Fig. 5.8 Distribution of average single-time charging duration of BEV private cars in 2022—by weekday and weekend

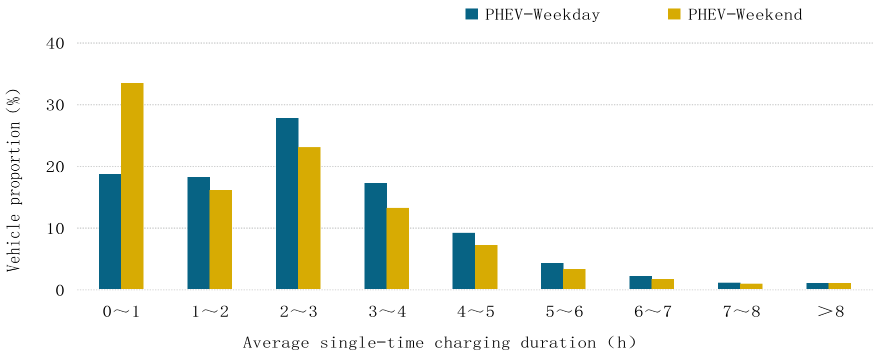


Fig. 5.9 Distribution of average single-time charging duration of PHEV private cars in 2022—by weekday and weekend

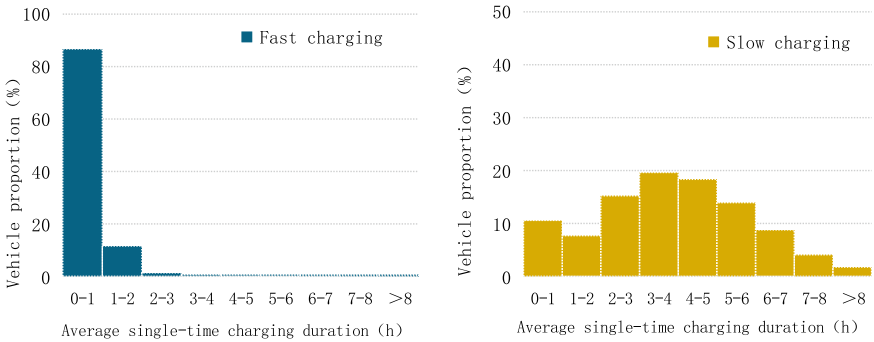


Fig. 5.10 Distribution of average single-time charging duration of new energy private cars in 2022—by fast charging and slow charging

The average single-time charging initial SOC of private cars declined year by year.

According to the data over the years, the average single-time charging initial SOC of new energy private cars in 2022 was 38.1%, with a decrease year by year (Table 5.4). By the distribution (Fig. 5.11), the proportion of new energy private cars with average single-time charging initial SOC in 20%-40% increased over 2020 and 2021.

For both BEVs and PHEVs, the proportion of those with average single-time charging initial SOC in weekends within 10% was higher (Figs. 5.12, 5.13), because users of private cars preferred medium- and long-distance travel in weekends, and

Table 5.4 Average single-time charging initial SOC of new energy private cars over the years

Year	2020	2021	2022
Average single-time charging initial SOC (%)	41.6	39.8	38.1

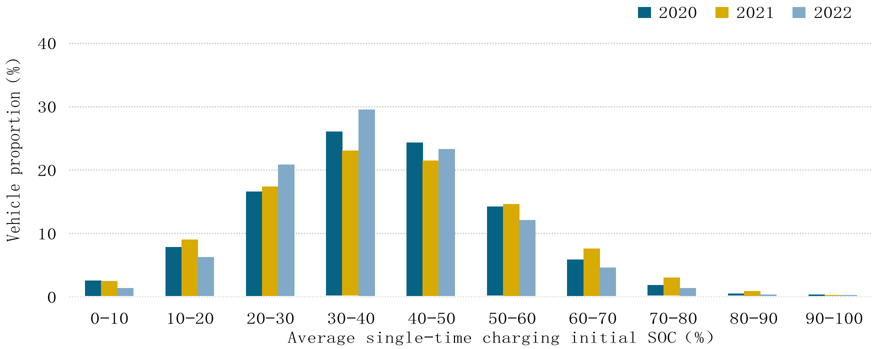


Fig. 5.11 Distribution of average single-time charging initial SOC of new energy private cars—by year

NEVs consumed more power, for which the remaining SOC of more vehicles stayed lower.

In terms of charging mode, the remaining SOC of new energy private cars under fast charging mode was mainly between 0 and 10%, and the proportion of the cars in such interval reached 50.3%. Some vehicles also featured a remaining SOC between 20 and 40%. Under the slow-charging mode, the average single-time charging initial SOC of new private cars mainly ranged from 20 to 60%, with a proportion of 77.1% (Fig. 5.14). The slow-charging mode was mainly applied is mainly for daily purpose, namely charging whenever stopped with piles for family use, with the remaining SOC distributed unevenly. Therefore, fast charging is more used for power replenishment when the battery is low, while slow charging is more used for regular replenishment.

2. **Average daily charging characteristics of new energy private cars**

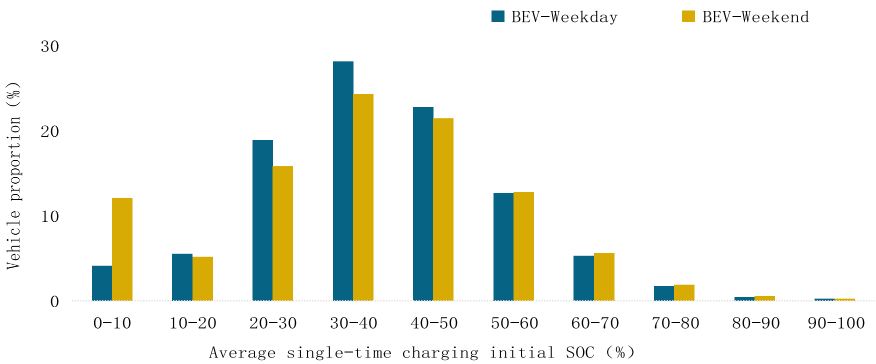


Fig. 5.12 Distribution of average single-time charging initial SOC of BEV private cars in 2022—by weekday and weekend

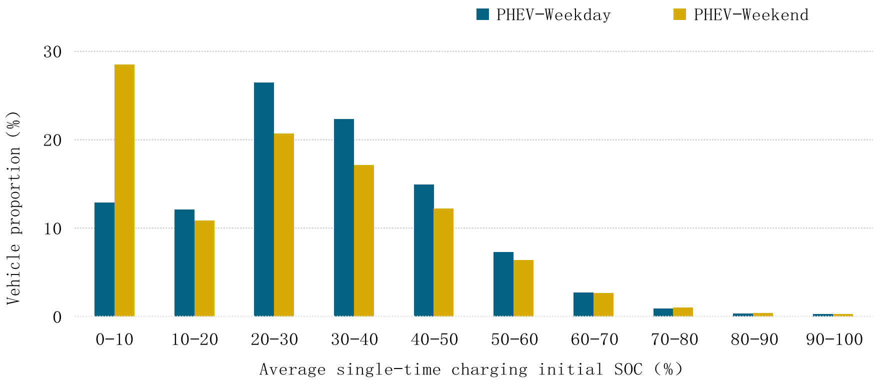


Fig. 5.13 Distribution of average single-time charging initial SOC of PHEV private cars in 2022—by weekday and weekend

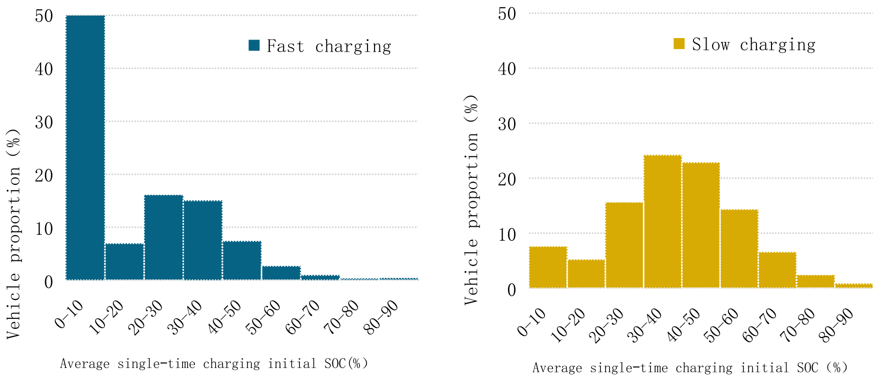


Fig. 5.14 Distribution of average single-time charging initial SOC of new energy private cars in 2022—by fast charging and slow charging

New energy private cars mainly charged at the destinations of commuting, with average daily charging time concentrated in the morning rush hours and nighttime, highlighting job-housing characteristics.

In terms of the distribution of charging hours, new energy private cars in 2022 mainly charged in the morning rush hours and at night (Fig. 5.15). 08:00 in the morning was the peak time for charging with a concentration ratio of 6.74%; and 17:00 was another peak time at night. The daily charging peak hours of private cars were characterized by power replenishment at commuting destinations and remarkable charging characteristics at the workplace and residential areas.

Given the average daily charging characteristics on weekdays and weekends, the proportion of BEV and PHEV private cars charging in the morning peak (07:00–09:00) on weekdays was higher than that on weekends (Figs. 5.16, 5.17). The

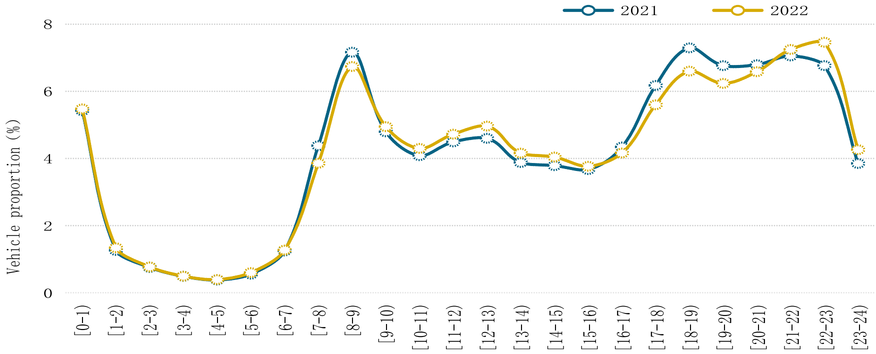


Fig. 5.15 Distribution of charging time of new energy private cars

charging peak occurs along with the morning rush hours in weekdays in light of the charging behaviors of users at the workplaces.

From the perspective of charging mode, private cars preferred fast charging mode for power replenishment during the daytime. The proportion of private cars using fast charging mode was higher than those using slow-charging mode from 10:00–17:00, while the proportion of those using slow-charging mode was higher from 08:00 to 18:00. (Fig. 5.18).

3. **Average monthly charging characteristics of new energy private cars**

New energy private cars charged 6.5 times per month on average in 2022, a slight decrease in frequency from previous years.

New energy private cars charged 6.5 times per month on average in 2022, with a decrease of 26.1% year on year (Table 5.5). From the distribution of average monthly charging frequency (by times) of NEVs, those charging less than 5 times per month on average accounted for 56.7% of the total, up 18 percentage points year-on-year

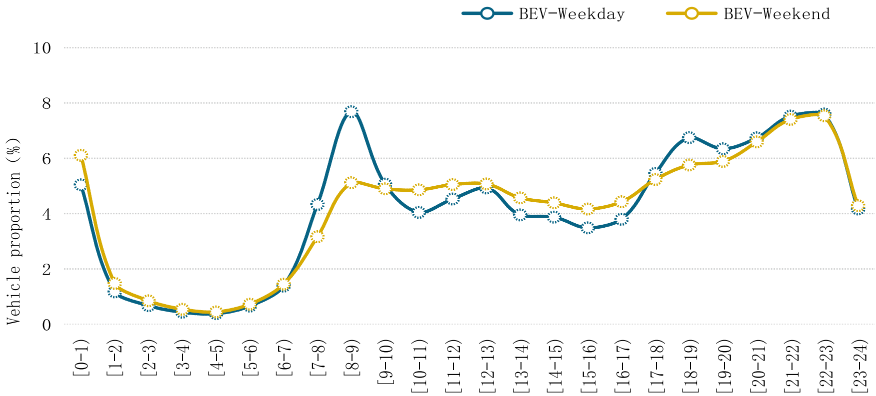


Fig. 5.16 Distribution of charging time of BEV private cars in 2022—by weekday and weeken

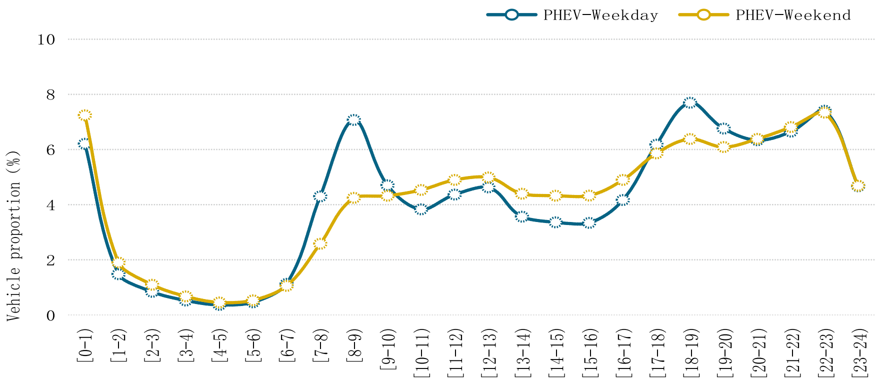


Fig. 5.17 Distribution of charging time of PHEV private cars in 2022—by weekday and weekend

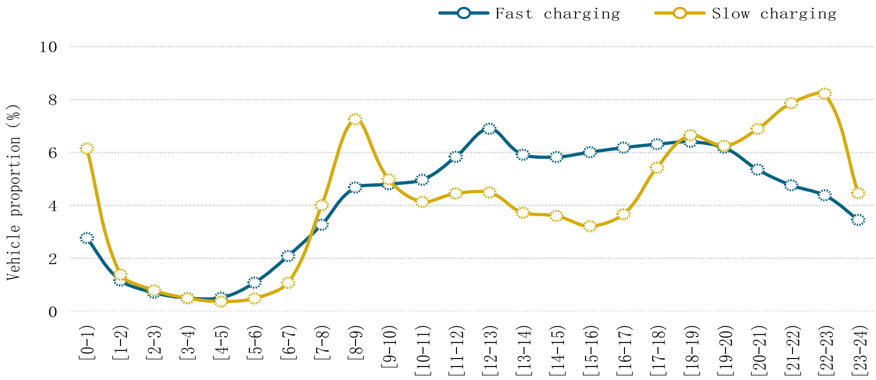


Fig. 5.18 Distribution of charging time of new energy private cars in 2021—by fast charging and slow charging

(Fig. 5.19). The average monthly charging frequency of BEVs was mainly less than 5 times, accounting for 59.1% of the total (Fig. 5.20). In 2022, the proportion of PHEV private cars charging less than 5 times per month on average increased by 30.5 and 26.9 percentage points from 2020 and 2021, respectively (Fig. 5.21).

In terms of changes in vehicle charging methods over the years, the average monthly fast charging times of new energy private vehicles accounted for 20.6% of the average monthly charging times in 2022, with an increase from previous years (Fig. 5.22).

Table 5.5 Average monthly charging times of new energy private cars over the years

Year	2020	2021	2022
Average monthly charging times	7.4	8.8	6.5

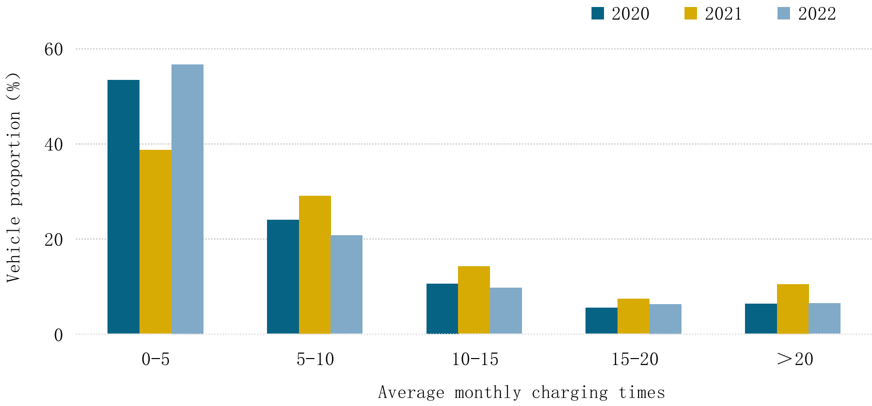


Fig. 5.19 Distribution of average monthly charging times of new energy private cars—by year

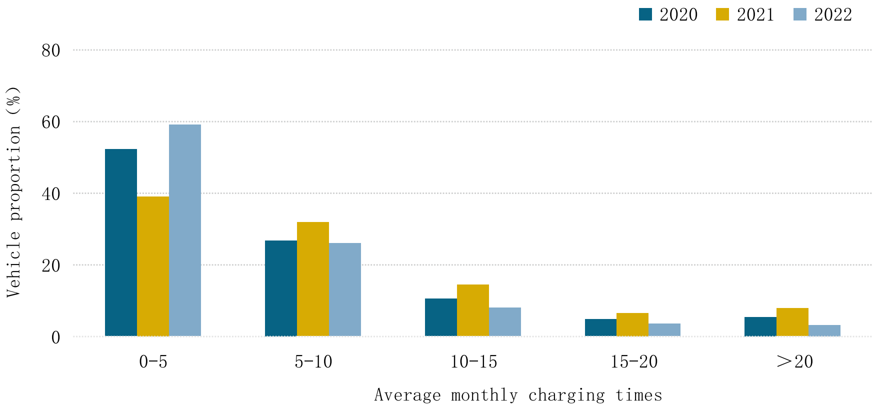


Fig. 5.20 Distribution of average monthly charging times of BEV private cars—by year

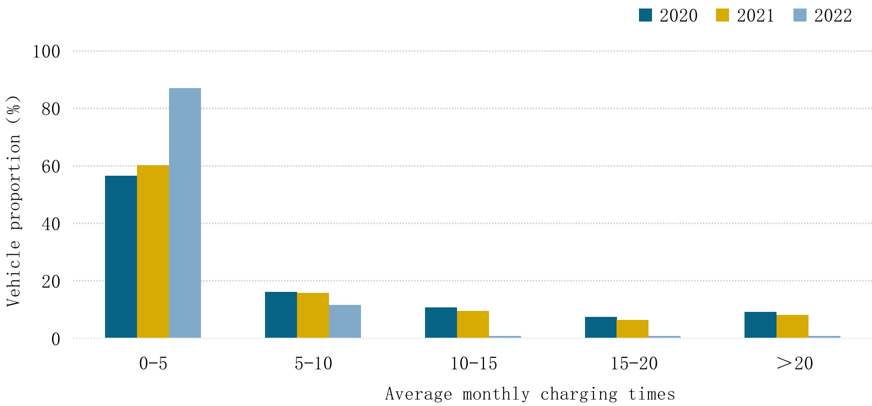


Fig. 5.21 Distribution of average monthly charging times of PHEV private cars—by year

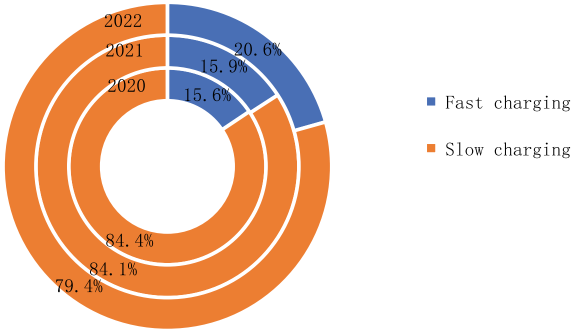


Fig. 5.22 Distribution of average monthly charging times of new energy private cars over the years—by fast charging and slow charging

In 2022, the average monthly fast charging times of new energy private cars read 1.3, basically the same as that in previous years.

After 2020, the average monthly fast charging times for new energy private cars remained basically the same over the years (Table 5.6). In view of the distribution of the proportion of new energy private cars with different fast charging times over the years (Fig. 5.23), most of the cars were charged within 5 times, and such proportion stayed above 80% for years. The changes in the proportion of fast charging times over the years show that the proportion of vehicles charging five times or more per month on average increased from 7.7% in 2020 to 12% in 2022. Possibly due to the fact that the rate of private piles to vehicles lagged behind the rapid growth of the holding volume of NEVs, an increasing number of private car users chose fast charging piles. Meanwhile, along with the rapid growth of the driving range of new energy private cars, more private car users preferred long-distance trips, during which the frequency of fast charging also improved.

In 2022, the average monthly slow charging times of new energy private cars read 5, with a decrease from previous years.

Slow charging was still the primary method for new energy private cars. The average monthly slow charging times of new energy private cars read 5 in 2022, with a decrease year on year and throughout 2022 (Table 5.7). From the distribution of times (Fig. 5.24), the proportion of vehicles with an average monthly slow charging time within 5 increased from 45.9% in 2021 to 73.2% in 2022. Due to the rapid growth of the overall driving range of private cars, the average monthly slow charging frequency declined in general.

Table 5.6 Average monthly fast charging times of new energy private cars over the years

Year	2020	2021	2022
Average monthly fast charging times	1.2	1.3	1.3

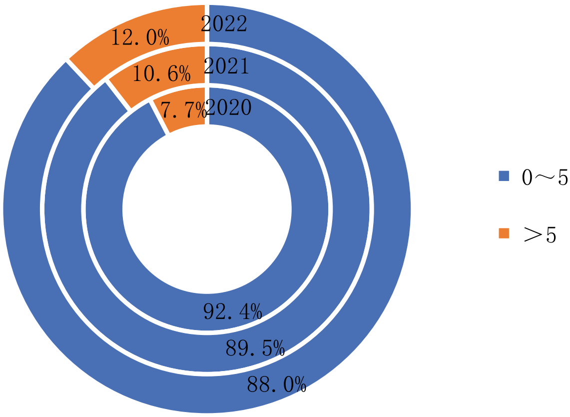


Fig. 5.23 Distribution of average monthly charging times of new energy private cars—by year for fast charging

Table 5.7 Average monthly slow charging times of new energy private cars over the years

Year	2020	2021	2022
Average monthly slow charging times	6.5	6.9	5

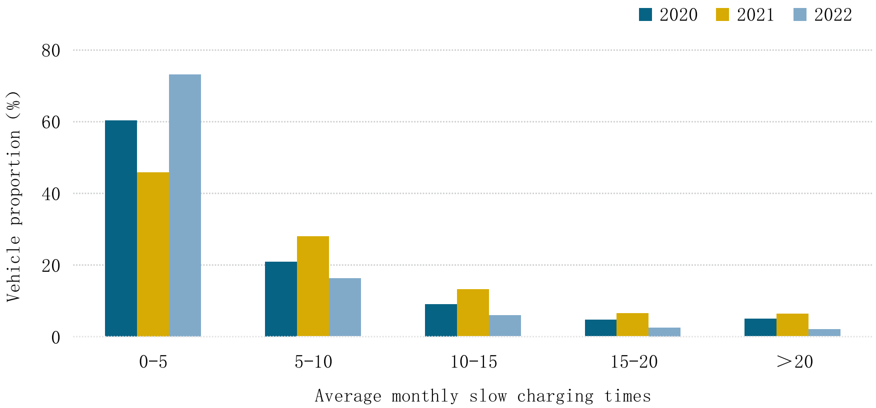


Fig. 5.24 Distribution of average monthly slow charging times of new energy private cars—by year

The average monthly charge of new energy private cars in 2022 was 85.4kWh, basically the same as that in 2022 (Table 5.8, Fig. 5.25).

Table 5.8 Average monthly charge of new energy private cars over the years

Year	2020	2021	2022
Average monthly charge (kWh)	84.2	105.5	85.4

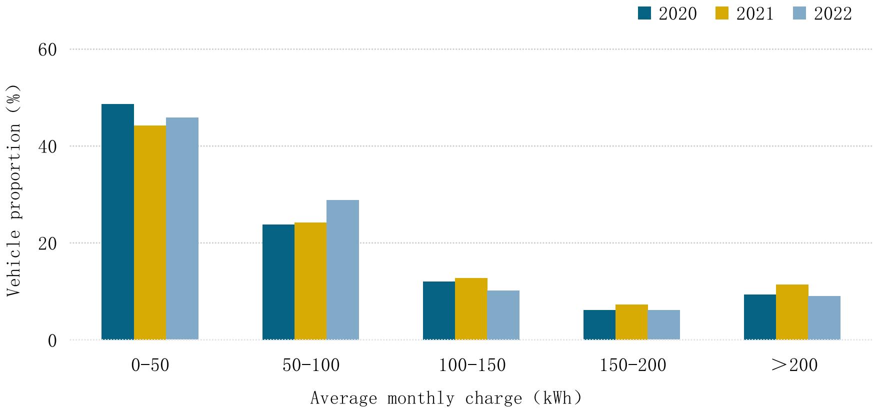


Fig. 5.25 Distribution of average monthly charge of new energy private cars—by year

5.2.2 Charging Characteristics of BEV e-taxis

1. **Average single-time charging characteristics of BEV e-taxis**

The average single-time charging duration of BEV e-taxis was 1.6h in 2022, mostly the same as that in 2021.

As shown in Table 5.9, the average single-time charging duration of BEV e-taxis was 1.6 h in 2022, which was mostly the same as that in 2021. According to the distribution of average single-time charging duration (Fig. 5.26), the proportion of BEV e-taxis with an average single-time charging duration from 1 to 5 h increased from 47.1% in 2021 to 52.4% in 2022 by 5.3 percentage points. In contrast, the proportion of those with the duration of less than 1 h declined yearly, which to some extent indicated the rise in frequency of slow-charging mode by e-taxis.

Regarding the charging mode, the average single-time duration under fast charging mode was mainly within 1 h, with the number of vehicles accounting for 88.2%; while the duration under slow-charging mode was unevenly distributed (Fig. 5.27).

The average single-time charging initial SOC of BEV e-taxis was 39.9% in 2022, with a decrease from previous years.

The average single-time charging initial SOC of BEV e-taxis was 39.9% in 2022 (Table 5.10), with a decrease from previous years. As the distribution shows (Fig. 5.28), the average single-time charging initial SOC of BEV e-taxis concentrated at 30%–50% over the years, with a proportion of higher than 55%, and the concentration of BEV e-taxis in such range of SOC improved year by year.

Table 5.9 Average single-time charging duration of BEV e-taxis over the years

Year	2020	2021	2022
Average single-time charging duration (h)	1.5	1.6	1.6

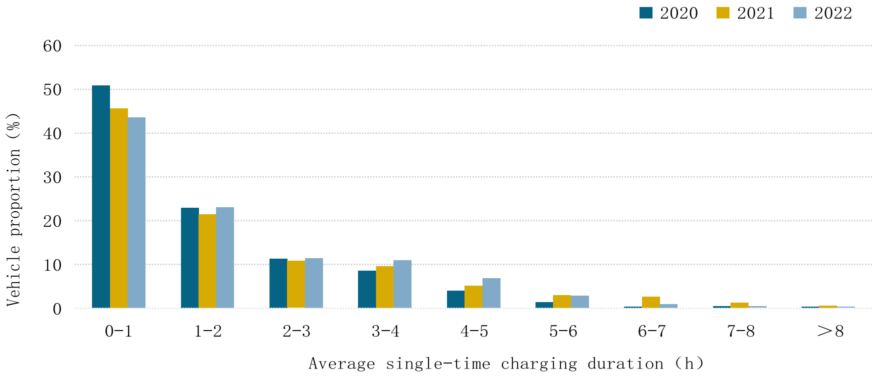


Fig. 5.26 Distribution of average single-time charging duration of BEV e-taxis—by year

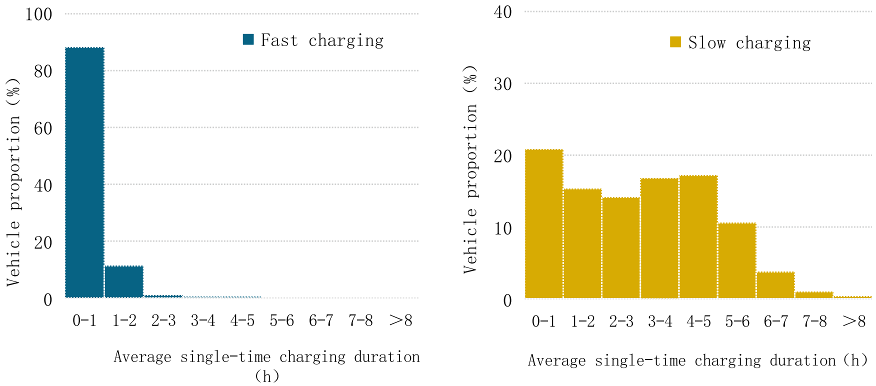


Fig. 5.27 Distribution of average single-time charging duration of BEV e-taxis in 2021—by fast charging and slow charging

Table 5.10 Average single-time charging initial SOC of BEV e-taxis over the years

Year	2020	2021	2022
Average single-time charging initial SOC (%)	43.4	42.5	39.9

In terms of charging mode (Fig. 5.29), the average single-time charging initial SOC of BEV e-taxis using fast charging was between 20 and 50%, with a concentrated proportion; and that using slow charging was relatively dispersed, mainly ranging from 30 to 70%.

2. **Average daily charging characteristics of BEV e-taxis**

In 2021, the overall charging time of BEV e-taxis was mainly distributed at 11:00 to 17:00 and in the period early in the morning.

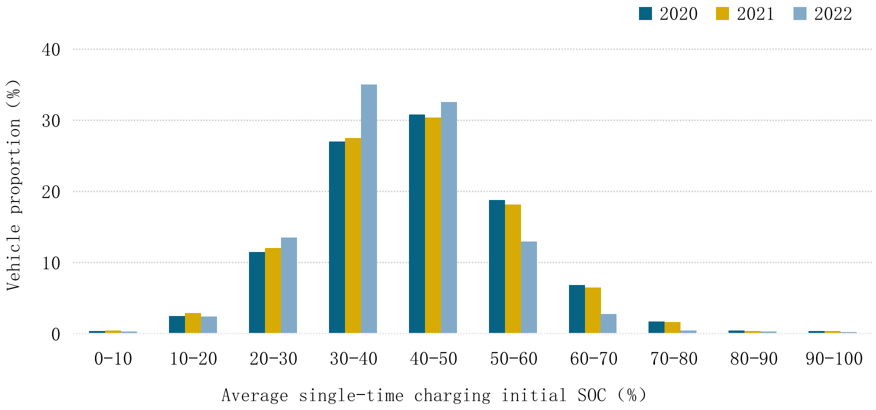


Fig. 5.28 Distribution of average single-time charging initial SOC of BEV e-taxis-by year

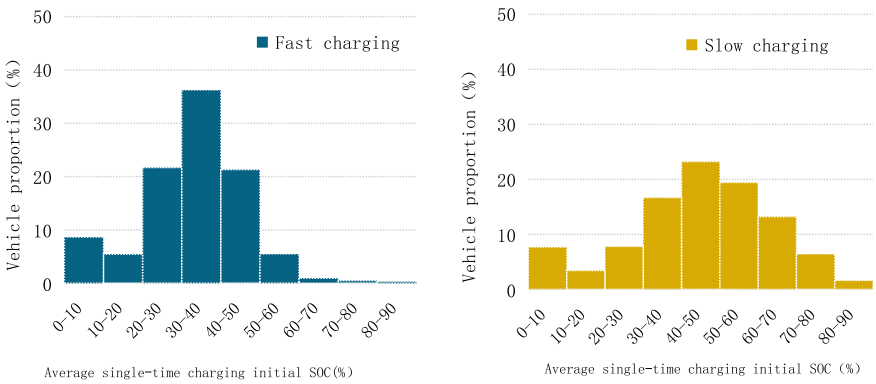


Fig. 5.29 Distribution of average single-time charging initial SOC of BEV e-taxis in 2022—by fast charging and slow charging

In 2022, BEV e-taxis were mainly charged at 11:00–17:00 in the daytime (peak at 12:00 for driver's rest and power replenishment). Compared to private cars, a smaller number of e-taxis charged during the morning and evening peak hours (Fig. 5.30), while a significantly higher number charged early in the morning.

From the perspective of charging mode, BEV e-taxis mainly took slow-charging mode in the early morning and fast charging mode temporarily in the daytime for power replenishment at 12:00 and 21:00 in the middle of the day. There were a large number of vehicles operating in the morning and evening rush hours, of which the e-taxis charging held a low proportion (Fig. 5.31).

3. **Average monthly charging characteristics of BEV e-taxis**

The average monthly charging times of BEV e-taxis read 30.9, and the monthly charging frequency rose steadily.

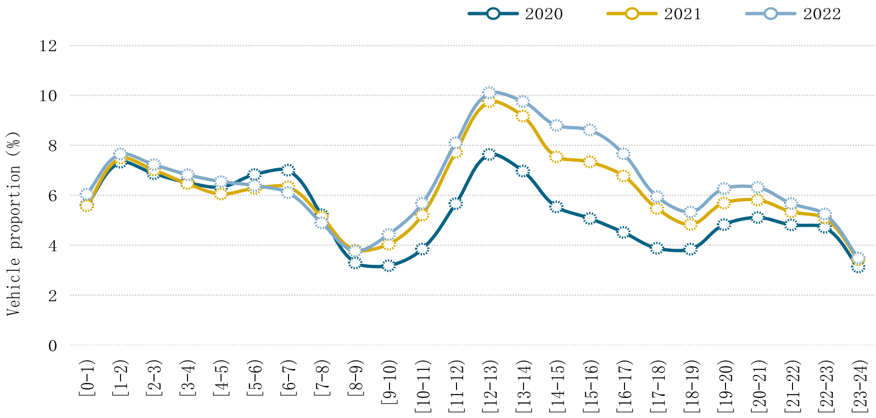


Fig. 5.30 Distribution of charging time of BEV e-taxis—by year

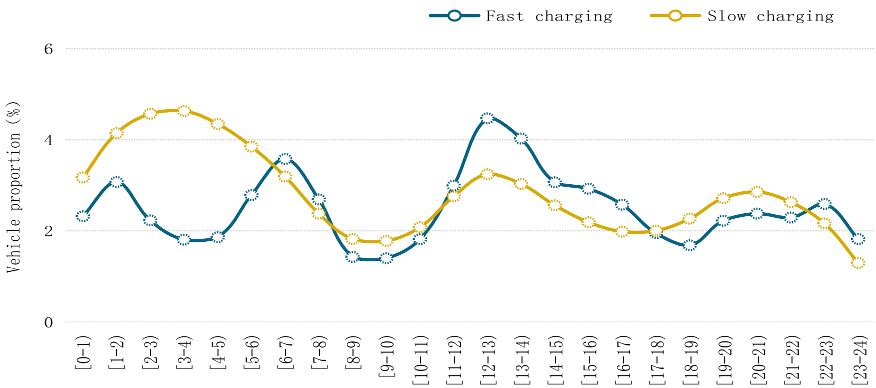


Fig. 5.31 Distribution of charging time of BEV e-taxis in 2022—by fast charging and slow charging

The average monthly charging times of BEV e-taxis reached 28.9 in 2022, which increased steadily in the past three years (Table 5.11). Regarding the average monthly charging times (Fig. 5.32), the average monthly charging times of BEV e-taxis in 2022 mainly ranged from 10 to 30, and the number of BEV e-taxis in such range accounted for nearly 50%. In view of charging mode, the proportion of fast charging for BEV e-taxis was 77.3% (Fig. 5.33), and the proportion of vehicles with fast charging over the years showed a momentum of constant growth over the years.

In 2022, the average monthly fast charging times of BEV e-taxis reached 23.9, with a slight increase.

Table 5.11 Average monthly charging times of BEV e-taxis over the years

Year	2020	2021	2022
Average monthly charging times	25.0	28.9	30.9

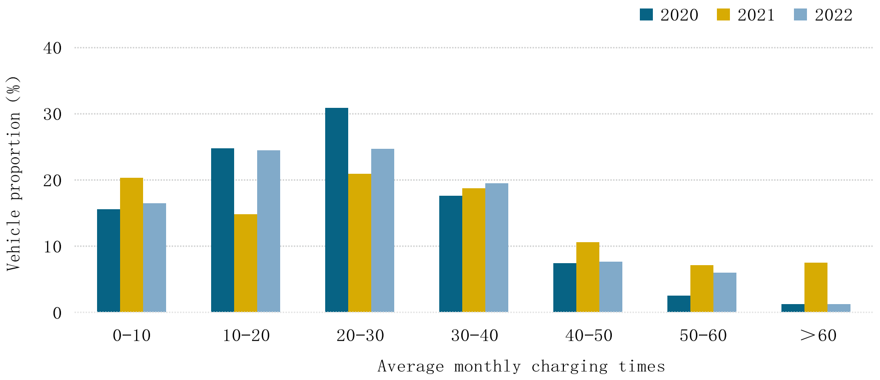
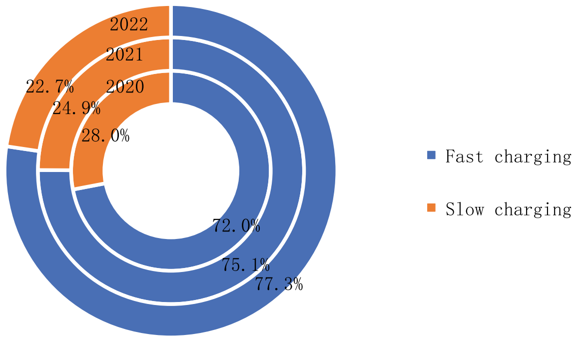


Fig. 5.32 Distribution of average monthly charging times of BEV e-taxis—by year

Fig. 5.33 Distribution of average monthly charging times of BEV e-taxis over the years—by fast charging and slow charging



The average monthly fast charging times of BEV e-taxis in 2022 reached 21.7, an increase from the past three years (Table 5.12). As the distribution shows (Fig. 5.34), the proportion of BEV e-taxis with an average monthly fast charging exceeding 10 times was 68%, with an increase of 3.9 percentage points from 2020 and 0.1 percentage point from 2021. More vehicles took fast charging for temporary power replenishment in 2022.

The monthly average slow charging times of BEV e-taxis maintained at around 7 as that in previous years.

The average monthly slow charging times of BEV e-taxis in 2022 stayed 7, mostly consistent with that in 2020 and 2021 (Table 5.13). By the distribution of the average monthly slow charging times (Fig. 5.35), the BEV e-taxis with an average monthly

Table 5.12 Average monthly fast charging times of BEV e-taxis over the years

Year	2020	2021	2022
Average monthly fast charging times	18.0	21.7	23.9

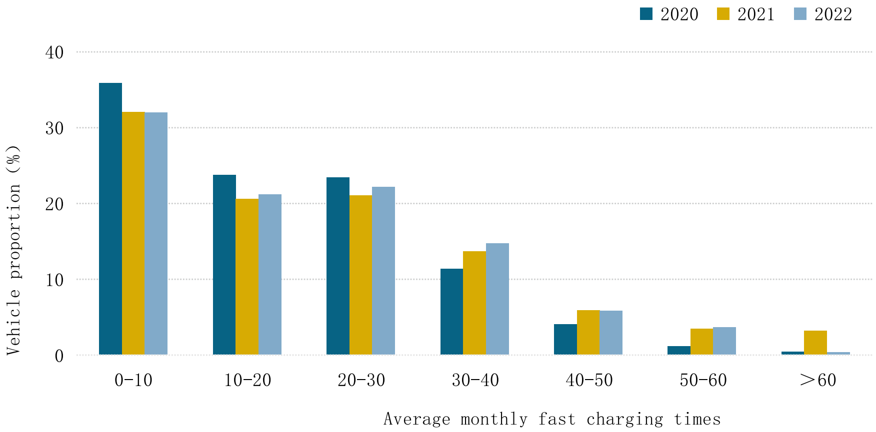


Fig. 5.34 Distribution of average monthly fast charging times of BEV e-taxis-by year

slow charging times fell within 10, with the number of vehicles involved accounting for more than 70% for the past three years.

The average monthly charge of BEV e-taxis in 2022 was 657.2kWh, with a slight increase year on year.

The average monthly charge of BEV e-taxis in 2022 was 657.2kWh, with a slight increase from 2020 and 2021 (Table 5.14). In terms of fast charging, the distribution of monthly average charge of BEV e-taxis in 2022 was relatively decentralized, in which the proportion of the BEV e-taxis with 400kWh-700kWh was higher,

Table 5.13 Average monthly slow charging times of BEV e-taxis over the years

Year	2020	2021	2022
Average monthly slow charging times	7.0	7.2	7

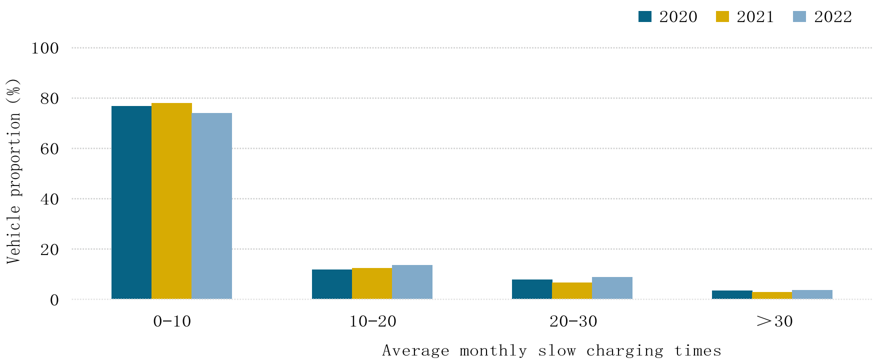


Fig. 5.35 Distribution of average monthly slow charging times of BEV e-taxis—by year

reaching 30.36% (Fig. 5.36); in terms of slow charging, the proportion of BEV e-taxis with monthly average charge of more than 500kWh slightly increased from 2020 (Fig. 5.37).

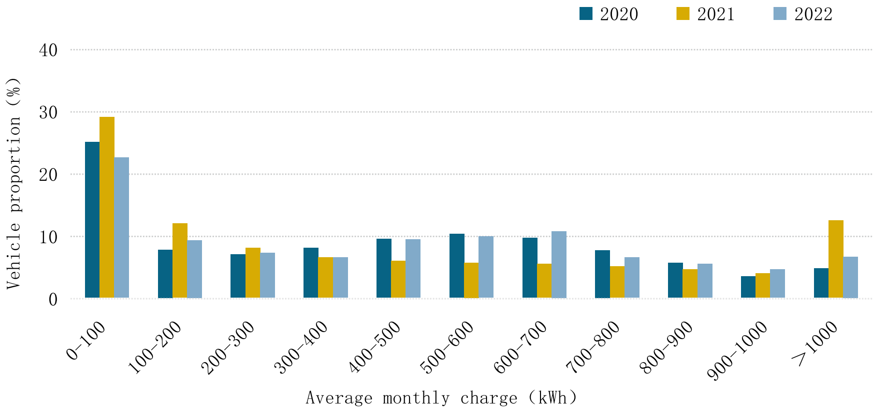


Fig. 5.36 Distribution of average monthly charge of BEV e-taxis—by year for fast charging

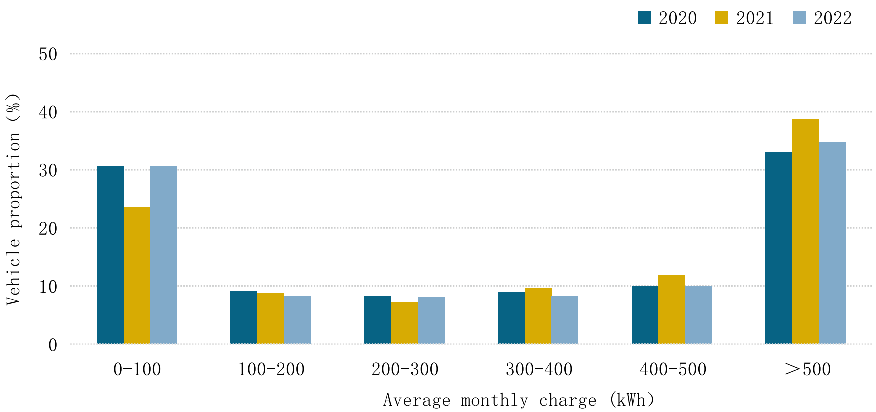


Fig. 5.37 Distribution of average monthly charge of BEV e-taxis—by year for slow charging

Table 5.14 Average monthly charge of BEV e-taxis over the years

Year	2020	2021	2022
Average monthly charge (kWh)	548.4	652.8	657.2

5.2.3 Charging Characteristics of BEV Taxis

1. **Average single-time charging characteristics of BEV taxis**

The distribution of BEV taxis' annual average single-time charging duration was mainly within 1h.

The average single-time charging duration of BEV taxis in 2022 was 1.4 h, higher than that in previous years (Table 5.15) As the distribution shows (Fig. 5.38), the distribution of average single-time charging duration of BEV taxis was mainly concentrated within 1 h, and the proportion of vehicles with an average charging single-time charging duration of less than 1 h increased was higher than 60%, maintaining an upward momentum in 2022 since an increasing number of users take slow charging for replenishment.

Regarding charging mode, BEV taxis with shorter average single-time charging duration were dominant, with those using fast charging with an average single-time charging duration of less than 1 h accounting for 88.2% and those using slow charging with an average single-time charging duration of less than 2 h accounting for 59.9% (Fig. 5.39). Regardless of fast or slow charging, it is a practical requirement for BEV taxis to enhance charging efficiency and shorten charging duration.

The average single-time charging initial SOC of BEV taxis declined steadily on a yearly basis.

In 2022, the average single-time charging initial SOC of BEV taxis was 41.4%, with a slight decrease from 2002 and 2021 (Table 5.16). As the distribution shows (Fig. 5.40), the average single-time charging initial SOC of BEV taxis was mainly

Table 5.15 Average single-time charging duration of BEV taxis-average

Year	2020	2021	2022
Average single-time charging duration (h)	1.2	1.1	1.4

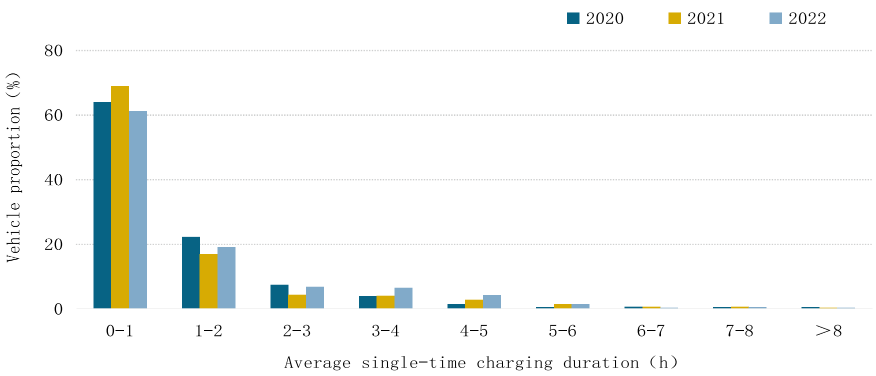


Fig. 5.38 Distribution of average single-time charging duration of BEV taxis—by year

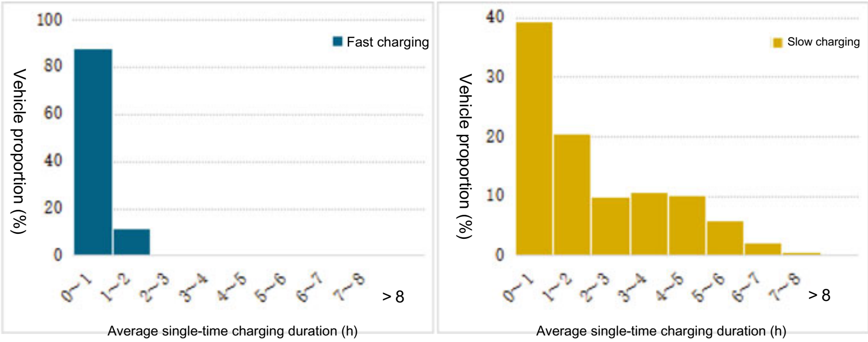


Fig. 5.39 Distribution of average single-time charging duration of BEV taxis in 2021—by fast charging and slow charging

distributed in the range of 30%–50%, and the proportion of vehicles within such range increased from 58.7% in 2020 to 72.2% in 2022.

As regards the charging mode, the average single-time charging initial SOC of BEV taxis using fast charging was mainly concentrated at 30%–50% (with number of vehicles concerned accounting for 69.25%), and that using slow charging was relatively dispersed (Fig. 5.41).

2. **Average daily charging characteristics of BEV taxis**

BEV taxis mainly charged between 11:00 and 18:00 and in the early morning.

Table 5.16 Average single-time charging initial SOC of BEV taxis over the years

Year	2020	2021	2022
Average single-time charging initial SOC (%)	43.3	42.2	41.4

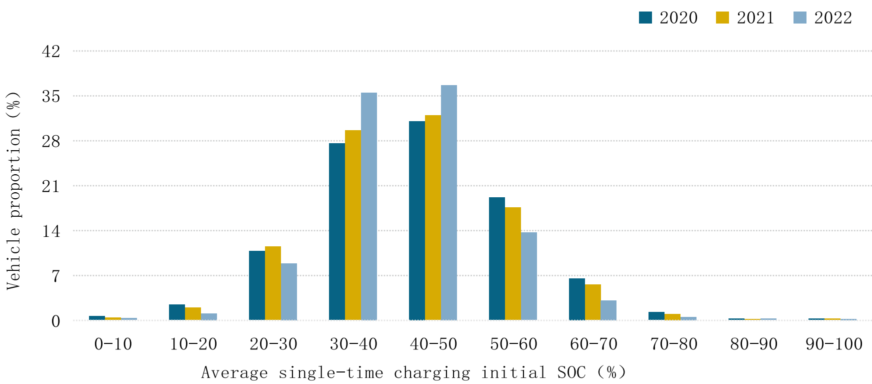


Fig. 5.40 Distribution of average single-time charging initial SOC of BEV taxis—by year

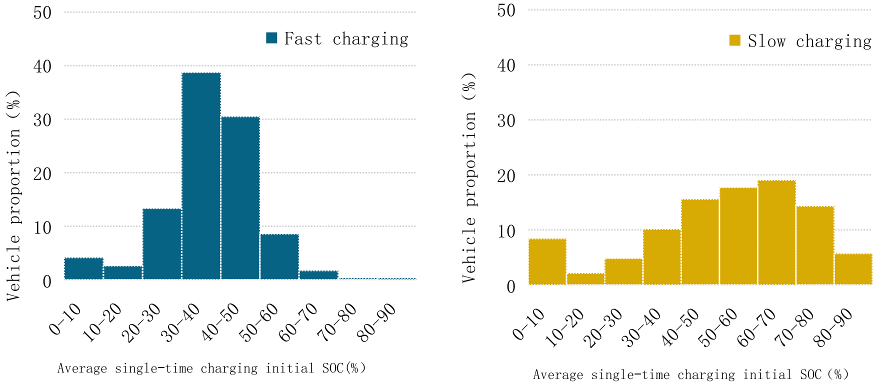


Fig. 5.41 Distribution of average single-time charging initial SOC of BEV taxis in 2022—by fast charging and slow charging

According to the distribution of charging time (Fig. 5.42), in 2022, BEV taxis charged more intensively between 11:00 and 18:00 as well as in the early morning after 0:00. By the charging mode, BEV taxis mainly took fast charging, and the proportion of those using slow charging was relatively low (Fig. 5.43).

3. Average Monthly Charging Characteristics of BEV Taxis

The average monthly charging times of BEV taxis in 2022 read 30.1, with a decrease from 2021 but a slight increase over 2020 (**Table 5.17**).

Regarding the average monthly charging times, most of the BEV taxis charged 10 to 40 times on average in a month with a proportion of taxis involved accounting for 60.5% (Fig. 5.44). Considering the charging mode, 82.4% of the BEV taxis mainly chose fast charging for power replenishment in 2022 (Fig. 5.45). BEV taxis mainly took fast charging for power replenishment and the proportion of fast charging showed an upward momentum.

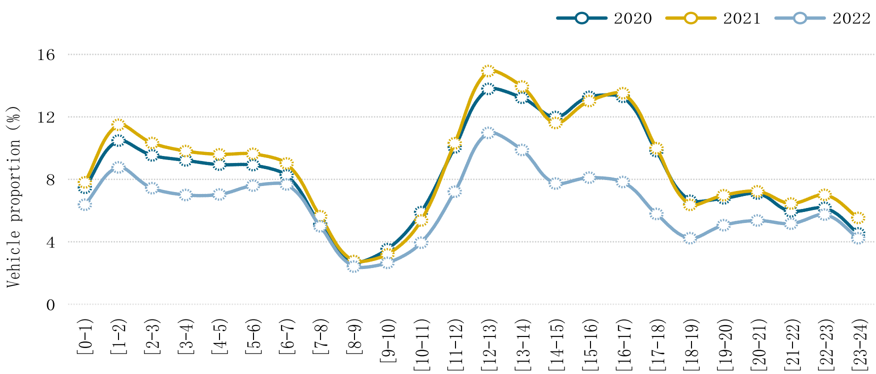


Fig. 5.42 Distribution of charging time of BEV taxis—by year

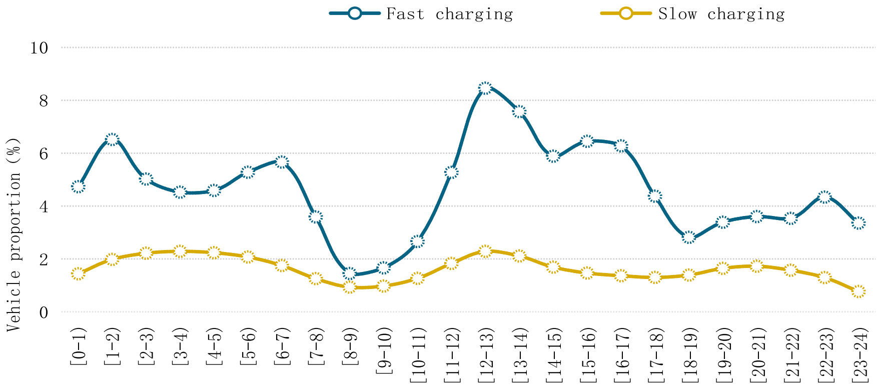


Fig. 5.43 Distribution of charging time of BEV taxis in 2022—by fast charging and slow charging

Table 5.17 Average monthly charging times of BEV taxis over the years

Year	2020	2021	2022
Average monthly charging times	28.6	41.0	30.1

Table 5.18 Average monthly fast charging times of BEV taxis over the years

Year	2020	2021	2022
Average monthly fast charging times	22.7	32.9	24.8

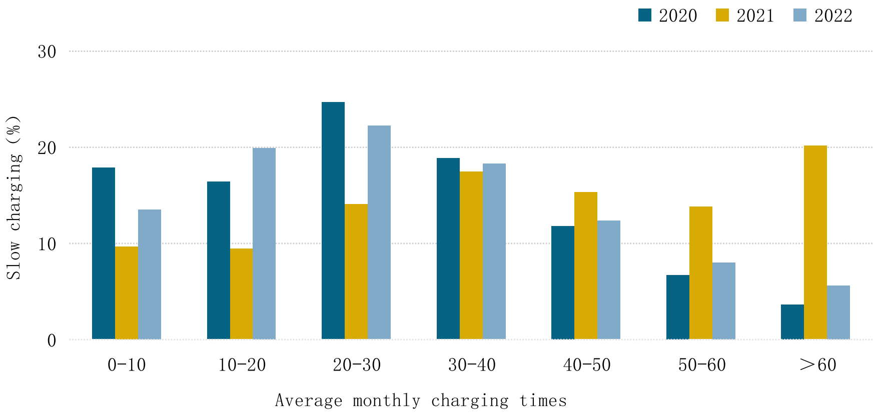


Fig. 5.44 Distribution of average monthly charging times of BEV taxis—by year

In 2022, the average monthly fast charging times of BEV taxis read 24.8, showing a decrease year on year(Table 5.18.)

As per the distribution of average monthly fast charging times (Fig. 5.46), the average monthly fast charging times of BEV taxis n 2022 mainly fell within 30 times, with 67.8% of the taxis involved, an increase of 26.8 percentage points year-on-year.

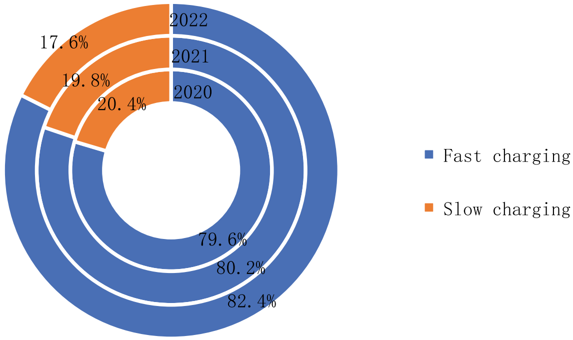


Fig. 5.45 Distribution of average monthly charging times of BEV taxis over the years—by fast charging and slow charging

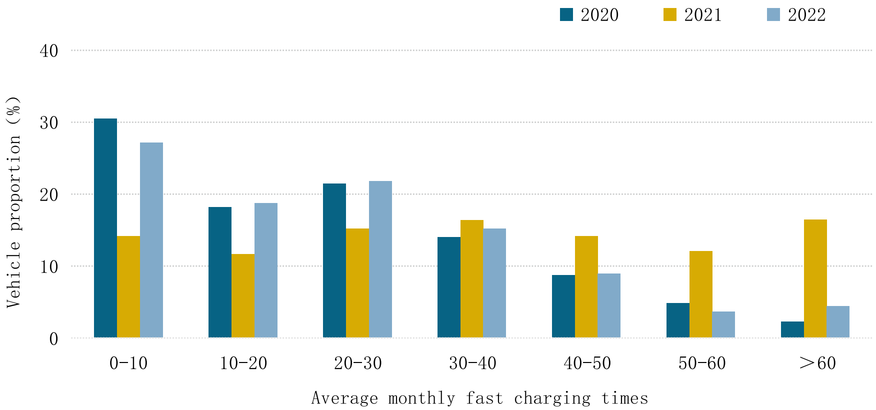


Fig. 5.46 Distribution of average monthly fast charging times of BEV taxis—by year

The average monthly slow charging times of BEV taxis in 2022 were 4.3 times, with an increase compared with that in 2021.

The average monthly slow charging times of BEV taxis in 2022 were 4.3 times, with a decrease compared with 2021 (Table 5.19). According to the distribution of monthly average slow charging times (Fig. 5.47), the slow charging frequency of BEV taxis was mainly 10 times per month.

The average monthly charge of BEV taxis was 686.5kWh in 2022, with a YoY decrease of 27.3% but slightly higher than that in 2020.

The average monthly charge of BEV taxis was 944.5kWh in 2022, with a YOY decrease from 2021 but slightly higher than that in 2020 (Table 5.20). From the distribution of average monthly charge (Fig. 5.48), 55.2% of BEV taxis used fast

Table 5.19 Average monthly slow charging times of BEV taxis over the years

Year	2020	2021	2022
Average monthly slow charging times	5.8	8.1	4.3

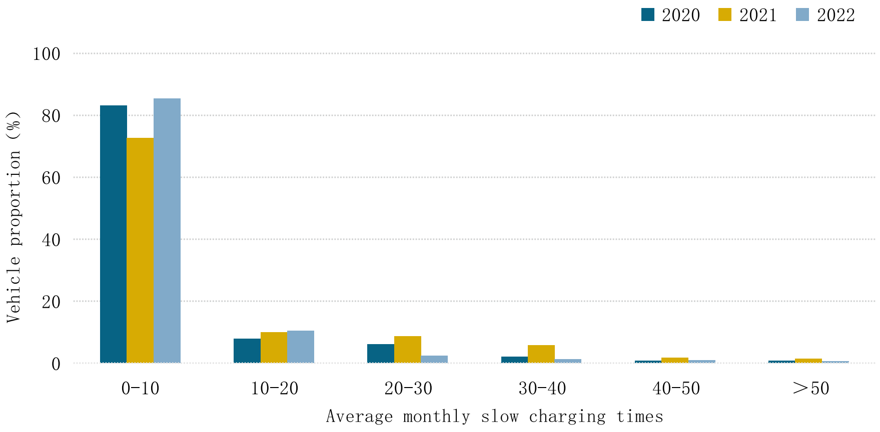


Fig. 5.47 Distribution of average monthly slow charging times of BEV taxis—by year

charging with an average monthly charge between 200 and 800kWh, with an increase of 8.5 percentage points from 2020 and 23.8 percentage points from 2021; while those using slow charging mainly charged within 200kWh per month on average (Fig. 5.49).

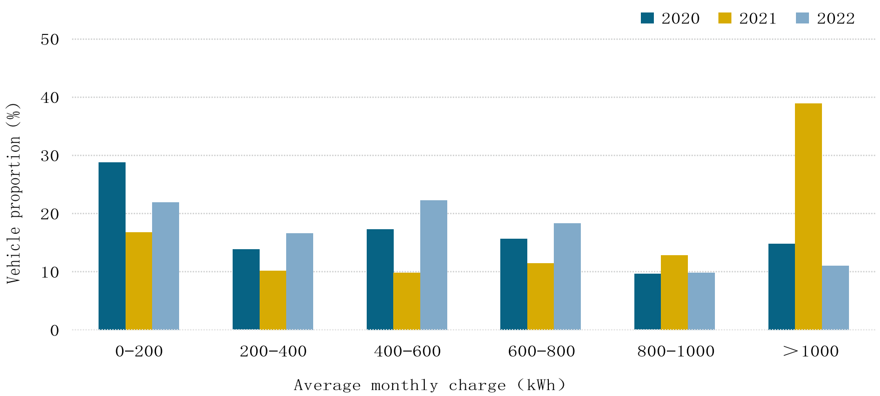


Fig. 5.48 Distribution of average monthly charge of BEV taxis—by year for fast charging

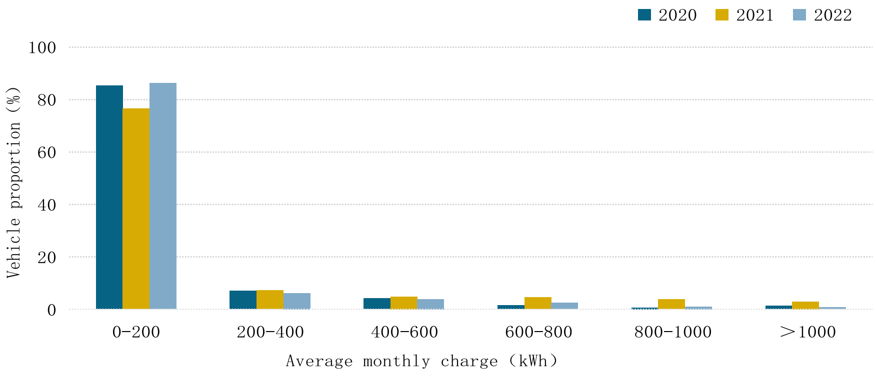


Fig. 5.49 Distribution of average monthly charge of BEV taxis—by year for slow charging

Table 5.20 Average monthly charge of BEV taxis over the years

Year	2020	2021	2022
Average monthly charge (kWh)	656.5	944.5	686.5

5.2.4 Charging Characteristics of BEV Cars for Sharing

1. **Average single-time charging characteristics of BEV cars for sharing**

The average single-time charging duration of BEV cars for sharing was mainly concentrated within 1h.

The average single-time charging duration of BEV cars for sharing in 2022 was 2 h, with a slight increase for the past three years (Table 5.21). As the distribution shows (Fig. 5.50), the proportion of BEV cars for sharing with an average single-time charging duration from 1 to 5 h in 2022 reached 54.2%, with a significant increase year on year.

Considering the charging duration on weekdays and weekends, the proportion of BEV cars for sharing with an average single-time charging duration of less than 2 h during weekdays was lower than that during weekends (Fig. 5.51).

Regarding the charging mode, the average single-time charging duration of over 85% of BEV cars for sharing using fast charging was mainly concentrated within 1 h; the average single-time charging duration of BEV cars for sharing using slow charging was relatively dispersed. Those with charging time within 5 h accounted for 86.65% (Fig. 5.52).

Table 5.21 Average single-time charging duration of BEV cars for sharing over the years

Year	2020	2021	2022
Average single-time charging duration (h)	1.7	1.4	2

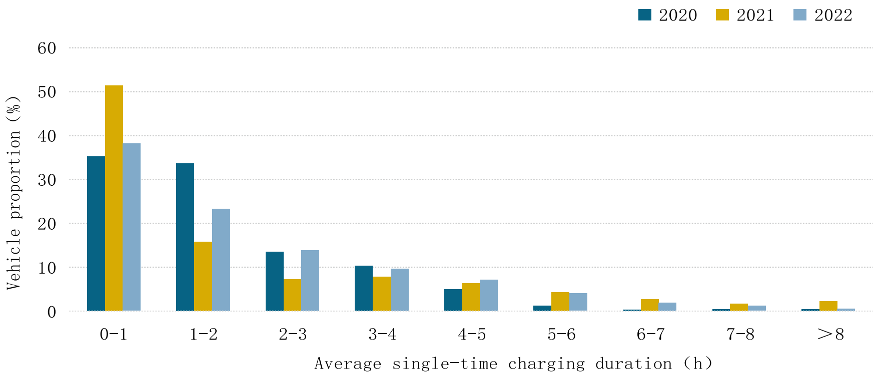


Fig. 5.50 Distribution of average single-time charging duration of BEV cars for sharing—by year

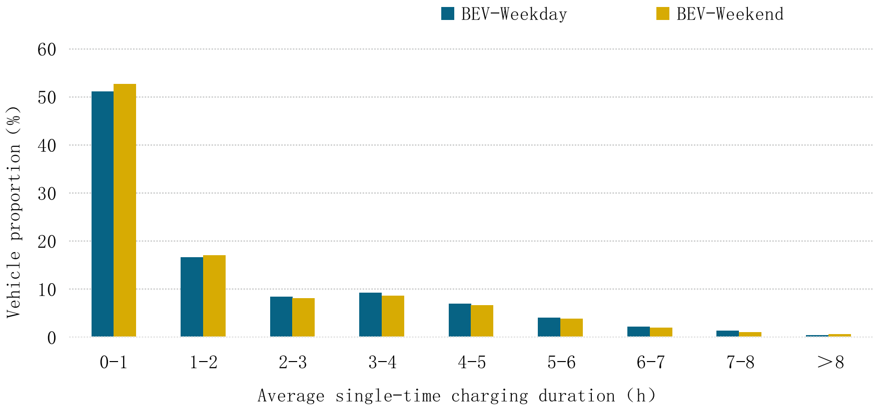


Fig. 5.51 Distribution of average single-time charging duration of BEV cars for sharing in 2022—by weekday and weekend

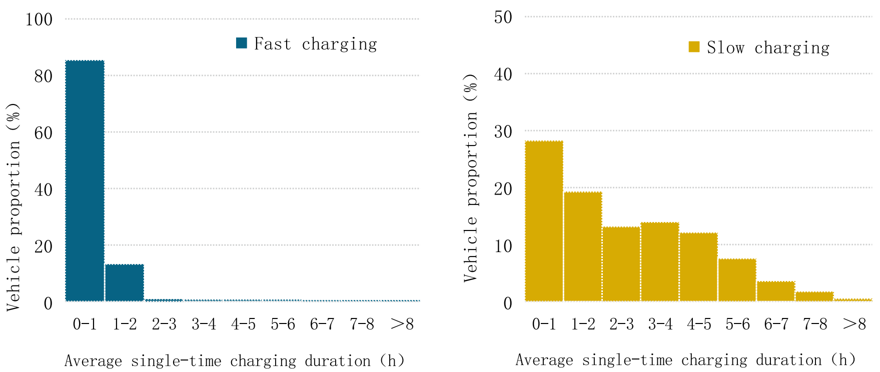


Fig. 5.52 Distribution of average single-time charging duration of BEV cars for sharing in 2022—by fast charging and slow charging

The average single-time charging initial SOC of BEV cars for sharing declined year by year.

The average single-time charging initial SOC of BEV cars for sharing was 41.8% in 2022, showing a downward trend for the past three years (Table 5.22). As the distribution shows (Fig. 5.53), the average single-time charging initial SOC of BEV cars for sharing was mainly concentrated at 30%–50%, and the proportion of vehicles within this range over the years was higher than 50%.

From the distribution by weekdays and weekends, the average single-time charging initial SOC on weekdays was generally higher than that on weekends (Fig. 5.54), and the proportion of those charging in high SOC on weekdays was higher.

Regarding charging methods, the average single-time charging initial SOC of BEV cars for sharing using fast charging was mainly concentrated at 30%–50%, with the proportion of vehicles in such range accounting for 56.3%, and that using slow charging was relatively dispersed (Fig. 5.55).

2. **Average daily charging characteristics of BEV cars for sharing**

The proportion of BEV cars for sharing mainly charged in the daytime, peaking at 12:00.

Regarding the charging time (Fig. 5.56), BEV cars for sharing mainly charged from 11:00 to 17:00, with a large proportion of vehicles charging in the daytime; by charging mode, the cars for sharing in fast charging mode mainly charged from 6:00 to 7:00, 12:00 to 13:00, and 1:00 to 2:00 (next morning). While the vehicles charged

Table 5.22 Average single-time charging initial SOC of BEV cars for sharing over the years

Year	2020	2021	2022
Average single-time charging initial SOC (%)	42.6	42.5	41.8

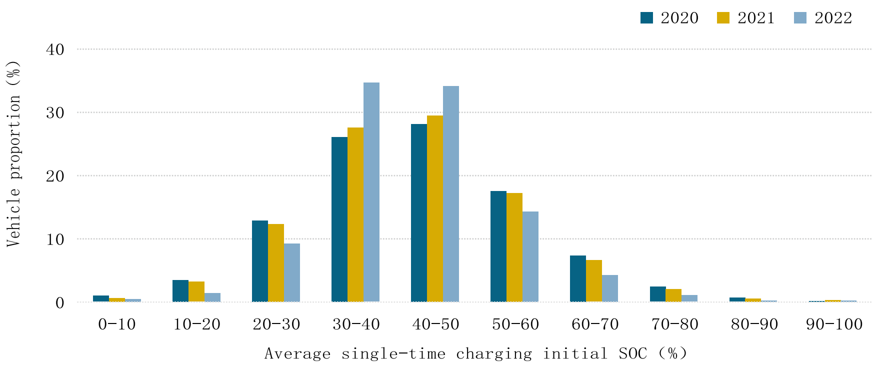


Fig. 5.53 Distribution of average single-time charging initial SOC of BEV cars for sharing—by year

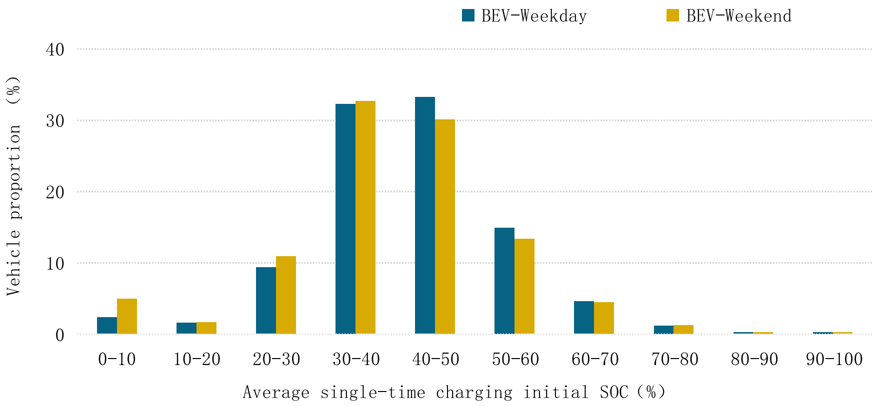


Fig. 5.54 Distribution of average single-time charging initial SOC of BEV cars for sharing in 2022—by weekday and weekend

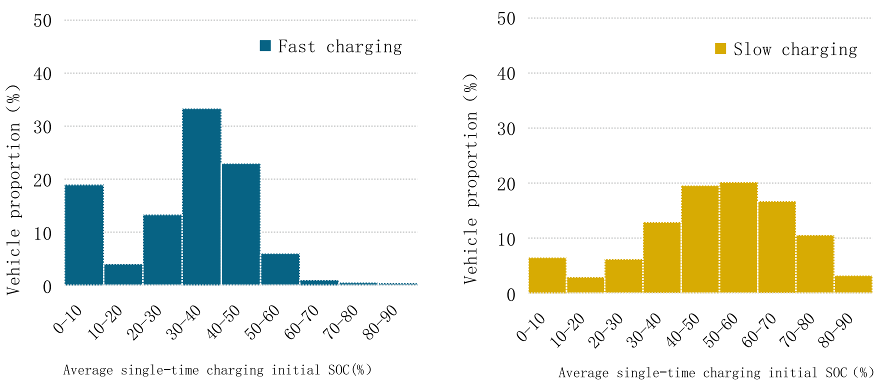


Fig. 5.55 Distribution of average single-time charging initial SOC of BEV cars for sharing in 2022—by fast charging and slow charging

under slow charging mode were distributed dispersedly in different periods of time (Fig. 5.57).

3. **Average monthly charging characteristics of BEV cars for sharing**

The average monthly charging times of BEV cars for sharing in 2022 read 21.8, with an increase year by year.

The average monthly charging times of BEV cars for sharing in 2022 read 21.8, with a steady growth for the past three years (Table 5.23). As the distribution shows (Fig. 5.58), the proportion of BEV cars for sharing with average monthly charging times between 20 and 40 ascended to 35% by 7.2 percentage points from 2020 and 3.2 percentage points from 2021.

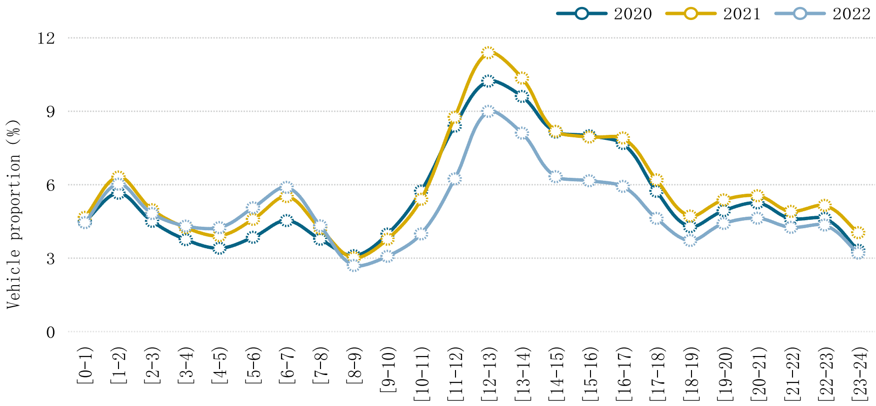


Fig. 5.56 Distribution of charging time of BEV cars for sharing—by year

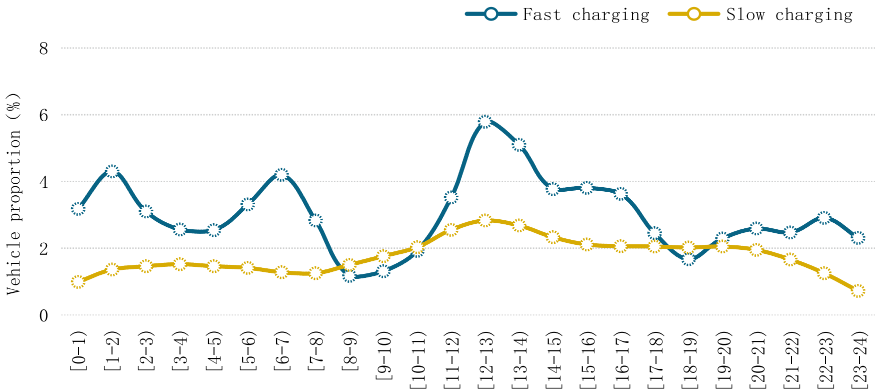


Fig. 5.57 Distribution of charging time of BEV cars for sharing in 2022—by fast charging and slow charging

Table 5.23 Average monthly charging times of BEV cars for sharing over the years

Year	2020	2021	2022
Average monthly charging times	16.1	19.2	21.8

By the charging mode, fast charging has become the major charging mode for BEV cars for sharing with those using fast charging accounting for 79% in 2022(Fig. 5.59), showing an increase from 2020 and 2021.

The average monthly fast charging times of BEV cars for sharing showed a growing trend yearly.

The average monthly fast charging times of BEV cars for sharing were 16, with an increase of 0.6 times compared with 2021 (Table 5.24). As the distribution shows

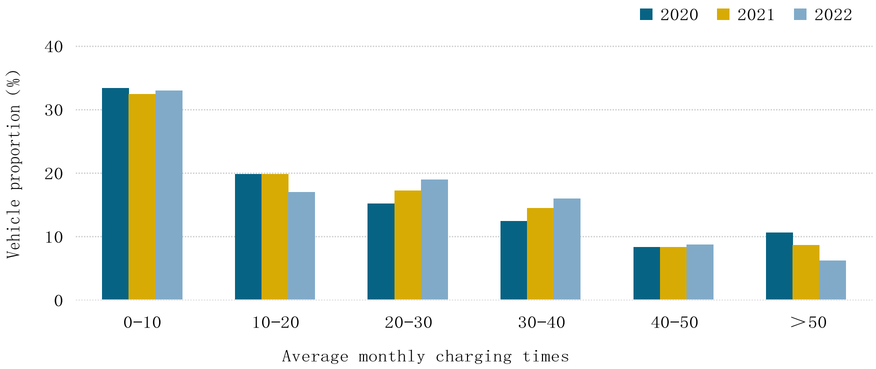
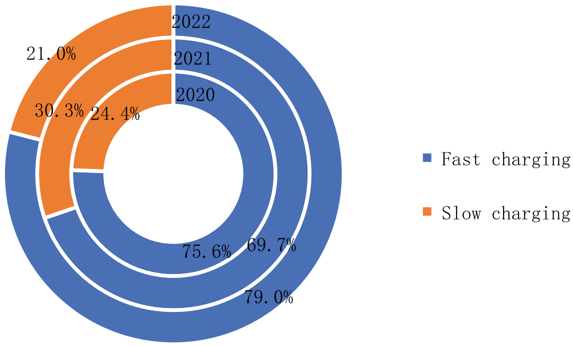


Fig. 5.58 Distribution of average monthly charging times of BEV cars for sharing—by year

Fig. 5.59 Distribution of average monthly charging times of BEV cars for sharing over the years—by fast charging and slow charging



(Fig. 5.60), the proportion of BEV cars for sharing with average monthly fast charging times between 20 and 40 increased from 29.8% in 2020 to 32.6% in 2022.

The average monthly slow charging times of BEV cars for sharing in 2022 read 11.8, with a slight decrease from 2021.

The average monthly slow charging times of BEV cars for sharing in 2021 recorded 11.8, with a slight decrease from 2021 (Table 5.25). As the distribution indicates (Fig. 5.61), in the past three years, the average monthly slow charging times of BEV cars for sharing were mainly concentrated within 10 times, within which the proportion of vehicles involved was 79%, with an increase of 18 percentage points from 2021 and basically the same as that in 2020.

The monthly average charge of BEV cars for sharing was 463.4kWh, with a slight increase year on year.

Table 5.24 Average monthly fast charging times of BEV cars for sharing over the years

Year	2020	2021	2022
Average monthly fast charging times	10.9	15.4	16

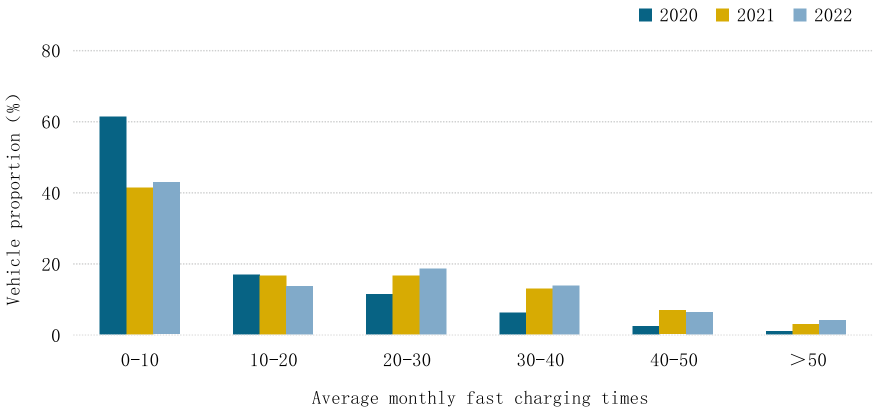


Fig. 5.60 Distribution of average monthly fast charging times of BEV cars for sharing—by year

Table 5.25 Average monthly slow charging times of BEV cars for sharing over the years

Year	2020	2021	2022
Average monthly slow charging times	5.2	11.8	5.8

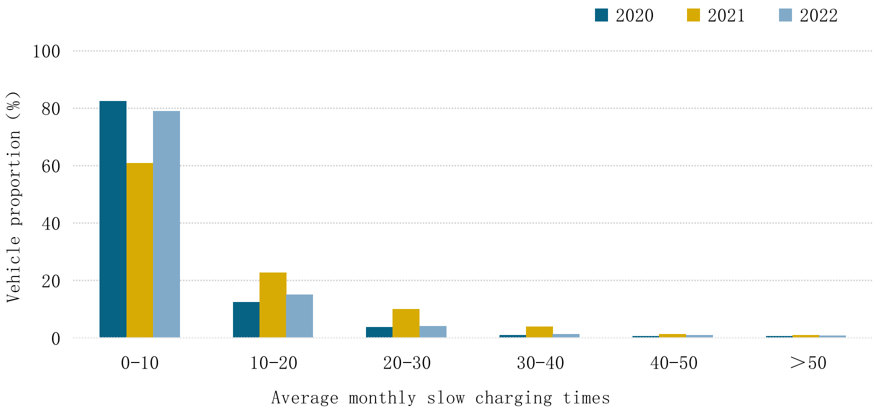


Fig. 5.61 Distribution of average monthly slow charging times of BEV cars for sharing—by year

The monthly average charge of BEV cars for sharing was 463.4kWh in 2022, with a slight increase year on year (Table 5.26). From the distribution of average monthly charge (Fig. 5.62), the proportion of BEV cars for sharing using fast charging with an average monthly charge of 400kWh to 1,000kWh was significantly higher than that in 2021, from 21.9% in 2020 to 40.2% in 2022.

Compared to 2021, in 2022, the average monthly charge of BEV cars for sharing using slow charging decreased (Fig. 5.63), wherein those with an average monthly charge within 100kWh accounted for 73.4%, up 32.6 percentage points year on year.

Table 5.26 Average monthly charge of BEV cars for sharing over the years

Year	2020	2021	2022
Average monthly charge (kWh)	293.9	463.4	491.1

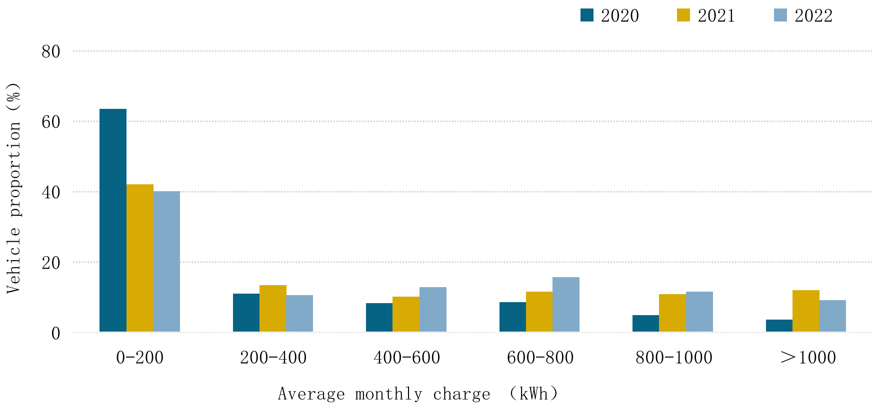


Fig. 5.62 Distribution of average monthly charge of BEV cars for sharing—by year for fast charging

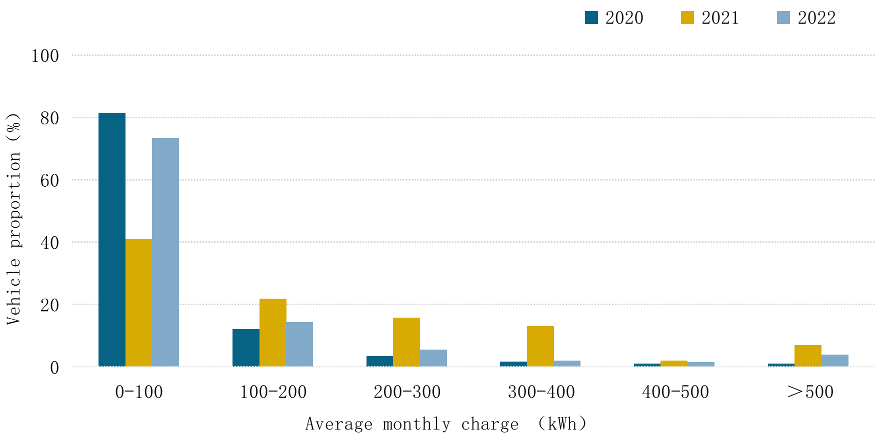


Fig. 5.63 Distribution of average monthly charge of BEV cars for sharing—by year for slow charging

5.2.5 Charging Characteristics of BEV Logistics Vehicles

1. **Average single-time charging characteristics of BEV logistics vehicles**

The average single-time charging duration of BEV logistics vehicles in 2022 decreased from 2021.

The average single-time charging duration of BEV logistics vehicles in 2022 was 1.8 h, down 0.3 h from 2021 (Table 5.27). From the distribution of average single-time charging duration (Fig. 5.64), the proportion of vehicles with an average single-time charging duration of less than 1 h increased compared with the previous two years.

The distribution pattern of the number of BEV logistics vehicles with an average single-time charging duration was mostly consistent on both weekdays and weekends, and those with an average single-time charging duration of less than 2 h exceeded 70% (Fig. 5.65). There was little change in the working intensity of BEV logistics vehicles seven days a week given the basically consistent changes of charging duration on both weekdays and weekends.

The average single-time charging initial SOC of BEV logistics vehicles was 46.1%, with a slight decrease from past years.

The average single-time charging initial SOC of BEV logistics vehicles was 46.1% in 2022, showing a downward trend (Table 5.28). As the distribution shows (Fig. 5.66), the average single-time charging initial SOC of BEV logistics vehicles was concentrated at 40%–60%, and the proportion of vehicles in such range in 2022 slightly increased from past years. The distribution of vehicles featuring high charging initial SOC during weekends was higher that during weekdays (Fig. 5.67).

2. **Average daily charging characteristics of BEV logistics vehicles**

Logistics vehicles mainly charged in the rush hours in the morning, at noon, and in the evening, of which the proportion at noon and night was higher.

Table 5.27 Average single-time charging duration of BEV logistics vehicles over the years

Year	2020	2021	2022
Average single-time charging duration (h)	2.0	2.1	1.8

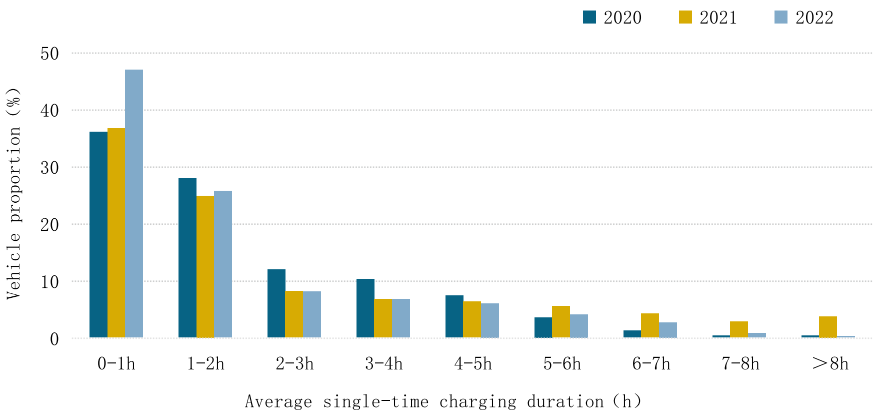


Fig. 5.64 Distribution of average single-time charging duration of BEV logistics vehicles—by year

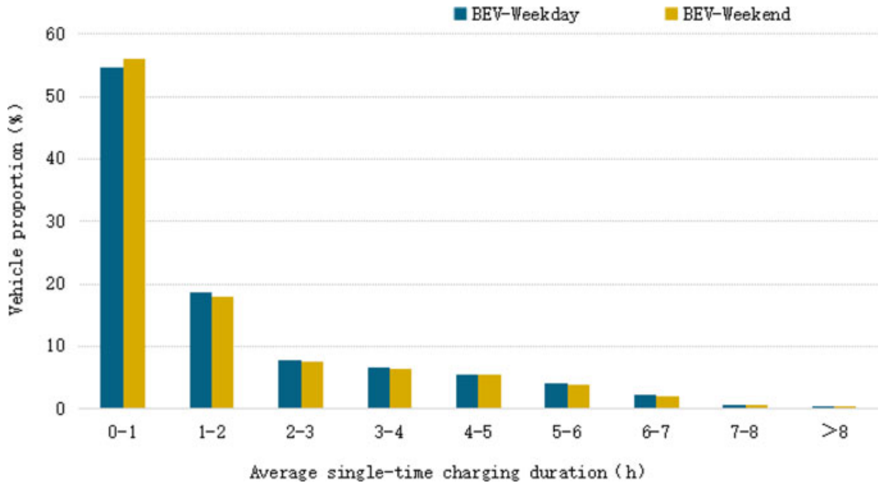


Fig. 5.65 Distribution of average single-time charging duration of BEV logistics vehicles in 2022—by weekday and weekend

Table 5.28 Average single-time charging initial SOC of BEV logistics vehicles over the years

Year	2020	2021	2022
Average single-time charging initial SOC (%)	49.0	48.4	46.1

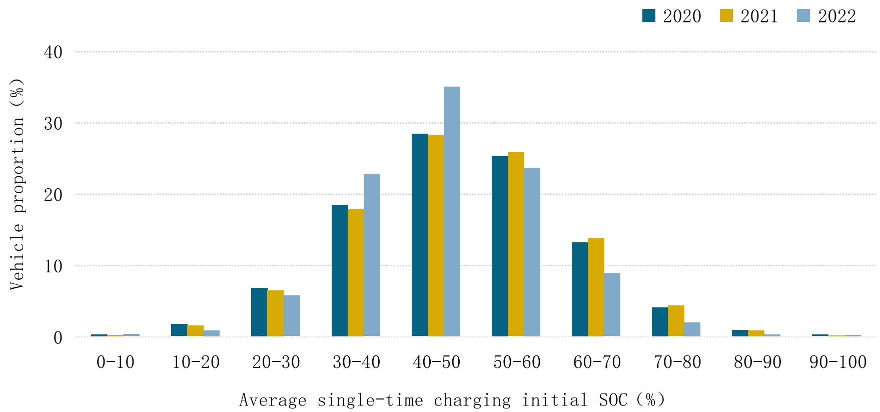


Fig. 5.66 Distribution of average single-time charging initial SOC of BEV logistics vehicles—by year

BEV logistics vehicles in 2022 mainly charged at three periods, namely at 07:00, at 13:00, and around 18:00–19:00 (Fig. 5.68). In view of the changes in the proportion of vehicles changing within the day, the proportion of BEV logistics vehicles charging after 08:00 in the morning in 2022 was significantly higher than that in

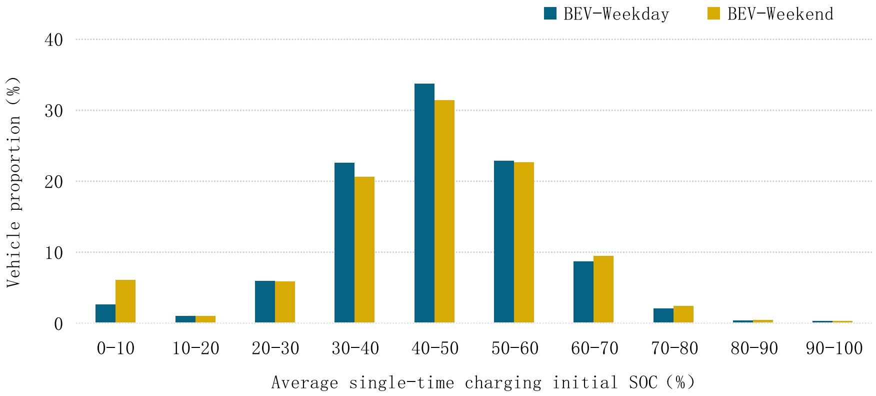


Fig. 5.67 Distribution of average single-time charging initial SOC of BEV logistics vehicles in 2022—by weekday and weekend

2021. According to the distribution of the proportion of vehicles in each period of time under different charging modes, the proportion of those with fast charging was significantly higher than that with slow charging (Fig. 5.69), indicating that BEV logistics vehicles preferred fast charging mode.

3. **Average monthly charging characteristics of BEV logistics vehicles**

The average monthly charging times of BEV logistics vehicles in 2022 logged 22.3, with a slight increase from 2020.

The average monthly charging times of BEV logistics vehicles read 22.3 in 2022, showing a YoY decrease, but an increase of 8.3% over 2020 (Table 5.29). As the distribution shows (Fig. 5.70), the average monthly charging times of BEV logistics vehicles fell in 30, with the proportion of vehicles concerned exceeding 75%.

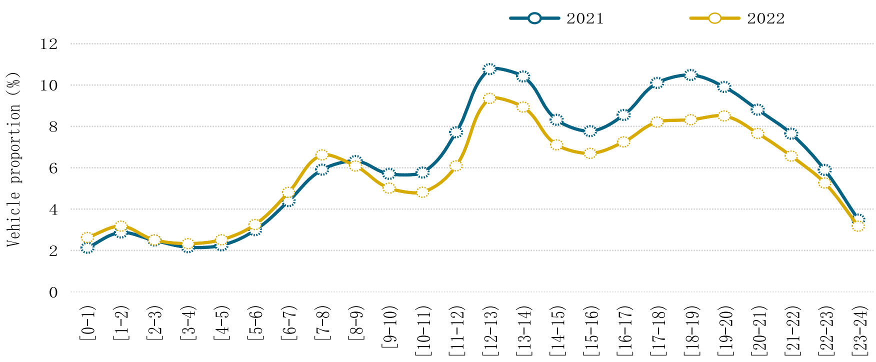


Fig. 5.68 Distribution of charging time of BEV logistics vehicles in 2022

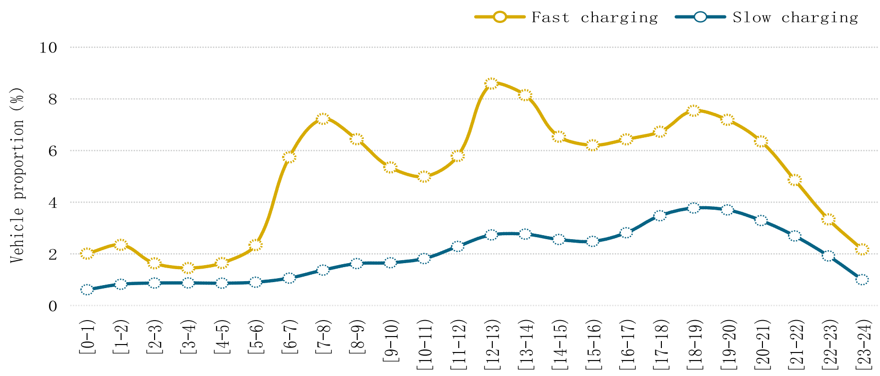


Fig. 5.69 Distribution of charging time of BEV logistics vehicles in 2022—by weekday and weekend

Table 5.29 Average monthly charging times of BEV logistics vehicles over the years

Year	2020	2021	2022
Average monthly charging times	20.6	25.7	22.3

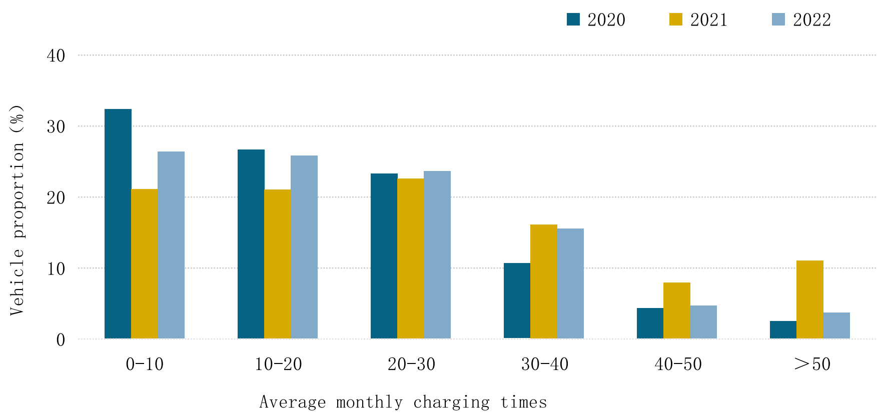


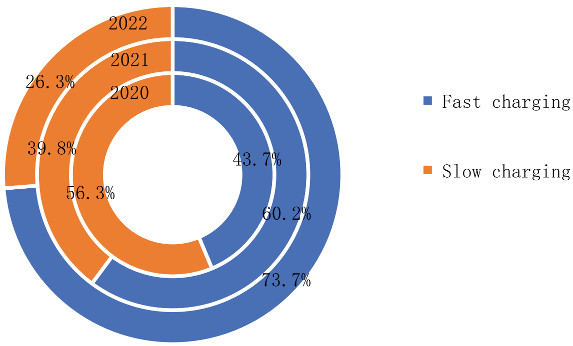
Fig. 5.70 Distribution of average monthly charging times of BEV logistics vehicles—by year

Considering the charging mode (Fig. 5.71), the proportion of BEV logistics vehicles taking fast charging increased year by year, and proportion of vehicles taking fast charging in 2022 reached 73.7%.

The average monthly fast charging times of BEV logistics vehicles steadily increased.

In 2022, the average monthly fast charging times of BEV logistics vehicles read 15.4, up 74.4% in 2020 and 1.9% in 2021 (Table 5.30). As the distribution shows (Fig. 5.72), the average monthly charging times of BEV logistics vehicles gradually

Fig. 5.71 Distribution of average monthly charging times of BEV logistics vehicles over the years—by fast charging and slow charging



concentrated to 10 to 30, during which the proportion of vehicles within such range reached 53%, up 15.6 percentage points year on year.

The average monthly slow charging times of BEV logistics vehicles in 2022 logged 5.6, with a significant decrease within the past three years.

The average monthly slow charging times of BEV logistics vehicles in 2022 logged 5.6 (Table 5.31), showing a fall in the past three years. Specifically, the proportion of BEV logistics vehicles with average monthly slow charging times of less than 10 was 82.3% (Fig. 5.73), and the number of BEV logistics vehicles using slow charging decreased. Under the coexistence of multiple charging modes, BEV logistics vehicles tended to choose fast charging considering the cost in time.

Average monthly charge of BEV logistics vehicles in 2022.

Table 5.30 Average monthly fast charging times of BEV logistics vehicles over the years

Year	2020	2021	2022
Average monthly fast charging times	9.0	15.4	15.7

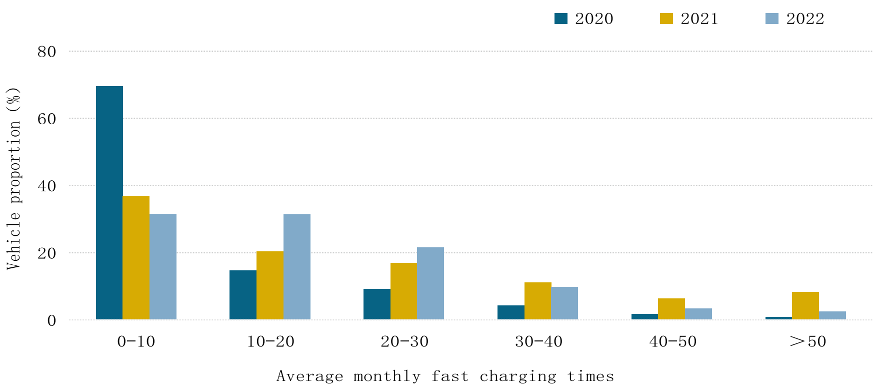


Fig. 5.72 Distribution of average monthly fast charging times of BEV logistics vehicles—by year

Table 5.31 Average monthly slow charging times of BEV logistics vehicles over the years

Year	2020	2021	2022
Average monthly slow charging times	11.6	10.2	5.6

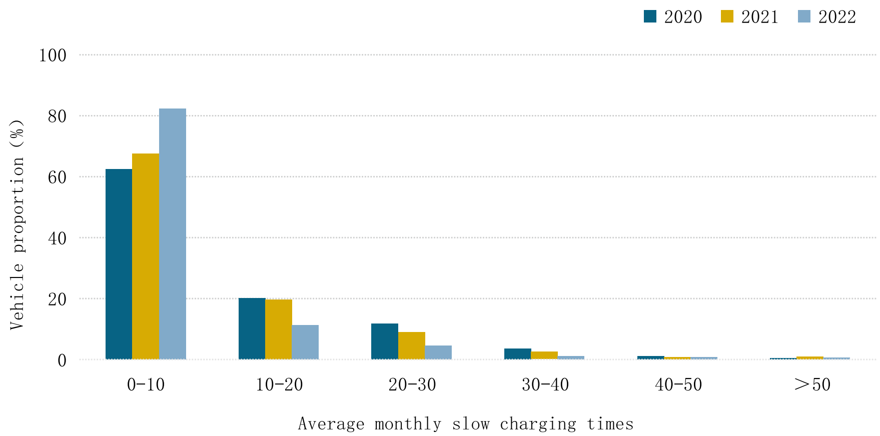


Fig. 5.73 Distribution of average monthly slow charging times of BEV logistics vehicles—by year

The operational capacity of logistics vehicles is still recovering from the impact of the pandemic (Table 5.32). The average monthly charge of BEV logistics vehicles reached 468.1kWh in 2022, showing a YoY decrease, but an increase of 7.5% over 2020. As the distribution shows (Fig. 5.74), the proportion of BEV logistics vehicles using fast charging with an average monthly charge of more than 400kWh increased from 20.1% in 2020 to 29%% in 2022 by 8.9 percentage points. Based on the average power consumption of BEV logistics vehicles of 32.2kWh/100 km in 2022, nearly 20% of BEV logistics vehicles drove a daily mileage exceeding 120 km.

The average monthly charge of BEV logistics vehicles using slow charging was mainly concentrated within 200kWh, and the proportion of vehicles with such range rose from 69.4% in 2020 to 85.8% in 2022 (Fig. 5.75), indicating that fast charging was more favored by BEV logistics vehicles.

Table 5.32 Average monthly charge of BEV buses over the years

Year	2020	2021	2022
Average monthly charge (kWh)	435.6	552.5	468.1

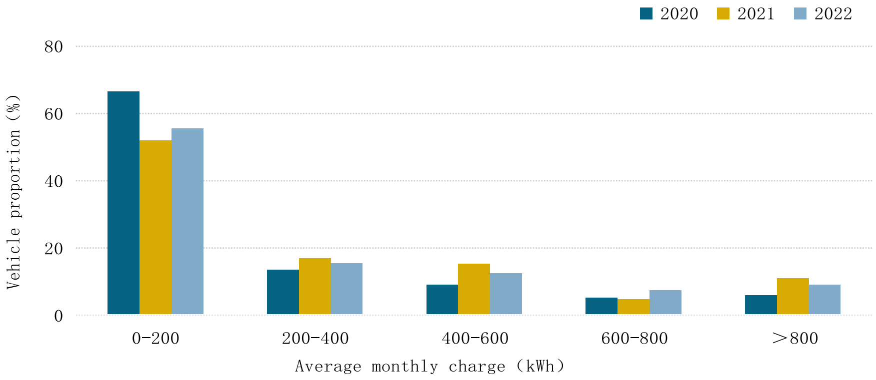


Fig. 5.74 Distribution of average monthly charge of BEV logistics vehicles—by year for fast charging

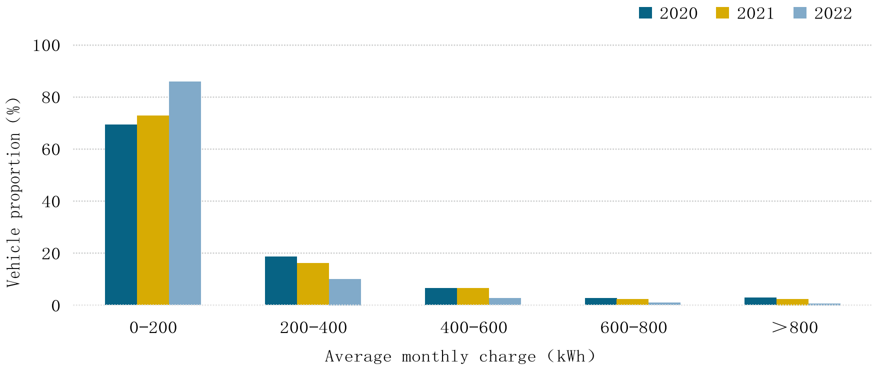


Fig. 5.75 Distribution of average monthly charge of BEV logistics vehicles—by year for slow charging

5.2.6 Charging Characteristics of BEV Buses

1. **Average single-time charging characteristics of BEV buses**

The average single-time charging duration of BEV buses was mainly concentrated around 1h, mostly consistent with that in previous years.

The single-time charging duration of BEV buses was 1.2 h in 2022, mostly consistent with that in previous years (Table 5.33). The proportion of BEV buses with an average single-time charging duration of less than 2 h in 2022 was the highest, with the proportion of vehicles over the years of more than 70% (Fig. 5.76).

The distribution of charging initial SOC maintained consistent over the years, and the average single-time charging initial SOC of BEV buses in 2022 was 56.5%.

Table 5.33 Average single-time charging duration of BEV buses over the years

Year	2020	2021	2022
Average single-time charging duration (h)	1.0	1.1	1.2

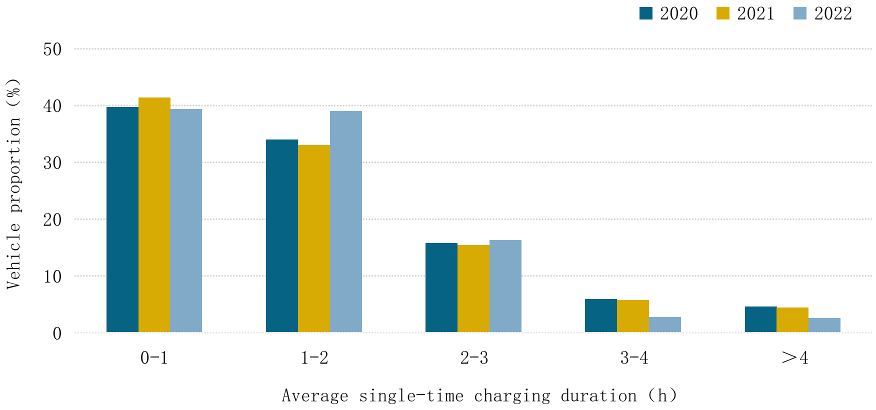


Fig. 5.76 Distribution of average single-time charging duration of BEV buses—by year

In 2022, the average single-time charging initial SOC of BEV buses was 56.5%, which was basically the same as that in the past two years (Table 5.34). As the distribution shows (Fig. 5.77), the average single-time charging initial SOC of BEV buses concentrated at 40%–70%, and the proportion of vehicles within such range in 2022 exceeded 75%. With the gradual completion of the charging infrastructure of public transport stations, bus charging has now become accessible where needed, and the single-time charging initial SOC basically remained the same over the years. In addition, the regular charging operation mechanism lifted the initial SOC.

The average charging rate of buses has basically remained stable over the years at above 0.7C. BEV buses mainly used fast charging for power replenishment. From changes in the average charging rate of BEV buses over the years (Table 5.35), the charging rate of BEV buses has basically remained stable over the years at above 0.7C, namely 1 h-2 h on average for full replenishment.

The proportion of BEV buses with a charging rate ranging from 0.2C to 0.8C was relatively high, reaching 71.8% (Fig. 5.78), indicating that most new energy buses took about 2 h-3 h for full replenishment. The proportion of BEV buses with a charging rate ranging from 0.2C to 0.8C kept increasing, from 64.0% in 2020 to 71.8% in 2022, with a higher concentration of vehicles in such range.

Table 5.34 Average single-time charging initial SOC of BEV buses over the years

Year	2020	2021	2022
Average single-time charging initial SOC (%)	58.0	54.6	56.5

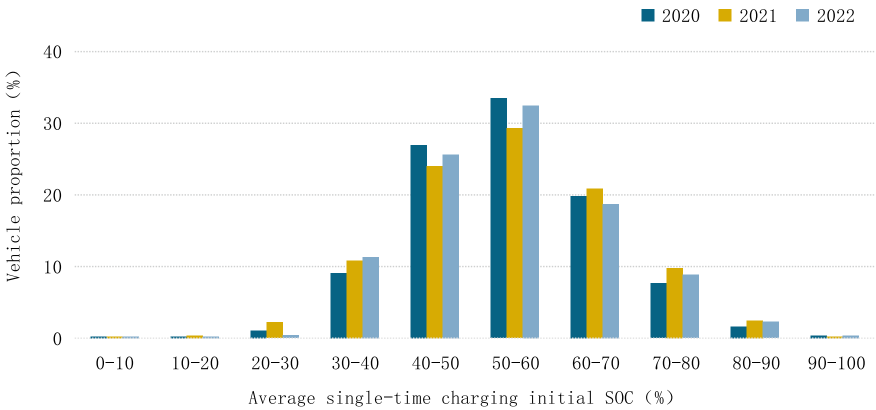


Fig. 5.77 Distribution of average single-time charging initial SOC of BEV buses—by year

Table 5.35 Average charging rate of BEV buses over the years

Year	2020	2021	2022
Average Charging Rate of Pure Electric Bus (C)	0.78	0.81	0.72

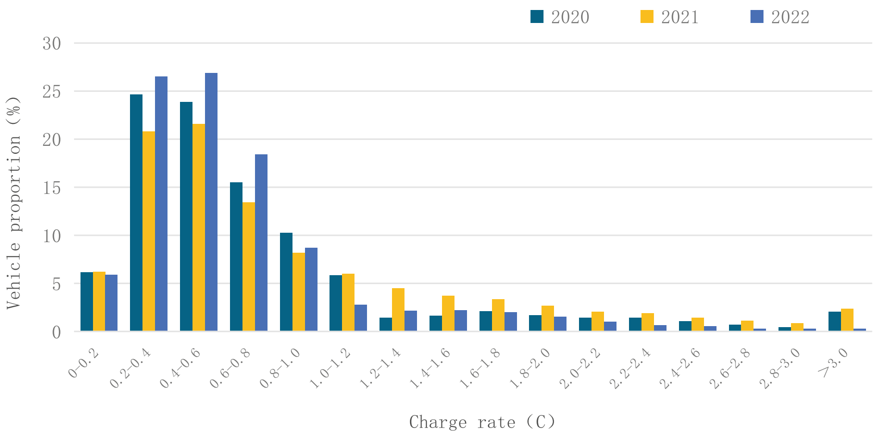


Fig. 5.78 Distribution of charging rate of BEV buses over the years

2. **Average daily charging characteristics of BEV buses**

BEV buses mainly charged in the daytime, especially at 12:00 (noon) and in the evening.

As the distribution shows (Fig. 5.79), the charging peaks of BEV buses were found at 12:00 (noon), 22:00, and 03:00, representing a higher attendance in the morning and at night with higher frequency of dispatching and a smaller number of charges.

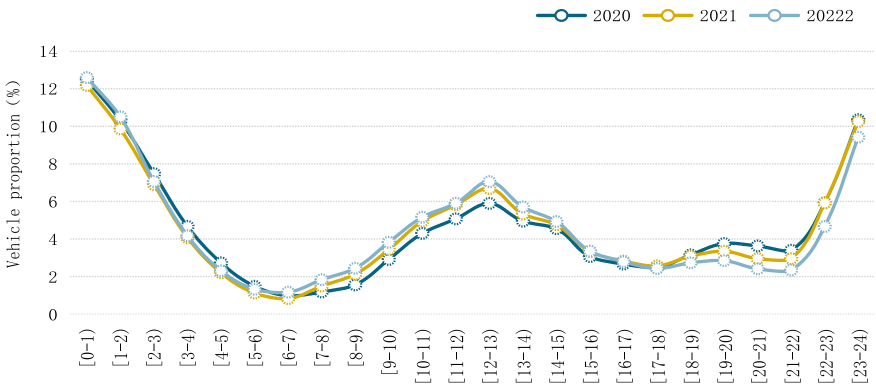


Fig. 5.79 Distribution of charging time of BEV buses—by year

Table 5.36 Average monthly charging times of BEV buses over the years

Year	2020	2021	2022
Average monthly charging times	32.3	44.7	33.6

3. Average monthly charging characteristics of BEV buses

The average monthly charging times of BEV buses in 2022 were 33.6 times, higher than that in 2020.

The average monthly charging times of BEV buses in 2022 were 33.6 times, with a slight increase compared with 2020 (Table 5.36). The average monthly charging times of BEV buses mainly ranged from 20 to 30 (Fig. 5.80), with the proportion of vehicles concerned accounting for 28.6%.

The average monthly charge of BEV buses was 2,071.5kWh in 2022, with a decrease from 2021 and an increase from 2020.

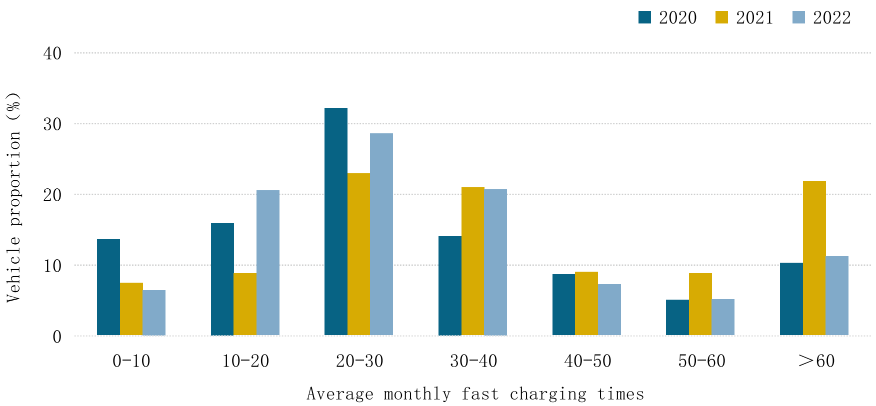


Fig. 5.80 Distribution of average monthly charging times of BEV buses—by year

Table 5.37 Average monthly charge of BEV buses over the years

Year	2020	2021	2022
Average monthly charge (kWh)	1,913.1	2,607.7	2,071.5

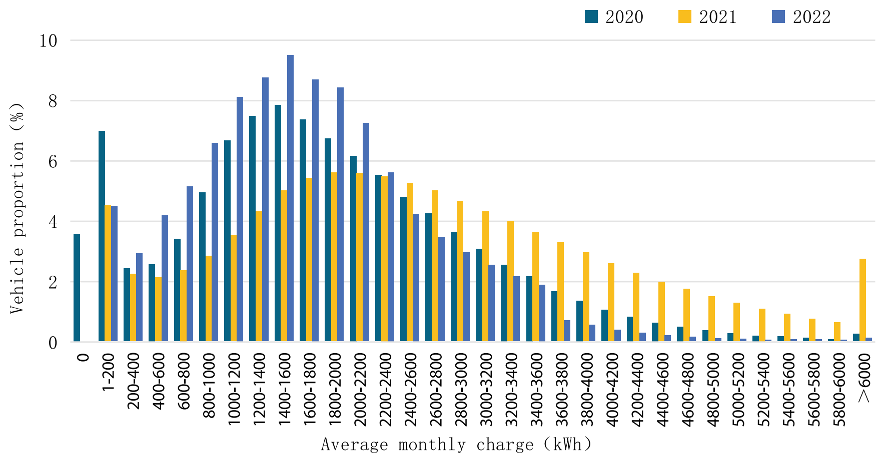


Fig. 5.81 Distribution of average monthly charge of BEV buses—by year

In 2022, the average monthly charge of BEV buses was 2,071.5kWh, with an increase of 8.3% from 2020 (Table 5.37). As the distribution shows (Fig. 5.81), the distribution of average monthly charge of BEV buses in 2022 was basically the same as that in 2020. In 2022, a larger number of vehicles fell in the range of 1,000kWh and 3,000kWh for average monthly charge than that in 2020, with the proportion increasing from 60.6% in 2020 to 67.1% in 2022.

5.2.7 Charging Characteristics of BEV Heavy-Duty Trucks

1. **Average single-time charging characteristics of BEV heavy-duty trucks**

The average single-time charging duration of BEV heavy-duty trucks was 1.6h, basically the same as that in previous years.

The average single-time charging duration of BEV heavy-duty trucks in 2022 was 1.6 h, mostly consistent with that in previous years (Table 5.38). As the distribution shows (Fig. 5.82), the proportion of vehicles with a single-time charging duration of less than 1 h increased from 21% in 2020 to 90.4% in 2022. The improvement of charging facilities increased the application of fast charging. Since the charging power of fast charging piles gradually increased, charging time kept shortening.

Table 5.38 Average single-time charging duration of BEV heavy-duty trucks over the years

Year	2020	2021	2022
Average single-time charging duration (h)	1.5	1.5	1.6

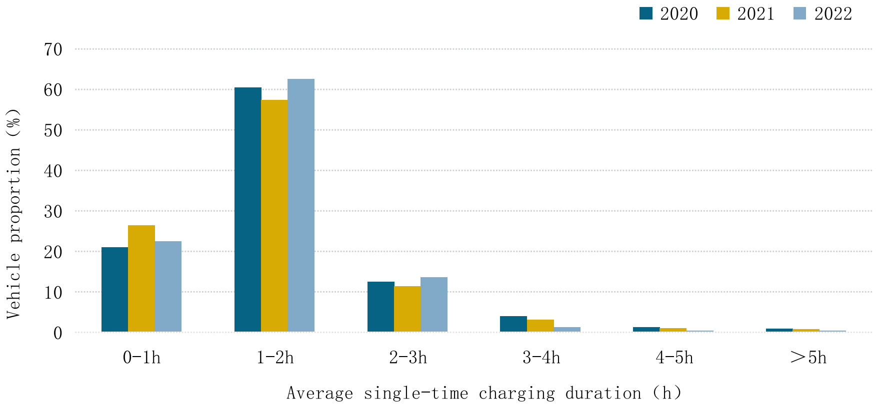


Fig. 5.82 Distribution of average single-time charging duration of BEV heavy-duty trucks—by year

The average single-time charging initial SOC of BEV heavy-duty trucks was 47.8%, mostly the same as that in previous years.

The average single-time charging initial SOC of BEV heavy-duty trucks was 47.8% in 2022, which was mostly the same as that in previous years (Table 5.39). As the distribution shows (Fig. 5.83), the average single-time charging initial SOC of BEV heavy-duty trucks was mainly from 40 to 60%, and the proportion of vehicles concerned exceeded 60% for years. Thanks to the improvement of charging infrastructure for BEV heavy-duty trucks, the average single-time charging initial SOC of BEV heavy-duty trucks maintained basically unchanged in the past three years.

2. **Average daily charging characteristics of BEV heavy-duty trucks**

The charging time for BEV heavy-duty trucks throughout the day was mainly from 16:00 to 19:00 and in the early morning.

By the distribution of vehicles in each charging period throughout the day (Fig. 5.84), the charging time of BEV heavy-duty trucks mainly fell between 16:00 and 19:00 and in the early morning. In 2022, the proportion of BEV heavy-duty trucks are scattered in different periods of time.

Table 5.39 Average single-time charging initial SOC of BEV heavy-duty trucks over the years

Year	2020	2021	2022
Average single-time charging initial SOC (%)	48.6	49.5	47.8

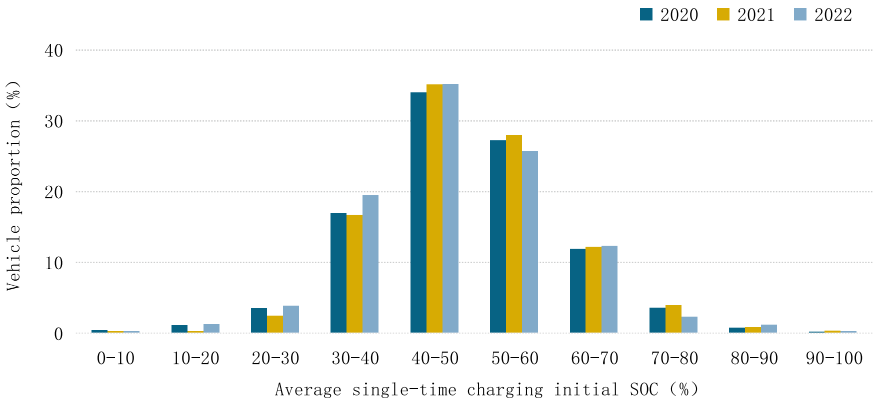


Fig. 5.83 Distribution of average single-time charging initial SOC of BEV heavy-duty trucks—by year

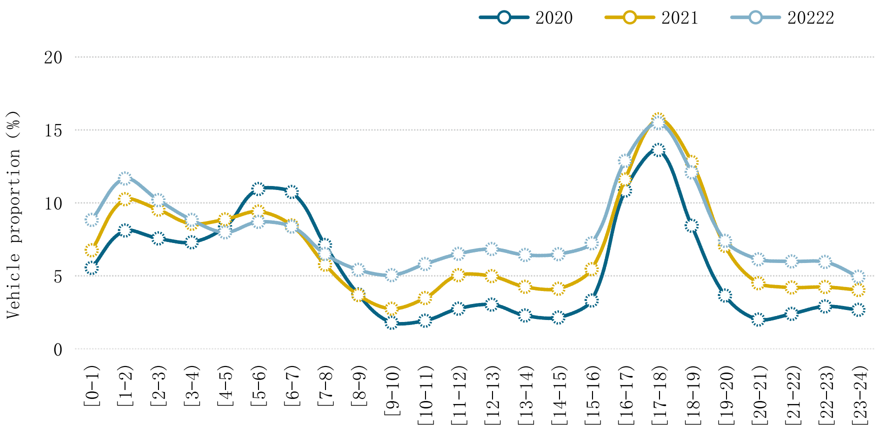


Fig. 5.84 Distribution of charging time of BEV heavy-duty trucks—by year

3. **Average monthly charging characteristics of BEV heavy-duty trucks**

The average monthly charging times of BEV heavy-duty trucks reached 29.4, with a slight growth over 2020 and 2021.

The average monthly charging times of BEV heavy-duty trucks were 29.4 times in 2022, showing a slight growth from 2020 and 2021 (Table 5.40). As the distribution shows (Fig. 5.85), the average monthly charging times of most heavy-duty trucks fell between 20 and 40, with the proportion of such trucks accounting for 50.5%.

Considering the charging mode, BEV heavy-duty trucks mainly took fast charging for power replenishment. As shown in Fig. 5.86, the proportion of fast charging times for BEV heavy-duty trucks increased year by year, and the highest data was recorded in 2022, reaching 83.7%. Since commercial vehicles laid higher stress on time costs,

Table 5.40 Average monthly charging times of BEV heavy-duty trucks over the years

Year	2020	2021	2022
Average monthly charging times	25.7	28.7	29.4

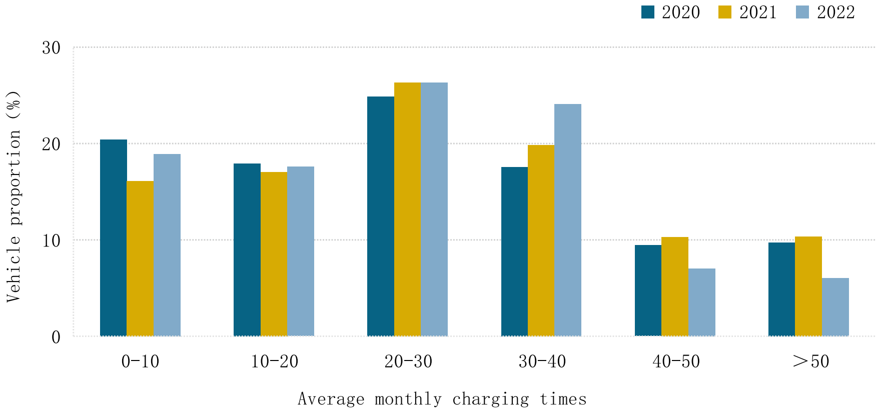


Fig. 5.85 Distribution of average monthly charging times of BEV heavy-duty trucks—by year

shortening the charging time becomes an important approach to speed up the energy transformation and ensure the operational efficiency of the fleet for BEV heavy-duty trucks.

The average monthly fast charging times of BEV heavy-duty trucks showed an increasing trend yearly.

The average monthly fast charging times of BEV heavy-duty trucks were 24.6 times in 2022, showing stable growth for the past three years (Table 5.41). As the

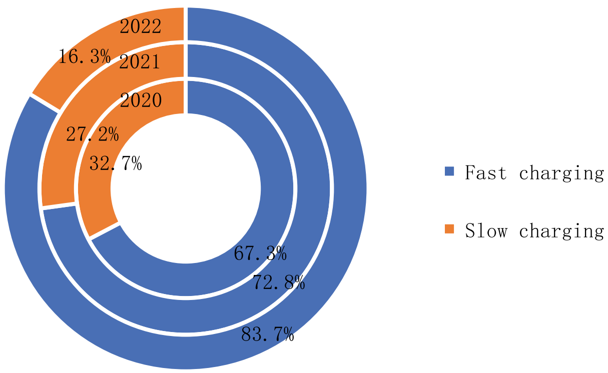


Fig. 5.86 Distribution of average monthly charging times of BEV heavy-duty trucks over the years—by fast charging and slow charging

Table 5.41 Average monthly fast charging times of BEV heavy-duty trucks over the years

Year	2020	2021	2022
Average monthly fast charging times	17.3	20.9	24.6

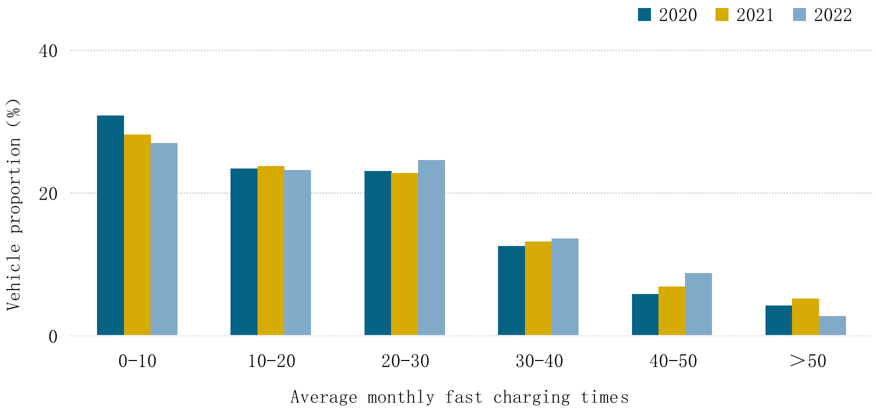


Fig. 5.87 Distribution of average monthly charging times of BEV heavy-duty trucks—by year for fast charging

distribution manifests (Fig. 5.87), the proportion of BEV heavy-duty trucks with average monthly fast charging times between 20 and 50 increased from 41.5% in 2020 to 47.1% in 2022.

The monthly average slow charging times of BEV heavy-duty trucks showed an overall downward trend.

The average monthly slow charging times of BEV heavy-duty trucks in 2022 read 4.8 times, with a slight decrease in the past three years (Table 5.42). As the distribution indicates (Fig. 5.88), the proportion of BEV heavy-duty trucks with less than 10 slow charging times per monthly on average increased to 72.1% in 2022.

The average monthly charge of BEV heavy-duty trucks increased steadily in 2022.

In 2022, the average monthly charge of BEV heavy-duty trucks was 4,601.7kWh, with an increase of 6.7% from 2020 and 1.9% from 2021 (Table 5.43). As the distribution shows, BEV heavy-duty trucks with an average monthly charge of more than 1,000kWh accounted for the absolute majority (Fig. 5.89).

Table 5.42 Average monthly slow charging times of BEV heavy-duty trucks over the years

Year	2020	2021	2022
Average monthly slow charging times	8.4	7.8	4.8

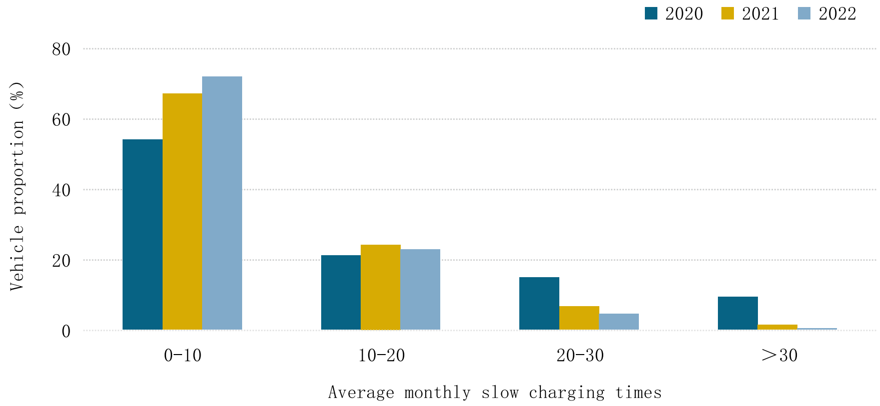


Fig. 5.88 Distribution of average monthly charging times of BEV heavy-duty trucks—by year for slow charging

Table 5.43 Average monthly charge of BEV heavy-duty trucks over the years

Year	In 2020	2021	2022
Average monthly charge (kWh)	4.314.7	4.516.1	4.601.7

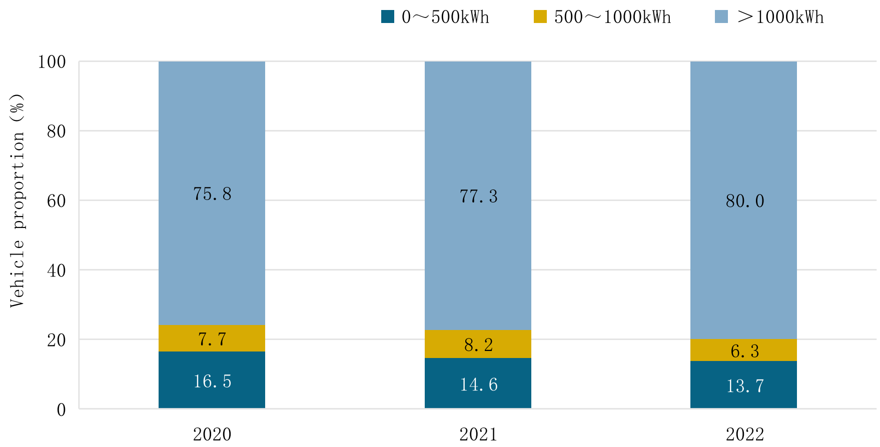


Fig. 5.89 Distribution of average monthly charge of BEV heavy-duty trucks—by year for fast charging

5.3 Analysis of User Charging Behavior in Different Charging Scenarios

Considering that under different charging scenarios, there may be great differences in the type of charged vehicle, the distribution of charging start time, and the charging duration, this Section, based on four different charging scenarios, namely urban public charging station, community charging station, expressway charging station, and township charging station, analyzes the characteristics of users' charging behaviors.

5.3.1 Analysis of Charging Behavior of Users in Public Charging Stations

Fast-changing mode took a dominant position in the public charging stations, and the charging duration was less than 1h.

A public charging station is the station built in a public place in the city and accessible to all vehicles in the whole society. In order to accurately describe the charging behavior of users in public charging stations, this Section is intended to identify the features related to public charging stations by fitting vehicle charging data and charging station locations in a city. As shown in Fig. 5.90, the service targets of public charging stations were mainly private cars and taxis, e-taxis, and the proportion of passenger cars charged in public stations in 2022 was 80.2%, up 5.2 percentage points year on year.

Fast charging piles were the major charging facilities in the public charging stations, which were operated in the manner close to public gas stations. As shown in Fig. 5.91, in 2022, the proportion of private cars, taxis, e-taxis, logistics vehicles,

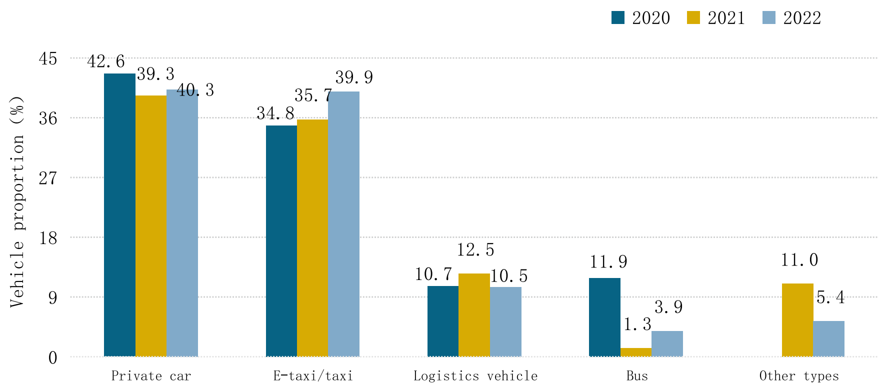


Fig. 5.90 Difference in distribution of vehicles charged in public charging stations—by key segments

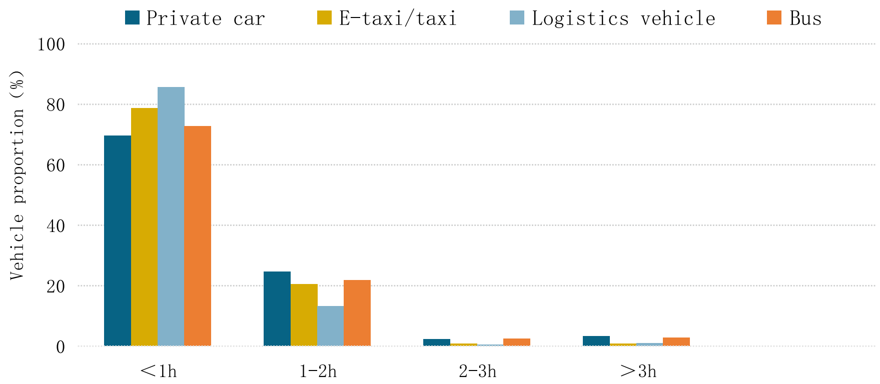


Fig. 5.91 Distribution of single-time charging staying duration of vehicles in public charging stations—by key segments

and buses staying in public charging places for less than 1 h all accounted for higher than 60%. With the rapid growth of NEV holding volume, the proportion of high-power charging piles in public charging stations kept increasing, which might result in higher pressure on power grid during the peak hours of charging.

5.3.2 Analysis of Charging Behavior of Users in Community Charging Stations

Private cars and taxis/e-taxis played a major role among the vehicles charging in community stations, and the charging duration was less than 1h in general.

community charging station is a station established to provide external services within the boundaries of urban residential neighborhoods. In order to accurately describe the charging behavior of users in community charging stations, this Section is intended to identify the features related to community charging stations by fitting vehicle charging data and charging station locations in a city. As indicated in Fig. 5.92, the community charging stations were mainly intended for private cars, taxis/e-taxis, and other vehicles, of which private cars dominated. The proportion of private cars charged at community charging stations was above 60% in 2020 and 2021. Regarding the changes in the type of vehicles charged over the years, the proportion of private cars and taxis/e-taxis charging in community charging stations increased.

As shown in Fig. 5.93, the single-time staying duration of private cars and taxis/e-taxis in community charging stations was less than 1 h, and the proportion of private cars and taxis/ e-taxis with a staying duration of less than 1 h after charging reached 77.5%, significantly higher than that of private cars.

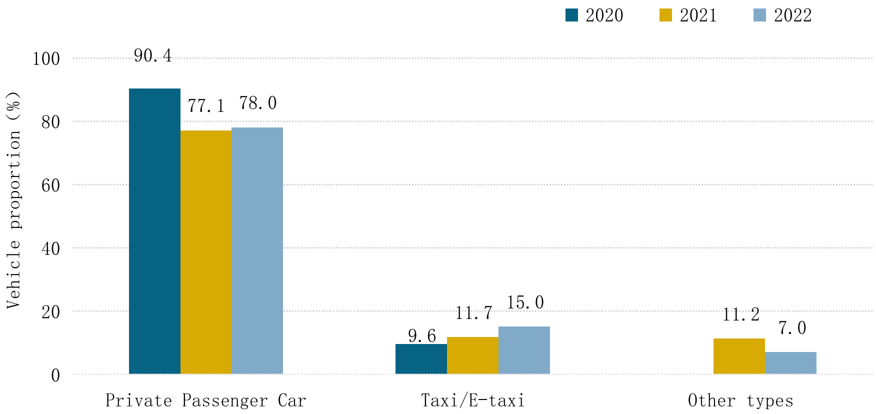


Fig. 5.92 Distribution of vehicles in community charging stations over the years—by key segments.

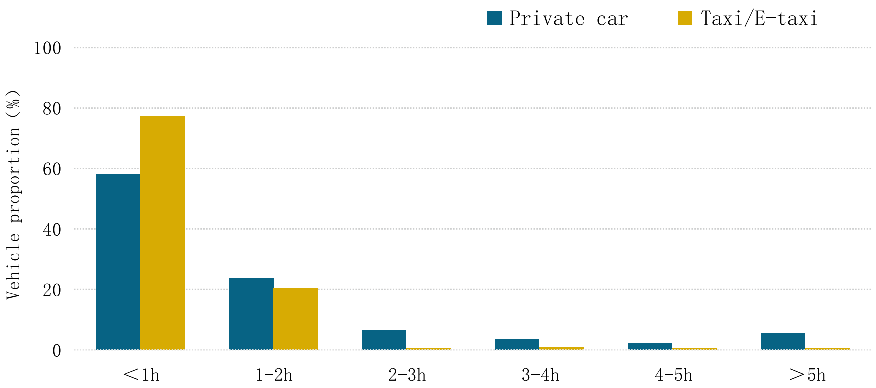


Fig. 5.93 Distribution of single-time charging staying duration of vehicles in community charging stations—by key segments

5.3.3 Analysis of Charging Behavior of Users in Expressway Charging Stations

The charging stations along the expressway were mainly for private cars, which stayed less than 1h after charging.

An expressway charging station is a station established on the expressway and accessible to all vehicles in the society. In order to accurately describe the charging behavior of users in expressway charging stations, this Section is intended to identify the features related to expressway charging stations by fitting vehicle charging data and charging station locations in a city. In view of Fig. 5.94, the proportion of private cars charging in expressway charging stations was higher, and, with the rapid growth of market demand, the proportion of private cars charging in expressway charging stations grew steadily from 43.6% in 2020 to 51.4% in 2022. With the growing holding volume of private cars and demand for long-distance self-driving tour, the charging pressure along the expressway keeps increasing during holidays. It is imperative to make rational plans for building charging facilities along the expressway and conducting information operation and normal maintenance.

In terms of the distribution of average single-time charging duration (Fig. 5.95), the staying duration of private cars, taxis/e-taxis, and logistics vehicles at expressway charging stations in 2022 mainly fell within 1 h, and the proportion of vehicles in such range was about 90%.

Charging stations along expressways exhibit typical holiday peak characteristics.

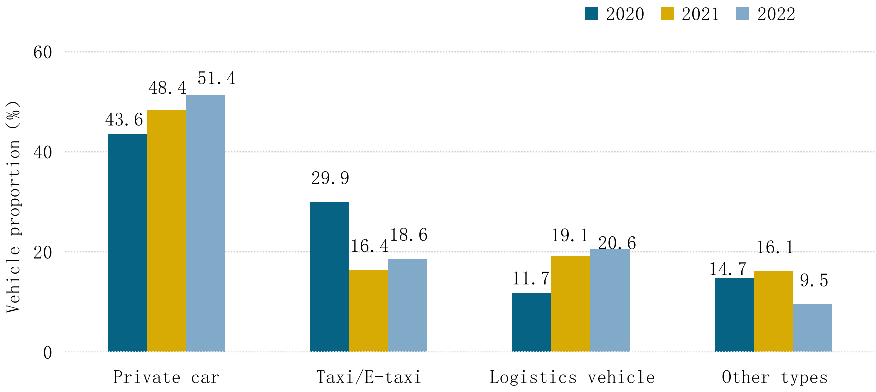


Fig. 5.94 Distribution of vehicles charged in expressway charging stations—by key segments

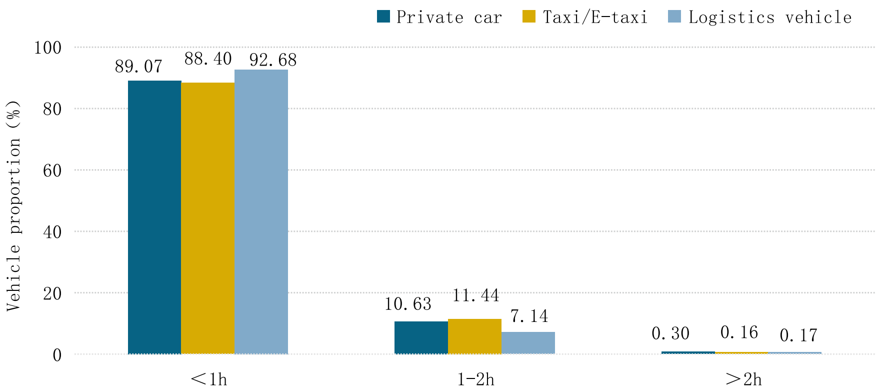


Fig. 5.95 Distribution of single-time charging staying duration of vehicles in expressway charging stations-by key segments

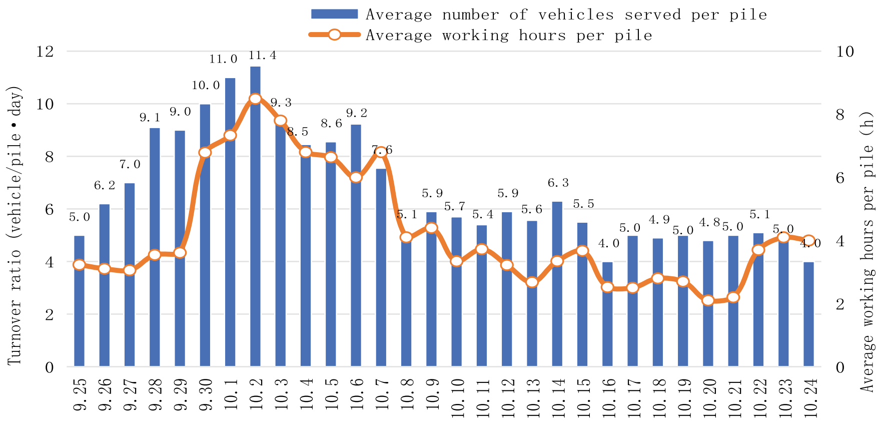


Fig. 5.96 Daily turnover rate of charging stations along the intercity expressway in the Yangtze River Delta before and after the National Day in 2022

Taking the National Day of 2022 as an example, 66 charging stations along the Shanghai-Suzhou-Wuxi-Changzhou intercity expressway in the Yangtze River Delta were selected as the research objects to analyze the charging and waiting characteristics of vehicles in expressway charging stations in order to provide a relevant reference for further optimizing the layout of expressway charging stations. According to the statistics, the average daily turnover rate of a single pile of 66 charging stations along the Shanghai-Suzhou-Wuxi-Changzhou intercity expressway in the Yangtze River Delta increased from 6.5 vehicles/pile·day in 2021 to 6.7 vehicles/pile·day in 2022. The weekly turnover rate of charging piles during National Day was significantly higher than that on normal days. In specific, the turnover rate during the National Day holiday in 2022 (October 1–7), the weekly turnover rate reached 9.4 vehicles/pile·day, 180.6% of that on normal days (5.2 vehicles/pile·day) (Fig. 5.96). In terms of the working hours of charging piles at charging stations along the expressway, the average charging duration per pile during the National Day was about twice as long as that on a normal day, and the peak characteristics of the holiday were more highlighted.

5.3.4 Analysis of Charging Behavior of Users in Township Charging Stations

The township charging stations were mainly used by private cars, with the proportion of taxis/e-taxis growing rapidly.

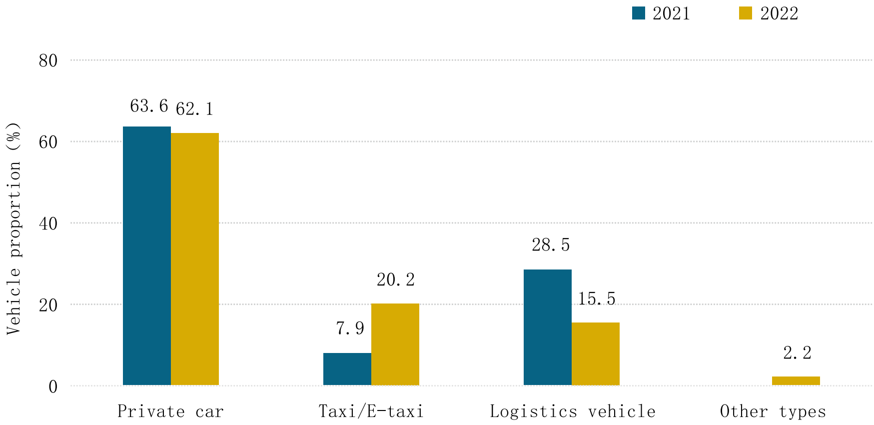


Fig. 5.97 Difference in distribution of vehicles charged in township charging stations in 2021—by key segments

A township charging station is a station established to provide external services within the territorial scope of a township. In order to accurately describe the charging behavior of users in township charging stations, this Section is intended to identify the features related to township charging stations by fitting vehicle charging data and charging station locations in a township. As Fig. 5.97 indicates, as the main service object of the charging stations in the township, private cars accounted for more than 60% of the total. In terms of annual changes, in 2022, the proportion of new energy taxis/e-taxis charged was 20.2%, a significant increase year-on-year. Thanks to the superior operating costs of new energy taxis/e-taxis over traditional fuel vehicles, new energy taxis/e-taxis were growing rapidly within townships and villages.

In respect of the single-time charging staying duration (Fig. 5.98), the charging duration of private cars, taxis/e-axis, and logistics vehicles in township charging stations was concentrated within 1 h, and the proportion of each type of vehicles in such range was above 60%. Compared with private cars, the single-time charging staying duration of operating vehicles was shorter.

5.4 Charging Characteristics of New and Old Residential Areas in Typical Cities

Charging infrastructure provides battery swapping and swapping services for BEVs as an important infrastructure featuring transportation and energy integration. With the rapid growth of the holding volume of NEVs in China, the charging infrastructure was facing improper structure in layout and distribution. In particular, charging infrastructure is difficult to be properly built and established, while the newly-built

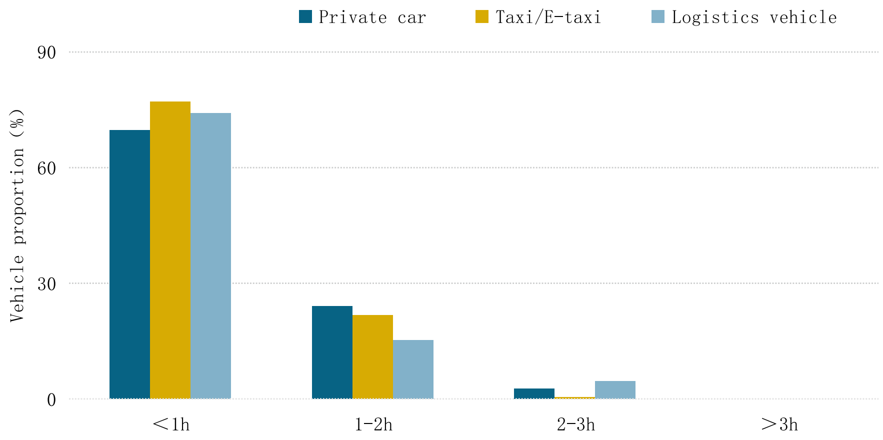


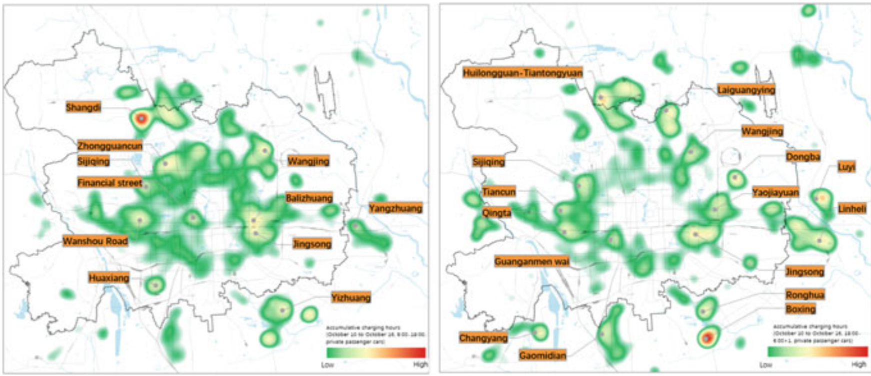
Fig. 5.98 Distribution of single-time charging staying duration of vehicles in township charging stations—by key segments

residential areas have certain advantages in contrast. Referring to the *Charging Infrastructure Monitoring Report of Major Cities in China in 2023* jointly compiled by China Academy of Urban Planning & Design and the National Big Data Alliance of New Energy Vehicles, this Section analyzes the spatial and temporal distribution of charging demand for new energy passenger vehicles, the convenience of charging for different types of passenger vehicles, and the convenience of charging for passenger vehicles within the scope of different regions in Beijing, with the aim to provide suggestions for the development of the construction of NEV charging facilities for new and old residential areas and boost the growth of NEV industry.

5.4.1 Temporal and Spatial Distribution of Charging Demand for Passenger Cars by Type

The charging position of private passenger cars in the nighttime and the daytime was highly consistent with that in job-housing spaces.

The charging demand for private passenger cars in the daytime in Beijing was mainly in employment centers, while that in the nighttime was mainly in major residential areas (Fig. 5.99). During the day, the charging duration in Shangdi Street had the highest record, and the charging demand in major employment centers around Tongzhou District, the China World Trade Center, Financial Street, Wanshou Road, Wangjing Subdistrict, Zhongguancun, Huaxiang Street, and Yizhuang Area was high. At night, Huilongguan-Tiantongyuan region, Wangjing Subdistrict, Jinsong, Qingta, Guang'anmenwai Subdistrict, Tiancun Village, Sijiqing, and other areas showed high charging demand, while Boxing Street in Yizhuang logged the highest charging demand within the whole city. However, for the lack of charging infrastructure, the



(1) Charging Hours in the Daytime (2) Charging Hours in the Nighttime

Fig. 5.99 Relationship between charging position and job-housing space of private passenger cars at different periods of time

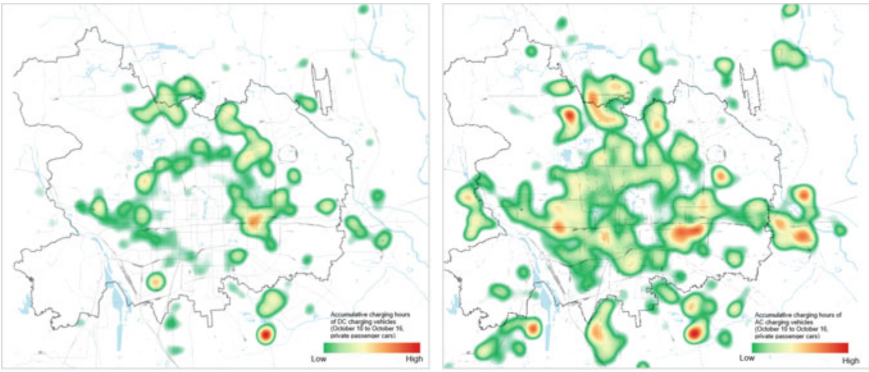
charging demand of the old residential areas in Dongcheng and Xicheng Districts failed to be satisfied in the daytime and nighttime.

The total charging hours and space of private passenger with DC charging cars were less than those with AC charging.

DC charging has not yet become the mainstay of the charging of private passenger cars. The DC charging hours of private passenger cars was only about 77.0% of AC charging hours (Fig. 5.100). DC charging features good spatial continuity in the expressway loop in the north of the city, with high demand for DC charging in such regions as the China World Trade Center, Wangjing Subdistrict, Huilongguan-Tiantongyuan section, Shangdi, and Sijiqing. There lied an uncovered area of DC charging infrastructure in the south of Beijing. The coverage of AC charging was significantly larger than that of DC charging, with high demand for charging in suburban settlements around Changping, Tongzhou, Daxing, Liangxiang, and Mentougou.

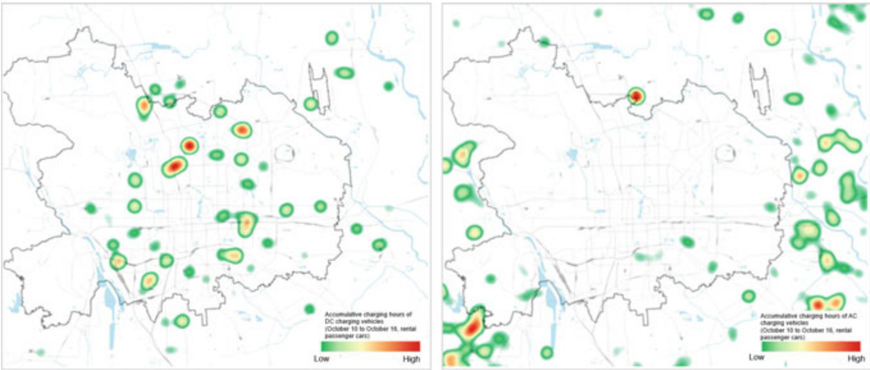
For rental passenger cars, DC charging mainly centered in the downtown areas, while AC charging in the surrounding areas.

The spatial distribution of DC charging was consistent with that of charging in the daytime. Xueyuan Road, Laiguangying, Shuangjing, Shilihe, Huaxiang, and Wulidian on the ring roadfeatured high charging hours (Fig. 5.101). AC charging was spatially far away from the downtown. Huilongguan-Tiantongyuan section in Changping District in the north, Nangong in the southwest, and Sanjianfang in the southeast are the three main suburban charging areas, while outer suburban charging areas were mainly in Fangshan District.



(1) AC Charging Hours (b) DC Charging Hours

Fig. 5.100 Relationship between charging hours and spatial scope of private passenger cars under different charging modes



(1) AC Charging Hours (b) DC Charging Hours

Fig. 5.101 Relationship between charging hours and spatial scope of rental passenger cars under different charging modes

5.4.2 Analysis of Charging Convenience of Passenger Cars by Type

The samples of NEVs in UPOR was sourced as of the end of December 2022 at the locations where NEVs were usually parked at night during the period from October to December 2022 as the points of attribution of the vehicles. October 2022 was selected as the month of characteristics for charging convenience indicator, for which the proportion of charging times, charging degrees, and charging hours of the NEVs within a certain radius (500 m, 1 km, 2 km, 5 km, and 10 km) in the UPOR at night to the total the month of characteristics. The indicator for the UPOR in the nighttime in this Section was selected from the period of October to December 2022. The locations where vehicles were parked for more than four hours between 18:00 and 06:00 the next day and had the highest number of stops were assigned as the indicators.

The charging convenience of private passenger cars within 500 meters of the UPOR was poor and improved rapidly within 1km.

According to the statistics, the average charging times of private passenger cars in Beijing held an account of 56% within 500 m around the UPOR, which is lower than the average (70%) for rental passenger cars and the average (79%) for buses (Fig. 5.102). In terms of the distribution (Fig. 5.103), 68.7% of private passenger cars within 500 m had charging behavior; when the radius increased from 500 m to 1 km, the average of the proportion of charging times of private passenger cars increased rapidly to 70%, and approximately 85% of the cars could be recharged within 500 m of UPOR. It reflected the urgent demand of private electric vehicle owners in Beijing for charging within 1 km around UPOR and also indicated that whether charging is available within 1 km of UPOR is an important factor affecting the promotion of private passenger cars. As the radius gradually increased to 10 km, the average proportion of charging times for private passenger cars countered that of rental passenger cars and buses, reaching 88%, which was related to the wide range and type of charging piles available for private passenger cars, including private and public piles at the UPOR and special and public piles at the second parking locations (e.g., workplace).

The driving and charging characteristics of private passenger cars were positively correlated with the convenience of charging within 500 meters of the UPOR.

The correlation analysis of charging convenience within 500 m of the UPOR was conducted based on the results of the index set of each street in townships Beijing. The results (Fig. 5.104) showed that the average charging duration and average monthly

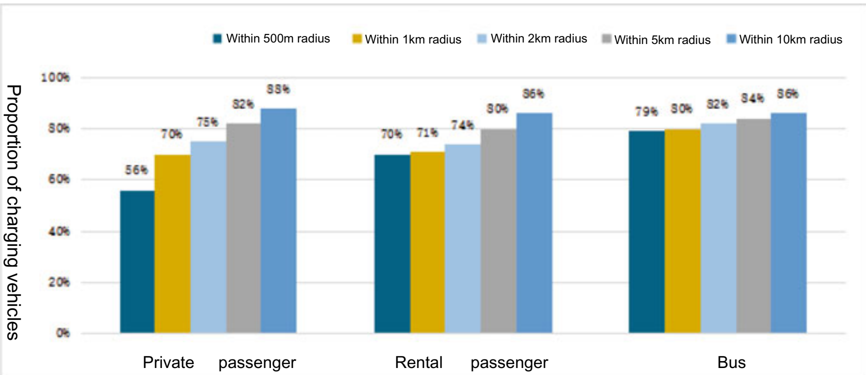


Fig. 5.102 Average proportion of charging times of three types of BEVs at UPOR within different radii in Beijing

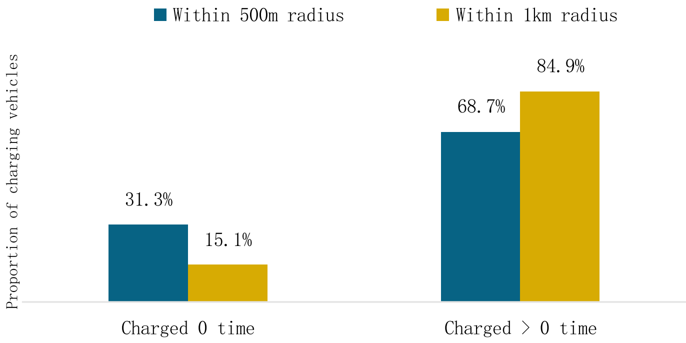


Fig. 5.103 Proportion of private passenger cars charging at UPOR within different radii in Beijing

mileage are positively correlative to the proportion of charging times within a radius of 500 m. The improved accessibility of charging within 500 m of UPOR means that private car owners are provided with better conditions for long-term replenishment to secure sufficient driving mileage, thus enhancing users' willingness to drive and increasing the range of travel.

The better the charging convenience of new energy passenger cars, the longer the single-time charging duration.

As the proportion of vehicles charging within 500 m of UPOR increases, the single-time charging duration of all four types of passenger cars also showed an upward trend. The single-time charging duration reached the acme for the four types of passenger cars when the proportion of charging times of each within a 500 m radius at respective UPOR ranged from 80 to 100% (Fig. 5.105). As the proportion of charging times within a 500 m radius of UPOR rose, the average single-time charging duration for passenger cars increased from 1.8 h to 3.5 h. Where charging conditions permit, more users preferred slow charging due to advantages in charging

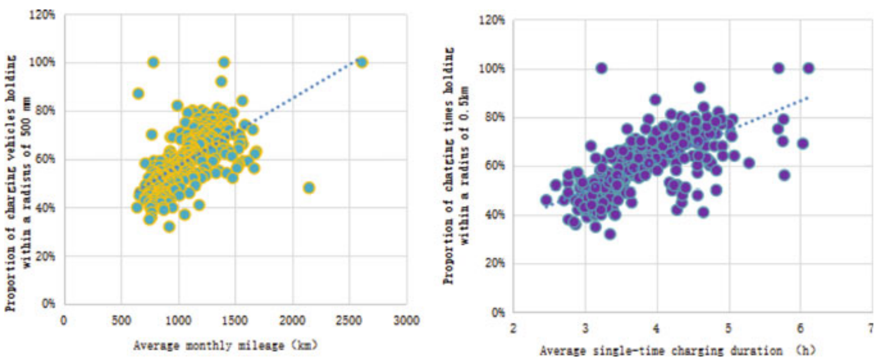


Fig. 5.104 Relationship between driving and charging characteristics and charging convenience of private passenger cars in Beijing. Remark The number of dots represents the number of communities with charging facilities for NEVs in Beijing

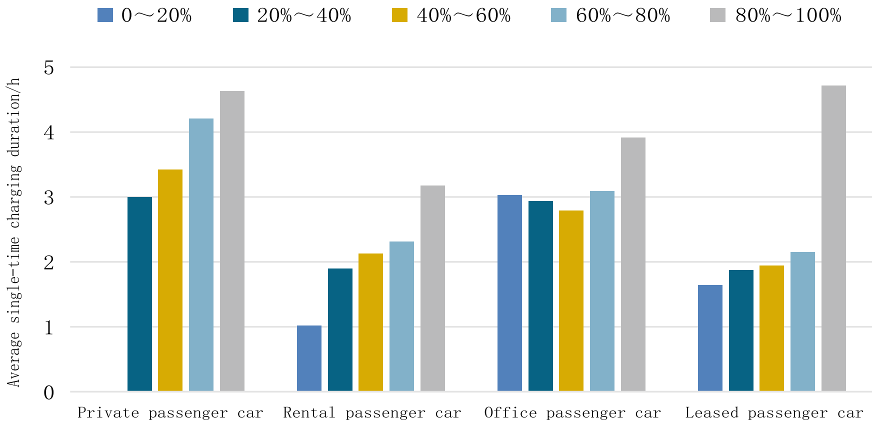


Fig. 5.105 Comparison between the proportion of passenger cars charging within a 500 m radius of UPOR and single-time charging duration in Beijing—by type

cost and more users preferred to charge more to guarantee sufficient power. Therefore, charging convenience played an important role in saving users' charging costs and reducing mileage anxiety.

The charging convenience of private passenger cars in urban area of Beijing was generally low.

According to the statistics of BEV private passenger cars in Beijing by administrative areas, the proportion of private passenger cars with charging behaviors within a 500 m radius of UPOR was only 57.3% of those parking at night in the functional core area of Beijing (UPOR), meaning that the rest 42.7% had no charging behavior within a 500 m radius of UPOR (Fig. 5.106). For private passenger cars located in other urban areas such as Haidian District, Chaoyang District, Fengtai District, and Shijingshan District, the charging convenience was slightly higher than that of the core area in Beijing, with 65.8% of private passenger cars having charging behaviors within a 500 m radius of UPOR (the rest 34.2% not). By sorting all the townships and streets in Beijing by the mean value of the proportion of charging times within a 500 m radius of UPOR, it can be found that the 30 townships and streets at the bottom of the list in terms of charging convenience were mainly located in the six districts of Beijing, of which more than half were located in the core area of Beijing, represented by Chaoyangmen Street, Donghuashijie Street, Dashilar Street, and Desheng Street, and more than one third are located in the other urban districts, represented by Chaowai Street, Yanyuan Street, and Maizidian Street.

The charging convenience of suburban streets was generally better than that of urban areas, while concerns should be put on some towns and villages.

The median of the proportion of charging times for private passenger cars in Beijing within a 500 m radius of UPOR was 59%, indicating that the convenience should be improved (Fig. 5.107). Private passenger cars in Beijing were distributed in 319 streets within the urban area, with the largest coverage among the four types

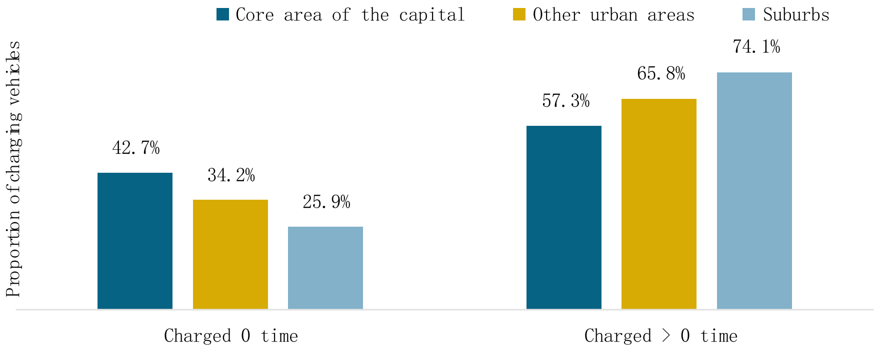


Fig. 5.106 Distribution of charging convenience within 500 m of UPOR of private passenger cars by district in Beijing. Remarks The functional core areas as highlighted in the picture above include Dongcheng District and Xicheng District; other urban areas include Haidian District, Chaoyang District, Fengtai District, and Shijingshan District; the suburbs include other areas except the aforesaid six districts

of passenger cars and special logistics vehicles. The median of the proportion of charging times for private passenger cars within a 500 m radius and a 500 m to 1 km radius of UPOR was 59% and 14%, respectively, with the overall convenience of charging to be improved.

The 20 streets featuring the highest charging convenience were mainly located in the outer suburbs, since private piles can be easily installed given the large number of bungalows with courtyards in the suburbs and it is easier to erect public charging piles in areas featuring better promotions. TOP20 streets covered Fengjiayu Town and Puwa Township in Miyun and Fangshan Districts.

The 20 streets at the bottom were mainly distributed in the six major districts of Beijing. Within a 500 m radius of UPOR, the 20 streets ranking in the bottom were

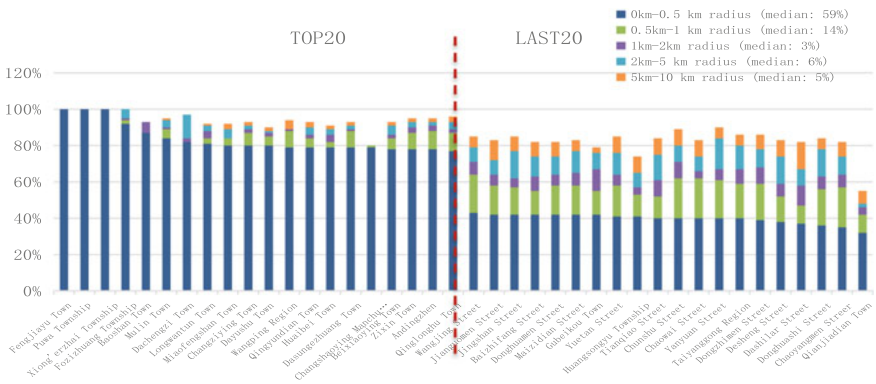


Fig. 5.107 Distribution of charging convenience within 500 m of UPOR of private passenger cars by district in Beijing

mainly distributed in six city districts, such as Dashilar Street, Chaoyangmen Street, and Donghuashixi Street, in descending order of the proportion of charging times of private passenger cars are charged at night within a 500 m radius of UPOR. The lower ranking of the streets concerned was mainly affected by the insufficient fixed parking spaces in old residential areas, the difficulty in installing piles for vehicles, as well as the constraints on the installation and distribution of public piles. Qianjiadian Town, Yanqing, located in the suburbs, also ranked lower in charging convenience, indicating that the promotion and construction of charging piles should not be ignored in the outer suburbs with a smaller number of NEVs.

5.5 Summary

By analyzing the charging data of NEVs accessed to the National Monitoring and Management Platform, this Section draws the following conclusions based on the charging characteristics of NEVs in key segments:

Driven by the rapid growth of NEV industry, the construction of charging infrastructure in China has shifted from policy-driven to market demand-driven. By the end of 2022, China had a total number of 13.1 million NEVs. With the full marketization of the NEV industry, the charging demand of NEVs keeps increasing. In 2021 and 2022, the increment of China's charging infrastructure was 1.01 million units and 2.451 million units, respectively, up 114.6% and 142.7%, respectively. The construction of charging facilities in China still lagging behind the NEV industry, despite the encouraging growth rate. How to improve the construction and distribution of charging facilities has become a great challenge for the market-oriented development of NEV across the board.

Fast charging could greatly improve the charging experience, making it a major trend towards the evolution of power replenishment technology for NEVs in the future. In terms of the charging characteristics in typical application scenarios, in 2022, the proportion of fast charging times of all types of vehicles kept rising year on year. For operating vehicles, the increase in the proportion of fast charging times would enhance the profitability of operators moving towards the inflection points. Given the changes in the average power of public charging facilities over the years, the number of high-power charging piles of 120 kW and above accounted for 24.4% of the national total in 2022, up 4.7% compared with 2017, indicating that the high-power fast charging piles have become a trend. As for vehicle manufacturers, those represented by Tesla (400 V supercharging), XPeng, and GAC Aion are also stepping up the distribution and construction of supercharging stations to further promote the supercharging models.

In terms of charging habits and preferences, the charging performance of private cars and operating vehicles greatly varied. By the charging frequency of vehicles in different application scenarios, in 2022, the new energy private cars in

China charged 6.5 times per month and 1–2 times per week. The operating vehicles featured high charging frequency. The average monthly charging frequency of e-taxis and taxis exceeded 30 times, with the average daily frequency of 1–2 times, mainly in fast charging mode. Commercial vehicles, logistics vehicles, buses, and heavy-duty trucks were mainly charged with exclusive charging facilities, with an average monthly charging frequency of more than 20 times. In terms of charging duration, the average single-time charging duration of private cars in China in 2022 was 2 h, which was longer. As for operating passenger cars, the average charging duration of e-taxi and taxis was 1.6 h and 1.4 h, respectively. As to commercial vehicles, the average charging duration of logistics vehicles, buses, and heavy-duty trucks was less than 2 h.

The rapid increase of vehicles in volume, fast charging mode, disorderly charging, and other factors posed load pressure to the urban distribution network. According to data on the National Monitoring and Management Platform, a total of 7,926,300 new energy private cars accessed to the platform in 2022. Based on the monthly charge of BEV private cars of 85.4kWh, the charge demand of new energy private cars in China reached 8,122.9GWh in 2022. With the rapid growth the volume of NEVs in China, such variables as the peak charging demand of private cars and the random load incurred from disorderly charging resulted in drastic changes in the power load in various locations, thus causing over-capacity of distribution transformers, affecting the safe and stable operation of the power grid.

The "last mile" charging in old residential areas is a new problem in development, which requires overall coordination in joint efforts of various parties concerned. This Section, with new energy passenger cars in Beijing as the object of research, analyzes the charging demands and convenience of passenger cars, and suggests that DC fast charging network be installed as needed for operating vehicles with regard to the charging characteristics and major problems of new energy passenger vehicles in different types and in different urban areas. For the operating vehicles subject to fixed routes, points, and stations, it is recommended that the proportion of DC fast charging piles be satisfied as per the planning of vehicle stations and the monthly charging demand of vehicles and other data; for rental passenger cars, leased passenger cars, and other vehicles not subject to fixed points and routes, it is recommended that, considering the charging demands in time and space, more piles be erected in the downtown areas, such as transportation hubs, business centers and other areas; for private cars, it is recommended to make up the shortcomings for charging infrastructure at the UPOR under the mode of "one pile for several vehicles while sharing" for economical purpose. In addition, private cars have a higher demand for charging at nighttime and for charging convenience in UPOR, making it necessary to set more charging infrastructure near the frequently parking locations.

Chapter 6
Battery-Swapping Battery Electric Vehicles

The "separation of vehicles and battery" is of great significance for building a green energy ecology, lowering users' costs for vehicle purchase, alleviating mileage and charging anxiety, and prolonging the battery degradation cycle. The state supports the popularization and application of such mode in specific areas around the world and encourages enterprises to develop battery-swapping mode pertinent to application scenarios. The construction of battery-swapping infrastructure and battery-swapping model demonstration and application are of great significance for promoting the in-depth integration of regional NEV industry and energy industry, constantly optimizing and perfecting the application scenarios and environment, and boosting the development of local new energy industry. This Section, based on the data of models accessed to National Monitoring and Management Platform, analyzes the battery-swapping vehicle promotion and application, battery-swapping vehicle operation, and battery-swapping characteristics, summarizes the current achievements of battery-swapping industry and the key problems, and proposes the suggestions for the development of the industry.

6.1 Industrial Policies and Standard System for Battery Swapping Mode

The upper-level planning was more detailed and specific as battery-swapping model was encouraged.

In November 2020, the General Office of the State Council issued the *New Energy Vehicle Industrial Development Plan for 2021 to 2035*, which explicitly proposed to step up the construction of battery charging and swapping infrastructure, scientifically laying out charging and switching infrastructures, and strengthening the integration and coordination with urban and rural construction planning, electric power grid planning, and property management, and urban parking. The application

Z. Wang, *Annual Report on the Big Data of New Energy Vehicle in China (2023)*,
https://doi.org/10.1007/978-981-97-4840-2_6

of battery-swapping mode has been encouraged by strengthening the research and development of new charging technologies such as intelligent and orderly charging, high-power charging, and wireless charging, in a bid to improve charging convenience and product reliability. The state has further clarified the macro trend for the development of NEV battery-swapping mode, which laid a solid foundation for the construction and development of battery-swapping mode and network construction. On December 15, 2022, the Central Committee of the Communist Party of China and the State Council issued the *Outline of the Plan for the Domestic Demand Expansion Strategy (2022–2035)* (the "Outline"), which specifies that "efforts shall be made to optimize the distribution of urban transportation network for vigorous development of intelligent transportation; to promote the transformation of vehicle consumption from purchase management to use management; and to promote the development of vehicles towards electrification, networking, and intelligence and strengthen the construction of supporting facilities such as parking lots, charging piles, battery swapping stations, and hydrogen refueling stations. "

Relevant ministries and commissions encourage the exploration of pilot programs for battery swapping in different fields, and the battery-swapping vehicle industry is expected to grow faster.

On October 28, 2021, the *Ministry of Industry and Information Technology issued the Notice on Starting the Pilot Application of New Energy Vehicle Battery-Swapping Mode* ("Notice"), deciding to start the pilot program on the application of new energy vehicle battery-swapping mode. 11 cities were included in the scope for pilot application of battery swapping, covering 8 cities for comprehensive application (Beijing, Nanjing, Wuhan, Sanya, Chongqing, Changchun, Hefei, and Ji'nan) and 3 heavy-duty trucks featured cities (Yibin, Tangshan, and Baotou). The Notice aims to promote more than 100,000 battery-swapping vehicles in pilot cities and build more than 1,000 new battery-swapping stations. In February 2023, the Ministry of Industry and Information Technology and other seven ministries launched a pilot program for comprehensive vehicle electrification of vehicles in the public sector, requiring that the proportion of NEVs in urban buses, taxis, sanitation vehicles, postal courier carriers, urban logistics and distribution vehicles reaching 80%.

The competent authorities and industry associations and organizations have been striving to form relevant standards on battery swap into a system that covers energy industry and automotive industry. Pursuant to the *Report of the Study of Standardization of Pilot Cities for New Energy Vehicle Battery Swap* released by the Electric Transportation and Energy Storage Branch of the China Electricity Council, nearly 50 standards have been approved for the battery swap system in China, and the Technical Committee for the Standardization of Electric Vehicle Charging Facilities has completed more than 30 standards on battery swap, including *Communication Protocols for Swapping Battery Pack of Electric Vehicle* (GB/T 32895-2016) and other four national standards issued by the Standardization Administration; *Code for Design of Electric Vehicle Battery-swap Station* (GB/T 51077-2015) issued by the Ministry of Housing and Urban–Rural Development; *General Technical Requirements for Chassis-type Battery Replacement Systems for Pure Electric Passenger Cars* (NB/T 10434-2020), *Code for Construction and Completion Acceptance of*

Electric Vehicle Charging/Battery Swap Infrastructure (NB/T 33004-2020), and *Safety Requirements of Electric Vehicle Battery Swap Station* (NB/T 10903-2021) issued by National Energy Administration; *Dimension of Traction Battery for Electric Vehicles* (GB/T 34013-2017) and *Coding Regulation for Automotive Traction Battery* (GB/T 34014-2017) issued by the Ministry of Industry and Information Technology.

Local governments have been formulating policies to encourage battery swap in line with industrial development.

The development of battery-swapping mode helps further extend the automotive industry chain and develop new growth poles for the industry, thus providing strong support for regional economic development. In addition to the national policy support for battery swap, Sichuan, Chongqing, Shandong, and other provisions or regions also issued support policies and specific subsidies related to battery swap or battery-swapping stations in 2022 (Tables 6.1 and 6.2). Sichuan gave an additional subsidy of RMB300 perkWh for the purchase of a battery-swapping heavy-duty truck. Chongqing, Shandong, Inner Mongolia, Beijing, Shanghai, and other provinces and regions gave a lump-sum subsidy for the battery-swapping stations in operation: RMB 1 million per station. Guangdong and Guangxi are working on the subsidy for the battery-stations already built.

In terms of local standards, a guiding document *Technical Requirements for Battery Swapping of Electric Heavy-duty Trucks* was issued in Tangshan, Hebei; in April 2022, the Technical Specifications on Battery Swapping Pack System for BEV Heavy-duty Trucks in Jiangsu Province was issued in Jiangsu, regulating the physical dimensions of the battery packs and the interchangeability indexes of power interfaces of new energy heavy-duty trucks in the application scenarios of batter swapping on the city level; and the opinions *Compatibility of On-board Battery Swap System for Battery Electric Heavy Duty Trucks—Part 1: Battery Swap Electric Interface* and other four local standards have solicited in Yibin, Sichuan for regulating the battery swapping cooling interface, battery swapping mechanism, battery swapping battery pack, and vehicle and battery pack communication protocols.

In November 2022, the *Technical Specification on Battery Swapping Stations for Electric Medium- and Heavy-duty Trucks and Vehicle Battery Swapping System* was issued in the Inner Mongolia Autonomous Region, involving eight group standards that regulated the technical requirements for battery swapping box and battery swapping bracket, battery swapping connectors, and battery swapping controls of battery swapping vehicles, the technical requirements on technical safety and communication protocols of battery swapping facilities, the technical requirements on data safety management and risk early warning, and the requirements on planning layout, installation, and protection of battery swapping stations.

Table 6.1 Support policies for battery-swapping industry in some cities or regions in China since 2022

S/N	Province/city	Time	Issuing authority	Document	Contents
1.	Chongqing	2022/5/11	Chongqing Municipal Bureau of Economy and Information Technology	*Pilot Program for the Application of New Energy Vehicle Power Exchange Mode in Chongqing*	**By 2023, more than 200 battery swapping stations will be built and more than 10,000 new energy vehicles in battery swapping mode will be promoted;** In the field of heavy-duty trucks, commercial vehicle enterprises are encouraged to work battery swapping operators in demonstration applications in such areas such as model research and development and battery swapping station construction, and support will be given to initiate pilot projects in such places as ports, slag yards, and mines to lead the large-scale development of the market of battery-swapping heavy-duty trucks
2.	Beijing	2022/6/23	Beijing Municipal Commission of Urban Management	*Electricity Development Plan for the "14^{th} Five-Year Plan" Period in Beijing*	By the end of 2025, the total number of charging piles and **battery swapping stations** in Beijing will reach 700,000 and **310**, respectively. The average service radius of public charging facilities for electric vehicles in the plains will be less than 3 km. Efforts will be made to establish charging demonstration zones in Zhongguancun Science City, Huairou Science City, Future Science City, Beijing Economic-Technological Development Area, and other places

(continued)

Table 6.1 (continued)

S/N	Province/city	Time	Issuing authority	Document	Contents
3.		2022/8/5	Beijing Municipal Commission of Urban Management	*Development Plan for New Energy Vehicle Battery Charging and Swapping Facilities in Beijing for the "14th Five-Year Plan" Period*	A social evaluation mechanism with user experience as the core is to be established during the "14th Five-Year Plan" period. **The quality supervision and safety monitoring system of battery charging and swapping facilities should be improved. Efforts will be made to constantly strengthen the quality supervision and management of product production, construction and installation of battery charging and swapping facilities, and strengthen the product quality and safety accountability of vehicles, batteries, and battery charging and swapping facility manufacturers.** It is also necessary to strengthen the quality testing of battery charging and swapping facilities and equipment, the management of identity assessment and construction project acceptance, and strengthen the quality supervision of charging facilities in residential areas
4.	Anhui Province	2022/7/4	Anhui Provincial Development and Reform Commission	*Several Policies to Support New Energy Vehicle and Intelligent Connected Vehicle Industries towards Higher Quality, Quantity, and Efficiency*	The infrastructure construction will step up. By 2025, there will be more than 70,000 public charging piles **and over than 180 batter swapping stations** within the whole province. **All cities are encouraged to subsidize the construction and operation of battery charging (swapping) facilities.** In specific, Hebei will become a pilot city for battery swapping and for "smart city infrastructure and intelligent connected cars" while **stepping up the construction of the service network of battery swapping stations in the principle of "appropriate advance, intensity, and efficiency" with priority to establish battery swapping stations in the segments of private cars, operating vehicles, and e-taxis**

(continued)

Table 6.1 (continued)

S/N	Province/city	Time	Issuing authority	Document	Contents
5.	Guangxi Zhuang Autonomous Region	2022/9/1	General Office of the People's Government of Guangxi Zhuang Autonomous Region	*"14th Five-Year" Plan for the Energy Development of Guangxi*	The *Plan* clearly states to constantly increase consumption on clean energy and enhance low-carbon effects and electrification for energy use on terminals. It is required to further promote the vehicles with such clean energy as electricity, hydrogen, natural gas and automotive ethanol gasoline, and to encourage the use of such clean fuels as LNG for heavy-duty trucks and ships. The Plan also requires improving the layout of battery charging and swapping stations and hydrogen and gas filling stations, conducting pilot demonstrations of new charging and swapping stations integrating PV, storage, charging, and swapping, building **80,000 new charging infrastructures**, **setting up pilot swapping stations in Nanning, Liuzhou, and other cities**, and encouraging the construction of oil–gas-electricity-hydrogen integrated energy-supply service stations for traditional petrol and gas filling stations, with an aim of building and upgrading 600 new and renovated integrated energy-supply service stations
6.	Guangdong	2022/9/16	People's Government of Guangdong Province	*Implementation Plan for Energy Conservation and Emission Reduction in the "14th Five-Year" Plan of Guangdong Province*	Public institutions are required to take the lead in eliminating old cars and applying new energy vehicles and maintain at least 60% of new energy vehicles and energy-saving vehicles in new and renewed vehicles for official use each year, of which the proportion of new energy vehicles should be no less than 30% in principle. **Efforts should be made to boost the construction of automobile charging (swapping) facilities and equipment in newly-built and existing parking lots and encourage that internal charging (swapping) facilities and equipment to be accessible to the public**

(continued)

Table 6.1 (continued)

S/N	Province/city	Time	Issuing authority	Document	Contents
7.	Jiangsu Province	2022/10/19	Industry and Information Technology Department of Jiangsu and other 13 departments	*Implementation Opinions on Further Promoting the Healthy Development of Electric Vehicle Charging (Swapping) Infrastructure*	It is required to speed up the application of "PV, storage, and charging" pilot programs, support the construction and layout of special battery swapping stations around ports, urban transit, and other scenarios, expedite the exploration and promotion of "separation of vehicles and battery" mode, and explore the application of "PV, storage, and charging" integration. It is also necessary to promote the formation of unified technical standards for battery swapping in major application areas to **enhance the safety, reliability, and economic effects of the battery swapping mode**
8.	Jilin Province	2022/12/9	People's Government of Jilin Province	*Circular on Issuing the Strategic Plan for High-quality Development of New Energy Industry in Jilin Province (2022–2030)*	It is required to build and improve the infrastructure of electric vehicle charging piles, **green battery swapping stations**, hydrogen refueling stations, and power battery centralized maintenance facilities; **promote the demonstration application of the "Hongqi E-City in Jilin" project in an orderly manner to build a battery charging (swapping) service network covering the whole province**; and strive to **build 500 charging (swapping) stations by 2025**, with the number of charging piles exceeding 10,000 to satisfy the demands of over 100,000 electric vehicles

(continued)

Table 6.1 (continued)

S/N	Province/city	Time	Issuing authority	Document	Contents
9.	Fujian Province	2022/12/15	Fujian Provincial Development and Reform Commission	*Implementation Opinions on Accelerating the High-quality Development of the Lithium-ion New Energy and New Materials Industry*	**It is required to actively incorporate battery swapping infrastructure and network construction into the scope of new infrastructure;** step up the construction of battery swapping infrastructure and network in an orderly manner, and develop demonstration pilots for battery swapping; support districted cities to incorporate the land for battery swapping infrastructure into the scope of the land for sales network of public utilities, arrange a certain amount of construction land to support the building of battery swapping stations as needed every year, and prioritize the arrangement of construction land for the sharing of battery swapping stations that serve three (or more) brands. **Efforts will be made to build a total number of more than 1,000 electric vehicle battery swapping within Fujian by 2025**
10.	Sichuan Province	2023/1/5	Sichuan Provincial People's Government	*Implementation Plan for Peaking Carbon Dioxide Emission in Sichuan Province*	**It is required to steadily promote the pilot application of battery swapping mode and hydrogen fuel cells in the field of heavy-duty trucks and operating buses;** upgrade the infrastructure of urban public transportation, speed up the distribution of public charging (swapping) network in rural and urban areas, actively build intercity charging (swapping) grids, and encourage enterprises to invest in the construction and operation of related facilities. By 2030, it is expected to achieve a full coverage of charging (swapping) facilities in highway service areas and full electrification of vehicles in civil airports

Source Official websites of governments of provinces, municipalities, and autonomous regions

Table 6.2 Subsidy policies for battery swapping and battery swapping facilities in some cities or regions in China since 2022

S/N	Province/city	Time	Issuing authority	Document	Contents of the policy
1.	Sichuan Province	2022/3/26	General Office of the People's Government of Yibin City	*Implementation Plan for Comprehensively Promoting the "Electrification of Yibin" (2022–2025)*	**It is planned to build over 20 battery swapping stations and promote more than 1,000 battery-swapping heavy-duty trucks within two years; and build 60 heavy-duty truck battery-swapping stations and promote 3,000 battery-swapping heavy-duty trucks by 2025. Subsidies will be provided at a rate of RMB300 per kilowatt-hour for each heavy-duty truck purchased**
2.		2022/12/20	Sichuan Provincial Development and Reform Commission, Energy Administration of Sichuan Province, Sichuan Provincial Finance Department, and other six departments	*Promotion Plan for Electric Energy Substitution in Sichuan Province (2022–2025)*	**The centralized charging and swapping infrastructure for electric vehicles subject to two-part tariff will be exempted from demand (capacity) charge until the end of 2025**, while other charging facilities will enjoy the corresponding tariffs according to their locations. The time-sharing tariffs will be implemented for charging with charging and swapping facilities for electric vehicles
3.	Chongqing	2022/4/20	Chongqing Municipal Finance Department	*Notice on Financial Subsidy Policy for New Energy Vehicles and Charging and Swapping Infrastructure in Chongqing for 2022*	For **each medium- and heavy-duty truck battery swapping station, a one-time construction subsidy of RMB 400/kW will be given by the rated charging power of the charging module of each battery swapping facility, and the maximum subsidy for a single station will not exceed RMB 800,000**

(continued)

Table 6.2 (continued)

S/N	Province/city	Time	Issuing authority	Document	Contents of the policy
4.	Shandong Province	2022/6/15	General Office of Shandong Provincial People's Government	*Implementation Opinions on Accelerating the Promotion and Application of New Energy Vehicles*	It is required to build more than 3,000 new charging and swapping stations of various types. **For each medium- and heavy-duty truck battery swapping station, a one-time construction subsidy of RMB 400/kW will be given by the rated charging power of the charging module of each battery swapping facility. The maximum subsidy for a single station and a single enterprise will not exceed RMB 1,000,000 and RMB 10,000,000, respectively**
5.	Guangdong	2022/6/27	Energy Bureau of Guangdong Province	*Notice on the Verification of Construction Projects for Electric Vehicle Charging Infrastructure and Subsidy Arrangement of Central Incentive Funds in 2019–2020*	For eligible charging and swapping facilities in 2019–2020, the subsidy rate will be RMB600-800/kW for each battery swapping facility
6.	Guangxi Zhuang Autonomous Region Autonomous region	2022/7/11	Industry and Information Technology Department, Department of Finance, Department of Science and Technology, and Development and Reform Commission of Guangxi Zhuang Autonomous Region	*Notice on Organizing the Declaration of Subsidy Funds for Charging Infrastructure of New Energy Vehicles for 2017–2019*	**RMB500/kW will be provided for each battery swapping station. The subsidy for a single station will not exceed RMB200,000**

(continued)

Table 6.2 (continued)

S/N	Province/city	Time	Issuing authority	Document	Contents of the policy
7.	Inner Mongolia Autonomous region	2022/9/19	Department of Transport of Inner Mongolia Autonomous Region Transportation and Department of Finance of United Autonomous Region	*Rules for Implementation on Rewards and Subsidies for Promotion and Application of New Energy Cruising Taxis in the "14th Five-year Plan" Period*	Two types of subsidies for the purchase of new energy vehicles: (1). For the purchase of eligible charging **(plug-in), charging & swapping new energy vehicles (including batteries)**, a subsidy of RMB40,000 for each vehicle will be provided; (2) for the **"separation of vehicles and battery" mode** adopted by the operator, namely the purchase of vehicle bodywork (excluding batteries) alone, **a subsidy of RMB20,000 for each vehicle will be provided to the actual purchaser**. In terms of charging and swapping station construction and operation, each **eligible swapping station will be subsidized RMB800/kW, to the maximum of RMB1.5 million of a single station.** For the **charging and swapping stations for the cars for sharing that have passed annual assessment, a subsidy of RMB 0.2/kWh will be provided, with the maximum subsidized hours not exceeding 1,000 h per year**
8.	Hainan Province	2022/8/5	Industry and Information Technology Department of Hainan Province, Department of Transport of Hainan Province, and Department of Finance of Hainan Province	*Notice on the Declaration of Demonstration and Application Projects in Key Application Fields of Battery Charging and Swapping Mode for New Energy Vehicles*	**A one-time incentive of RMB 4 million will be given to medium- and heavy-duty truck projects that place no fewer than 50 battery-swapping vehicles and actually operate in the battery-swapping mode**

(continued)

Table 6.2 (continued)

S/N	Province/city	Time	Issuing authority	Document	Contents of the policy
9.	Sanya City	2022/9/17	General Office of the People's Government of Sanya City	*Action Plan for Coordinating Epidemic Prevention and Control and Boosting Economic Growth in Sanya City*	From September 17, 2022 to March 31, 2023, the **actual users of the newly purchased and registered battery-swapping vehicles** in Sanya, Hainan will be subsidized for the price difference for energy use, and given an appropriate amount of allowance by grade corresponding to the price of purchase, with the maximum of **RMB10,000 for a single vehicle**
10.	Shanghai	2022/9/26	General Office of the Shanghai Municipal People's Government	*Measures to Encourage the Development of Electric Vehicle Battery Charging and Swapping Facilities in Shanghai Municipality*	For general-purpose battery swapping stations (cross-brand and cross-model services), 30% of the amount of financial subsidies will be given to battery swapping facilities (exclusively the charging system of the battery swapping equipment and the battery replacement system, excluding batteries), with a cap of RMB600/kW; for non-general-purpose stations, 15% of the amount of financial subsidies will be given with a cap of RMB300/kW
11.	Hunan Province	2022/12/30	Industry and Information Technology of Hunan Province, Development and Reform Commission of Hunan Province and Hunan Provincial Department of Finance	*Several Policies and Measures on Supporting the High-Quality Development of New Energy Vehicle Industry*	Invention patents related to new energy vehicles are encouraged. In specific, for enterprises and institutions applying for and obtaining the authorization of invention patents in new energy vehicles (including intelligent connected vehicles and fuel cell vehicles), charging (swapping) infrastructure and other related fields within the implementation period of the policy within the province, a cumulative incentive of RMB500,000, RMB1,500,000, and RMB3,000,000 will be granted, respectively, to the total number of 20, 50, and 100 patents, respectively

Source Official websites of the governments of provinces, municipalities, and autonomous regions and Hua Chuang Securities

6.2 Promotion of Battery-Swapping BEVs and Infrastructure

6.2.1 Promotion of Battery-Swapping BEVS

(1) **National promotion**

As of the end of 2022, China has promoted over 290,000 battery-swapping BEVs, with battery-swapping BEV private passenger cars in the majority.

According to the National Monitoring and Management Platform, as of the end of 2022, over 290,000 battery-swapping BEVs have been accessed to the platform on a national scale, including 279,999 battery-swapping passenger cars and 11,000 commercial vehicles, accounting for 96.1% and 3.9%, respectively, with battery-swapping passenger cars in the majority. The battery-swapping commercial vehicles accessed to the platform are all vehicles for special purpose.

Battery-swapping BEV passenger cars played a major role in the battery-swapping passenger cars. By the end of 2022, 156,000 battery-swapping BEV private passenger cars have been accessed to the platform, accounting for 53.7% of the total, followed by 62,000 commercial passenger cars and 46,000 rental passenger cars, accounting for 21.4% and 15.9%, respectively. In the field of battery-swapping BEVs, logistics Vehicle for special purpose s took a dominant position, with a number of 0.9 million accessed, accounting for 3.1% of the total in China (Fig. 6.1).

Battery-swapping passenger cars face great market demand, and the market for battery-swapping commercial vehicles was growing rapidly.

From the perspective of the access of battery-swapping BEVs over the years (Fig. 6.2), the access volume grew rapidly in 2022 to 147,000 vehicles, an increase of 51.5% compared to 2020. The battery-swapping passenger car is the key model for promotion over the years, with the access volume of 96,000 and 137,000 in 2021

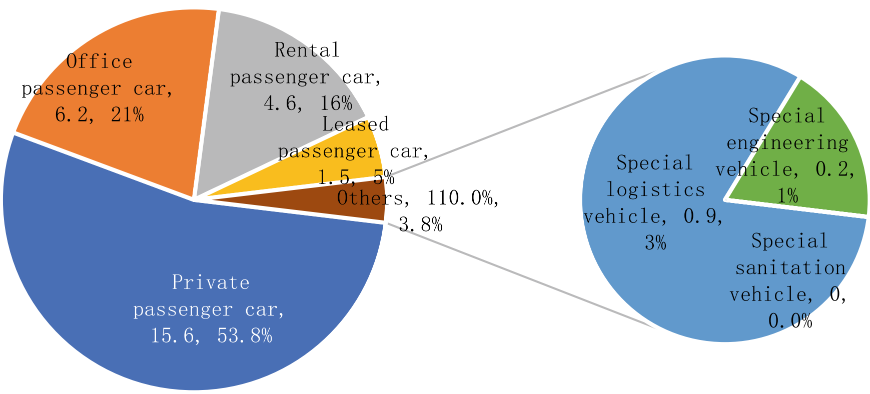


Fig. 6.1 Cumulative access volume (in 10,000) and proportion of battery-swapping BEVs by type

and 2022, respectively. In the field of battery-swapping commercial vehicles, with the implementation of "dual-carbon" strategies, the access volume witnesses rapid growth, with a record 941 and 10,461 in 2021 and 2022, respectively.

(2) **Market concentration**

Featuring a high market concentration of battery-swapping vehicles, the cumulative access volume of TOP3 manufacturers of battery-swapping passenger car and TOP3 manufacturers of battery-swapping commercial vehicle accounted for 87% and 61% of the national total, respectively.

The market concentration of battery-swapping BEVs was relatively high. As to the passenger cars, by the end of 2022, NIO had accessed a total of 175,000 battery-swapping BEVs to the platform, accounting for 62.7% of the cumulative amount nationwide (Table 6.3). BAIC Motor, BAIC BJEV, and BAIC Yunnan Ruili Automotive Co., Ltd. under BAIC Group focused on rental and leased passenger cars, with a total access volume of 45,000, 22,000 and 2,300 battery-swapping passenger cars, respectively.

In the field of commercial vehicles, battery-swapping BEV trucks became the key breakthrough for the electrification of heavy-duty trucks under the "dual-carbon" strategy given less time consumption and higher operational efficiency of battery swap. With the support of national and local policies, the leading commercial vehicle manufacturers in China stepped up the strategic distribution, launching a variety of models to the market. In terms of the promotion by the manufacturers of battery-swapping BEV heavy-duty trucks (Table 6.3), Hanma Technology and XCMG ranked the top two, with cumulative access of 2,655 units and 2,126 units, respectively, accounting for 25.3% and 20.3%., respectively.

The leading enterprises in the industry have been stepping up the pace of distribution in the segment of battery swap. Geely Automobile, for instance, set up a joint venture Livan Automobile with Lifan Technology in January 2021, with battery-swapping plans for e-taxis for business end and consumer end. Livan Automobile

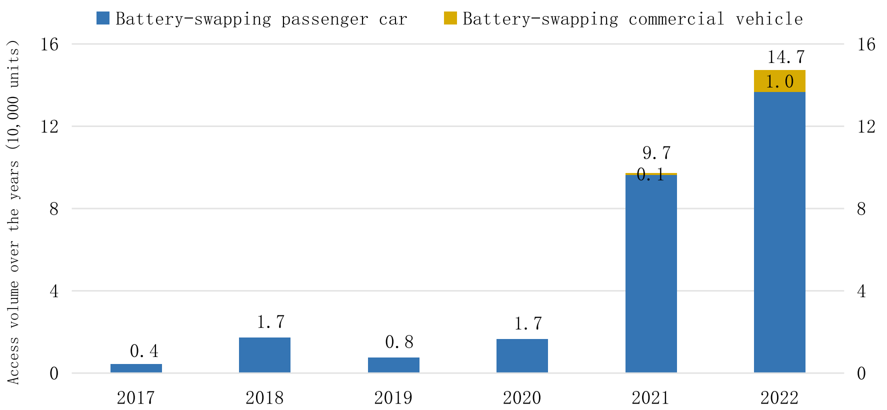


Fig. 6.2 Access volume of battery-swapping BEVs of different types over the years

Table 6.3 Cumulative access of vehicle manufacturers of battery-swapping BEVs in China–by segment (vehicle, %)

Ranking	Passenger car			Commercial vehicle		
	Name of enterprise	Cumulative access volume	Proportion in national total	Name of enterprise	Cumulative access volume	Proportion in national total
1.	NIO	174,893	62.7	Hanma Technology	2655	25.3
2.	BAIC Motor	45,488	16.3	XCMG	2126	20.3
3.	BAIC BJEV	22,180	8.0	SAIC Hongyan	1617	15.4
4.	Livan Automobile	9685	3.5	FAW Jiefang	868	8.3
5.	FAW	7230	2.6	Dongfeng Liuzhou Motor	574	5.5
6.	SAIC	5241	1.9	Beiben Trucks	428	4.1
7.	Maple	3738	1.3	SANY	394	3.8
8.	Dongfeng Motor	2493	0.9	Foton	329	3.1
9.	BAIC Yunnan Ruili	2300	0.8	Dayun Auto	309	2.9
10.	Dongfeng Liuzhou Motor	2219	0.8	Dongfeng Trucks	205	2.0

plans to build more than 5,000 intelligent battery-swapping stations by 2025, In addition, Maple, a subsidiary of Geely, also plans to engage in batter-swapping businesses. In the field of commercial vehicles, Geely New Energy Commercial Vehicle Group acquired part of the shares of CAMC in July 2020, and CAMC officially changed its name to Hanma Technology in November 2020. With focus on the research, development, and manufacturing of heavy-duty trucks, heavy-duty Vehicle for special purpose s, and core components, Hanma Technology has been making efforts in battery-swapping heavy-duty trucks. By the end of 2022, Hanma Technology has accessed a total of 2,655 battery-swapping commercial vehicles to the platform, accounting for 25.3% of the national total.

(3) **Regional concentration**

By the end of 2022, the TOP 10 provinces had a total of 231,000 battery-swapping vehicles accessed, accounting for 79.5% of the national total.

As to the promotion of battery-swapping BEVs in TOP10 provinces (Fig. 6.3), Beijing had a total of 55,000 battery-swapping BEVs accessed, accounting for 19% of the total in China; Zhejiang, Shanghai, and Guangdong also recorded more than

30,000 vehicles accessed respectively, each accounting for more than 10% of the national total.

By the end of 2022, the TOP 10 cities had a total of 168,000 battery-swapping vehicles accessed, accounting for 58% of the national total.

The promotion of battery-swapping BEVs was highly concentrated in cities (Fig. 6.4). In specific, Beijing had the highest cumulative access of battery-swapping BEVs, reaching 55,000 vehicles, accounting for nearly 20% of the national total; Shanghai, Hangzhou, and Guangzhou also had 15,000 vehicles accessed, each accounting for more than 5% of the national total.

By the proportion of cumulative access volume of battery-swapping BEVs by region (Fig. 6.5), East China had a higher proportion of 42.2%, followed by North China, with a proportion of 23.8%. Battery-swapping BEV commercial vehicles were centrally distributed in North China, with the proportion of cumulative access volume reaching 64.2%.

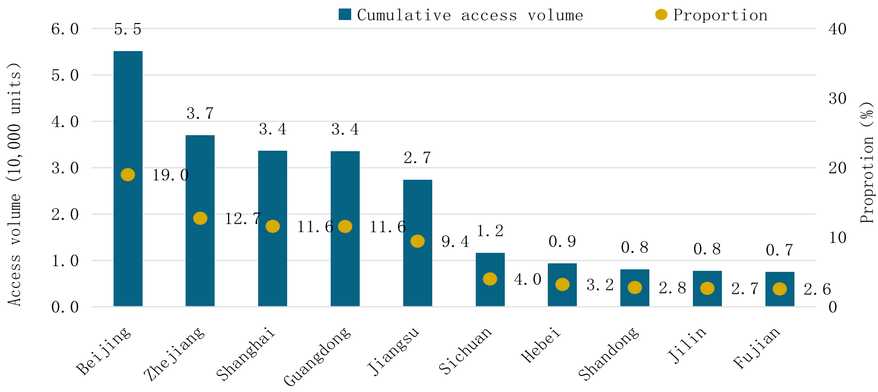


Fig. 6.3 Cumulative access volume and proportion of BEVs in TOP10 provinces

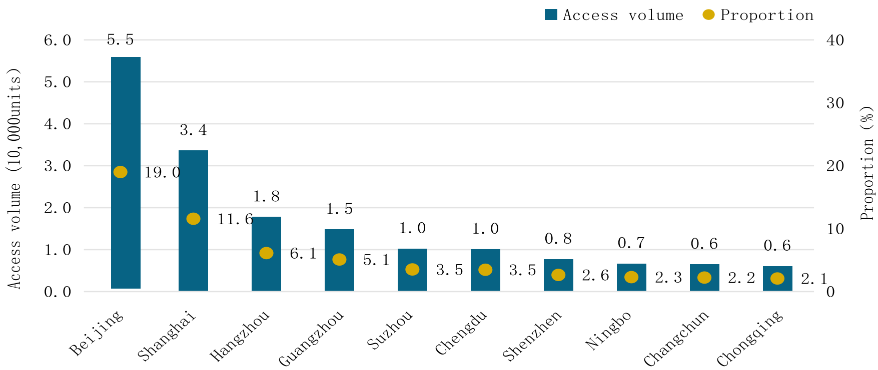


Fig. 6.4 Cumulative access volume and proportion of BEVs in TOP10 cities

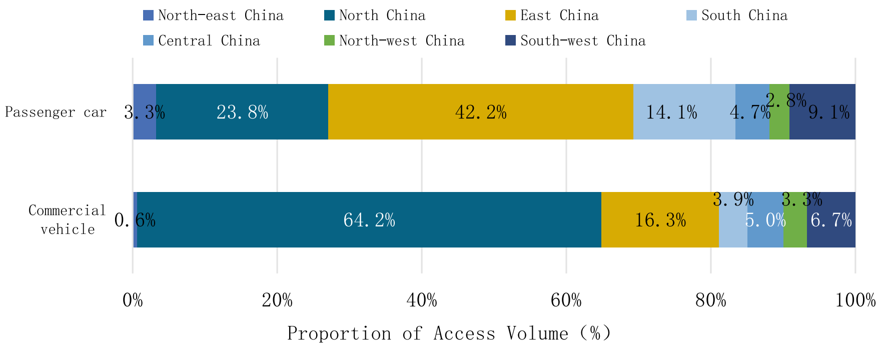


Fig. 6.5 Proportion of cumulative access volume of battery-swapping BEVs by region

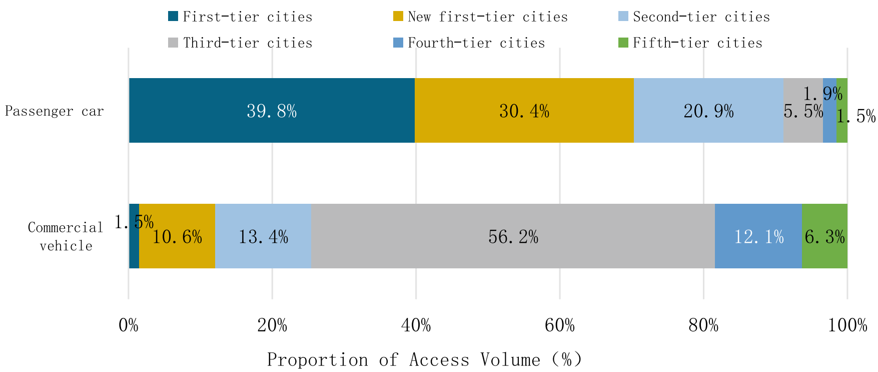


Fig. 6.6 Proportion of cumulative access volume of battery-swapping BEVs by city tier

In terms of the proportion of cumulative access volume by city tier (Fig. 6.6), the proportion of cumulative access volume of battery-swapping BEV passenger cars in first-tier, new first-tier, and second-tier cities totaled 91.1%, of which the proportion in first-tier cities reached 39.8%; while battery-swapping BEV commercial vehicles were mainly promoted in third-tier cities, with the cumulative access volume accounting for more than 50%.

6.2.2 Promotion of Battery-Swapping Heavy-Duty Trucks

New energy heavy-duty trucks were driven by environmental protection policies, while battery-swapping heavy-duty trucks driven by users' demands for efficient operation. In order to thoroughly implement requirements under the *Opinions of the CPC Central Committee and the State Council on Comprehensively Strengthening Ecological and Environmental Protection and Resolutely Fighting the*

Uphill Battle for the Prevention and Control of Pollution and the *Three-year Action Plan for Keeping Our Sky Blue* issued by the State Council, and strengthen the excessive emission control of diesel trucks, in November 2022, the Ministry of Ecology and Environment and other 10 ministries jointly issued the *Action Plan for Pollution Control of Diesel Trucks*, which explicitly requires that, by 2025, the emission of nitrogen oxides from diesel trucks nationwide shall drop by 12%, and the holding volume of trucks with new energy and under China VI emission standards should exceed 40%.

Under the background of national and local policy support and product supply in diversified forms, battery-swapping heavy trucks have become the highlight of the industry of new energy heavy-duty trucks. In 2022, a total of 12,431 battery-swapping heavy-duty trucks were sold within China, accounting for 48.8% of the sales volume of new energy heavy-duty trucks, a year-on-year increase of 273.6%. The battery-swapping heavy-duty trucks have become the key model under the new energy heavy-duty trucks (Fig. 6.7). The commercial operation mode of battery-swapping heavy-duty trucks in such enclosed scenarios as steel mills, power plants, mining areas (short haul) and short-distance transportation in ports is going matured, as the market of battery-swapping heavy-duty trucks is under rapid development.

The market concentration of heavy-duty trucks was high, and the sales volume of TOP3 enterprises accounted for over 50% of the national total.

In 2022, Hanma Technology sold 2,434 battery-swapping heavy-duty trucks, with a market share of 19.6%, ranking first in China. The sales volume of traditional heavy-duty truck manufacturers, including XCMG, SAIC Hongyan, and Dongfeng Motor, also exceeded 1,000 respectively, accounting for more than 10% of the national total (Fig. 6.8).

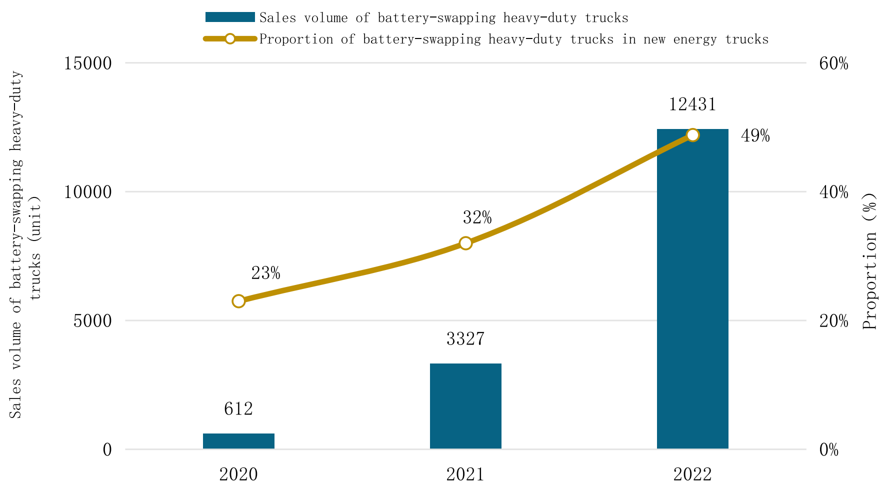


Fig. 6.7 Sales volume of battery-swapping heavy-duty trucks over the years. *Sources* cvword.cn and evpartner.com

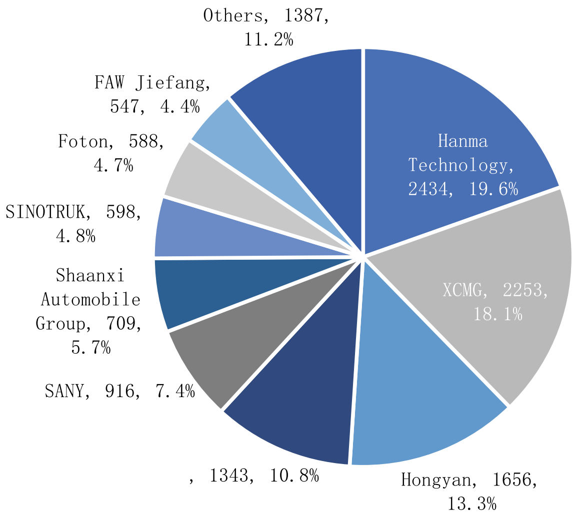


Fig. 6.8 Sales volume and proportion of battery-swapping heavy-duty trucks in China (vehicles, %). *Sources* cvword.cn, evpartner.com, and truckview.cn

By the end of 2022, more than 10,000 battery-swapping BEV heavy-duty trucks accessed to the National Monitoring and Management Platform, with tractor-trailer heavy-duty trucks as the main type for promotion.

According to the statistics of National Monitoring and Management Platform, by the end of 2022, China had a total of 11,402 battery-swapping BEV commercial vehicles accessed (Fig. 6.9), including 454 battery-swapping BEV vans below 12 tons and 10,948 battery-swapping BEV heavy-duty trucks above 12 tons, mainly involving battery-swapping BEV dump trucks, battery-swapping BEV tractor-trailers, battery-swapping concrete mixers, and other models. This Section focuses on the battery-swapping BEV heavy-duty trucks.

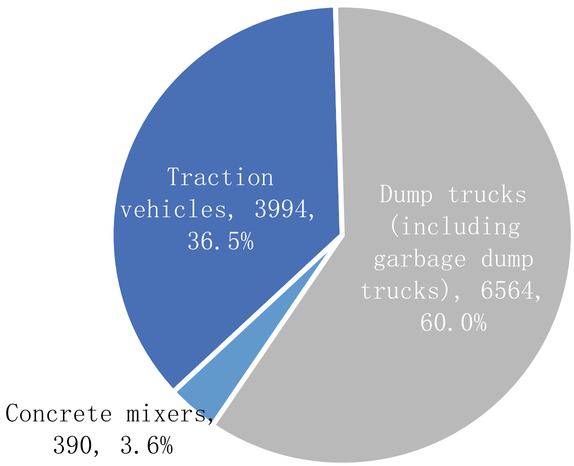


Fig. 6.9 Cumulative access volume and structure proportion of battery-swapping BEV heavy-duty trucks by type (vehicles, %)

By application scenarios (Fig. 6.10), special logistics vehicles were the leading model for promotion. As of the end of 2022, the cumulative access volume to special logistics vehicles amounted to 7,885, accounting for 69.2%, while that of special sanitation vehicles and special engineering vehicles reached 1,952 and 1,565, respectively, accounting for 17.1% and 13.7%, respectively.

The regional concentration for promotion of battery-swapping BEV heavy-duty trucks was high, mainly in resource-oriented cities.

The regional concentration for promotion of battery-swapping BEV heavy-duty trucks was high. By the end of 2022, a total of 6,057 battery-swapping BEV heavy-duty trucks in He'nan accessed to the National Monitoring and Management Platform, accounting for 55.3% of the total. The cumulative access volume of battery-swapping BEV heavy-duty trucks in Shanxi Province and Shandong Province amounted to 598 and 581, respectively, each with a national share of more than 5% (Fig. 6.11). By city (Fig. 6.12), in Tangshan, a total of 3,212 battery-swapping BEV heavy-duty trucks accessed to the platform, accounting for 29.3% of the national total and 43.9% of the volume of new energy Vehicle for special purpose s for promotion within the city.

Tangshan, as an important port city and industrial powerhouse in the Bohai Economic Rim for the transportation of bulk materials (iron and steel) and goods, was listed in the pilot cities for application of NEV battery-swapping heavy-duty trucks by the Ministry of Industry and Information Technology in 2021. The frequent short haul within plants and trunk movement from the outward transportation of finished crude steel within the city have become important application scenarios for the electrification of freight vehicles. Given the less time consumption and high operational efficiency for power replenishment, battery-swapping heavy-duty trucks are now the key model promoted in Tangshan. Other port cities and heavy-industry cities, such as Qinhuangdao, Maanshan, Handan, and Cangzhou, recorded a cumulative access volume of more than 300 battery-swapping BEV heavy-duty trucks on average,

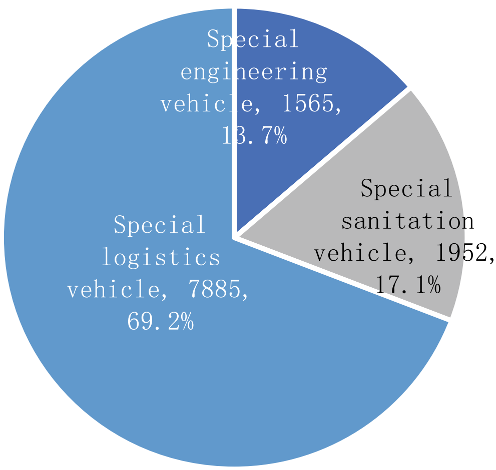


Fig. 6.10 Cumulative access volume and structure proportion of battery-swapping BEV heavy-duty trucks by scenario (vehicles, %)

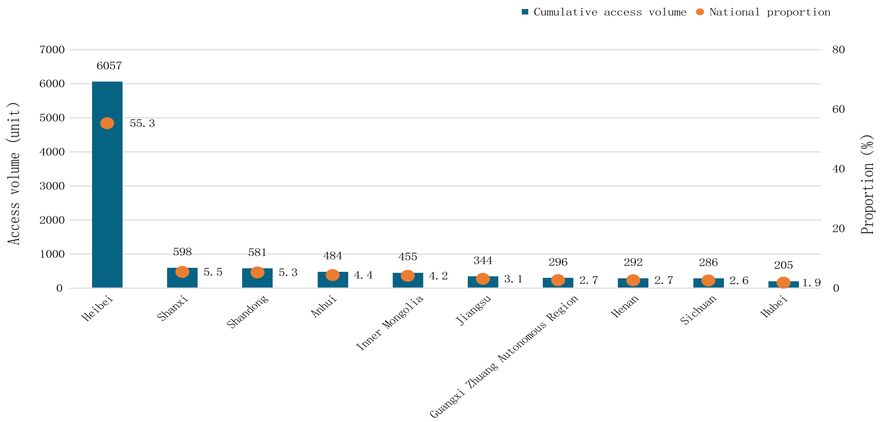


Fig. 6.11 Cumulative access volume and proportion of battery-swapping BEV heavy-duty trucks in the TOP10 provinces

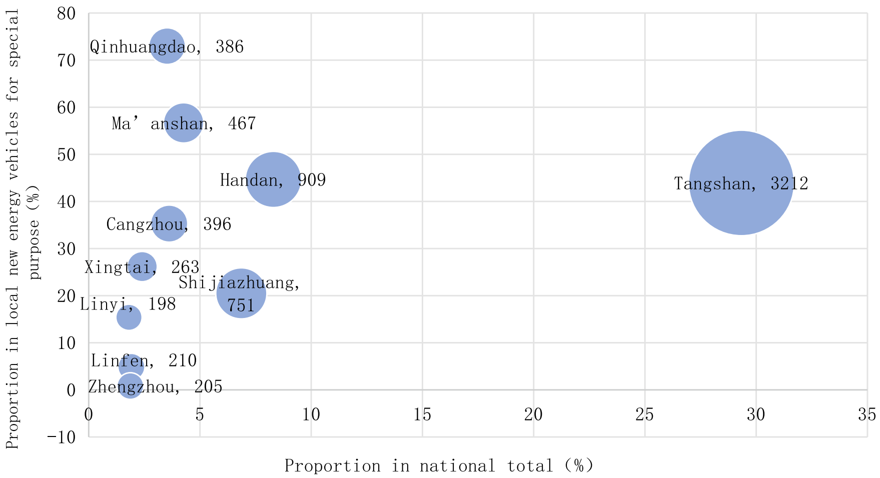


Fig. 6.12 Cumulative access volume and proportion of battery-swapping BEV heavy-duty trucks in the TOP10 cities

accounting for more than 35% of that of new energy Vehicle for special purpose s locally.

According to the regional distribution of the cumulative access volume of the battery-swapping BEV heavy-duty trucks (Fig. 6.13), Tangshan held a large proportion of the cumulative access volume and the Vehicle for special purpose s for various purposes were mainly distributed in North China. By city tier (Fig. 6.14), the battery-swapping BEV heavy-duty trucks were concentrated in the third-tier cities, and the cumulative access volume accounted for more than 40% of the total.

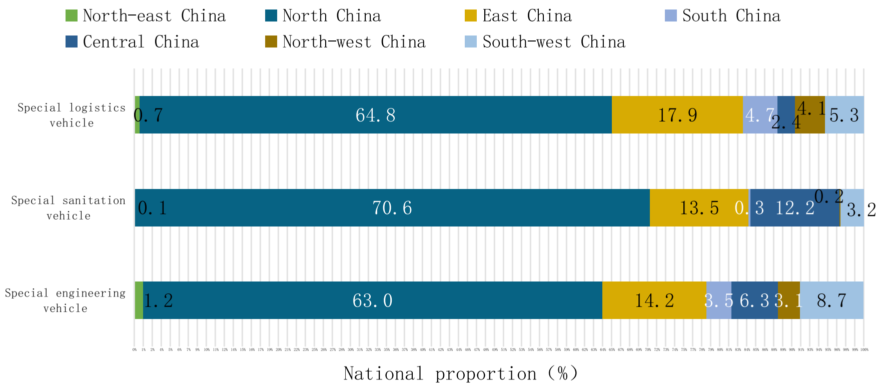


Fig. 6.13 Cumulative access volume and proportion of battery-swapping BEV heavy-duty trucks by region

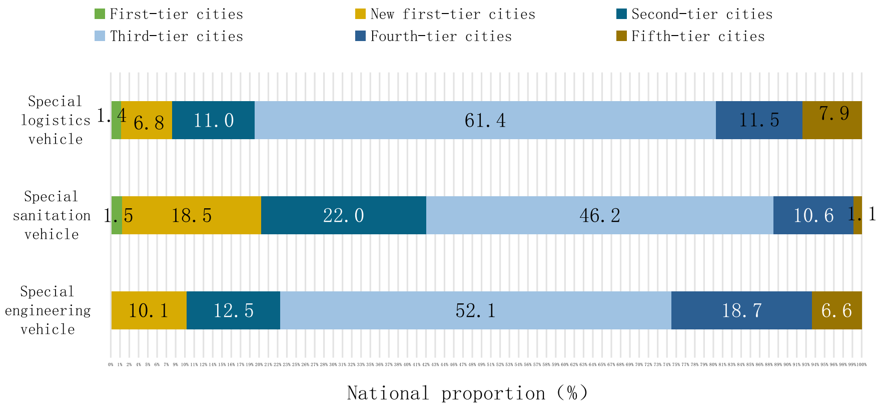


Fig. 6.14 Cumulative access volume and proportion of battery-swapping BEV heavy-duty trucks by city tier

6.2.3 Construction of Battery-Swapping Infrastructure

According to the statistics of China Electric Vehicle Charging Infrastructure Promotion Alliance (EVCIPA), by the end of 2022, there were 1,973 battery-swapping stations for passenger cars within China, of which 289 were built in Beijing, accounting for 14.6% of the total. Operators of battery-swapping stations mainly included NIO, Aulton, and First Technology whose service covered private cars, operating passenger cars, e-taxis, and rental cars. In the field of battery swap for heavy-duty trucks, since the commissioning of the first batch of battery-swapping heavy-duty trucks and the first battery-swapping station in China in July 2020, nearly 400 battery-swapping stations for heavy-duty trucks have been put into operation nationwide, covering more than 70 cities across China. The operators of heavy-duty truck battery-swapping infrastructure represented by State Power Investment Corporation Limited (SPIC) and State Grid Commercial Electric Vehicle Investment Co., Ltd. have been engaged in pilot demonstration under enclosed scenarios like mines, steel mills, harbors, urban slag dumps, and power plants, forming matured technical solutions and business models.

6.3 Operation Characteristics of Battery-Swapping Vehicles

By selecting battery-swapping BEVs on the National Monitoring and Management Platform, this Section compares and analyzes the operation characteristics of various types of vehicles and summarizes the travel characteristics of battery-swapping vehicles and the progress of battery-swapping pilot work, in a bid to provide experience and reference for the operation of battery-swapping vehicles towards more extensive application.

6.3.1 Operation Characteristics of Battery-Swapping Passenger Cars

The actual battery-swapping rate of operating passenger cars increased significantly with the gradual improvement of the battery-swapping infrastructure.

As for passenger cars, the actual battery-swapping rate of BEV passenger cars in different types of battery-swapping increased sharply year on year. The actual battery-swapping rate of private cars in 2022 was 91.4% (Fig. 6.15), while that of taxis and cars for sharing reached 97% and 99.2%, respectively, with the number of battery-swapping vehicles increasing significantly. The actual battery-swapping rate in the field of operation significantly increased thanks to the constant improvement of battery-swapping infrastructure and rapid growth of the quantity of battery-swapping vehicles.

The average monthly battery-swapping times of taxis were obviously higher than those of private cars, showing a higher battery-swapping frequency.

As shown in Fig. 6.16 on the distribution of the average monthly battery-swapping times per battery-swapping BEV passenger car, 87.9% of the BEV passenger cars had battery-swapping behavior, and the average monthly battery-swapping times of the vast majority of such cars were less than 10, with a proportion reaching 83.4%. 85.9% of the battery-swapping BEVs and 71.7% of the battery-swapping BEV cars for sharing had less than 10 battery-swapping times per month. The distribution of battery-swapping times was relatively dispersed, and the proportion of taxis with more than 30 battery-swapping times per month reached 22.0%.

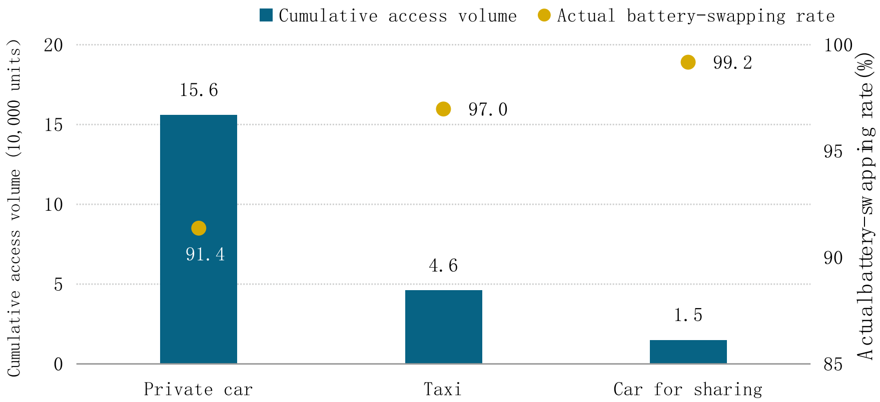


Fig. 6.15 Actual battery-swapping rate of battery-swapping BEV passenger cars in 2022—by type (*Note* Actual battery-swapping rate = Quantity of battery-swapping BEVs with actual battery-swapping behavior in the year/Cumulative quantity of battery-swapping BEVs accessed to the National Monitoring and Management Platform)

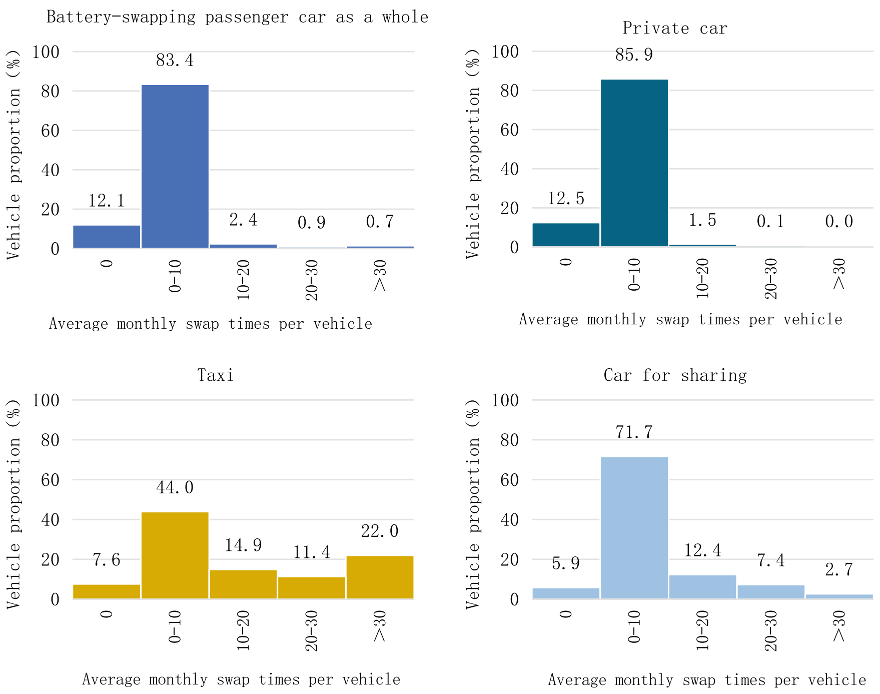


Fig. 6.16 Distribution of average monthly battery-swapping times of BEV passenger cars in 2022—by type

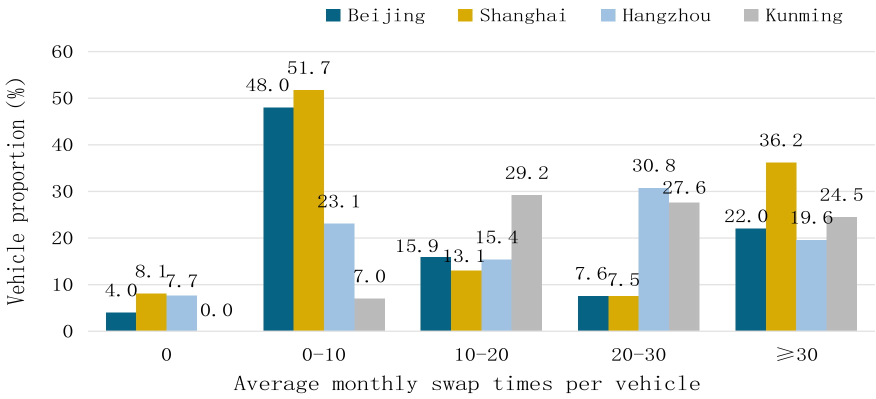


Fig. 6.17 Distribution of average monthly battery-swapping times of BEV taxis in 2022

The average monthly battery-swapping frequency of taxis was relatively scattered, and more than 90% of taxis had battery-swapping behavior.

The distribution of the average monthly battery-swapping times of taxis were decentralized. In terms of the distribution of the average monthly battery-swapping times per battery-swapping BEV taxi in typical cities in 2022 (Fig. 6.17), more than 90% of the battery-swapping taxis in Beijing, Shanghai, and Hangzhou had battery-swapping behaviors, while all of the battery-swapping taxis cabs in Kunming had so. By the distribution of the average monthly battery-swapping times per vehicle, the proportion of vehicles with more than 30 battery-swapping times per month per vehicle in typical cities was over 20%, namely one battery swap per day for a single vehicle. 36.2% of battery-swapping BEV taxis in Shanghai had at least one battery swap per day.

The average single-time mileage of passenger cars upon a single battery swap increased year by year, and the single-vehicle mileage of private cars upon battery swap was longer.

The average monthly single-time mileage for private cars in 2022 was significantly higher than that of taxis and cars for sharing (Fig. 6.18). The average mileage of private cars upon a single battery swap represented by NIO reached a high level to 262 km. The average monthly mileage of taxis and cars for sharing upon a single battery swap was 203 km and 234 km respectively.

The average monthly mileage of battery-swapping passenger cars upon a single battery swap showed significant seasonal differences.

In terms of average monthly mileage upon a single battery swap (Fig. 6.19), the average monthly mileage of battery-swapping private cars upon a single battery swap was generally higher than that of operating vehicles. Since the battery-swapping private cars were mainly high-range models and the battery-swapping operating passenger cars had high requirements on operational efficiency and were sensitive to the remaining driving range, the mileage per battery-swapping operating passenger car upon battery swap was in general lower than that of battery-swapping private car.

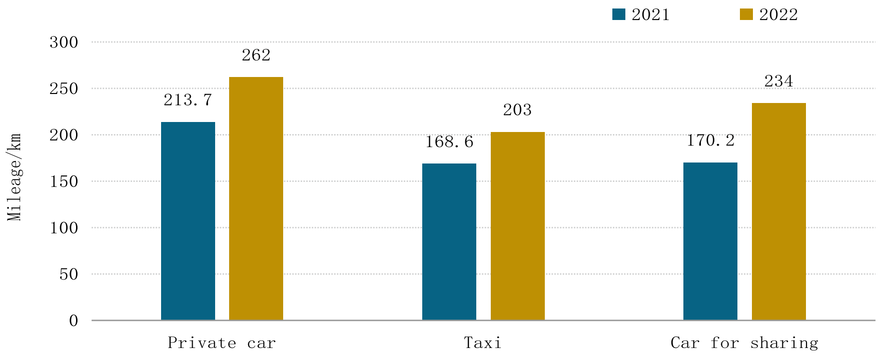


Fig. 6.18 Average mileage of BEV passenger cars upon a single battery swap over the years—by type

By season, the mileage of some battery-swapping passenger cars upon a single battery swap was affected given the charge–discharge characteristics of power batteries and the use of air conditioning within the vehicle under the low temperature in winter. In consequence, the mileage upon a single battery swap in winter was significantly lower than that (basically between 250 and 300 km) in other seasons.

The average daily travel characteristics of battery-swapping passenger cars in operation was quite different from those of private cars. As indicated in Table 6.4, the average daily mileage and duration of battery-swapping private cars in 2022 was 47.7 km and 1.4 h, respectively. Since the battery-swapping private cars were mainly distributed in first-tier and new first-tier cities, with longer one-way commuting mileage to and from work, the average daily mileage of battery-swapping private

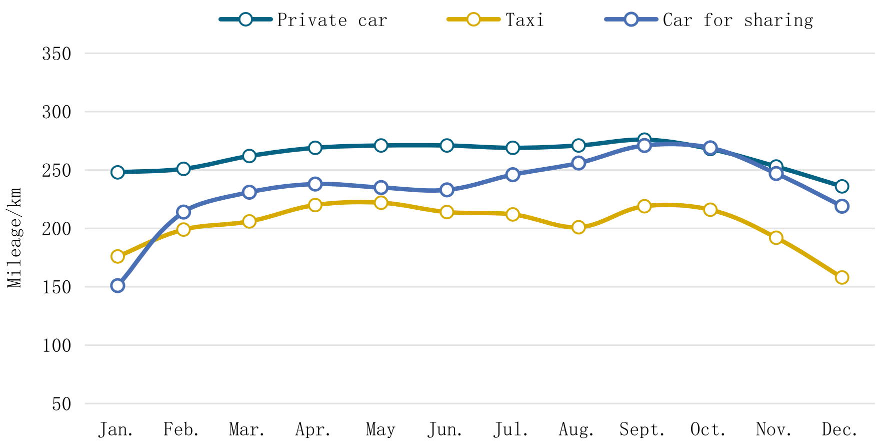


Fig. 6.19 Comparison of the average monthly mileage of battery-swapping BEV passenger cars upon a single battery swap in 2022

Table 6.4 Average daily travel characteristics of battery-swapping BEV passenger cars in 2022—by type

Indicator	Private car	Taxi/e-taxi	Car for sharing
Average daily mileage (km)	47.7	204.1	222.7
Average daily driving duration (h)	1.4	8.9	10.9

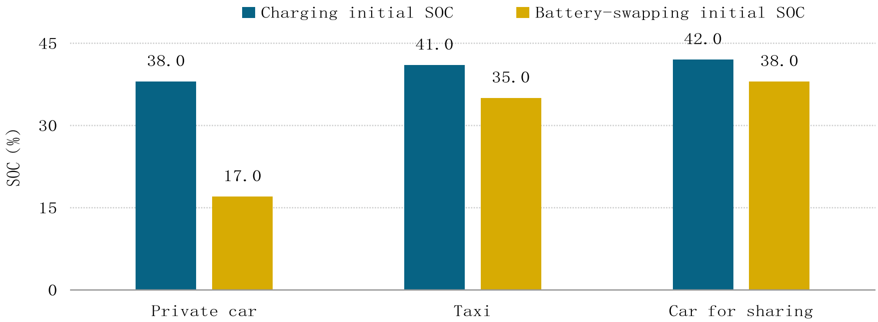


Fig. 6.20 Comparison of average initial SOC between battery-swapping vehicles and BEVs of the same type in 2022

cars was significantly higher than the average daily mileage of new energy private cars in China.

The average monthly battery-swapping initial SOC of all types of battery-swapping passenger cars was generally lower than the average charging initial SOC.

Based on the comparison of the average battery-swapping initial SOC of battery-swapping BEVs by type (Fig. 6.20), the battery-swapping initial SOC of all types of passenger cars was generally lower than their average monthly figures, mainly due to the long driving range and low battery-swapping initial SOC of passenger cars.

From the distribution of the starting SOC of power exchange for different power exchange vehicles (Fig. 6.21), the starting SOC of power exchange for private cars is generally concentrated in more than 20%, and the percentage of vehicles reaches 68.3%; the starting SOC of power exchange for rentals/network taxis and shared rental cars is mainly concentrated in 30–40%, and the percentage of vehicles reaches more than 18%.

6.3.2 Operation Characteristics of Battery-Swapping Heavy-Duty Trucks

Battery-swapping commercial vehicles mainly include battery-swapping BEV logistics vehicles below 12 tons and battery-swapping heavy-duty trucks above 12 tons.

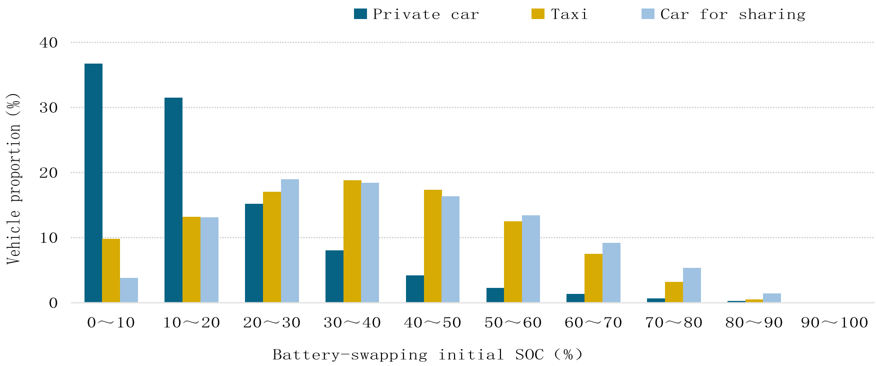


Fig. 6.21 Distribution of SOC at the beginning of power exchange for pure electric passenger cars in 2022

Due to the small quantity of battery-swapping BEV light logistics vehicles, this Section, with focus on the battery-swapping heavy-duty trucks above 12 tons, analyzes the overall battery-swapping characteristics of battery-swapping commercial vehicles in three types, namely dump trucks, tractor-trailers, and sanitation vehicles.

The actual battery-swapping rate of heavy-duty trucks significantly increased, and that of heavy-duty dump trucks was higher.

In 2022, the actual battery-swapping rate of heavy-duty trucks increased significantly year on year, and that of all types of vehicles exceeded 50%. The actual battery-swapping rate of dump trucks reached a high level of 80.7% (Table 6.5). The battery-swapping dump trucks are mainly used in short haul scenarios such as steel mills, power plants, and coal yards as well as medium and short-distance transportation scenarios like urban slag cars. Given the fixed routes and highly regular operation, it will be more convenient and less-consuming for battery-swapping dump trucks if battery-swapping facilities are provided along the way for the purpose of continuous operation.

Nearly 80% of the battery-swapping heavy-duty trucks in China had battery-swapping behavior, and 24.9% of the heavy-duty trucks had battery swap over 30 times per month.

Table 6.5 Actual battery-swapping rate of heavy-duty trucks in 2022—by type

Vehicle type	Cumulative access volume (vehicle)	Actual battery-swapping rate (%)
Battery-swapping BEV tractor-trailer	3,994	99.98
Battery-swapping BEV dump truck	6,564	99.98

From the distribution of the average monthly battery-swapping times of battery-swapping heavy-duty trucks in China (Fig. 6.22), nearly 80% of the battery-swapping heavy-duty trucks in China had battery-swapping behaviors, which could meet the demands under some scenarios. In addition, the proportion of vehicles recording over 30 average battery-swapping times per month reached 24.9%, indicating that nearly 1/4 of the battery-swapping heavy-duty trucks basically had a battery swap one day in daily operations.

According to the distribution of the average monthly battery-swapping times in typical cities (Fig. 6.23), there were significant differences in the battery-swapping behaviors of heavy-duty trucks in different cities given such factors as quantity of vehicles for promotion and degree of improvement for the network of battery-swapping facilities. Tangshan has promoted a large number of battery-swapping heavy-duty trucks, of which 51% recorded less than 10 battery-swapping times per vehicle per month. In comparison, 33.7% of such heavy-duty trucks in Yulin had 50 to 60 battery-swapping times per vehicle per month, some of which featured high operating efficiency.

The mileage of heavy-duty trucks upon single-time battery swap had little difference in seasons.

The average mileage of BEV tractor-trailers and battery-swapping BEV dump trucks upon single-time battery swap was 117 km and 116 km, respectively. Based on the comparison of mileages upon single-time battery swap by month in 2022 (Fig. 6.24), the average mileage per vehicle upon battery swap was around 100 km for both battery-swapping BEV tractor-trailers and battery-swapping BEV dump trucks. In the second half of 2022, battery-swapping BEVs had satisfactory operation effects and slight difference in the mileage upon single-time battery swap.

In terms of the distribution of the mileage upon single-time battery swap (Fig. 6.25), such mileage of battery-swapping BEV tractor-trailers was mainly distributed within 80 km and between 120 and 160 km, with the proportion of vehicles accounting for 36.9% and 28.4%, respectively; and such mileage of battery-swapping

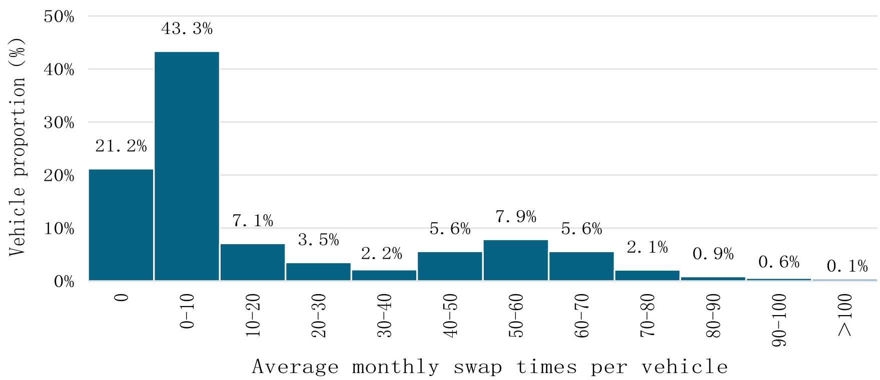


Fig. 6.22 Distribution of monthly average battery-swapping times of heavy-duty trucks in China in 2022

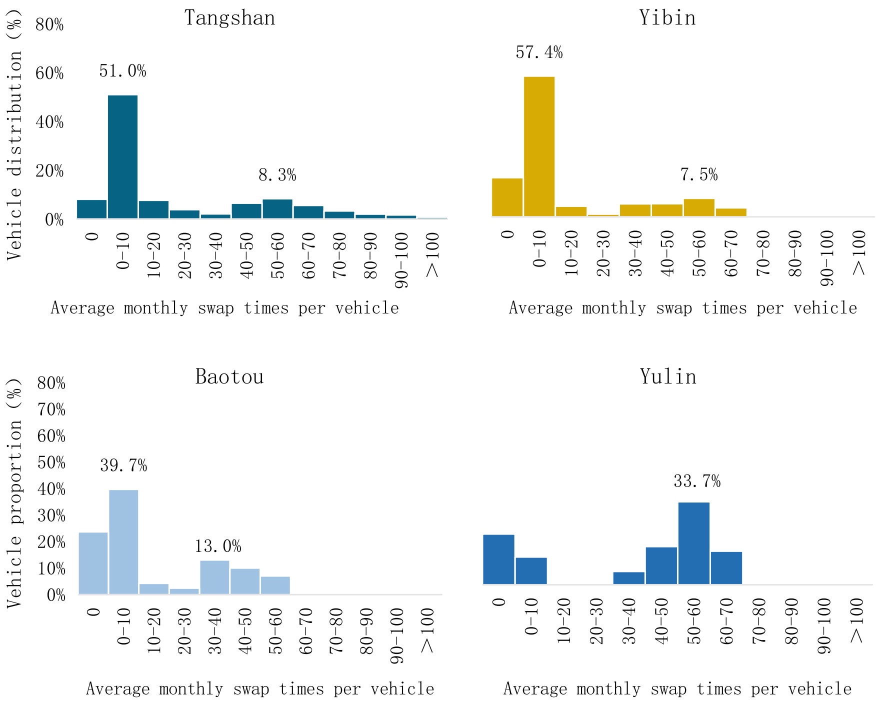


Fig. 6.23 Distribution of monthly average battery-swapping times of heavy trucks for a single vehicle in key cities in 2022

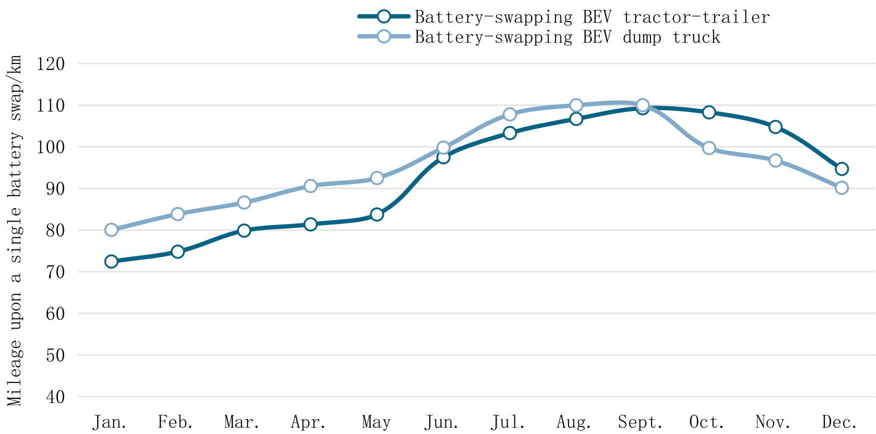


Fig. 6.24 Comparison of monthly mileage of battery-swapping trucks upon single-time battery swap in 2022

dump trucks was mainly concentrated within 100 km, with the proportion of vehicles accounting for more than 60%.

Battery-swapping heavy-duty trucks are mainly used for short- and medium-distance transportation for now, indicating space of further development of medium- and long-distance transportation scenarios.

In 2022, the average daily mileage of battery-swapping BEV tractor-trailers and battery-swapping BEV dump trucks was 208.9 km and 183.7 km, respectively, and the average daily driving duration was 10.2 h and 8.9 h, respectively (Table 6.6). In terms of the distribution (Fig. 6.26), the average daily mileage of battery-swapping BEV tractor-trailers and battery-swapping BEV dump trucks was mainly distributed in the range of 80 km to 120 km. Another 23.9% of battery-swapping BEV tractor-trailers had an average daily mileage exceeding 320 km, mainly serving the medium- and long-distance transportation scenarios on trunk lines.

From the distribution of charging heavy-duty trucks driving at different hours of the day (Fig. 6.27), the proportion of ordinary charging heavy-duty trucks and battery-swapping heavy-duty trucks in all hours of the day was above 40%, which basically met the daily operational demands. At all hours of the night, the proportion of battery-swapping heavy-duty trucks in operation was higher than that of charging heavy-duty trucks.

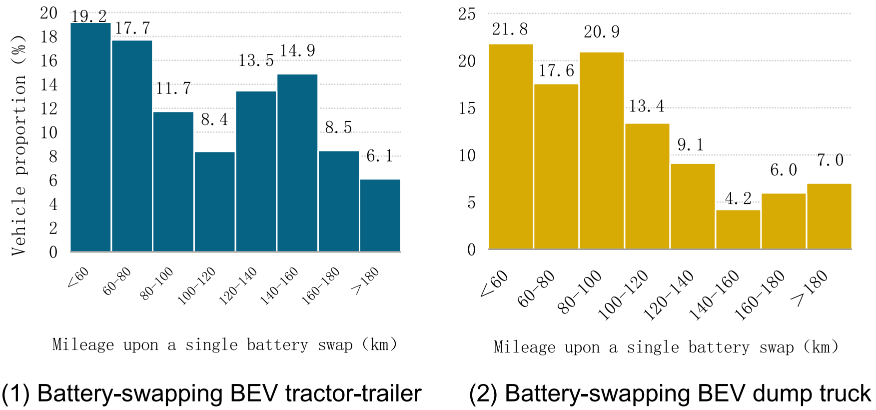


Fig. 6.25 Distribution of mileages of battery-swapping BEV heavy-duty trucks upon single-time battery swap in 2022—by type

Table 6.6 Average daily travel characteristics of battery-swapping heavy-duty trucks in 2022—by type

Indicator	Battery-swapping BEV tractor-trailer	Battery-swapping BEV dump truck
Average daily mileage (km)	208.9	183.7
Average daily driving duration (h)	10.2	8.9

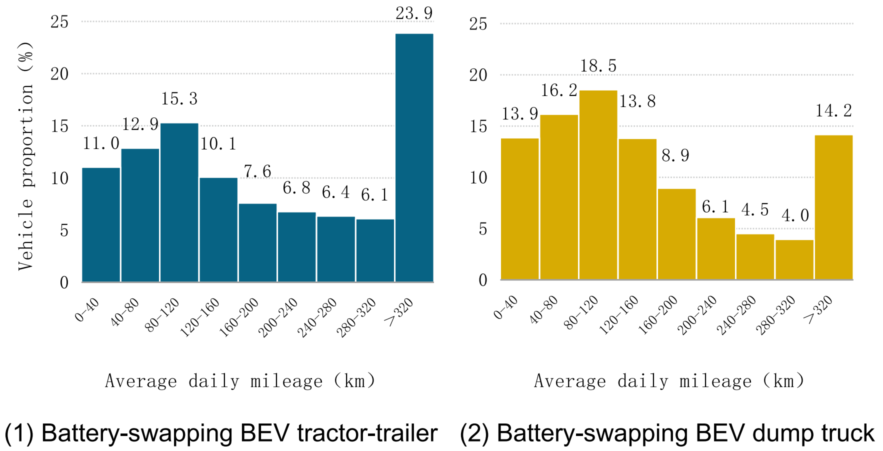


Fig. 6.26 Distribution of daily average mileage of battery-swapping heavy-duty trucks in 2022—by type

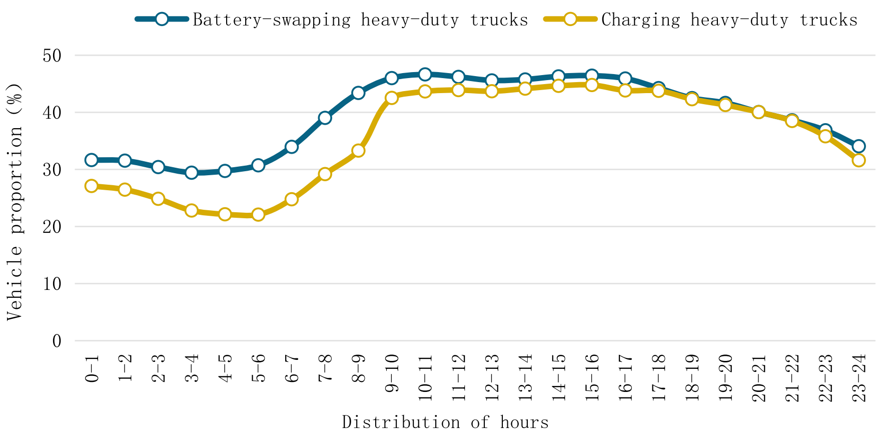


Fig. 6.27 Distribution of battery-swapping heavy-duty trucks running at different hours of the day in 2022

The battery-swapping mode could effectively alleviate the demand of new energy heavy-duty truck fleet for power supply efficiency.

BEV heavy-duty trucks are now mainly used in the way of battery swapping on top lift, with 4 min of battery swap for a single time and a success rate of more than 99%. With constant breakthroughs of intelligent and fast battery-swapping technology, the degree of battery-swapping automation was basically fully automatic and unattended. The battery-swapping time was equivalent to the refueling time of fuel vehicles, and the development of battery-swapping technologies could effectively alleviate mileage anxiety. By the distribution of charging initial and end SOCs of power batteries of battery-swapping vehicles, the battery-swapping initial SOC of more than 50% of

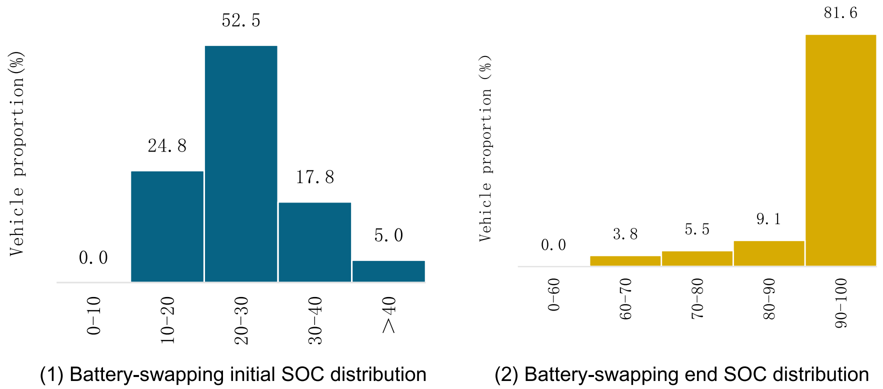


Fig. 6.28 Battery-swapping initial SOC and battery-swapping end SOC of battery-swapping heavy-duty trucks in 2022

the heavy-duty trucks fell in 20%-30%, and the battery-swapping end SOC of more than 80% of heavy-duty trucks was above 90% (Fig. 6.28) indicating that, once the power batteries under the battery-swapping mode was replaced, the driving mileage was longer, and the convenience was higher, which could help alleviate the user's mileage anxiety to a certain extent.

6.4 Promotion Achievements of Battery Swapping Vehicles in Pilot Cities

In 2021, the Ministry of Industry and Information Technology included 11 cities into the scope of battery-swapping pilot program in accordance with the *Notice on Initiating the Pilot Application of Battery-Swapping Mode for New Energy Vehicles*. This Section, with focus on the battery-swapping vehicles in the cities with comprehensive applications and the heavy-duty trucks featured cities, analyzes the promotion of battery-swapping vehicles, the construction of battery-swapping ecosystem, and the operation characteristics of the vehicles in the two cities for the past two years, in a bid to provide reference for the market promotion of battery-swapping vehicles towards a certain scale.

6.4.1 Promotion Outcome in Cities of Comprehensive Application

The pilot cities of battery-swapping had some experience in the field of battery-swapping BEVs. By the end of 2022, the eight pilot cities of comprehensive application of battery-swapping had a total of 82,634 battery-swapping BEVs accessed to the platform, of which Beijing held a major share, with private passenger cars and rental passenger cars as the mainstay; while the other pilot cities of comprehensive application all focused on the promotion of battery-swapping passenger cars (Figs. 6.29 and 6.30).

The average monthly mileage of single battery-swapping vehicle in pilot cities of comprehensive application is shown in Fig. 6.31, the mileage of battery-swapping

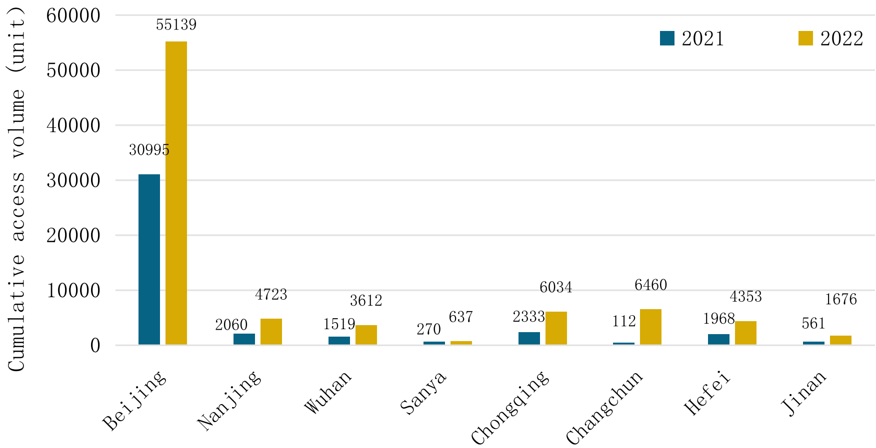


Fig. 6.29 Cumulative access volume of battery-swapping BEVs in pilot cities of comprehensive application over the years

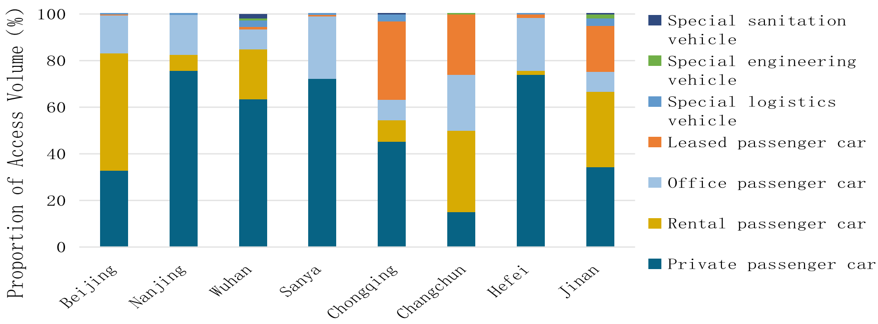


Fig. 6.30 Promotion structure of battery-swapping vehicles in pilot cities of comprehensive application in 2022

vehicles upon a single battery swap presents significant seasonal characteristics, for which the mileage in winter was far lower than that in other seasons. In respect of the mileage of battery-swapping vehicles upon a single battery swap over the years, the average monthly mileage of battery-swap vehicles upon a single battery swap in 2022 was generally higher than that in 2021.

In view of the mileage of battery-swapping vehicles upon a single battery swap in pilot cities of comprehensive application by month (Fig. 6.32), in such cities as Changchun and Beijing at high latitude featuring lower temperature in winter (December, January and February), the mileage of battery-swapping vehicles upon a single battery swap was markedly low. In other cities, such as Sanya, due to the small temperature difference throughout the year, the monthly distribution of mileage of battery-swapping vehicles upon a single battery swap was basically the same.

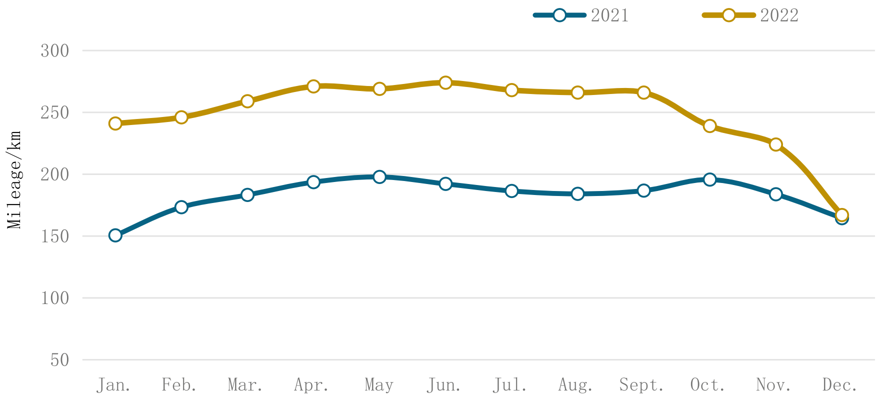


Fig. 6.31 Overview of average monthly mileage of battery-swapping vehicles upon a single battery swap in pilot cities of comprehensive application

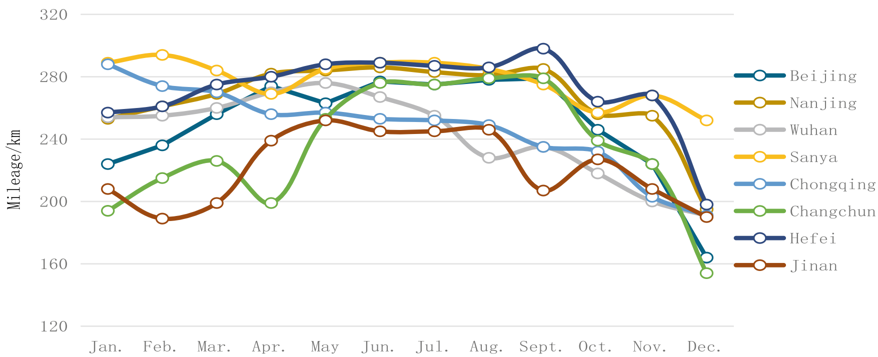


Fig. 6.32 Monthly distribution of mileage of battery-swapping vehicles upon a single battery swap in pilot cities of comprehensive application

6.4.2 Promotion Outcome of Heavy-Duty Trucks Featured Cities

Based on the operation data of battery-swapping vehicles on the National Monitoring and Management Platform, this Section selects Yibin, Tangshan, Baotou, and other battery-swapping heavy-duty trucks featured cities, as well as Chongqing, Shijiazhuang, Qinhuangdao, Ordos, Ma'anshan, Handan, Cangzhou, and other typical application cities for battery-swapping heavy-duty trucks to summarize the average daily travel characteristics of battery-swapping BEV tractor-trailers and battery-swapping BEV bump trucks in 10 key application cities for battery-swapping heavy-duty trucks.

A study shows that, in the field of tractor trailers (Fig. 6.33), the average daily mileage of battery-swapping BEV tractor-trailers in port cities like Tangshan and Qinhuangdao, mineral resource cities like Maanshan and Ordos, as well as Chongqing, exceeded 200 km, with the application scenarios covering ports, mines, and medium- and long-distance logistics transportation. In the field of dump trucks (Fig. 6.34), the average daily mileage of battery-swapping BEV dump trucks in Qinhuangdao, Cangzhou, Shijiazhuang, Tangshan, Maanshan, and Chongqing exceeded 200 km, and the average daily travel duration in Qinhuangdao, Cangzhou (Huanghua Port), and other port cities was more than 12 h, with a lower speed mainly for short-distance transportation within the port. However, the velocity of the battery-swapping BEV dump trucks in Chongqing was higher, is probably due to the fact that some of the vehicles were used for transportation on trunk line.

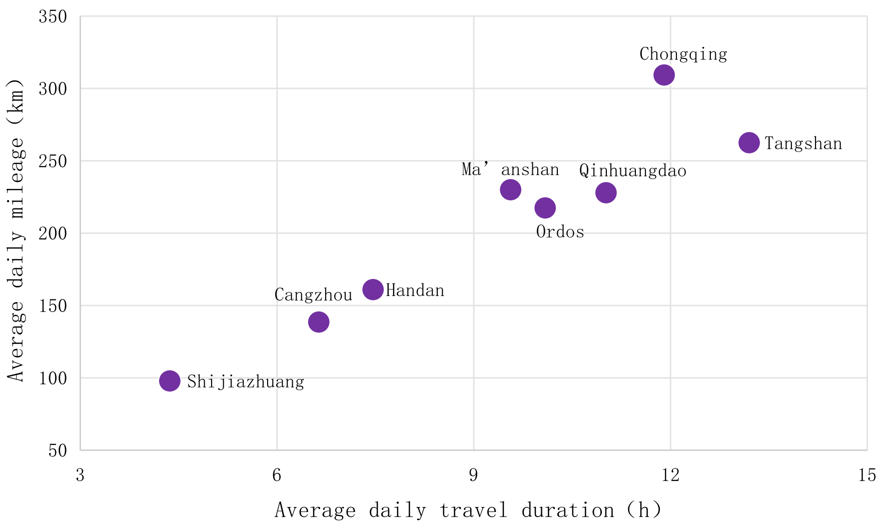


Fig. 6.33 Average daily travel characteristics of battery-swapping BEV tractor-trailers in typical cities in 2022

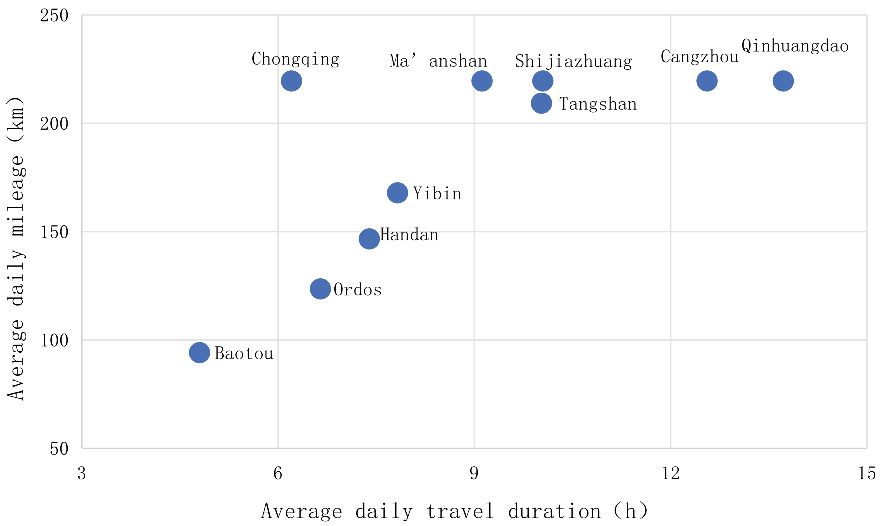


Fig. 6.34 Average daily travel characteristics of battery-swapping BEV dump trucks in typical cities in 2022

In terms of vehicle promotion and application, according to National Monitoring and Management Platform, by the end of 2022, three heavy-duty trucks featured cities had 3,924 battery-swapping BEVs accessed to the platform, including 3,431 battery-swapping BEV heavy-duty trucks. By city, Tangshan, Yibin, and Baotou had 3,212, 86 and 133 battery-swapping BEV heavy-duty trucks accessed, respectively.

By application scenario (Fig. 6.35), special logistics vehicle and special engineering vehicle were the major models for promotion. 100% the battery-swapping BEV heavy-duty trucks in Yibin were special logistics vehicles; over 71% of the battery-swapping BEV heavy-duty trucks in Tangshan were special logistics vehicles; while 75.9% of the battery-swapping BEV heavy-duty trucks in Baotou were special engineering vehicles.

By type (Fig. 6.36), battery-swapping tractor-trailer and dump truck in Tangshan were the major models for promotion; battery-swapping dump truck was the major model for promotion in Yibin, accounting for 97.7%, battery-swapping concrete mixer and battery-swapping dump truck were the major mode for promotion in Baotou, accounted for 58.6% and 39.8%, respectively.

The drivers for each of the three heavy-duty trucks featured cities varied with highly different work paths and progress in pilot program. **Tangshan: Environmental protection driven, application oriented, focusing on the development of the battery-swapping operation industries.**

With more than 100,000 heavy-duty trucks, Tangshan has clear goals on the pilot work under efficient coordination within the whole city in face of huge pressure

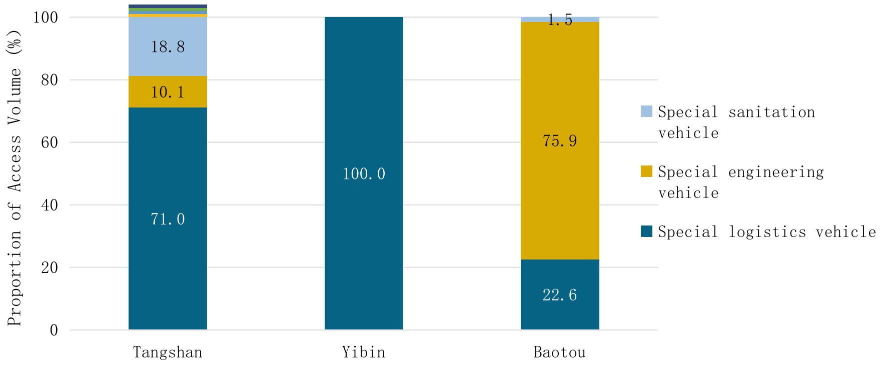


Fig. 6.35 Structure of promotion scenarios of battery-swapping heavy-duty trucks in heavy-duty trucks featured pilot cities in 2022

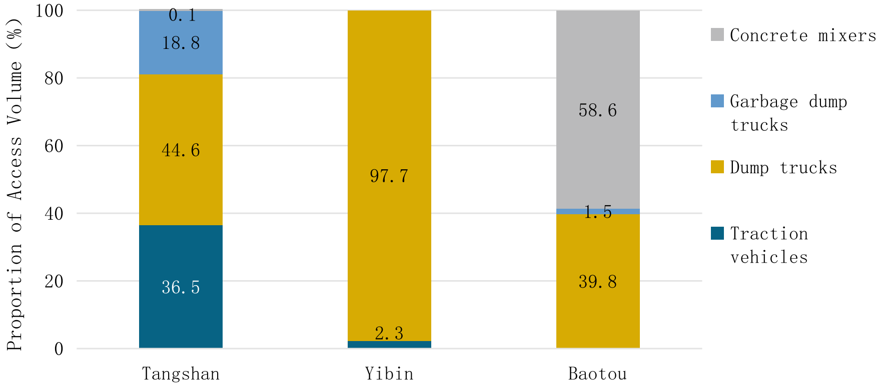


Fig. 6.36 Access structure of battery-swapping heavy-duty trucks in heavy-duty trucks featured pilot cities in 2022

on environmental protection. The government has provided support in the planning of land for battery-swapping stations, power expansion, and facility construction, such as the issuance of green pass for new energy heavy trucks and financing support for battery-swapping stations. In particular, a specialized power battery asset management company was established, which played an important role in the efficient utilization of battery resources and ensuring safety operations. By the end of 2022, the quantity of battery-swapping heavy-duty trucks put into operation in Tangshan exceeded the planning target during the pilot period. Tangshan has planned a city-level battery-swapping trunk network featuring "three vertical and one horizontal" and connecting nearly 20 large and medium-sized iron and steel enterprises, with a total length of about 620 km. 11 battery-swapping stations were built along the way and 14 are now under construction.

Yibin: industry driven, regional expansion, focusing on innovation exploration and overall distribution.

Yibin holds a relatively complete battery-swapping industrial chain for new energy heavy-duty trucks and accommodates such big businesses as Chery Commercial Vehicle and CATL Sichuan. Yibin issued several policies to subsidize the purchase of battery-swapping heavy-duty trucks at a rate of RMB300/kWh and gives priority to the land use right for battery-swapping stations. It also set up an industrial development funds (RMB6 billion from the first fund raising) to offer funds to high-quality battery-swapping projects. The pilot work has been extended to Chengdu, Ziyang, Leshan, Meishan, and other neighboring cities, with more than 300 battery-swapping heavy-duty trucks applied. In terms of station establishment, some battery-swapping stations were free from limited operation capacity for battery-swapping vehicles to a certain extent by means of compatibility design. In addition, Yibin has been making active explorations in PV, storage, and charging, battery-swapping for heavy-duty truck, and oil, gas, and hydrogen refueling integrated energy stations.

Baotou: industry and environmental protection driven and steady promotion of pilot work.

Baotou recorded an annual freight volume of nearly 120 million tons of raw materials like minerals, coal, steel, and aluminum, indicating a huge demand for transportation and carbon emission reduction. Beiben Trucks, as a leading vehicle enterprise in Baotou, started to deliver battery-swapping heavy-duty trucks in batch in 2019, forming a development pattern driven by both industry and environmental protection. In terms of supporting battery-swapping infrastructure construction, Beiben Trucks worked with Aulton, GCL-ET, and Unex on technological research and development of battery-swapping stations and planned to build more than 60 stations. In July, 2022, Baotou Market Supervision Administration organized examination and approval of the local standard—Technical Specifications for the *Construction of Shared Battery-Swapping Stations for Electric Medium- and Heavy-duty Trucks and Battery-Swapping Vehicles*, which was expected to serve a vital purpose in regulating and promoting the building of the battery-swapping interfaces and stations for BEV heavy-duty trucks as well as standardized operation and management.

In addition, Shanxi, Shandong, Henan, Jiangsu, and other provinces also put into operation several battery-swapping heavy-duty trucks in refreshing the market of heavy-duty trucks, of which Shanxi has built 12 battery-swapping stations, with another 6 stations under construction, which, to a certain extent, indicated that the model of battery-swapping heavy-duty trucks was recognized by the market.

6.5 Summary

6.5.1 Current Situation of Battery-Swapping Industry

Local governments have introduced incentive policies pertinent to the battery-swapping industry to boost production and sales. Each of the pilot cities has its own features in operation scenarios and industrial organization mode and has formed a complete industrial ecosystem. Based on the data of the National Monitoring and Management Platform and other public information, this Section preliminarily summarizes the industrial policies and promotion achievements of battery-swapping BEVs in China after the commencement of pilot work. In specific,

(1) **The policy support for the battery-swapping industry was enhanced, and local governments stepped up the implementation of the support guidelines and standards on battery swap.**

The central and local governments have been expediting the promulgation and implementation of support policies and standards for the battery-swapping industry since 2021. In addition to the national policy on tax reduction and exemption for the purchase of BEVs, Beijing, Shanghai, Chongqing, Guangdong, Guangxi, Sichuan, Shandong, Anhui, Hainan and other provinces have given subsidies of different amounts to the construction or operation of the battery-swapping stations. In face of the demands of users, entities on the national, industrial, and local level are working harder on the formulation of standards and specifications on battery swap. In 2022, Jiangsu issued a group standard for battery-swapping mode—*Technical Specification on Battery-swapping Battery Pack System for Battery Electric Heavy-duty Trucks*, and Baotou issued the local standard—*Technical Specification on Battery Swapping Stations for Electric Medium- and Heavy-duty Trucks and Vehicle Battery Swapping System.* In the meantime, the validation committee for group standards under the *Technical Specification for Construction of Shared Battery-swapping Stations for Battery Electric Medium- and Heavy-Duty Trucks and Battery-swapping Vehicles* deliberated and approved a number of battery-swapping standards for heavy-duty trucks. In January, 2023, the *Battery-swapping Stations for Battery-swapping Heavy-duty Trucks Part 1: Fire Safety Design Specifications* and other five local standards developed by Yibin Fire and Rescue Detachment and a number of units were approved for official release. The specification is composed of two sections: Battery-swapping stations for battery-swapping heavy-duty trucks and central charging stations for BEV bicycles.

(2) **Thanks to the support of industrial policies, the battery-swapping application scenarios were increasingly matured, with the rapid promotion of battery-swapping vehicles.**

The battery-swapping application scenarios are more diversified. In the field of passenger cars, for key scenarios such as taxis, private cars, official vehicles, and rental and leased vehicles, NIO, Geely, BAIC, and other vehicle manufacturers exerted forces in battery-swapping passenger cars. As to commercial vehicles, for engineering projects on mining areas, steel mills, power plants, and ports, as well as public fields like industrial ports, factories (short haul), and logistics transportation, Hanma Technology, XCMG, SAIC Hongyan, SANY, and other manufacturers are now speeding up the development of battery-swapping heavy-duty trucks towards a certain scale. In terms of promotion of BEVs, by the end of 2022, the National Monitoring and Management Platform recorded an access volume of more than 290,000 NEVs, including 279,000 BEV passenger cars and 11,000 BEV commercial vehicles.

(3) **The improvement of battery-swapping infrastructure boosted rapid growth in the volume and operational efficiency of battery-swapping vehicles.**

With the implementation of local battery-swapping industry policies, the battery-swapping infrastructure construction system has been gradually improved, along with operation intensity and frequency of application. In 2022, the actual battery-swapping rate of passenger cars and commercial vehicles increased significantly year on year, and the total volume of vehicles increased rapidly. Battery-swapping vehicles have great advantages in power replenishment efficiency: The battery-swapping initial SOC is generally lower than charging initial SOC (battery replaced in just 5 min), and the effective mileage between battery charging and discharging prolongs under battery-swapping mode. For the sectors of private vehicles facing difficulty in installing private charging piles and the public operation areas such as taxis, e-taxis, and heavy-duty trucks, it is more convenient to use BEVs According to the travel characteristics of battery-swapping vehicles over the years, the average daily mileage of passenger cars and heavy-duty trucks in 2022 increased significantly year on year, showing increasing operation efficiency.

(4) **Entities from different sectors work together to build the operation ecology of bevs to accelerate the business innovation of the "separation of vehicles and battery" model.**

With the increasing support of local governments for the battery-swapping industry and the extensive promotion and application of battery-swapping vehicles, vehicle manufacturers, power battery manufacturers, energy enterprises, and financial institutions are forced to join hands to speed up the innovation of "separation of vehicles and battery" model by various means: Establishing the service platform for battery-swapping assets, exploring a favorable business mode for life-cycle management of power batteries, purchasing vehicles (without non-standard parts) and leasing batteries to cater to users' demands, and applying battery recycling by grade for higher utilization and environmental protection. Credit and insurance innovation for battery-swapping NEVs are encouraged to support the development of consumer credit business for vehicles (without battery). Insurance companies are advised to develop exclusive insurance products for battery-swapping NEVs.

6.5.2 Suggestions for the Battery-Swapping Industry

Despite the rapid growth of battery-swapping vehicles and industry chain, China still faces some problems, such as inconsistent battery standards among different enterprises, lack of unified battery-swapping standards and battery-swapping vehicle interchangeability standards; difficulty in battery traceability management and insufficient emphasis on safety issues; and huge investment in the early stage for the battery-swapping industry, all of which hindered the industrial development to a certain degree and need to be resolved urgently. In view of the problems in the development of the battery swap industry, following are specific suggestions:

(1) **Strengthen the top-level design and improve the supporting policies and standards.**

In terms of standards, the draft of standards for the general platform for battery swap was already completed. It is recommended that the state speed up the research and formulation of national standards for vehicle-mounted battery-swapping systems and battery packs and regulate battery interchangeability and interface compatibility. As for the specifications for station building, provisions on the construction of battery-swapping stations should be clarified, in particular those on charging, swap, oil, and gas on a pilot basis to resolve the difficulty in land use for battery-swapping stations. With respect to industry management, it is suggested to optimize the laws and regulations on the announcement of BEVs, establish an exclusive announcement and certification system for NEVs, and apply a separate certification of vehicles and batteries. It is also recommended to further improve the battery traceability system of battery-swapping vehicles, improve the adaptability of "separation of vehicles and batter" model, and promote the comprehensive monitoring and management platform of station-vehicle-electricity for battery-swapping stations for the safety operation of battery-swapping heavy-duty trucks.

(2) **Give full play to financial instruments and data resources for the sustainable development of heavy-duty trucks**.

Support should be provided to eligible infrastructure construction enterprises to raise financing by issuing corporate bond and introducing green fund investment. Local governments and authorities are encouraged to provide financing support to the construction and operation enterprises of battery-swapping infrastructure in the form of financing credit enhancement and loan interest subsidies. "Battery banks" are encouraged to develop innovative business operations, make full use of the data from the life cycle of power batteries in battery-swapping stations, actively conduct in-depth integration and application of the battery data platform in technology research and development, product planning, used car market, financial insurance, cascade utilization, recycling and other scenarios, establish and improve battery data security and data asset trading mechanism, and expedite the circulation and integration of data resources at battery-swapping stations.

(3) **Evaluate the development path and the effectiveness of pilot work in a scientific manner guided by the concept of green transportation.**

Cities should, based on the characteristics of local industrial development, scientifically evaluate and prudently select the technical routes for battery charging and swap and hydrogen cell and electric commercial vehicles, rationally leverage the advantages on the modal shift from truck to rail, hydrogen heavy-duty trucks, and battery-swapping heavy-duty trucks under the national strategy of green transportation and in the principles of adjustment to local conditions and hydrogen and electricity application as appropriate under overall coordination. It is also necessary to study and appraise the effectiveness of the pilot work in due course based on full exchange and experience summary to timely solve problems and keep updated the pilot work, thus providing basis for resource coordination and unifying the thoughts of pilot cities to lay a solid foundation for pilot area expansion and other efforts.

Chapter 7
Fuel Cell Electric Vehicles (FCEVs)

Hydrogen energy, as a secondary energy source characterized by its amply supply, green and low-carbon nature, and extensive application, is gradually becoming one of the crucial pathways for achieving carbon neutrality goals in developed countries worldwide, including Japan, South Korea, the United States, and the European Union. It has been incorporated into China's "carbon neutrality" energy strategy, serving as a strategic choice to improve energy consumption structure and ensure national energy supply security. Fuel cell electric vehicles (FCEVs), playing a vital role as a key application in the downstream of the hydrogen energy industry chain, have become the primary entry point for early-stage developments in the hydrogen energy sector. Considerable achievements have been made in scaling up their practical applications. By examining the policy framework, the effectiveness of NEV demonstrations and promotions, as well as NEV operation and refueling characteristics at the national and local levels, this chapter presents an overview of the accomplishments and identified issues in the current phase of FCEV promotion. Its objective is to provide valuable data and decision support for the nationwide expansion and application of FCEVs.

7.1 Development Status of the FCEV Industry

7.1.1 Ongoing Improvements in Industrial Policies

(1) **As for top-level design, the "14th Five-Year Plan" clearly defines hydrogen energy as a key component of the national energy system**

Amid the context of achieving dual carbon goals, hydrogen energy has gained recognition as a crucial clean energy source and is considered as one of the essential energy routes for the future. The global consensus among major nations highlights the significance of hydrogen energy development. The Japanese government has

Z. Wang, *Annual Report on the Big Data of New Energy Vehicle in China (2023)*,
https://doi.org/10.1007/978-981-97-4840-2_7

taken steps to foster an international hydrogen supply chain, leveraging the collaboration of business alliances to coordinate the development of hydrogen energy. Furthermore, they have established an innovation platform for government-industry-academia collaboration to provide technical support for research and development. Through a top-down approach, the South Korean government has established a well-structured roadmap for hydrogen energy development, mitigating uncertainties for companies operating in the hydrogen energy industry. Additionally, they have allocated significant financial resources to incentivize social capital investment in the hydrogen energy sector. The United States regards the development of the hydrogen energy industry as a long-term strategic reserve, fostering collaboration among stakeholders within a competitive framework. In addition, the Department of Energy's Loan Programs Office (LPO) provides access to debt capital for deploying innovative clean-energy projects. The European Union (EU) is currently prioritizing hydrogen energy as a critical avenue for key industries to address carbon reduction, reduce emissions, and ensure national energy security.

At the national level, there is a consistent emphasis on the need for a transition to green energy, with hydrogen energy officially integrated into the national energy system and clear industry-level planning. As a crucial direction of energy technology revolution and a significant component of future energy strategy, the importance and crucial role of hydrogen energy in industrial development, technological innovation, and energy transition are emphasized in important documents such as the *14th Five-Year Plan for National Economic and Social Development and the Outline of the 2035 Long-Range Objectives*, as well as the *Opinions of the CPC Central Committee and State Council on the Complete, Accurate and Comprehensive Implementation of the New Development Concept to Do a Good Job in Carbon Peaking and Carbon Neutrality*. On March 23, 2022, the National Development and Reform Commission (NDRC) and the National Energy Administration (NEA) published the *Medium and Long-Term Plan for the Development of Hydrogen Energy Industry (2021–2035)* (hereinafter referred to as the "Plan"), specifying that hydrogen energy is an integral part of the future national energy system, a crucial vehicle for achieving green and low-carbon transformation in end-use sectors, and a strategic emerging industry and key focus for future development (Table 7.1). The Plan sets three five-year development plans for the hydrogen energy industry: by 2025, a relatively complete supply chain and industrial system will be established, and the fleet of fuel cell electric vehicles (FCEVs) will reach approximately 50,000 units; by 2030, a more comprehensive technological innovation system for the hydrogen energy industry, along with a clean energy hydrogen production and supply system, will take shape; and by 2035, a hydrogen energy industry system will be in place, creating a diverse hydrogen energy application ecosystem encompassing transportation, energy storage, power generation, and industrial sectors.

The government has introduced a range of dedicated initiatives for hydrogen standardization (Table 7.2) to propel the FCEV industry towards development characterized by high quality, scale, and agglomeration. On October 9, 2022, the NEA issued the *Action Plan for Improving Standardization of Carbon Peak and Carbon Neutrality in the Energy Sector* (hereinafter referred to as the "Action

Table 7.1 Key takeaways of FCEVs outlined in the *Medium and Long-Term Plan for the Development of Hydrogen Energy Industry (2021–2035)*

Indicator	Specific content
Strategic positioning of hydrogen energy	(1) Hydrogen energy is an essential component of the future national energy system; (2) Hydrogen energy acts as a key catalyst for enabling green and low-carbon transition in energy consumption (3) The hydrogen energy industry is a strategic emerging industry and a key focus for future industrial development
Principles of hydrogen energy development	(1) Innovation-driven, self-reliance and self-improvement; (2) Safety-first, clean and low-carbon; (3) Market-oriented, government-guided; (4) Prudent application, demonstration-led
Application scenarios	Across various sectors such as transportation, energy storage, power generation, and industry, with transportation encompassing not only vehicles but also ships, aircraft, and more
Application—transportation sector	Efforts are being directed towards the implementation of hydrogen fuel cell technology in medium- and heavy-duty vehicles, with a strategic expansion plan for the bus and truck markets. The complementary development of fuel cell vehicles and lithium-ion battery vehicles is being explored, while also delving into their potential applications in marine vessels, aircraft, and other relevant sectors
Vehicle holding target	Approximately 50,000 vehicles by 2025
Advancement of key technologies	(1) Proton exchange membrane fuel cells; (2) Core technologies in key areas including infrastructure for hydrogen production (3) Safety technologies across the entire industry chain; (4) Research and development of core technologies in key areas at each stage; (5) Scientific mechanisms related to hydrogen energy, such as photoelectrochemical water splitting, hydrogen embrittlement failure, low-temperature adsorption, as well as leakage, diffusion, and combustion

Source Medium and Long-Term Plan for the Development of Hydrogen Energy Industry (2021–2035)

Plan”). In the field of hydrogen energy, the Action Plan clearly outlines the need to further promote the standardization management of the hydrogen energy industry and accelerate the improvement of top-level design and standard system for hydrogen energy. It involves the development of technical standards for hydrogen production, storage, transportation, refueling, and diversified applications, supporting the full industry chain development of “production, storage, transportation, and utilization” of hydrogen energy. The focus is on the development of standards in areas such as renewable energy-based hydrogen production, hydrogen-electricity coupling, fuel cells, and systems, to increase the effective supply of standards. The establishment of a sound hydrogen energy quality and hydrogen energy testing and evaluation basic standard system is also emphasized.

The government has released a series of policies at the national level to support the technological innovation of common technologies and key components in the hydrogen energy industry in the field of fuel cell technology revolution. On April 27, 2022, the Ministry of Science and Technology issued the *Notification of Application for National Key R&D Program of "Advanced Structures and*

Table 7.2 Planning documents for fuel cell related standards introduced since 2022

Date	Ministry/ department	Document title	Specific content
January 2022	National Energy Administration	*Guidelines for Establishment of Energy Industry Standardization Projects in 2022*	Identify electrolytic hydrogen production and integrated applications in the field of hydrogen energy storage, hydrogen-electric coupling technology, hydrogen fuel cell power stations, and key components of fuel cells as the priority focus areas for establishing energy industry standardization projects
February 2022	Standardization Administration of the P. R. C	*Key Priorities of National Standardization Work for 2022*	Increase efforts in developing standards for new energy utilization and hydrogen-related fields
March 2022	National Energy Administration	*Guidance on Energy Work for the Year 2022*	1. Accelerating the green and low-carbon transformation of energy: Tailor renewable energy hydrogen demonstrations according to local conditions, and explore the development roadmap and commercialization path of hydrogen energy technologies; 2. Introduce multiple innovation platforms in six major priority areas: new power systems, novel energy Storage, hydrogen energy, and fuel cells
August 2022	Ministry of Transportation of the People's Republic of China	*Green Transportation Standard System (2022)*	Develop technical specifications for FCEV-buses, configuration requirements for FCEV-buses, and technical standards for hydrogen refueling stations
August 2022	National Energy Administration	*Action Plan for Improving Standardization of Carbon Peak and Carbon Neutrality in the Energy Sector*	Take more steps to advance standardization and management in the hydrogen energy industry, hasten the development of the top-level design and standard system for hydrogen energy standards

Source Official websites of various ministries and commissions

Composites" and other Special Programs 2022. The application guidelines cover the key special program on "Hydrogen Technology," which focuses on four technical directions: green hydrogen production and large-scale transfer storage system, safe hydrogen storage and rapid transmission and distribution system, convenient hydrogen upgrading and efficient power system, and comprehensive demonstration of "hydrogen entering thousands of households." On August 18, 2022, nine government departments, including the Ministry of Science and Technology, jointly issued the *Implementation Plan for Carbon Peak and Carbon Neutrality Supported by Science and Technology (2022–2030)* (hereinafter referred to as the "Implementation Plan"). Regarding hydrogen energy, the Implementation Plan explicitly states the research and development directions for renewable energy-based, high-efficiency, and low-cost hydrogen production technologies, large-scale physical and chemical hydrogen storage technologies, technologies of large-scale and long-distance transportation of hydrogen by pipeline, hydrogen safety technologies, as well as exploration and development of new hydrogen production and storage technologies. On October 9, 2022, the National Natural Science Foundation of China (NSFC) issued the *Guide to "Dual Carbon" Programs of the Department of Engineering and Materials Science – Fundamental Research on Hydrogen Production and Storage under Dual Carbon Goals* (hereinafter referred to as the "Guide"). The Guide specify three funding directions, which include the synergistic conversion of hydrogen and carbon, off-grid hydrogen production, energy transmission, and transformation using renewable energy, as well as hydrogen transportation and regulation within underground porous reservoirs.

The government has introduced policies at the national level to facilitate the training of hydrogen energy professionals and the establishment of related academic disciplines, fostering the sustainable and high-quality development of the hydrogen energy industry. On May 7, 2022, the Ministry of Education issued the *Work Plan for Strengthening the Development of Higher Education Talent Training System for Carbon Peak and Carbon Neutrality* (hereinafter referred to as the "Work Plan"). The Work Plan makes it clear that, in terms of talent cultivation in the hydrogen energy field, there is a need to strengthen the prediction of talent demand in key industries. By combining the laws of talent development, educational teaching, and technological innovation in the new era, it seeks to expedite the training of scarce talents in new energy, energy storage, hydrogen energy, carbon capture, and other areas. Moreover, it aims to accelerate the establishment of disciplines related to energy storage and hydrogen energy. With the goal of accommodating the large-scale consumption of renewable energy, it promotes the training of talents in energy storage and hydrogen energy at the institutions of higher education, catering to the demand for large-capacity and long-term energy storage, and achieving comprehensive coverage in the entire value chain. Additionally, there is an emphasis on increasing efforts to attract high-level talents from overseas, encouraging colleges and universities to actively seek outstanding talents in areas such as carbon capture, utilization, and sequestration, clean utilization of fossil energy, cutting-edge technologies in renewable energy, energy storage and hydrogen energy, as well as carbon economy and policy research. On top of that, efforts should be made to gather high-level talents from overseas to participate in the development and scientific research of carbon neutrality disciplines.

(2) **The ongoing implementation of local policies raises hopes of surpassing the target set for the promotion of FCEVs during the "14th Five-Year Plan" period.**

With the support of national policies and the driving role of demonstration urban agglomerations, typical provinces and cities have successively issued development plans for the hydrogen energy and FCEV industry. It is expected that the national scale of FCEV promotion will exceed the established target by the end of the "14th Five-Year Plan" period. By examining the development plans for the hydrogen energy industry and the specific policies for FCEVs released by various provinces and key cities (Table 7.3), it can be observed that the policy types mainly include industry development plans, guiding opinions for high-quality industry development, action plans, and supportive policies and measures for industry development. In addition to those in urban agglomerations, demonstration projects such as "Hydrogen entering thousands of households" and the Chengdu-Chongqing Hydrogen Corridor are also progressing. On April 16, 2021, the Ministry of Science and Technology and the Shandong provincial government co-organized and implemented the "Hydrogen entering thousands of households" technology demonstration project. The two parties signed a framework agreement for the project, along with multi-scenario demonstration applications of hydrogen production and utilization technologies launched in the cities of Jinan, Qingdao, Zibo, and Weifang. The plan is to establish "a hydrogen highway, two hydrogen ports, three popular science bases, four hydrogen industrial parks, and five hydrogen communities." On November 30, 2021, both Sichuan Province and Chongqing Municipality initiated the construction of the Chengdu-Chongqing Hydrogen Corridor, collaborating to create an interconnected hydrogen energy-enabled economic network. Looking at the phased promotion targets for the demonstration urban agglomerations, Shandong Province, the Chengdu-Chongqing region, and key provinces in the FCEV sector, the plan is to achieve a national promotion target of over 100,000 FCEVs by the end of 2025, surpassing China's target in this respect at the end of the "14th Five-Year Plan" period.

Local policies have broadened their scope of coverage, encouraging diversified applications. By examining the names and scope of hydrogen energy policies in various provinces and municipalities, it can be observed that the direction of industry support and guidance policies has gradually expanded from the transportation sector to include multiple sectors such as transportation, industry, energy storage, and power. The hydrogen energy ecosystem has been developing year by year, covering the entire industry chain of production, storage, transmission, and utilization, and a "1 + N" policy system that caters to multiple industries and scenarios is set to be launched at an accelerated pace. The upper-level guarantees and industrial environment for hydrogen energy development will continue to improve, in order to adapt to the future demands of diversified industrial development.

Table 7.3 National staged targets for promoting FCEVs in major provinces or municipalities and cities

Province or municipality/city	Policy document	Target for 2023 (units)	Target for 2025 (units)
Beijing	*Plan for the Development of Hydrogen Industry in Beijing (2021–2025) (Draft for Comments)*	3000	10,000
Shandong	*Medium- to Long-Term Plan for the Development of Hydrogen Industry in Shandong Province (2020–2030)*		10,000
Hebei	*Plan for the Development of Hydrogen Industry in Hebei during the 14th Five-Year Plan Period*		10,000
Henan	*Action Plan for the Development of HFCEV Industry in Henan Province*	3000	5000
Chongqing	*Action Plan for Accelerated Construction of a Comprehensive Smart New Energy Vehicle Industry Ecosystem in Chongqing*		5000
Tianjin	*Action Plan for the Development of Hydrogen Industry in Tianjin*		
Sichuan	*Plan for the Development of Hydrogen Industry in Sichuan Province*		6000
Zhejiang	*Guiding Opinions for Accelerating the Development of Hydrogen Industry in Zhejiang Province* and *Implementation Plan for Accelerating the Development of HFCEV Industry in Zhejiang Province*		5000
Shanghai	*Implementation Plan for the Innovation and Development of FCEV Industry*, *Implementation Plan for Carbon Peak in Shanghai*, *Medium- to Long-Term Plan for the Development of Hydrogen Industry in Shanghai (2022–2035)*, *Implementation Plan for Accelerated Development of the NEV Industry in Shanghai (2021–2025)*	10,000	10,000
Guangdong	*Action Plan for Accelerated Construction of FCEV Demonstration Cities in Guangdong Province (2022–2025)*		10,000
Inner Mongolia Autonomous Region	*Several Measures for Promoting the Development of FCEV Industry in Inner Mongolia Autonomous Region (Trial) (Draft for Comments)*	3830	10,000
Changzhi, Shanxi	*Plan for the Development of Hydrogen Industry in Changzhi City (2020–2030)*	3650	6830
Datong, Shanxi	*Plan for the Development of Hydrogen Industry in Datong City (2020–2030)*	952	5727

(continued)

Table 7.3 (continued)

Province or municipality/city	Policy document	Target for 2023 (units)	Target for 2025 (units)
Shaanxi	*Three-Year Action Plan for the Development of Hydrogen Industry in Shaanxi Province (2022–2024)* and *Plan for the Development of Hydrogen Industry in Shaanxi Province during the 14th Five-Year Plan Period*		10,000
Wuhan, Hubei	*Opinions on Supporting the Development of Hydrogen Industry in Wuhan*		3000
Lanzhou, Gansu	*Implementation Plan for the Development of Hydrogen Industry in Lanzhou (2022–2025)*		1000
Yueyang, Hunan	*Plan for the Construction of a Hydrogen City and the Development of Hydrogen Industry in Yueyang (2020–2035)*		1000
Zhuzhou, Hunan	*Plan for the Development of Hydrogen Industry in Zhuzhou*		5000
Ningxia Hui Autonomous Region	*Plan for the Development of Hydrogen Industry in Ningxia Hui Autonomous Region (Draft for Comments)*		500
Guizhou	*Plan for the Development of Hydrogen Industry in Guizhou Province during the 14th Five-Year Plan Period*		5000
Liaoning	*Plan for the Development of Hydrogen Industry in Liaoning Province (2021–2025)*		2000

Source Websites of various provincial/municipal governments

The support efforts of local policies in non-demonstration urban agglomerations are continually being reinforced. Apart from the five major FCEV demonstration urban agglomerations, non-demonstration cities actively refer to the national policies for FCEV demonstration applications and have implemented their own policy measures, demonstrating equal levels of support. For instance, Zhejiang Province has identified provincial-level FCEV demonstration zones and demonstration sites, prioritizing these areas to expedite the high-quality development of the FCEV industry in the province. In the policy document *Opinions on Supporting the Development of the Hydrogen Energy Industry* issued by Wuhan City, it is proposed to calculate the credits for vehicles and core components produced in the city based on the national credit accounting method, providing a financial reward of 200,000 yuan/credit to vehicle purchasing enterprises, and subsidies for the construction and operation of hydrogen refueling stations. Chengdu City issued a *Notice on Carrying out the Declaration Work for Fuel Cell Electric Vehicle Demonstration Application Projects in Chengdu City* in 2022–2023, proposing that newly licensed FCEVs within the demonstration application scope will be awarded demonstration application incentives for this level of NEVs in accordance with national reward credit criteria.

(3) **By leveraging the FCEV demonstration urban agglomerations as trailblazers in the development of hydrogen energy, China directs its strategic resources to propel the structured growth of the fuel cell industry.**

FCEVs represent a gateway to hydrogen energy applications, with the demonstration application focusing on urban agglomerations as carriers to centralize key resources, thereby propelling the development of China's fuel cell industry in an orderly manner. As of the end of 2021, the national "3 + 2" configuration of FCEV demonstration urban agglomerations was formally in place. Among the first demonstration urban agglomerations, the Beijing-Tianjin-Hebei Urban Agglomeration, Shanghai Urban Agglomeration, and Guangdong Urban Agglomeration demonstrate clear advantages in key technologies for fuel cells and FCEV promotion and application, alongside substantial economic strength, making them the pioneering regions for the nationwide promotion and application of FCEVs. Capitalizing on NEV demonstration applications as catalysts, the Hebei Urban Agglomeration and Henan Urban Agglomeration are leveraging their strengths to consistently foster localized promotion characteristics, poised to spur local industrial development. With a demonstration period of 4 years (2022–2025), the five major demonstration urban agglomerations are projected to introduce around 33,000 FCEVs of various types. As the number of demonstration vehicles continues to grow, there will be favorable opportunities for various technical breakthroughs along the fuel cell industry chain, product promotion on a large scale, hydrogen infrastructure development, and other related endeavors, exerting a leading demonstration effect nationwide.

7.1.2 Achievements in the Promotion of FCEVs

Following the principle of prioritizing commercial vehicles, the adoption of fuel cell technology in the transportation sector has demonstrated notable leading effects.

According to the Ministry of Industry and Information Technology of China's (MIIT) 2022 publication of the *Recommended Models Catalogue for New Energy Vehicle Applications* (Fig. 7.1), from the first to the twelfth batch, 99 FCEV enterprises and 289 product models were involved, including 1 passenger car, 74 buses, and 214 Vehicle for special purposes. Considering the overall number of recommended models for the year 2022, there were notably more recommended models of FCEV-Vehicle for special purposes that those of buses. Hydrogen fuel cells constitute a significant technological pathway for incorporating hydrogen into the transportation sector. Commercial vehicles powered by hydrogen and heavy-duty engineering machinery fueled by hydrogen have emerged as the principal modes of hydrogen

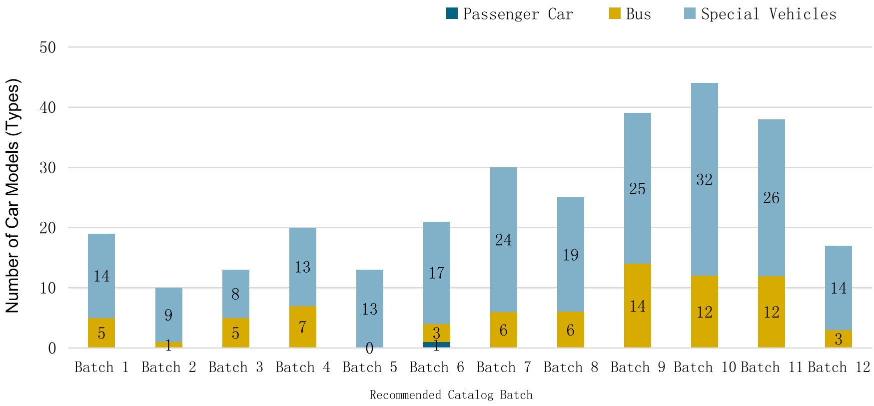


Fig. 7.1 Number of FCEV models in the 1st to 12th batch of *Recommended Models Catalogue for New Energy Vehicle Applications* published in 2022. *Source* The 1st to 12th batch of *Recommended Models Catalogue for New Energy Vehicle Applications* published in 2022

energy application in the transportation sector at present, with effective commercial operational practices being discovered across a range of application scenarios.

The demonstration and promotion of FCEVs have proven notably successful, with cumulative sales surpassing 12,000 units as of 2022.

Since 2016, China has witnessed a significant upswing in the sales of FCEVs, which surpassed 2737 units in 2019, representing a year-on-year increase of 79.2%. From 2020 onward, there has been a decrease in the sales of FCEVs compared to 2019, due to the influence of the Covid-19 pandemic. Driven by the top-level goals of "carbon peak" and "carbon neutrality," as well as the effect of demonstration urban agglomerations, the development of the FCEV industry has significantly accelerated nationwide. As of 2022, the cumulative sales of FCEVs across the country had hit 12,309 units (Fig. 7.2). With the gradual refinement of policy and regulatory frameworks and the wider adoption of multi-scenario application models, the scale of FCEV adoption is expected to continue its upward trend.

7.1.3 Development Status of the Upstream and Downstream of the FCEV Industry

(1) **The localization of fuel cell systems and key components is accelerating, with continuous enhancement of self-sufficiency capabilities**.

The FCEV industry chain is extensive and involves numerous stakeholders, with the fuel cell system positioned in the middle of the industry chain. The upstream fuel cell engine mainly includes the stack and its core components, auxiliary systems, etc. The stack, as the core component of the fuel cell system, has a significant impact on the key performance and cost of the fuel cell engine. The primary application

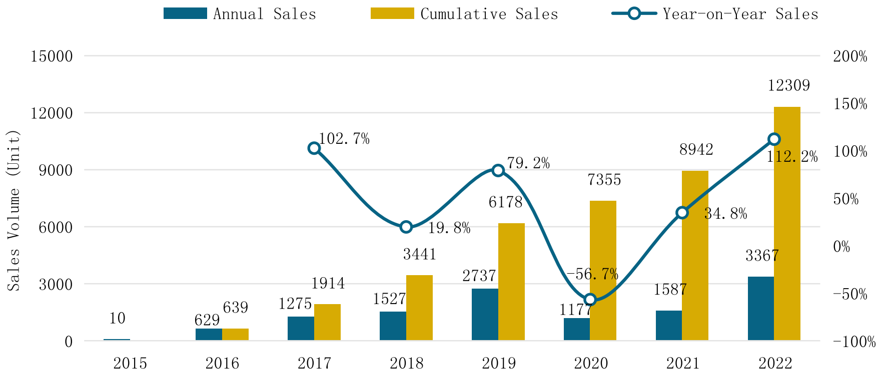


Fig. 7.2 Historical growth of FCEV sales in China. *Source* China Association of Automobile Manufacturers

scenario for fuel cells in the downstream industry is FCEVs, with OEMs being the main stakeholders.

When it comes to key components and raw materials in the fuel cell system, the stack is the core component with high entry barriers. Based on the published specifications of fuel cell system products in China, 100 kW fuel cell systems are already being installed, and the announced indicators of 200 kW systems are aligned with international standards. However, their durability still needs to be verified. Since 2022, SinoHytec, Weichai Power, SHPT, Sinosynergy, and SFCV have successively introduced fuel cell system products with a power of 200 kW or above. Based on the disclosed parameters, the performance indicators such as power rating, power density, and cold start performance of the stack and stack system are generally comparable to international standards. However, due to the lack of actual vehicle operation data, the durability targets of domestic systems and stacks over 20,000–30,000 h still need to be verified. As for core materials, China has achieved 100% self-sufficiency in the preparation of membrane electrode assemblies, bipolar plates, stack assembly, auxiliary systems, and other areas. This development has emerged as a key driving force behind the cost reduction of fuel cell systems over the past couple of years. However, core materials such as catalysts, proton exchange membranes, and gas diffusion layers heavily rely on imports. Only SPIC Hydrogen Energy has achieved complete self-sufficiency at the MEA level, placing it at the forefront domestically.

(2) **The ongoing support from local governments for infrastructure development is driving the evolution of hydrogen refueling stations towards "integrated fuel and hydrogen refueling."**

Hydrogen refueling stations, as the infrastructure providing hydrogen to fuel cell electric vehicles, serve as a crucial link connecting the upstream hydrogen production and downstream applications in the industry chain. They are an essential part of the FCEV industry. High-pressure hydrogen storage is currently adopted in the majority of hydrogen refueling stations in China, where hydrogen is mainly stored from various sources and compressed with compressors into high-pressure tanks, which is then dispensed to FCEVs using gas dispensers. In recent years, local governments have successively intensified policy support in the field of hydrogen infrastructure construction. This includes tax incentives, land usage policies, and financial support, all of which contribute significantly to expediting the commercial application of hydrogen energy. By the end of 2022, a total of 274 hydrogen refueling stations had been built nationwide (Fig. 7.3). In terms of new station additions, the focus in 2022 was on comprehensive energy service stations providing hydrogen, oil, electricity, and gas. The main consideration is the potential financial strain that independently operated hydrogen refueling stations could face. Choosing co-construction over standalone operation as hydrogen refueling stations can enhance the efficiency of station deployment and the ability to share costs. Looking at the deployment of hydrogen refueling station in China, it’s regional, primarily concentrated in economically developed provinces and municipalities like Guangdong, Shandong, Jiangsu, Shanghai, and Beijing.

Currently, the expansion and construction of hydrogen refueling stations are hindered by high construction costs and bottleneck components, resulting in a high dependency on policies. In terms of the cost composition of hydrogen refueling stations, the equipment costs primarily include hydrogen storage equipment, hydrogenation equipment, compressors, pipelines, and safety devices. Among them, hydrogen storage equipment and hydrogenation equipment are the main components, accounting for the majority of the equipment costs. The equipment costs of hydrogen refueling stations vary depending on the region and construction scale. Due to the early stage of promotion for FCEVs, the production and supply scale of hydrogen refueling station equipment are relatively small, leading to higher costs.

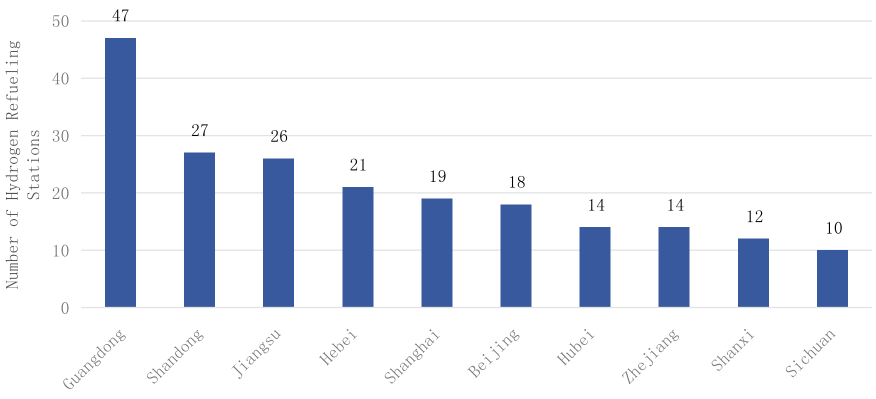


Fig. 7.3 Construction and operation status of the top 10 provinces/municipalities’ hydrogen refueling stations in China by the end of 2022. *Source* Hydrogen Industrial Technology Innovation Alliance of China (HITIA)

7.2 Operation Characteristics of FCEVs in China

The National Monitoring and Management Platform is capable of monitoring the nationwide access and operational status of FCEVs. Taking into account data as of the end of 2022 from the National Monitoring and Management Platform, including the cumulative access volume, online rate, travel characteristics, and refueling features of FCEVs, this report presents a comprehensive analysis of the operational patterns of FCEVs in China. The findings and insights derived from this analysis serve as valuable reference and practical experience for the commercialization and wider implementation of FCEVs.

7.2.1 Access Characteristics of FCEVs in China

By the end of 2022, there were a total of 10,564 FCEVs accessed nationwide, predominantly consisting of logistics vehicles.

As of December 31, 2022, the National Monitoring and Management Platform for NEVs had cumulatively had 10,564 FCEVs accessed (Fig. 7.4). When broken down by type, there were 4810 FCEV-buses accessed, accounting for 45.5% of the total access volume; 5532 FCEV-Vehicle for special purposes, including logistics, engineering, and sanitation vehicles, comprising 52.4% of the total access volume; and 222 FCEV-passenger cars, making up 2.1% of the total access volume.

(1) **Characteristics of Regional Concentration**

The deployment of FCEVs is highly concentrated in specific regions, particularly in demonstration urban agglomerations.

As of December 31, 2022, the cumulative access volume of FCEVs in the top 10 provinces/municipalities amounted to 9730 units, making up 92.1% of the total nationwide (Fig. 7.5). Examining the promotion of FCEVs in various provinces/municipalities, it is evident that the promotion efforts are mainly concentrated in the demonstration urban agglomerations. Specifically, Guangdong Province, Shanghai, and Beijing have a cumulative access volume of 6478 FCEVs, constituting 61.3% of the total nationwide. The overall regional concentration of FCEV promotion shows a downward trend year by year (Fig. 7.6). In the past three years, there has been a decreasing trend in the annual promotion share of FCEVs among the top 3 provinces/municipalities, top 5 provinces/municipalities, and top 10 provinces/municipalities.

A cumulative total of 4810 FCEV-buses have been accessed, with the promotion share hitting 95.0% across the top 10 provinces/municipalities.

As of December 31, 2022, there had been 4810 FCEV-buses accessed in the field, representing 45.5% of the total access volume of FCEVs on the National Monitoring and Management Platform (Fig. 7.7). The cumulative access of FCEV-buses in the top 10 provinces/municipalities amounted to 4431 units, responsible for 92.1% of the total nationwide. Regarding the distribution by province/municipality,

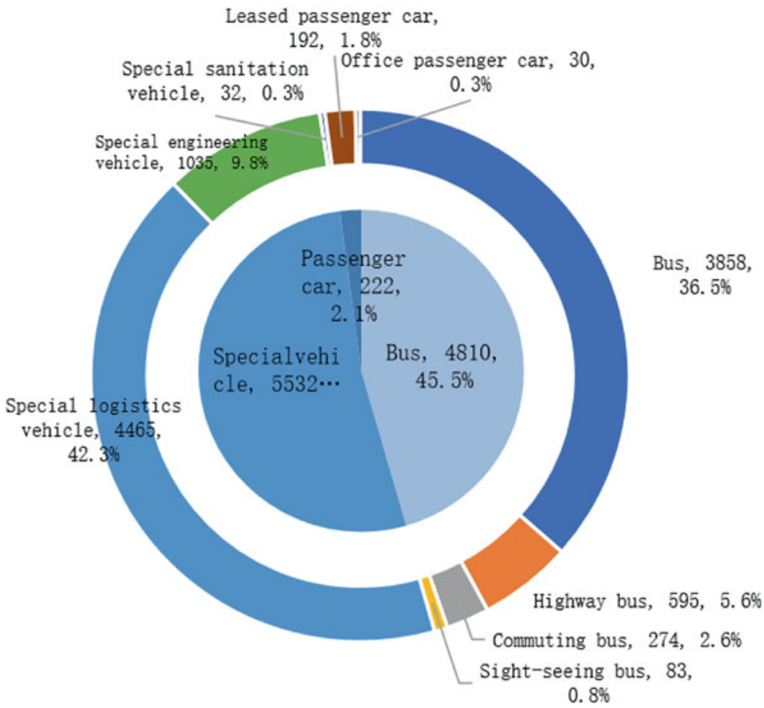


Fig. 7.4 Cumulative access volume and proportion of FCEVs in China (units, %)

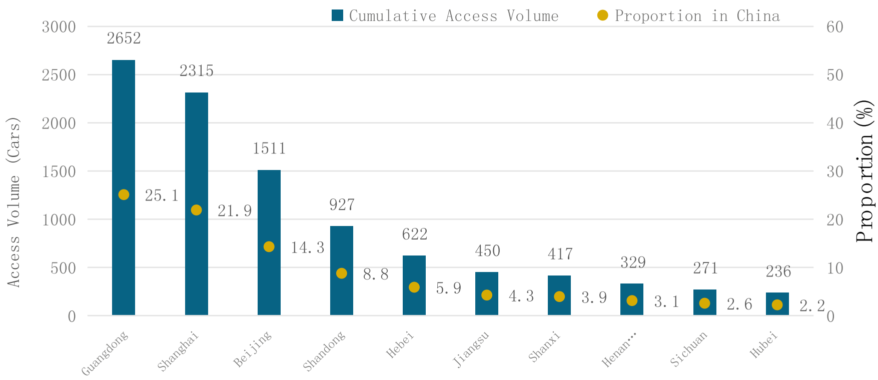


Fig. 7.5 Cumulative access volume and proportion of FCEVs for the Top 10 provinces/ municipalities

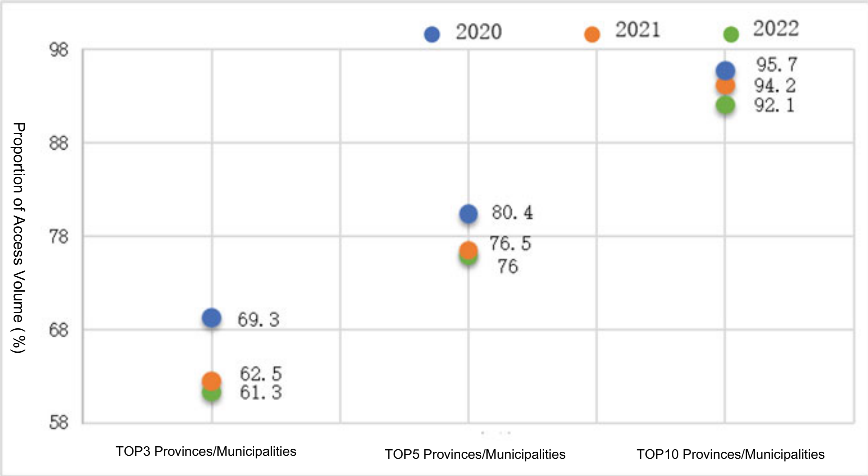


Fig. 7.6 Changes in regional concentration of FCEV promotion and application over the years

Guangdong Province stood out for having the highest access volume of FCEV-buses. By December 31, 2022, Guangdong Province had had the highest access volume of FCEV-buses, with 1049 units, or 21.8% of the total nationwide, which is followed by Beijing, Shandong, Hebei, Shanghai, and Henan with an access volume of more than 300 units each.

The cumulative access volume of FCEV-Vehicle for special purposes has reached 5532 units, with the top 10 provinces/municipalities accounting for 95.1% of the overall promotion.

As of December 31, 2022, a total of 5532 FCEV-Vehicle for special purposes have been accessed nationwide, representing 52.4% of the total access volume of FCEVs on the National Monitoring and Management Platform (Fig. 7.8). The cumulative

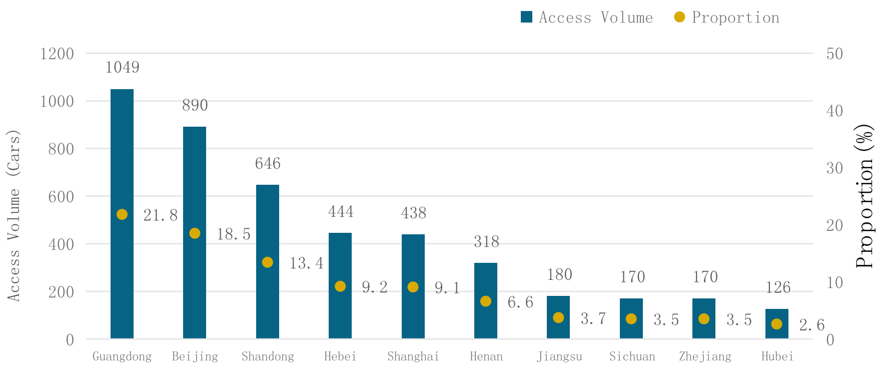


Fig. 7.7 Cumulative access volume and proportion of FCEV-buses in the top 10 provinces and municipalities

access volume among the top 10 provinces/municipalities was 5260 units, accounting for 95.1% of the total nationwide. Specifically, Shanghai and Guangdong ranked first and second, with a cumulative access volume of 1674 and 1593 units respectively, representing 30.3% and 28.8% of the national total, showcasing significant promotion effects.

The cumulative access volume of FCEVs among the top 10 cities has reached 7950 units, making up 75.3% of the national total.

As of December 31, 2022, the top 10 cities have cumulatively had 7950 FCEVs accessed, accounting for 75.3% of the nationwide promotion (Fig. 7.9). In these cities, Shanghai, Foshan, and Beijing had had over 1500 FCEVs accessed each, with each accounting for over 14% nationwide. The promotion structure of FCEVs in the top 10 cities exhibits significant diversity (Fig. 7.10). Zhangjiakou, Weifang, Foshan, Beijing, and Chengdu primarily promote FCEV-buses, while Shanghai, Shenzhen, Suzhou, Qingdao, and Guangzhou focus on FCEV-Vehicle for special purposes as the main promotion type.

(2) Market Concentration Characteristics

The FCEV market shows a high degree of concentration, with the top 10 companies collectively accessing 8540 FCEVs, representing over four-fifths of the national total.

Currently, there is a large number of OEMs involved in promoting FCEVs. As of 2022, a total of 56 enterprises nationwide had had their FCEVs accessed on the National Monitoring and Management Platform. From the perspective of market concentration in the industry, traditional automotive companies dominate the supply of FCEVs. As of December 31, 2022, the top 10 companies in the country had cumulatively had 8540 FCEVs accessed, accounting for 80.8% nationwide (Fig. 7.11). Among them, the top 3 companies, Zhongtong Bus, BAIC Foton, and Foshan Feichi, had cumulatively 1700, 1393, and 1392 FCEVs accessed respectively, with each

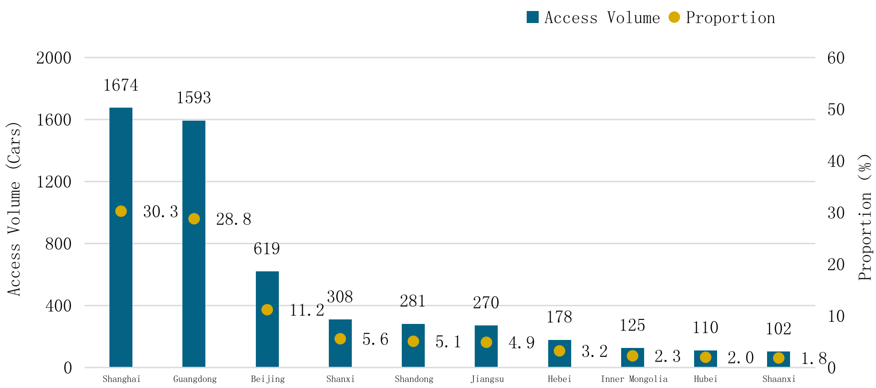


Fig. 7.8 Cumulative access volume and proportion of FCEV-Vehicle for special purposes among the top 10 provinces/municipalities

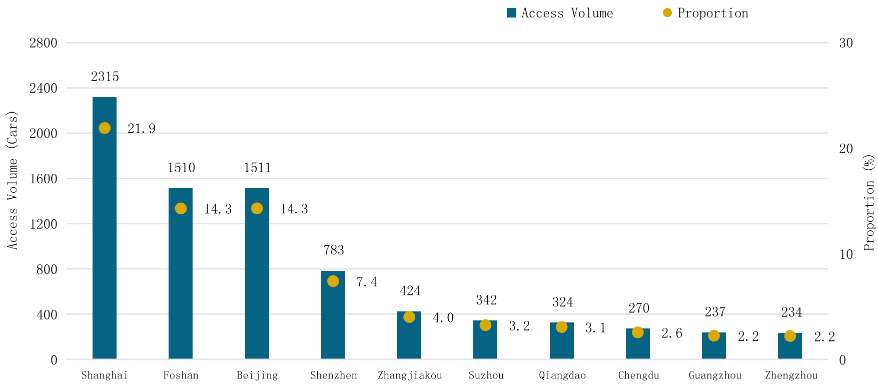


Fig. 7.9 Cumulative access volume and proportion of FCEVs among the top 10 cities

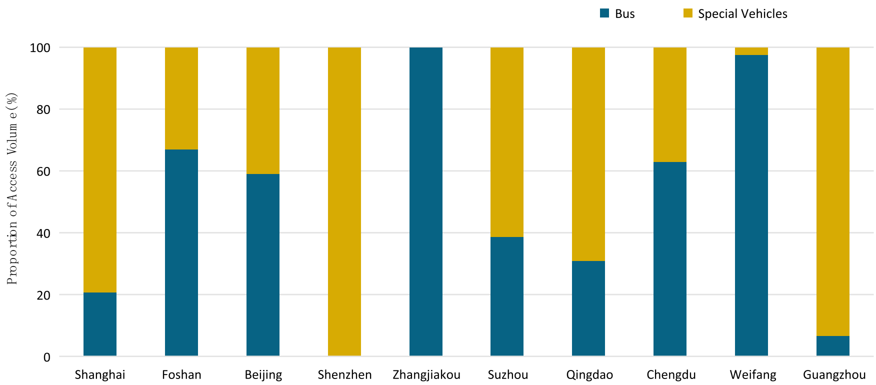


Fig. 7.10 Structure of the cumulatively access of FCEVs among the top 10 cities

accounting for over 13% nationwide. With the expansion of the hydrogen fuel cell market, whole OEMs possessing advantages in integrated technology, upstream costs, and order resources will see an increase in market share in the medium to long term.

When looking at the application scenarios for FCEV promotion among the top 10 enterprises (Fig. 7.12), traditional bus companies such as Foshan Feichi, BAIC Foton, Zhengzhou Yutong Bus, Xiamen Golden Dragon, and King Long mainly focus their promotion efforts in the bus sector. Meanwhile, Zhongtong Bus, Shanghai Shenlong, and Dongfeng Motor primarily promote applications in the logistics vehicle sector.

In both the bus and Vehicle for special purpose sectors, the FCEV market shows a high degree of concentration, with the top 3 companies collectively accounting for over one-third of the cumulative access volume.

In the bus sector, the top 3 companies, BAIC Foton, Foshan Feichi, and Xiamen Golden Dragon, have a cumulative access volume of 1865 FCEV-buses, accounting

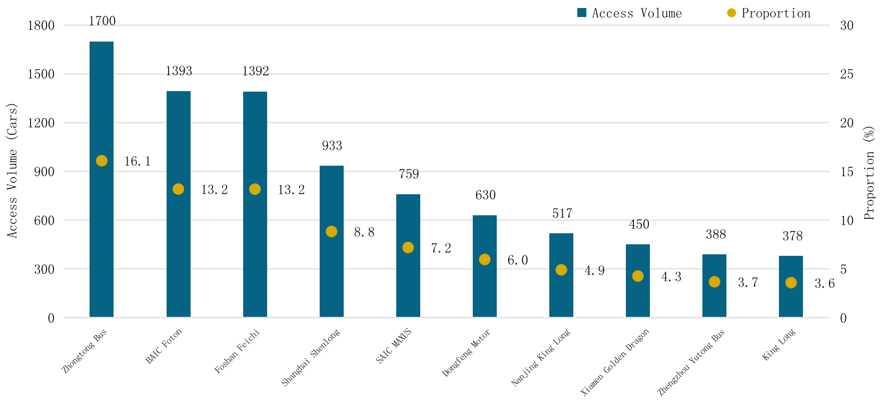


Fig. 7.11 Cumulative access volume and proportion of FCEVs by Top 10 companies

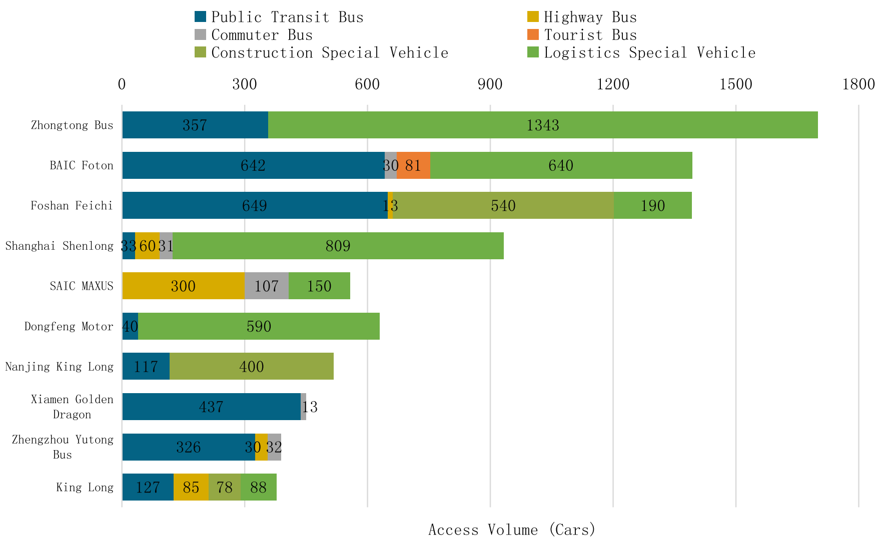


Fig. 7.12 Cumulative access volume of FCEVs by Top 10 companies—by application scenario

for 38.9% nationwide (Fig. 7.13); in the Vehicle for special purpose sector, the top 3 companies, Zhongtong Bus, Shanghai Shenlong, and Foshan Feichi, have had a total of 2882 FCEV-buses accessed, representing 52.1% nationwide (Fig. 7.14). Compared to the bus sector, the market concentration in the FCEV-Vehicle for special purpose sector is relatively higher. Zhongtong Bus, for instance, has had a cumulative total of 1343 FCEV-Vehicle for special purposes accessed, accounting for nearly one-fourth nationwide.

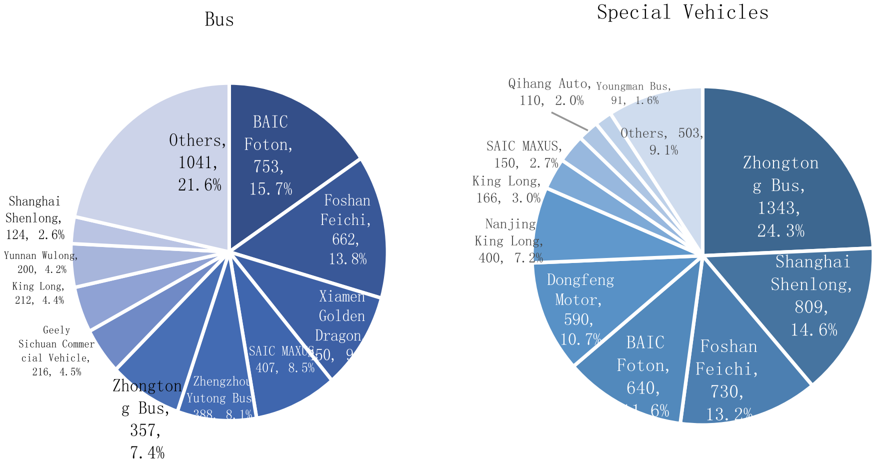


Fig. 7.13 Cumulative access volume and proportion of FCEVs by Top 10 companies—by sector (units, %)

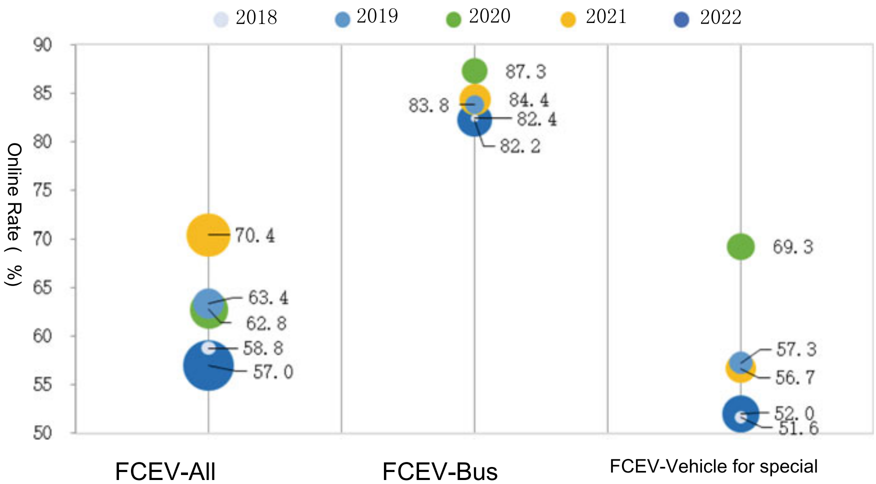


Fig. 7.14 Average monthly online rates of FCEVs over the years

7.2.2 Characteristics of Online Rate in China

The average monthly online rate of FCEVs has experienced some fluctuations over the years, with a slight decrease in the average monthly online rate in 2022 compared to the previous year.

Based on Fig. 7.14, the annual average access volume rate of FCEVs has shown an upward trend since 2018, followed by a period of stability. Around 2021, influenced by the Winter Olympics, the average monthly online rate of FCEVs reached a peak, and the operational performance was relatively good. However, in 2022, the overall online rate of vehicles was not high, partly due to the high cost of hydrogen sources and hydrogen refueling station construction, which to some extent affected the operational performance of FCEVs.

When considering application scenarios, the online rate of FCEV-buses overall exceeds that of FCEV-Vehicle for special purposes.

FCEV-buses demonstrate good operational performance. When examining the average monthly online rates of various vehicle types over the years, it's evident that FCEV-buses have consistently maintained rates above 80%, indicating effective operational performance. Conversely, the average monthly online rate of FCEV-Vehicle for special purposes peaked at 69.3% in 2020 but steadily declined in 2021 and 2022. This highlights the need for further pilot demonstrations in the FCEV industry to consolidate experiences in core equipment, key component development, and hydrogen refueling infrastructure construction, thereby accelerating the growth of the hydrogen and fuel cell industries.

Looking at the monthly online rate curve of FCEVs (Fig. 7.15), it's observed that in 2022, the monthly online rate of FCEVs remained lower than the same period of the previous year throughout the year, with online rates ranging from 46.3% to 68.9% each month. Throughout 2022, the average daily access volume of FCEVs per month remained predominantly around 2500 units. November saw the peak average daily access volume for the year, hitting 2873 units, while March recorded the lowest at 2152 units (Fig. 7.16).

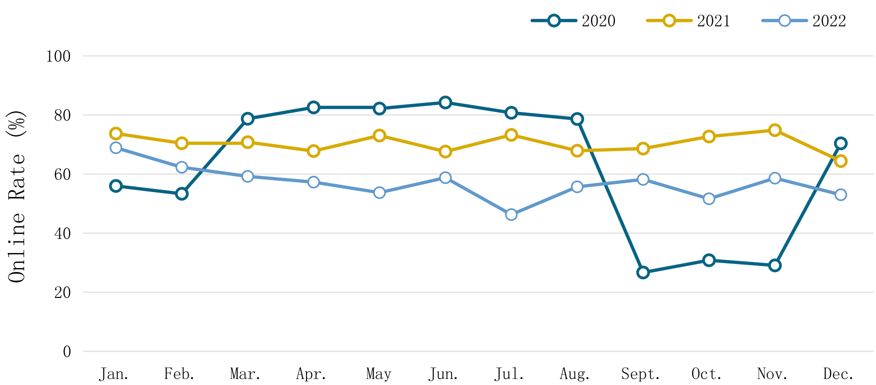


Fig. 7.15 Monthly online rates of FCEVs over the years

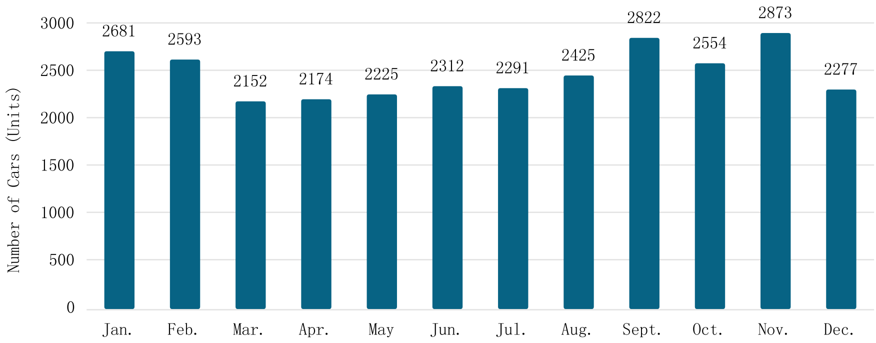


Fig. 7.16 Average daily access volume of FCEVs per month in 2022

7.2.3 Operation Characteristics of FCEVs in China

(1) **Cumulative Mileage and Travel Duration**

FCEVs have accumulated over 300 million kilometers in mileage in China, along with over 12.519 million hours in travel duration

As of December 31, 2022, the cumulative mileage of FCEVs had reached 307 million kilometers, with a total travel duration of 12.519 million hours. Among these figures, in 2022 alone, FCEVs traveled 109 million kilometers and accumulated 4.867 million hours of driving, accounting for 35.4% and 38.9% of the total cumulative mileage and travel duration of FCEVs, respectively.

When considering application scenarios, FCEV-buses and FCEV-special logistics vehicles take the lead. FCEV-buses have collectively traveled 210 million kilometers with a total travel duration of 9.066 million hours; FCEV-special logistics vehicles have covered 741.7 million kilometers with a travel duration of 2.215 million hours (Figs. 7.17 and 7.18).

Guangdong Province takes the lead in the scale of FCEV promotion in China, with favorable vehicle performance.

Considering the rankings of cumulative mileage and travel duration for FCEVs across various provinces/municipalities in China, it can be observed that as of the end of 2022, the top 10 provinces contributed to 95% of the nationwide figures, with a cumulative mileage of 291.49 million kilometers and a travel duration of 11.89 million hours. Notably, Guangdong Province exhibited a relatively favorable operational performance for FCEVs, with cumulative mileage and travel duration each exceeding one-third of the national total. Meanwhile, provinces/municipalities such as Shanghai and Beijing had a higher number of FCEV promotions. However, due to lower online rates in 2022, their overall mileage and travel duration were relatively lower (Fig. 7.19).

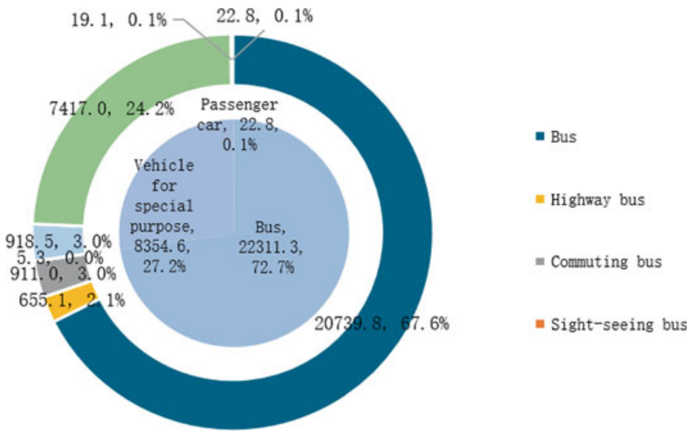


Fig. 7.17 Distribution of the cumulative mileage of FCEVs in different application scenarios (10,000 km, %)

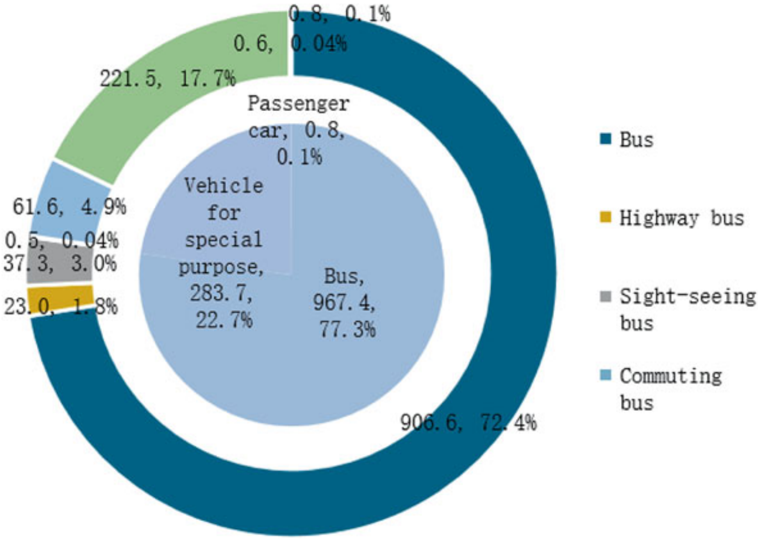


Fig. 7.18 Distribution of travel duration for FCEVs in different application scenarios (10,000 h, %)

(2) **Average daily mileage and travel duration per FCEV**

The majority of daily mileage of a single vehicle falls within the range of 160 to 200km.

Examining the distribution of daily mileage per FCEV (Fig. 7.20), we observe a gradual shift towards higher mileage segments over the past three years. average daily mileage per FCEV was predominantly in the 0 to 40 km range in 2020. However,

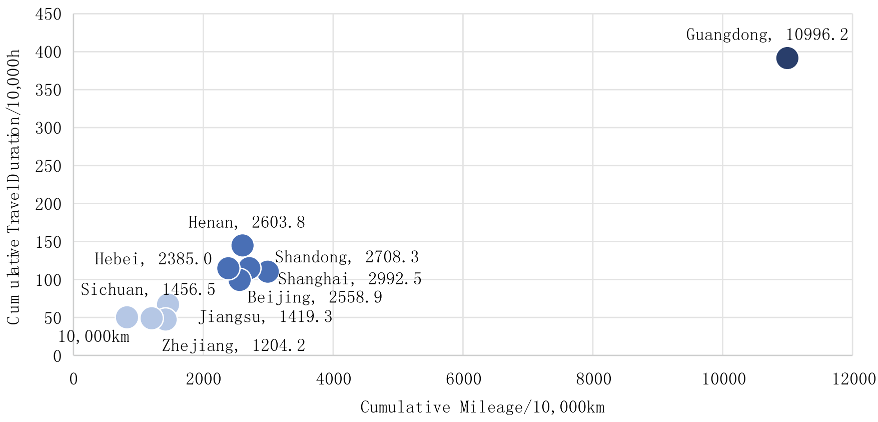


Fig. 7.19 Cumulative mileage and travel duration for FCEVs in the top 10 provinces/municipalities

by 2021 and 2022, it gradually concentrated in the 160 to 200 km range. This trend reflects the continued strengthening of policies supporting the hydrogen and fuel cell industry, improvements in FCEV device technology and hydrogen refueling infrastructure, all of which have significantly enhanced vehicle operational efficiency.

The majority of FCEV-buses have a mileage concentration within the range of 120 to 240 km, while there is a need for continuous improvement in the operational efficiency of FCEV-Vehicle for special purposes.

In terms of application scenarios, for FCEV-buses in 2022, the daily mileage per vehicle was mainly concentrated within the 120–240 km range, accounting for 58.7% of the FCEVs (Fig. 7.21). For FCEV-Vehicle for special purposes, the daily mileage per vehicle was primarily concentrated in the 0–160 km range, representing 67.9% of the FCEVs. Compared to FCEV-buses, FCEV-Vehicle for special purposes have

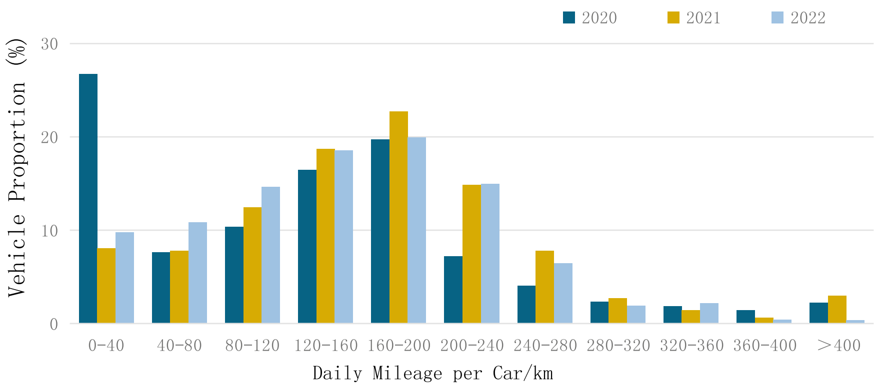


Fig. 7.20 Distribution of daily mileage per FCEV over the years

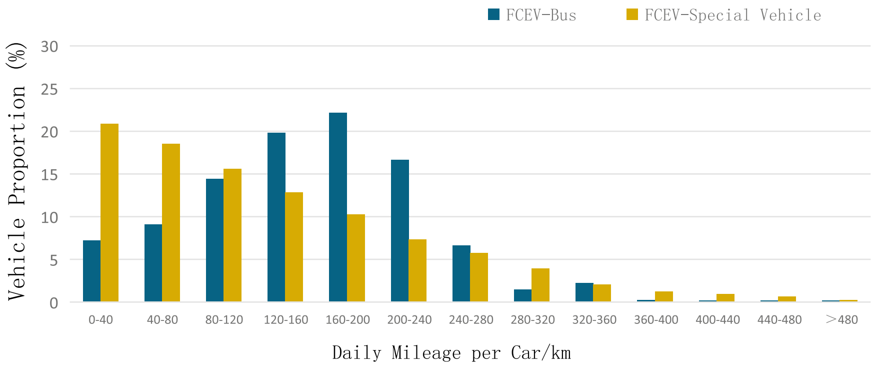


Fig. 7.21 Distribution of daily mileage per FCEV-bus and FCEV-Vehicle for special purpose in 2022

a significantly higher proportion of FCEVs with mileage below 200 km, indicating their primary role in short-distance urban transportation.

The distribution of daily travel duration per FCEV gradually transitions towards peak periods, indicating an increasing intensity of usage.

The distribution of daily travel duration per FCEV is relatively varied, with a presence observed across various time periods. In comparison to 2020, the proportion of FCEVs with a greater distribution in longer travel duration steadily increased in both 2021 and 2022 (Fig. 7.22). Notably, the proportion of FCEVs exceeding a daily travel duration of 10 h per vehicle reached 18.4% and 17.8% in the last two years, highlighting an increasing intensity of usage.

In general, FCEV-buses have a higher proportion of vehicles in the high travel duration segment than FCEV-Vehicle for special purposes.

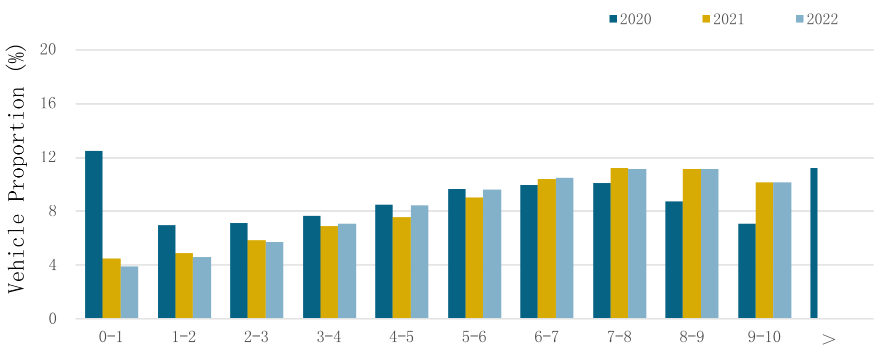


Fig. 7.22 Distribution of daily travel duration per FCEV from 2019 to 2022

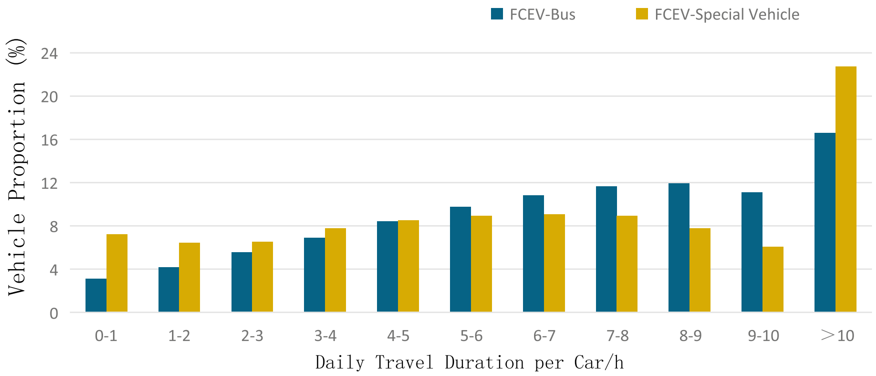


Fig. 7.23 Distribution of daily travel duration per FCEV-bus and FCEV-Vehicle for special purpose in 2022

Overall, FCEV-buses have a higher proportion of vehicles with higher travel duration compared to FCEV-Vehicle for special purposes (Fig. 7.23). From various application perspectives, the daily travel duration of individual FCEV-buses is predominantly concentrated above 5 h, accounting for 71.8% of the FCEVs (higher than the 63.6% of FCEV-Vehicle for special purposes). These FCEV-buses are mainly utilized for urban transportation. In contrast, the daily travel duration of a single FCEV-Vehicle for special purpose is comparatively uniform, with an emphasis on short-distance logistics and delivery within urban areas. Additionally, 22.7% of FCEV-Vehicle for special purposes have a daily travel duration exceeding 10 h, suggesting instances of intercity transportation for certain FCEV-Vehicle for special purposes.

7.3 Demonstration of Operational Characteristics of FCEVs in Demonstration Urban Agglomerations

This study focuses on the Beijing-Tianjin-Hebei Urban Agglomeration, the Shanghai Urban Agglomeration, the Guangdong Urban Agglomeration, the Hebei Urban Agglomeration, and the Henan Urban Agglomeration. It conducts a comparative analysis of the promotion, operation, and refueling characteristics of FCEVs in these five major demonstration urban agglomerations. The study summarizes the experiences and achievements of these demonstration urban agglomerations in the commercial promotion of FCEVs and provides valuable insights for their scale-up and application nationwide.

7.3.1 Promotion and Application Characteristics of FCEVs

This study focuses on the statistical scope of urban agglomerations as follows: the Beijing-Tianjin-Hebei Urban Agglomeration, which primarily examines the demonstration and application of FCEVs in Beijing and Tianjin; the Shanghai Urban Agglomeration, with a focus on the demonstration and application of FCEVs represented by Shanghai; the Guangdong Urban Agglomeration, which mainly analyzes the demonstration and application of FCEVs represented by Guangdong province; the Hebei Urban Agglomeration, which primarily investigates the demonstration and application of FCEVs represented by Hebei province; and the Henan Urban Agglomeration, which mainly studies the demonstration and application of FCEVs represented by Henan province.

The cumulative access volume of FCEVs in the Guangdong and Shanghai Urban Agglomerations is notably high, exceeding 2000 vehicles in both regions.

According to the comparison of the cumulative access volume of FCEVs among various demonstration urban agglomerations (Fig. 7.24), as of December 31, 2022, a total of 7521 FCEVs among the five major demonstration urban agglomerations had been accessed, accounting for 71.8% of the national total. Among the five major demonstration urban agglomerations, the Guangdong and Shanghai Urban Agglomerations rank first and second in terms of the cumulative access volume of FCEVs, with a cumulative access of 2652 and 2315 FCEVs respectively, mainly focused on FCEV-Vehicle for special purposes. The Beijing-Tianjin-Hebei, Hebei, and Henan Urban Agglomerations, on the other hand, primarily promote FCEV-passenger cars.

With leading enterprises acting as catalysts, the demonstration urban agglomerations are driving the convergence of upstream and downstream sectors of the entire FCEV industry chain.

As shown in Fig. 7.25, the cumulative access of FCEV-passenger cars by the top five enterprises in each demonstration urban agglomeration demonstrates the significant role played by leading companies in driving the development and growth of the local FCEV industry chain. Notably, BAIC Foton, SAIC MAXUS, Foshan Feichi,

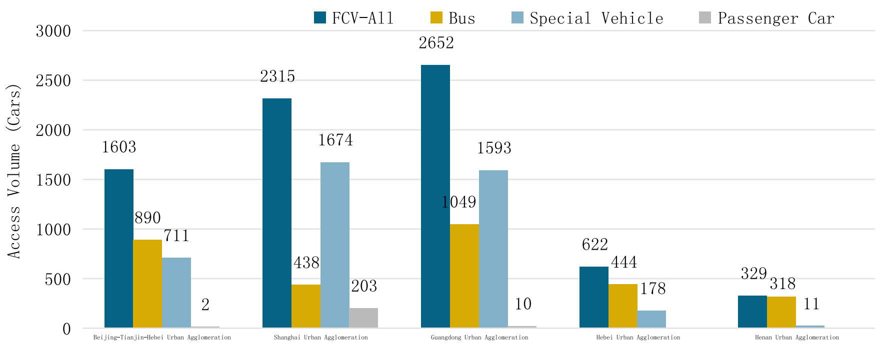


Fig. 7.24 Cumulative access of FCEVs across different demonstration urban agglomerations

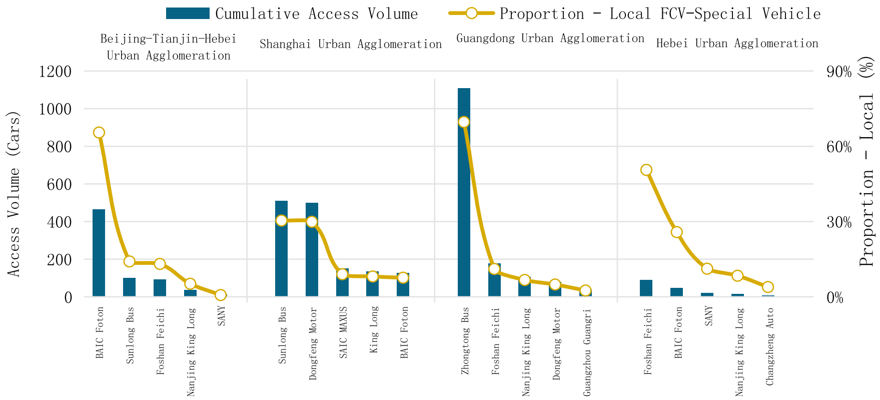


Fig. 7.25 Cumulative access for the FCEV-passenger car sector by the top 5 enterprises across different demonstration urban agglomerations

and Yutong Bus have accounted for over 40% of the cumulative access of FCEV-passenger cars in their respective demonstration urban agglomerations, securing the top position in the rankings across all demonstration urban agglomerations.

In the FCEV-Vehicle for special purpose sector, BAIC Foton in the Beijing-Tianjin-Hebei Urban Agglomeration, Sunlong Bus in the Shanghai Urban Agglomeration, Zhongtong Bus in the Guangdong Urban Agglomeration, and Foshan Feichi in the Hebei Urban Agglomeration have cumulatively accounted for over 30% of the cumulative access of FCEV-Vehicle for special purposes in their respective demonstration urban agglomerations (Fig. 7.26). Among them, Zhongtong Bus holds the top position in the Guangdong Urban Agglomeration, with a cumulative access of 1110 vehicles, representing 69.7% of the cumulative access of FCEV-Vehicle for special purposes in the Guangdong Urban Agglomeration.

7.3.2 Operation Characteristics of FCEVs

(1) **Online Rate**

The overall online rate for FCEV-buses in demonstration urban agglomerations is higher than that of FCEV-Vehicle for special purposes.

Comparing the online rates of FCEV-buses and FCEV-Vehicle for special purposes in demonstration urban agglomerations (Fig. 7.27), the overall online rate of FCEV-buses is higher than that of FCEV-Vehicle for special purposes. The year 2022 witnessed excellent performance in terms of the online rate for FCEV-buses in the Guangdong and Hebei Urban Agglomerations, where the proportion of average monthly access exceeded 80%. Conversely, the Shanghai Urban Agglomeration recorded a comparatively lower average monthly online rate for FCEV-buses. When it comes to FCEV-Vehicle for special purposes, the Beijing-Tianjin-Hebei Urban

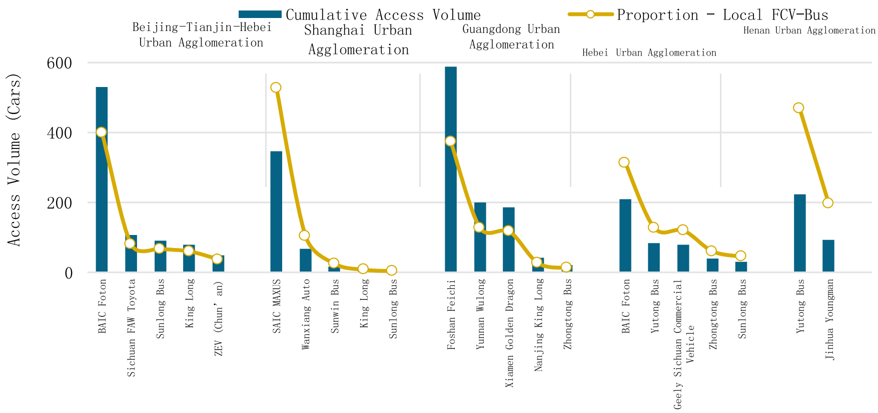


Fig. 7.26 Cumulative access for the FCEV-Vehicle for special purpose sector by the top 5 enterprises across different demonstration urban agglomerations

Agglomeration demonstrates a higher online rate for FCEV-Vehicle for special purposes compared to other demonstration urban agglomerations, reaching a access rate of 63.2%. Moreover, the online rate of FCEV-Vehicle for special purposes in Shanghai slightly surpasses that of FCEV-buses.

By examining the changes in monthly online rates of FCEVs (Figs. 7.28 and 7.29), it becomes apparent that the average monthly online rates for FCEV-buses in the Beijing-Tianjin-Hebei Urban Agglomeration, Guangdong Urban Agglomeration, Hebei Urban Agglomeration, and Henan Urban Agglomeration demonstrate a relatively stable distribution. Moreover, the online rates in the first half of the year are slightly higher than those in the second half. Starting from February 2022, the online rate in the Shanghai Urban Agglomeration consistently remained at a lower level throughout the year. On the other hand, when focusing on the FCEV-Vehicle for

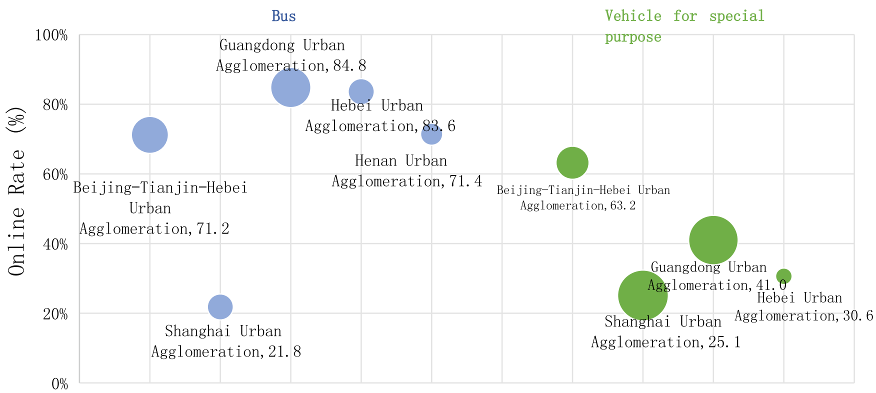


Fig. 7.27 Average monthly online rate of FCEVs in various demonstration urban agglomerations in 2022

special purpose sector, the monthly online rate for the Beijing-Tianjin-Hebei Urban Agglomeration displayed a relatively stable pattern, while the Hebei Urban Agglomeration witnessed a significant surge in the monthly online rate towards the end of the year. In December, the online rate reached its highest level at 84.3% throughout the year.

(2) Cumulative mileage and travel duration of FCEVs

The cumulative mileage and travel duration of FCEV-buses in demonstration urban agglomerations are significantly higher compared to those of FCEV-Vehicle for special purposes.

As of December 31, 2022, the cumulative mileage of FCEVs in various demonstration urban agglomerations had reached a total of 210 million kilometers, with a total travel duration of 8.443 million hours. Specifically, the Guangdong Urban

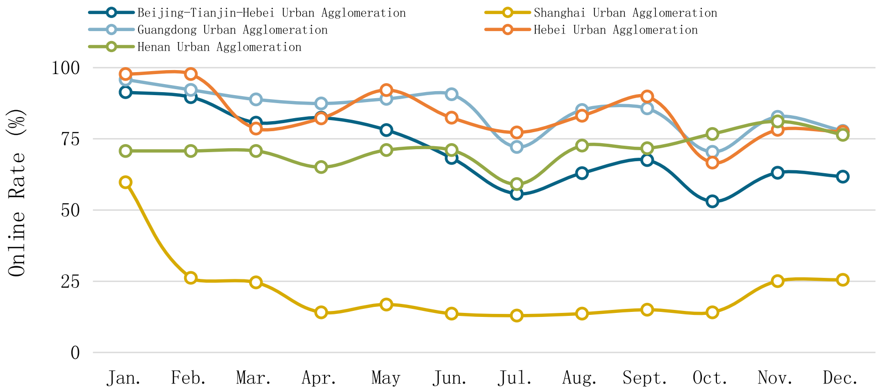


Fig. 7.28 Monthly online rates of FCEV-buses in various demonstration urban agglomerations in 2022

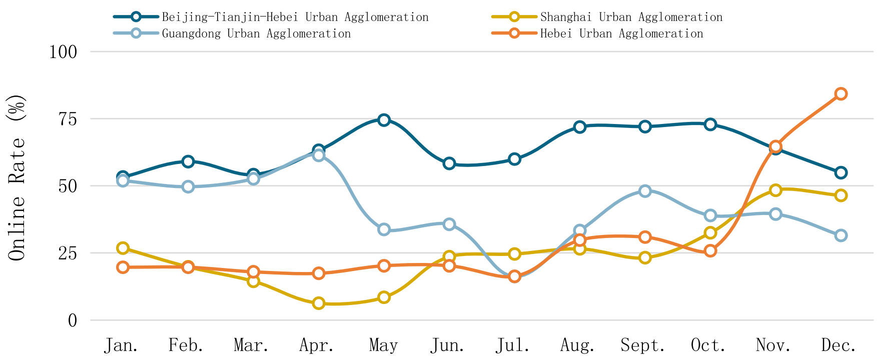


Fig. 7.29 Monthly online rates of FCEV-Vehicle for special purposes in various demonstration urban agglomerations in 2022

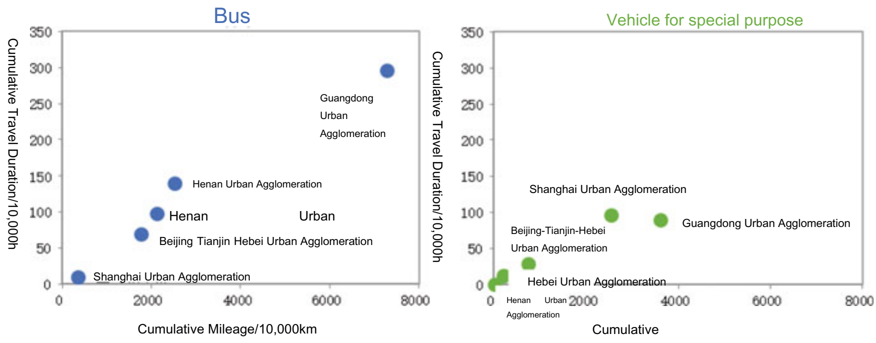


Fig. 7.30 Cumulative mileage and travel duration of FCEVs across various demonstration urban agglomerations

Agglomeration had shown impressive performance, accumulating a mileage of 110 million kilometers and a travel duration of 3.871 million hours (Fig. 7.30).

There is a significant variation in the cumulative mileage and travel duration of different FCEV types across various demonstration urban agglomerations, primarily due to differences in vehicle promotion structures and online rates within each demonstration urban agglomeration. In the bus field, the Guangdong Urban Agglomeration takes the lead in terms of cumulative mileage and travel duration of FCEV-buses among other demonstration urban agglomerations. In the Vehicle for special purpose domain, both the Guangdong and Shanghai Urban Agglomerations exhibit commendable performance. While evaluating the demonstration results of different FCEV types in diverse demonstration urban agglomerations, it is apparent that the cumulative mileage and travel duration of FCEV-buses in the Guangdong Urban Agglomeration, Hebei Urban Agglomeration, Henan Urban Agglomeration, and Beijing-Tianjin-Hebei Urban Agglomeration exhibit a noticeable advantage over those of FCEV-Vehicle for special purposes.

(3) **Average daily mileage and travel duration of FCEVs**

Generally speaking, FCEVs achieve higher average daily mileage compared to BEVs. Nevertheless, there is room for further development to fully exploit the long-range advantage of FCEVs.

In the realm of buses (Fig. 7.31), both the Shanghai Urban Agglomeration and the Guangdong Urban Agglomeration demonstrate FCEV-buses with a per-vehicle average daily mileage exceeding 180 km, significantly surpassing the average daily mileage of BEVs. The operational characteristics of FCEV-buses and BEVs in other demonstration urban agglomerations, such as the Beijing-Tianjin-Hebei Urban Agglomeration, Henan Urban Agglomeration, and Hebei Urban Agglomeration, are largely consistent. As for Vehicle for special purposes (Fig. 7.32), the Beijing-Tianjin-Hebei Urban Agglomeration, Shanghai Urban Agglomeration, and Henan Urban Agglomeration showcased FCEV-Vehicle for special purposes with an average daily mileage of approximately 150 km in 2022, significantly surpassing the average daily mileage of BEV-Vehicle for special purposes.

FCEVs offer a solution to the limitations in operational efficiency, charging duration, range degradation, and safety performance observed in BEV-commercial vehicles. They represent an important avenue in the pursuit of environmentally-friendly long-distance freight transport. In comparing the travel characteristics of FCEVs and BEVs, it is evident that the long-range advantage of FCEVs in China still has room for further development.

The daily mileage of FCEV-buses is mainly concentrated in the range of approximately 120-240 km, while the daily mileage of FCEV-Vehicle for special purposes is primarily focused within 200 km.

Regarding buses, the daily mileage of FCEV-buses is mainly concentrated within the 120–240 km range (Fig. 7.33). In both the Shanghai Urban Agglomeration and

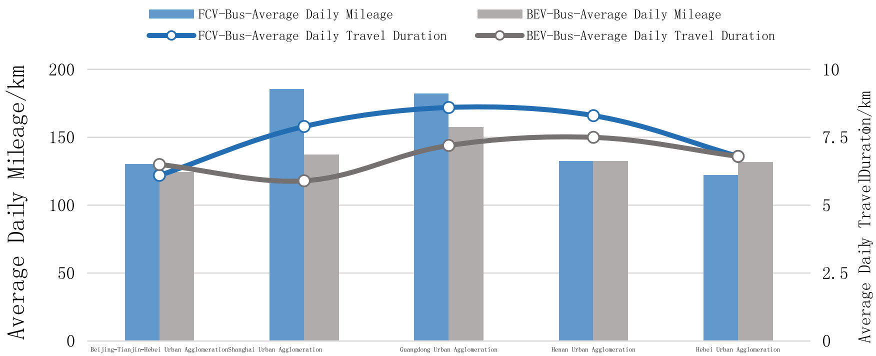


Fig. 7.31 Comparison of daily travel characteristics between FCEV-buses and BEV-buses in demonstration urban agglomerations

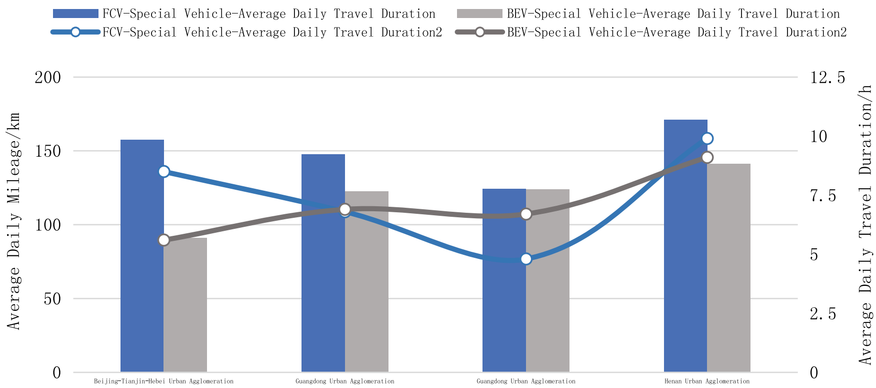


Fig. 7.32 Comparison of daily travel characteristics between FCEV-Vehicle for special purposes and BEV-Vehicle for special purposes in demonstration urban agglomerations

Beijing-Tianjin-Hebei Urban Agglomeration, there is a certain number of FCEV-buses with a high daily mileage exceeding 280 km. In the realm of FCEV-Vehicle for special purposes, the distribution of daily mileage in all demonstrative urban agglomerations is centered around the 0-200 km range, with a proportion exceeding 70% (Fig. 7.34).

The distribution of daily travel duration for FCEV-buses is relatively even, while for FCEV-Vehicle for special purposes, a small proportion exhibit longer daily travel duration.

The distribution of daily travel durations for individual FCEV-buses is depicted as relatively uniform across various demonstration urban agglomerations (Fig. 7.35).

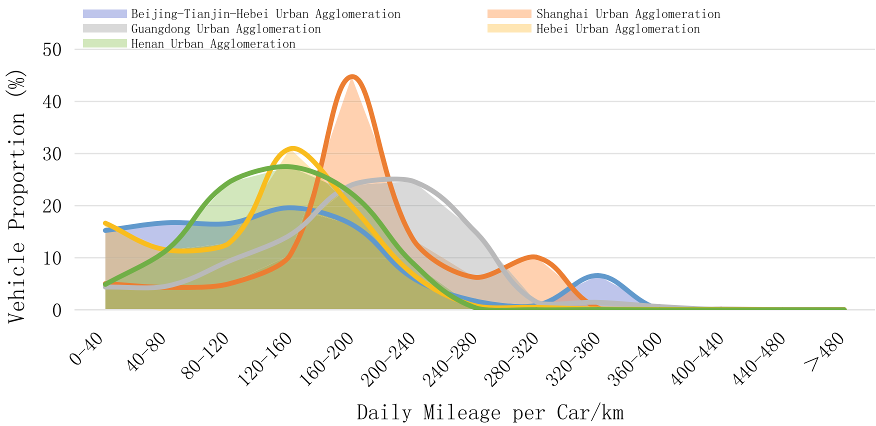


Fig. 7.33 Distribution of daily mileage of FCEV-buses in demonstrative urban agglomerations in 2022

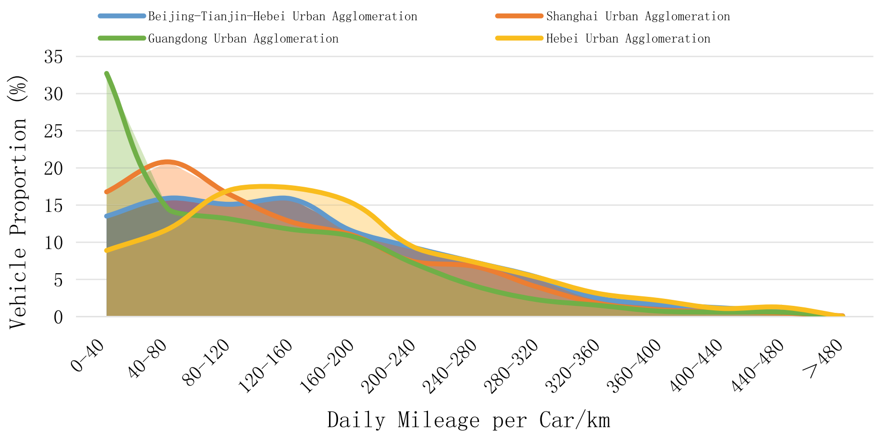


Fig. 7.34 Distribution of daily mileage of FCEV-Vehicle for special purposes in demonstrative urban agglomerations in 2022

Noteworthy is the higher proportion of FCEV-buses with extended travel durations in the Henan Urban Agglomeration, where 31.3% of FCEV-bus travel for over 10 h daily. As for FCEV-Vehicle for special purposes (Fig. 7.36), there are significant differences in the distribution of daily travel durations across various demonstration urban agglomerations. average daily travel durations per FCEV-Vehicle for special purpose exhibit a relatively even distribution in the Shanghai and Guangdong Urban Agglomerations. In contrast, within the Beijing-Tianjin-Hebei and Hebei Urban Agglomerations, the distribution of daily travel durations for certain FCEV-Vehicle for special purposes is centered around longer duration segments.

(4) **Mileage between two hydrogen refueling cycles**

The mileage between two hydrogen refueling cycles for FCEVs is markedly higher compared to BEVs.

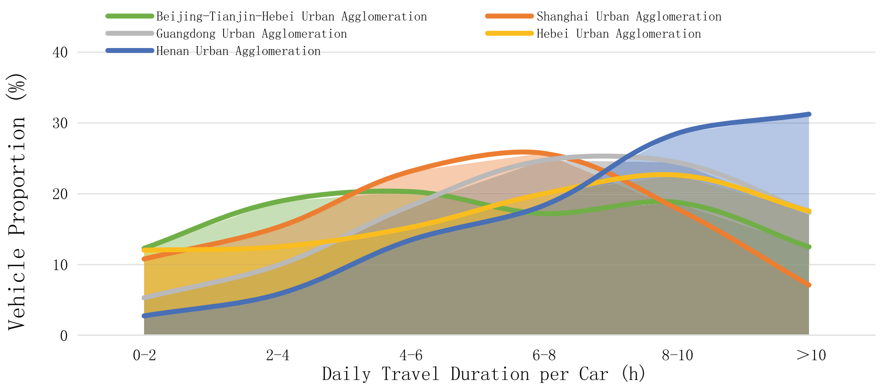


Fig. 7.35 Distribution of daily travel durations for FCEV-buses across demonstration urban agglomerations in 2022

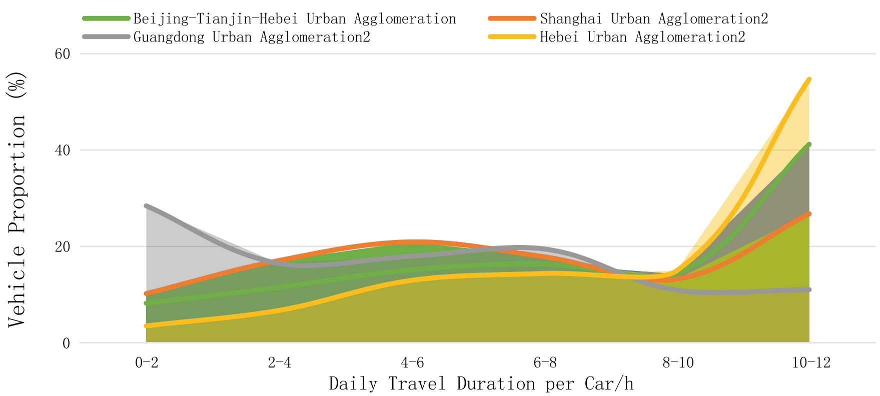


Fig. 7.36 Distribution of daily travel durations for FCEV-Vehicle for special purposes across demonstration urban agglomerations in 2022

In 2022, as shown in Fig. 7.37 and Fig. 7.38, the average mileage between two hydrogen refueling cycles for FCEV-buses and FCEV-Vehicle for special purposes in demonstration urban agglomerations was significantly higher compared to BEV models. Within the bus segment, the mileage between two hydrogen refueling cycles shows a year-on-year growth trend, reaching 566 km in 2022 for FCEV-buses in the Henan urban agglomeration. In the Vehicle for special purpose sector, the mileage between two hydrogen refueling cycles for FCEV-Vehicle for special purposes is around 200 km. In 2022, the mileage between two hydrogen refueling cycles for FCEV-Vehicle for special purposes in the Shanghai and Hebei Urban Agglomerations slightly increased.

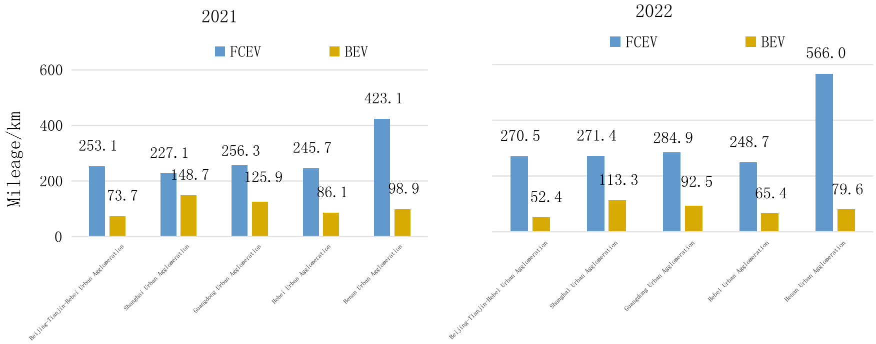


Fig. 7.37 Mileage between two hydrogen refueling cycles for different types of buses in demonstration urban agglomerations

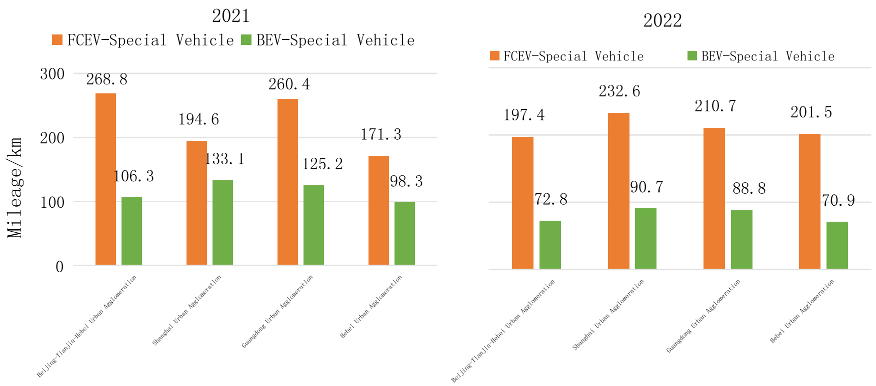


Fig. 7.38 Mileage between two hydrogen refueling cycles for different types of Vehicle for special purposes in demonstration urban agglomerations

7.3.3 Hydrogen Refueling Characteristics of FCEVs

(1) **Distribution of Daily Hydrogen Refueling Frequency per FCEV**

The analysis of the distribution of daily hydrogen refueling frequency per FCEV over the past two years reveals that in 2022, the proportion of FCEVs in demonstration urban agglomerations with less than one refueling per day increased. When it comes to the bus sector, there was a significant increase in the proportion of FCEV-buses with less than one daily refueling in each demonstration urban agglomeration to over 95% in 2022, markedly higher than the 2021 level (Fig. 7.39); a similar trend is observed in the Vehicle for special purpose sector, where the proportion of FCEV-Vehicle for special purposes with less than one daily refueling in 2022 showed a relative expansion compared to 2021 (Fig. 7.40). One of the main reasons for this phenomenon can be attributed to several factors. On one hand, the increase in hydrogen capacity per vehicle or the expansion of hydrogen station construction and operation may lead to a decrease in the daily refueling frequency of FCEV-buses. On the other hand, local hydrogen supply systems may suffer from issues such as a lack of domestic hydrogen sources and low efficiency in hydrogen storage and transportation, causing the supply capacity of hydrogen to lag behind the pace of fuel cell adoption and to some extent impacting the operational efficiency of FCEVs.

(2) **Average hydrogen refueling duration of FCEV**

In 2022, the average hydrogen refueling duration for various FCEV types in each demonstration urban agglomeration was primarily concentrated around 15 min, as depicted in Fig. 7.41. The Hebei Urban Agglomeration exhibits higher overall average hydrogen refueling durations for FCEV-buses and FCEV-Vehicle for special purposes, with single refueling durations of 17.3 min and 15.8 min, respectively. Compared to BEVs, FCEVs boast the advantages of shorter refueling time and longer driving range.

7.4 Summary

Drawing on the promotion and industry demonstration achievements of FCEVs in demonstration urban agglomerations in China, this chapter summarizes the operational and refueling characteristics of FCEVs, leading to the following main conclusions:

As China has seen a deployment scale of over 10 million FCEV-commercial vehicles, demonstration urban agglomerations play a significant leadership role in promoting these FCEVs nationwide. Thanks to the policy guidance from national ministries and commissions as well as local governments, the promotion of FCEVs in China has yielded remarkable results. By the end of 2022, a total of 10,564 FCEVs had accessed the National Monitoring and Management Platform, with the vehicle holding steadily growing. Spearheaded by the “3 + 2” demonstration

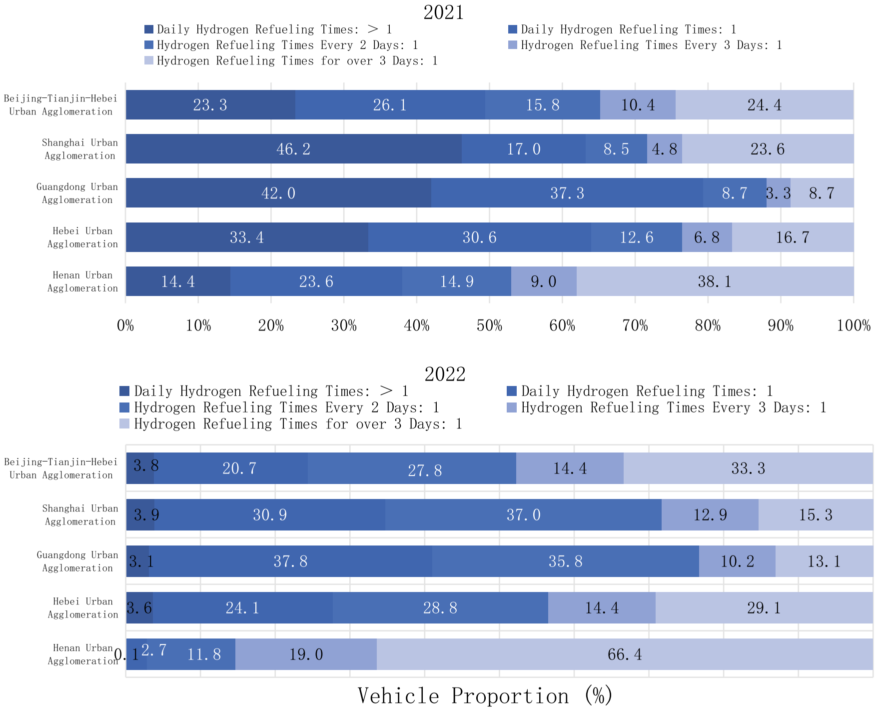


Fig. 7.39 Distribution of hydrogen refueling frequency per FCEV-bus in demonstration urban agglomerations over the years

urban agglomerations, the cumulative access volume of FCEVs in demonstration regions has reached 7521 units, making up 71.8% of the national total. FCEVs have expanded from a single application scenario to multiple application scenarios. With the gradual enrichment of models for buses and Vehicle for special purposes, FCEVs have achieved comprehensive coverage in the fields of buses and Vehicle for special purposes; in the realm of buses, they have covered public transportation, highways, commuting, and tourism. In the Vehicle for special purpose sector, there is coverage in logistics, engineering, and sanitation fields; in the passenger car sector, there is also a certain level of promotion and application in government affairs and leasing fields.

Local governments need to combine their local resource endowments and advantage in industrial foundations to promote vehicle demonstrations and cultivate industries, ultimately establishing regional hubs for FCEV development. The hydrogen energy and fuel cell industry chain is long, with numerous stakeholders from upstream to downstream, making it a popular industry for inter-regional competition. Yet, an analysis of early-stage promotion policies by local governments suggests that certain cities share similar promotion objectives to some

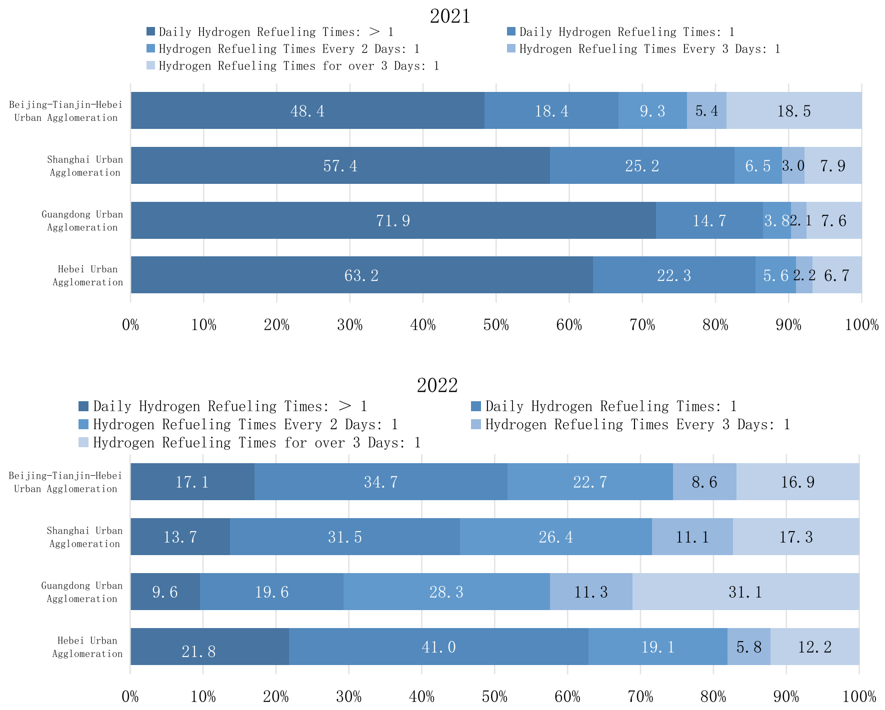


Fig. 7.40 Distribution of hydrogen refueling frequency per FCEV-Vehicle for special purpose in demonstration urban agglomerations over the years

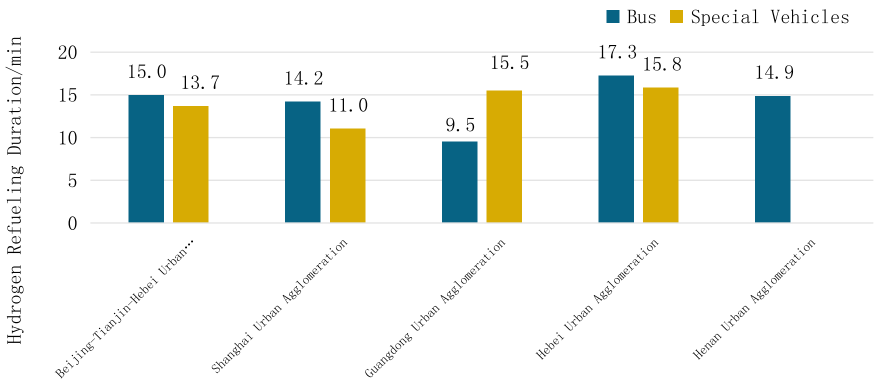


Fig. 7.41 Average hydrogen refueling duration for FCEVs across demonstration urban agglomerations in 2022

extent. Hence, in terms of national-level planning guidance, demonstration applications are conducted through the "3 + 2" FCEV demonstration agglomerations and the tracking of key projects. The transportation sector is chosen as a breakthrough point for the downstream application market development of hydrogen energy and fuel cells, with subsequent expansion into sectors such as energy storage, industry, and construction. One aspect entails breaking down administrative regional limitations and advocating for cross-regional industrial collaboration. Simultaneously, it is important to fully leverage local advantages in industries and resource endowments, promoting rapid breakthroughs in critical technologies and accelerating the commercialization efforts in key sectors.

As the demonstration urban agglomerations following the "3 + 2" model have been put into practice for a year, accompanied by the gradual improvement of the national "dual carbon" strategy and the upstream and downstream sectors in the industry chain, the FCEV market is poised to enter a period of stable and linear growth. By seizing the opportunity of the convening of Beijing 2022 Winter Olympics and guided by the three-year action plan to fight air pollution, also called the Blue Sky Protection Campaign, the Beijing-Tianjin-Hebei Urban Agglomeration and the Hebei Urban Agglomeration have achieved remarkable results in the promotion of FCEV-buses. This success is attributed to the close collaboration among industry, academia, and research institutions, facilitated by the local industrial foundation and research resources. With Shanghai serving as the anchor city, the Shanghai Urban Agglomeration extends its influence to surrounding developed cities like Suzhou and Nantong. By leveraging the dynamism of companies in the entire FCEV industry chain, it has the potential to become a region that rapidly matures the industry chain in China. The Guangdong Urban Agglomeration has significantly outperformed other demonstration urban agglomerations in terms of the number of FCEVs deployed. As of the end of 2022, it had had a total of 2652 FCEVs accessed, making it the largest in scale and with the longest operational mileage among all the demonstration urban agglomerations in China. The Henan Urban Agglomeration hinges on leading enterprise Yutong Bus to drive the collaboration of key component companies in the upstream and downstream sectors of the industry chain. With a focus on the demonstration and operation of FCEV-buses, the initial formation of the hydrogen energy and FCEV industry landscape is taking shape.

With a market-oriented approach, there is a drive to expand the demonstration application scenarios for FCEVs and accelerate the exploration of suitable commercial application models. From the NEV operating characteristics observed on the National Monitoring and Management Platform, FCEVs demonstrate significant advantages over BEVs in terms of mileage and hydrogen refueling efficiency. Relative to BEVs, FCEVs offer advantages such as shorter refueling time, extended driving range, and better adaptability in low-temperature environments. Under ideal conditions, hydrogen fuel cell technology is better suited for medium to long-distance or heavy-duty trucking, helping to address the drawbacks of high-capacity BEV-heavy-duty trucks in terms of payload and the emissions of pollutants associated with diesel heavy-duty trucks. However, due to the current limitations of hydrogen storage technology and the need for further development of hydrogen refueling infrastructure and other supporting facilities, the use of FCEV-Vehicle for special purposes in the long-distance transportation sector is still in need of expansion. In this regard, they complement BEVs in certain applications. Additionally, through demonstration applications, efforts are being made to drive the continuous improvement of the industrial chain and the enhancement of standards and evaluation systems. The goal is to establish a robust industry improvement system that promotes the sound development of the sector.

The level of perfection in the hydrogen supply system and the reduction of costs within the industry chain are crucial to achieving the promotion goals for FCEVs by the end of the "14th Five-Year Plan" period. According to the National Monitoring and Management Platform, in 2022, the online rate of FCEVs in certain regions was relatively low, partly due to the weaker capacity of hydrogen supply sources. Using Foshan as a case study, the limited availability of hydrogen sources is a significant challenge for the development of the hydrogen energy industry in the city. Foshan heavily depends on externally transported hydrogen due to a shortage of local sources. Moreover, the sluggish approval process for hydrogen refueling stations places restrictions on the supply of hydrogen for FCEVs, thereby impacting their operational capabilities to some extent. Moreover, regarding key components, while China has achieved initial self-supply capabilities in core materials for fuel cells in key areas, the slow operation of the industry's "technology upgrade - large-scale application - technology upgrade" cycle system is primarily due to the limited scale of FCEV promotion during the initial stage of the industry and the weak ability to distribute costs. Over the next period, expediting the construction of hydrogen refueling station systems, advancing the breakthroughs of key technology in hydrogen storage systems, and establishing an independent and controllable supply chain will contribute to the promotion of commercialization for FCEVs.

Chapter 8
Plug-In Hybrid Electric Vehicles (PHEVs)

Plug-in Hybrid Electric Vehicles (PHEVs), including Extended-Range Electric Vehicles, are recognized as a viable solution in the automotive industry's quest for low carbonization. Their adoption plays a pivotal role in expediting energy conservation and carbon reduction efforts, driving the transformation and sustainable development of the automotive sector in the short to medium term. Recently, the market demand for PHEVs has been rapidly increasing due to their capability to satisfy diverse consumer application scenarios and requirements. In this chapter, we center our research on PHEVs. We conduct a comparative analysis of the industry policies and market landscapes for PHEVs at national and regional levels. Furthermore, we delve into the operation of PHEVs and their operational characteristics in typical urban settings. Our aim is to gain insight into operation patterns of PHEVs and user preferences, contributing to the technological progress and sustainable growth of PHEVs.

8.1 Current Status of the PHEV Market

With the tightening emissions regulations, the supply of PHEVs has witnessed a rapid growth in the market.

Against the backdrop of increasingly stringent emissions regulations, OEMs are facing mounting pressure from dual credit requirements. On June 29, 2023, five ministries and commissions including the MIIT jointly issued the *Decision on Amending the Measures for the Parallel Administration of the Average Fuel Consumption and New Energy Vehicle Credits of Passenger Car Enterprises*, effective August 1, 2023. In terms of the credit calculation for new energy passenger car models (Table 8.1), during the period from 2024 to 2025, the credit score for standard vehicle models will be reduced by around 40% compared to the previous stage (which is generally in line with the reduction range of 32% to 52% during the period

Z. Wang, *Annual Report on the Big Data of New Energy Vehicle in China (2023)*,
https://doi.org/10.1007/978-981-97-4840-2_8

from 2021 to 2023). The credit assessment ratio for NEVs is set at 28% and 38%. Furthermore, the credit calculation formula for BEV models has been revised from 0.0056R + 0.4 in 2021 to 0.0034R + 0.2 in 2024, aiming to encourage enterprises to achieve greater breakthroughs in the energy density, consumption, and driving range of new energy power batteries. Relative to BEV models, compliant PHEV models are eligible for fixed standard vehicle scores of 1.6 and 1.0 from 2021 to 2023 and from 2024 to 2025, respectively. As the dual credit policy becomes increasingly stringent, energy conservation and emissions reduction in the automotive industry are no longer solely focused on BEV options, but rather on a combination of diverse technical routes.

To adapt to the nation's long-term energy strategic transformation and address the pressure of dual credit requirements, major domestic OEMs are actively expanding their portfolio of NEV products. Taking into account the driving habits of conventional vehicle users, the plug-in hybrid technology roadmap has emerged as the optimal choice for a rapid transition away from traditional fuel-powered vehicles. Proprietary Chinese brands have embarked on a comprehensive hybridization process, with the new generation of plug-in hybrid products experiencing significant performance enhancements and a substantial increase in market acceptance. For instance, BYD's DM-i hybrid system has successfully accomplished the transformation of their original fuel-powered vehicles into hybrid powertrains. Apart from BYD, leading OEMs such as Great Wall Motor, Geely, Chang'an Automobile, GAC Motor, and Chery have also introduced their latest generation of hybrid powertrain systems. These products have gained a competitive edge over international mainstream hybrid powertrain systems in terms of overall vehicle performance and fuel efficiency. As technology evolves and costs decline, hybrid offerings from proprietary brands are steadily approaching the price level of conventional fuel-powered vehicles. This trend aids in accelerating the breakthrough of proprietary brands in overcoming technological blockades imposed by foreign counterparts.

Plug-in hybrids have successfully accommodated the diverse usage needs of consumers, resulting in an explosive surge in market demand.

By considering both power performance and fuel efficiency, PHEVs are well positioned to satisfy the diverse usage needs of consumers. From a market demand perspective, as the competitiveness of plug-in hybrids continues to improve, there

Table 8.1 Credit calculation method for new energy passenger car models

Type	Implemented since 2019	Implemented since 2021	Implemented since August 1, 2023
BEV-passenger car	0.012*R + 0.8	0.0056*R + 0.4	0.0034*R + 0.2
PHEV-passenger car	2	1.6	1
FCEV-passenger car	0.16*P	0.08*P	0.05*P

Note R represents the BEV driving range (inkm), while P denotes the rated power of the fuel cell system (in kW)
Source Official website of the MIIT

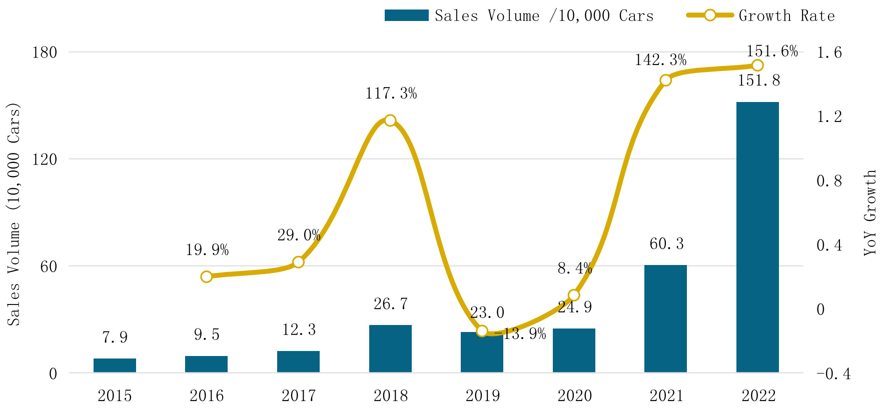


Fig. 8.1 Sales and growth of PHEVs over the years. *Source* China Association of Automobile Manufacturers

has been a significant increase in consumer acceptance. Over the past two years, the PHEV market has demonstrated a rapid growth trend (Fig. 8.1). In 2022, annual sales of PHEVs came at 1.518 million units, representing a year-on-year (YoY) growth of 151.6%, outpacing the YoY growth rate of 81.6% in the BEV market.

Looking at the sales mix in the NEV market in the past two years (Fig. 8.2), the market share of PHEVs (PHEVs) reached 22% in 2022, expanding by 4.9 percentage points compared to the previous year. The PHEV market has been consistently heating up, emerging as a significant contributor to the growth of the NEV market.

In 2022, the top 5 best-selling PHEV models in China were all from proprietary brands, specifically from the BYD brand. These models included BYD Song PLUS DM-i, BYD Qin PLUS DM-i, BYD Han DM, BYD Tang DM, and BYD Destoryer 05 (Table 8.2). They have set industry standards in terms of curb weight, price, and other aspects, garnering positive market feedback in the PHEV market. The statistical findings of potential user model comparisons conducted by Autohome Inc. (Fig. 8.3) indicate that multiple models from BYD have directly competed with conventional fuel vehicles, successfully gaining market share from their fuel-powered counterparts. The popular extended-range electric vehicle models such as Li Auto and AITO primarily compete with other NEV models, while their competition with the traditional fuel vehicle market is relatively limited.

8.2 Promotion Status of PHEVs

Based on the data about cumulative access volume from the National Monitoring and Management Platform, this study analyzes the promotion and application of PHEVs (including extended-range electric vehicles) from multiple dimensions such as vehicle types and regional distribution. Considering the extensive promotion of

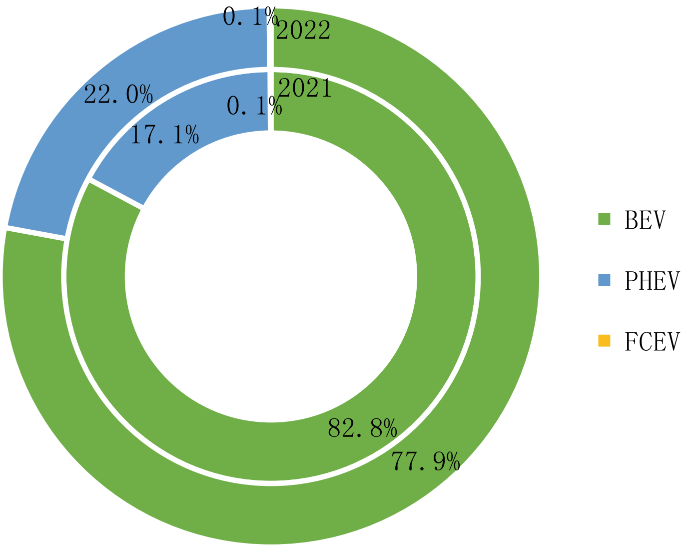


Fig. 8.2 Sales mix of new energy vehicles over the years—by drivetrain. *Source* China Association of Automobile Manufacturers

Table 8.2 Top 5 PHEV models by sales in 2022

No	Model	Sales (vehicles)	Vehicle level	NEDC (km)	Maximum batter capacity (kWh)	MSRP (10,000 yuan)
1	BYD Song PLUS DM-i	388,048	Compact SUV	51–110	8.30–18.30	15.48–21.88
2	BYD Qin PLUS DM-i	188,522	A-class sedan	55–120	8.32–18.32	11.38–13.78
3	BYD Han DM	128,524	C-class sedan	121–242	18.3–37.6	21.78–32.18
4	BYD Tang DM	125,368	Mid-size SUV	112–215	19.96–45.8	20.98–33.18
5	BYD Destroyer 05	61,949	A-class sedan	55–120	8.3–18.3	12.18–15.78

Note The manufacturer's suggested retail price (MSRP) is determined based on the prices provided by automotive vertical media websites, with data collected until the end of February 2023

PHEVs in the passenger car segment, this study undertakes a comprehensive analysis of passenger cars as the primary research focus.

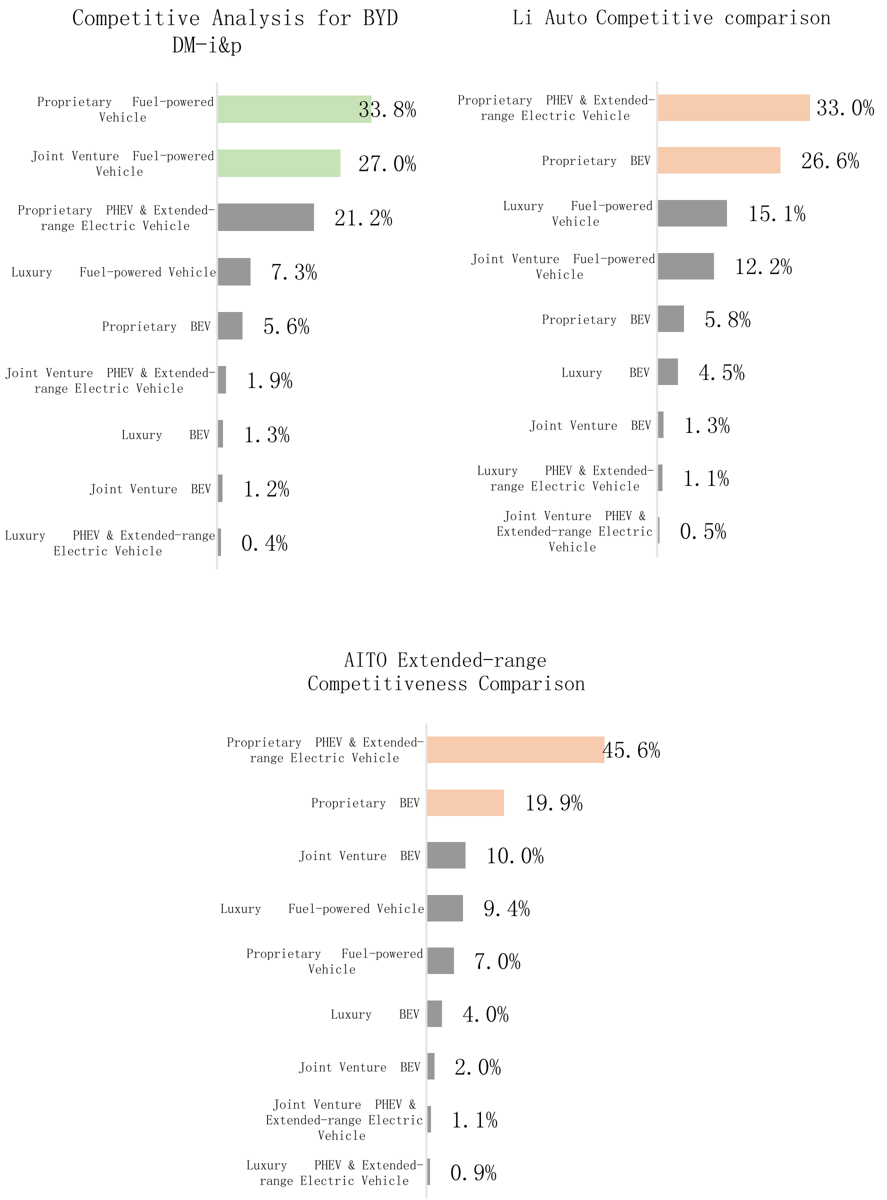


Fig. 8.3 Competitive analysis of major brands and models of PHEVs (including extended-range electric vehicles). *Source* Autohome Inc

8.2.1 Overall Access of PHEVs

(1) **Cumulative PHEV access characteristics**

The access volume of PHEVs is rapidly increasing, and a total of over 2.298 million PHEVs have accessed the National Monitoring and Management Platform.

As of December 31, 2022, 2.298 million PHEVs had been accessed to the National Monitoring and Management Platform, including, by type, 2.255 million PHEV-passenger cars, accounting for 98.1% of PHEVs (Fig. 8.4). 1.938 million private passenger cars had been accessed, accounting for around 84.4% of PHEV-passenger cars.

The provincial/municipal concentration of PHEVs is relatively high, with Guangdong province taking a significant lead.

From the perspective of the cumulative access of PHEVs across provinces/municipalities (Fig. 8.5), Guangdong, Shanghai, and Zhejiang rank in the top three with cumulative access volume of 456,000, 353,000, and 205,000, respectively. The provincial/municipal concentration of PHEVs is high, with the cumulative access volume of PHEVs in the top 3 provinces/municipalities accounting for 44.1% of the total in China.

In cold regions during the winter season, PHEVs have a higher share in the cumulative access volume number of locally registered NEVs.

Based on the proportion of cumulative access volume and the distribution of access structure of PHEVs among 31 provinces/municipalities (Fig. 8.6), Guangdong, Shanghai, and Zhejiang show a significant presence in the PHEV market in China. When considering the ratio between the cumulative access volume of PHEVs and the total cumulative promotion volume of locally registered NEVs, provinces/municipalities such as Heilongjiang, Ningxia Hui Autonomous Region, Xinjiang Uygur Autonomous Region, Liaoning, Jilin, Inner Mongolia Autonomous Region, and Tibet Autonomous Region demonstrate a higher suitability of PHEVs in cold temperatures due to their prolonged winter seasons in high latitude regions. In these

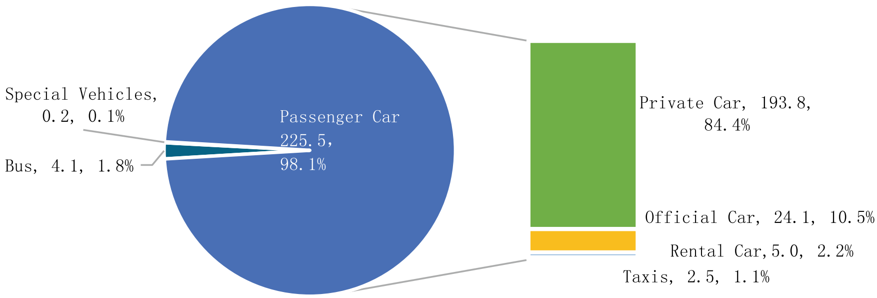


Fig. 8.4 Cumulative access volume and proportion of PHEVs—by type

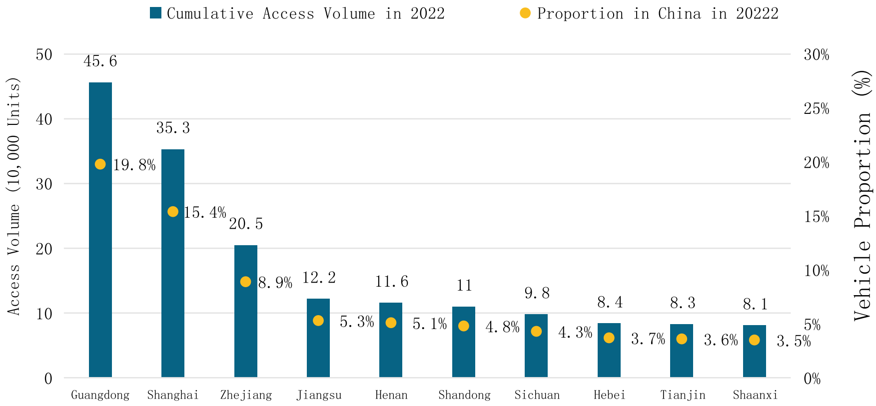


Fig. 8.5 Cumulative access volume and proportion of PHEVs in the top 10 provinces/municipalities

regions, the proportion of cumulative access volume of PHEVs to the total cumulative access volume of locally registered NEVs exceeds 30%.

(2) Cumulative access of PHEV-passenger cars

Passenger cars are the mainstream models driving the PHEV market, with PHEV-passenger cars representing over 90% of the cumulative access volume of locally registered PHEVs in the top 15 provinces/municipalities.

In terms of the concentration of promotion for PHEV-passenger cars across provinces/municipalities (Fig. 8.7), Guangdong, Shanghai, and Zhejiang occupy the first three spots in terms of the cumulative access volume. By December 31, 2022,

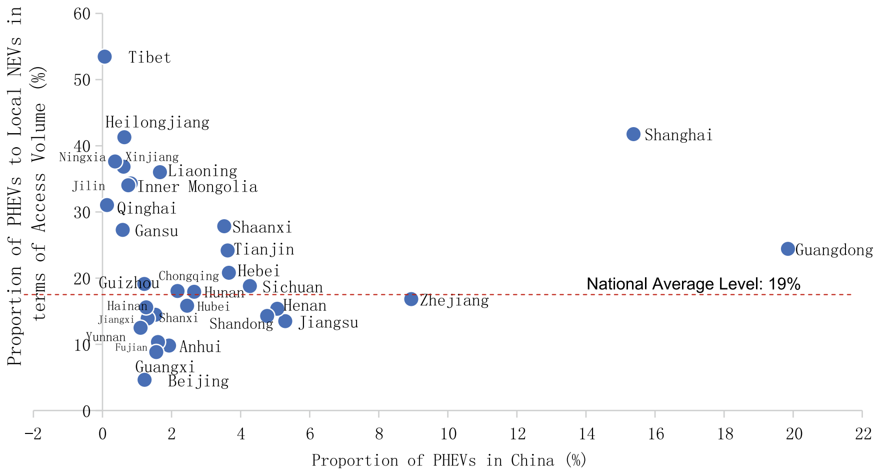


Fig. 8.6 Proportion of cumulative access volume of PHEVs across 31 provinces/municipalities in 2022

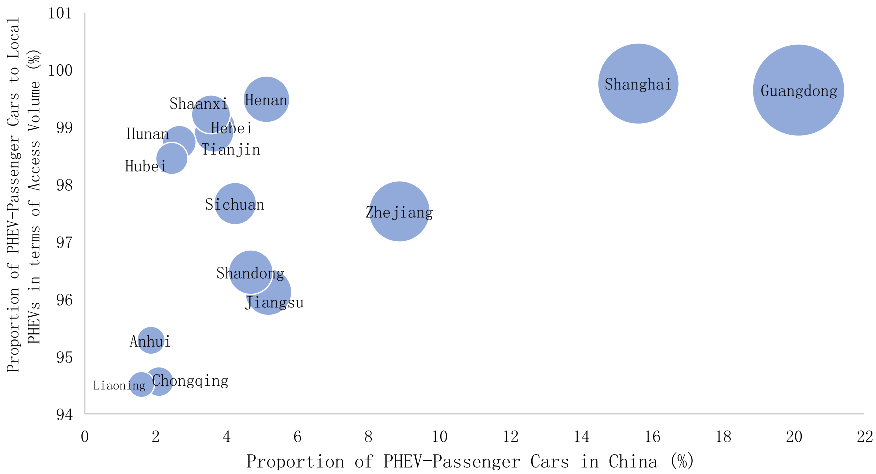


Fig. 8.7 The top 15 provinces/municipalities in terms of the cumulative access of PHEV-passenger cars and their respective proportions

three provinces (municipalities) had accumulated access of 454,000, 352,000, and 200,000 vehicles, representing 20.2%, 15.6%, and 8.9% respectively of the total in China. From the viewpoint of the access structure of PHEVs, passenger cars in the top 15 provinces/municipalities hold a dominant position in the PHEV market, with a market share exceeding 90%.

In terms of promotion in cities, there is a strong demand for PHEV-passenger cars in Shanghai and Shenzhen.

When examining the promotion situation across different cities (Fig. 8.8), Shanghai and Shenzhen rank as the top two cities with the highest cumulative access volume of PHEV-passenger cars. Up until December 31, 2022, Shanghai had had an accumulative access of 353,000 PHEV-passenger cars, while Shenzhen had 228,000, responsible for 15.6% and 10.1% of the total in China, respectively. When it comes to the share of PHEV-passenger cars in the local NEV market, Shanghai, Shenyang, and Shenzhen have displayed a stronger demand. The proportion of PHEV-passenger cars in these cities amounts to 41.7%, 34.4%, and 32.4%, respectively.

Proprietary brands are speeding up the deployment of plug-in hybrids, reshaping the market landscape.

Market promotion concentration in the PHEV-passenger car sector (Fig. 8.9) reveals that as of December 31, 2022, four companies—BYD, Li Auto, SAIC Motor, and BMW Brilliance—have accumulated access in excess of 100,000 vehicles each, or over 5% of the cumulative access volume. With the proportion of cumulative access volume at 53%, the BYD DM and DM-i&p models successfully gained significant traction in the market. As Chinese car manufacturers ramp up their efforts, the introduction of BYD DM hybrid system, Geely GHS hybrid system, GAC Motor GMC hybrid system, and Chang'an Blue Whale iDD platform signifies an accelerated phase of restructuring in the plug-in hybrid system landscape.

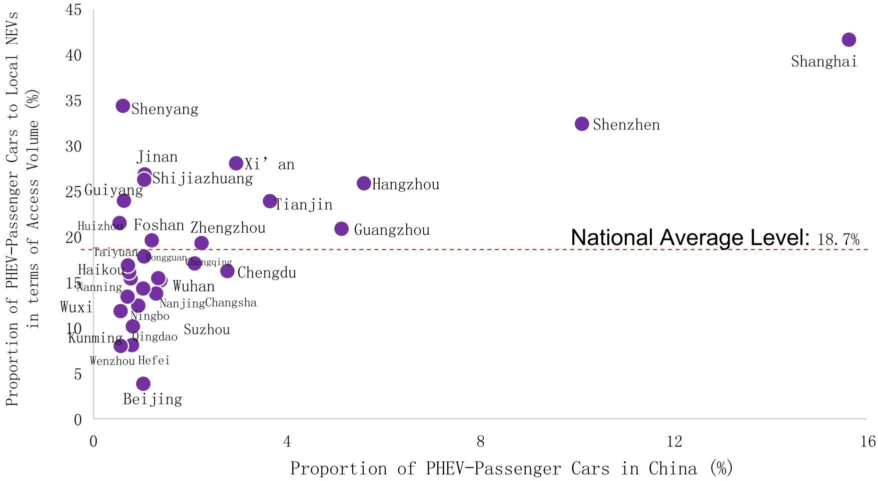


Fig. 8.8 Proportion of cumulative access volume of PHEV-passenger cars in the TOP30 cities in 2022

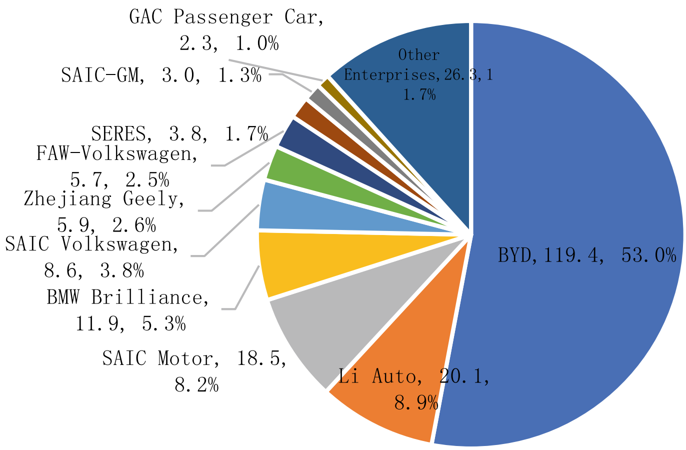


Fig. 8.9 Cumulative access volume of PHEV-passenger car by top 10 companies

8.2.2 Access Characteristics of PHEVs over the Years

The PHEV market is experiencing rapid growth, with a year-over-year increase of nearly 150% in 2022.

Analysis of access over the years (Table 8.3) reveals that the access volume of PHEVs in 2022 stood at 1.1911 million, representing a remarkable 147.8% year-on-year increase. By examining the monthly access volume data, it becomes apparent that in 2022, the access volume of PHEVs accessed on a monthly basis consistently remained at a high level. Moreover, the fourth quarter exhibited a significant "carryover effect," with a total of 400,000 PHEVs accessed during that period (Fig. 8.10).

The market demand for PHEVs is gradually shifting towards cities not subject to purchase restriction.

From the perspective of the access characteristics over the years, the market demand for PHEVs is gradually shifting to cities not subject to purchase restriction. Figure 8.11 shows that in recent years, the market share of PHEVs in cities not subject to purchase restriction has proliferated, and the market share has significantly increased. In 2019, the market share of PHEVs in cities not subject to purchase restriction was 37.8%. By 2021, the market share of PHEVs in these cities had reached 69.3%, with an increase of 31.5 percentage points compared with 2019. The market share of PHEVs in cities not subject to purchase restriction is rapidly expanding.

The share of PHEVs in first-tier cities has decreased, and market demand is gradually releasing to lower-tier cities.

Based on the access characteristics of PHEVs in cities of different tiers over the years (Fig. 8.12), the proportion of access volume of PHEVs in first-tier cities has shown a decreasing trend yearly, while other cities of different tiers have witnessed significant increases in the access volume over the years. Due to the gradual restriction of green license plates and driving rights for PHEVs (including extended-range electric vehicles) in Beijing and Shanghai, the annual proportion of PHEV access volume in first-tier cities has gradually narrowed, declining from 47.5% in 2019 to 21.5% in 2022. In contrast, other cities of different tiers have experienced varying degrees of increase in their PHEV access share over the years. In 2022, the proportion of

Table 8.3 Cumulative access volume of PHEVs over the years

Year	2020	2021	2022
Access volume of PHEVs (10,000 units)	14.99	48.08	119.11

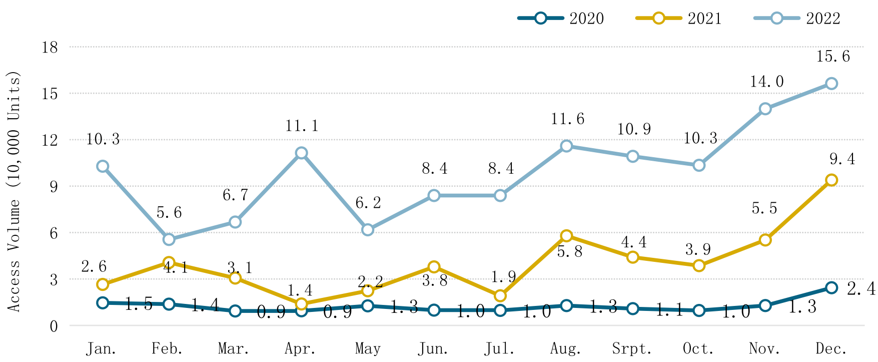


Fig. 8.10 Monthly access volume of PHEVs over the years

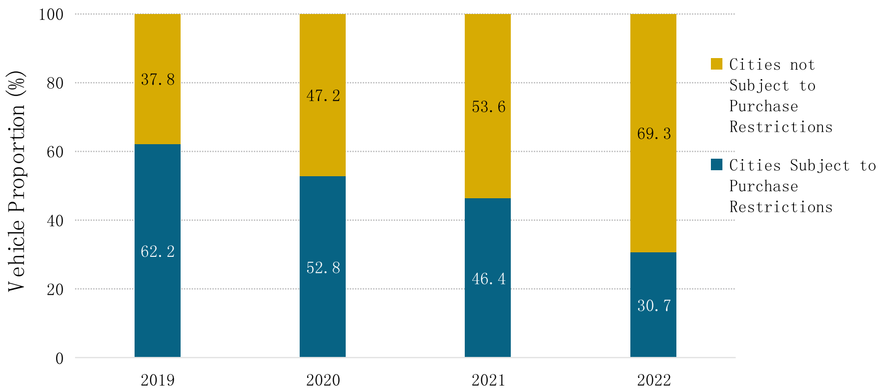


Fig. 8.11 Changes in the proportion of access volume of PHEVs in cities subject to and not subject to purchase restriction over the years

PHEV access in cities below the first-tier level reached 78.5%, representing a significant increase of 26 percentage points compared to 2019. On one hand, the overall cost-effectiveness of PHEVs (including extended-range electric vehicles) compared to conventional fuel vehicles is gradually becoming more apparent, leading to a significant increase in consumer purchasing desire and a rapid release of market demand. On the other hand, automotive manufacturers are adopting decentralized sales area distribution to ensure long-term stability and mitigate the impact of policy limitations.

East China and South China are the main promotion regions. In 2022, the market share of PHEVs in Northeast, Central, and Northwest, and Southwest China increased.

Based on the access characteristics of PHEVs by region over the years (Fig. 8.13), East China and South China are the main promotion regions for PHEVs. The robust

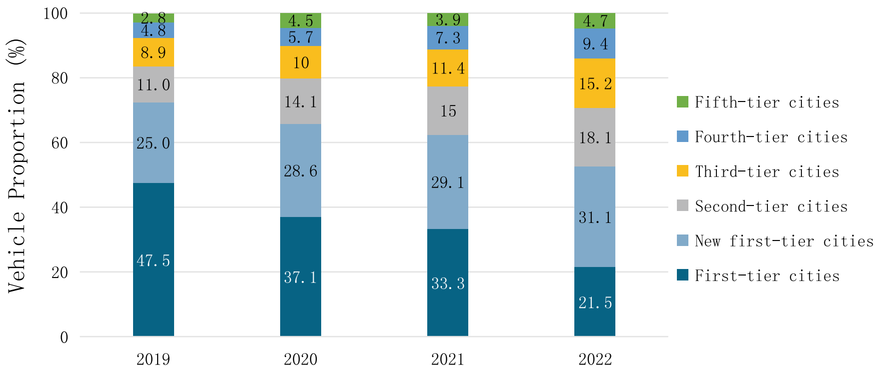


Fig. 8.12 Changes in the proportion of access volume of PHEVs in cities of different tiers over the years

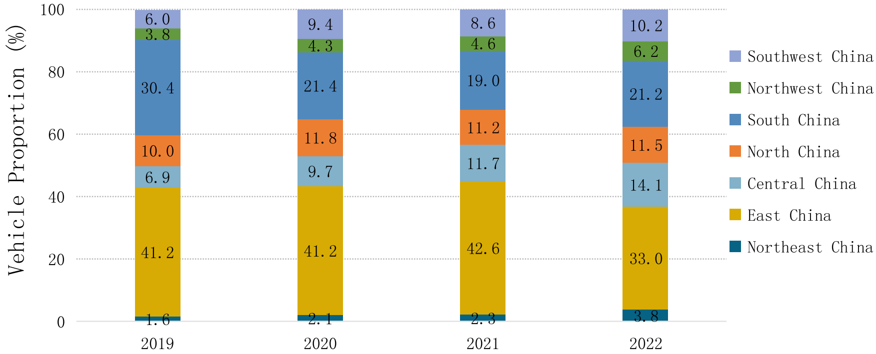


Fig. 8.13 Changes in the proportion of access volume of PHEVs in different regions over the years

market demand for PHEVs in Shanghai and Guangdong resulted in a combined proportion of annual access volume at 54.2% in these two regions in 2022.

From the change in PHEV access volume in recent years, the proportion of PHEVs in Northeast China, Central China, Northwest China, and Southwest has shown an upward trend, while the proportion of access volume in North China has remained relatively stable over the years.

8.2.3 Access of Extended-Range Electric Vehicles

By the end of 2022, there had been an accumulative total of 262,000 extended-range electric vehicles accessed to the National Monitoring and Management Platform.

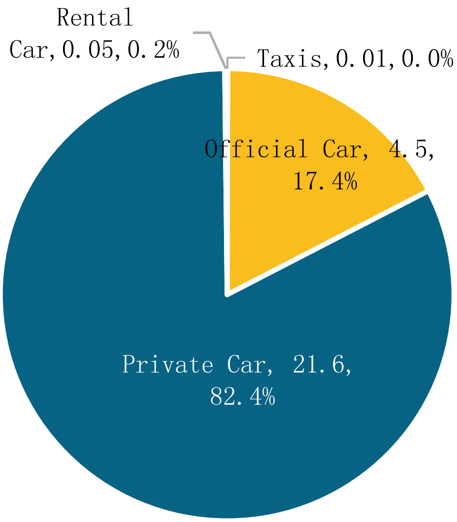
By the end of 2022, there had been an accumulative total of 262,000 extended-range electric vehicles accessed to the National Monitoring and Management Platform. In this regard, private passenger cars represent the majority of the promoted vehicle models, with a cumulative access of 216,000 vehicles, accounting for 82.4% of the total. Official cars come next, with a cumulative access of 45,000 vehicles, responsible for 17.4% (Fig. 8.14).

In terms of companies with extended-range electric vehicle access, Li Auto takes the lead with a cumulative access of 181,000 vehicles, accounting for 69.4% of the total, followed by Jinkang SERES and Fujian ENOVATE, with a cumulative access of 69,000 and 5,100 vehicles, accounting for 26.6% and 1.9%, respectively.

Shanghai, Hangzhou, and Shenzhen all have a cumulative access volume of extended-range electric vehicles exceeding 5% of the total in China.

Until the end of 2022, Shanghai, Hangzhou, and Shenzhen recorded a cumulative access of 19,000, 17,000, and 15,000 extended-range electric vehicles respectively, accounting for 7.2%, 6.6%, and 5.7% of the total in China. The cumulative access of the top 3 cities represents close to 20% (Fig. 8.15). The yearly access volume tells

Fig. 8.14 Cumulative access and proportion of extended-range electric vehicles in different application scenarios (10,000 vehicles, %)



us that in 2022, Hangzhou and Shenzhen had the first two highest annual access of extended-range electric vehicles, both exceeding 10,000 vehicles (Fig. 8.16).

Second- and lower-tier cities witness an expanding proportion of extended-range electric vehicle access volume year by year.

Based on the proportion of access volume of extended-range electric vehicles across cities of different tiers over the years (Fig. 8.17), there has been a gradual decrease in first-tier and new first-tier cities, while second- and lower-tier cities experienced an increase from 33.3% in 2020 to 42.7% in 2022, marking a growth of 9.4 percentage points.

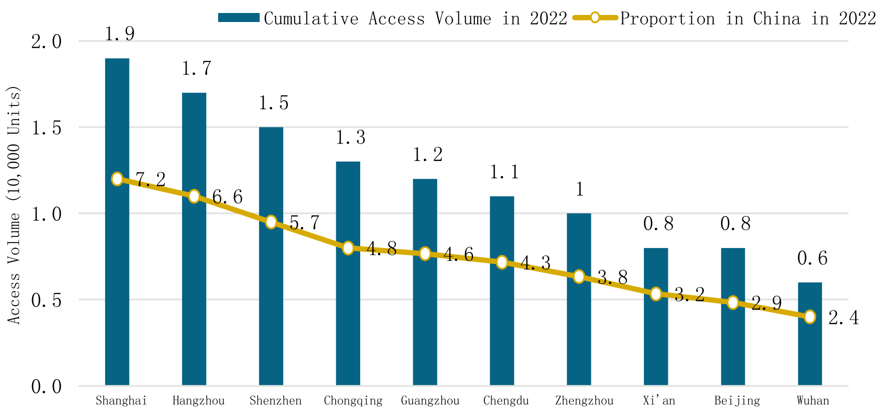


Fig. 8.15 Cumulative access volume and proportion of extended-range electric vehicles in the top 10 cities

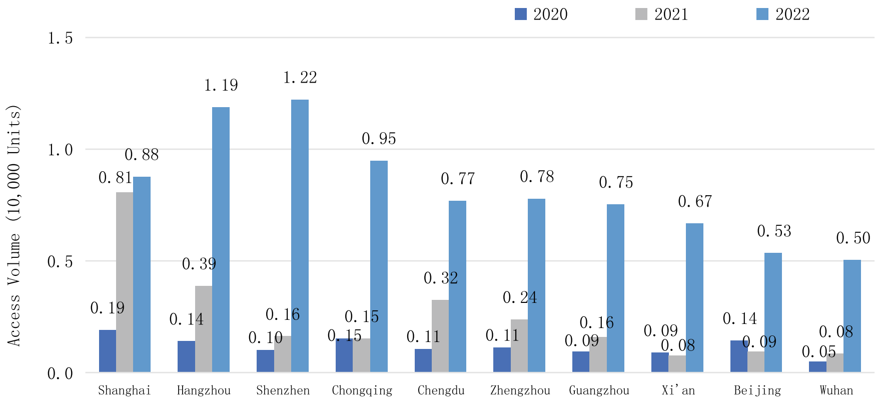


Fig. 8.16 Access volume of extended-range electric vehicles in the top 10 cities over the years

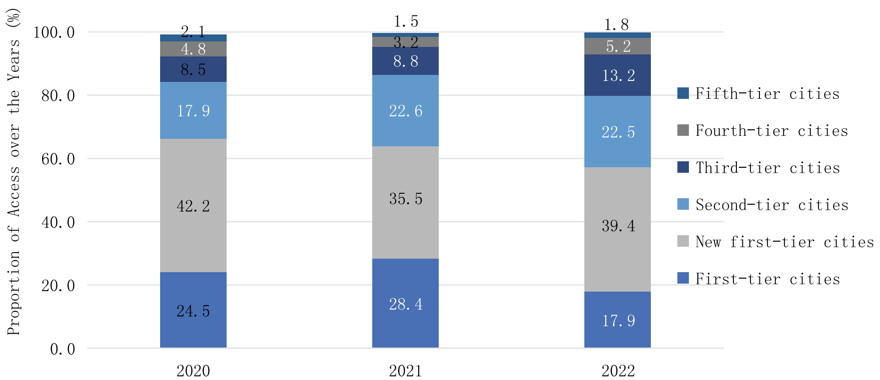


Fig. 8.17 Changes in the proportion of access volume of extended-range electric vehicles across cities of different tiers over the years

There has been a substantial increase in the annual proportion of access volume of extended-range electric vehicles in South China.

Based on the proportion of access volume of extended-range electric vehicles across different regions over the years (Fig. 8.18), East China has consistently held the top position, with the annual proportion exceeding 30% from 2020 to 2022. With the rapid release of demand for extended-range electric vehicles in the national market, regions outside East China show an increasing trend in the proportion of access volume. From 2020 to 2022, South China experienced a notable increase in the annual proportion of access volume of extended-range electric vehicles, rising from 14.5% to 21.7% and expanding by 7.2 percentage points. Similarly, other regions including Northeast China, Central China, and Northwest China also saw a modest growth.

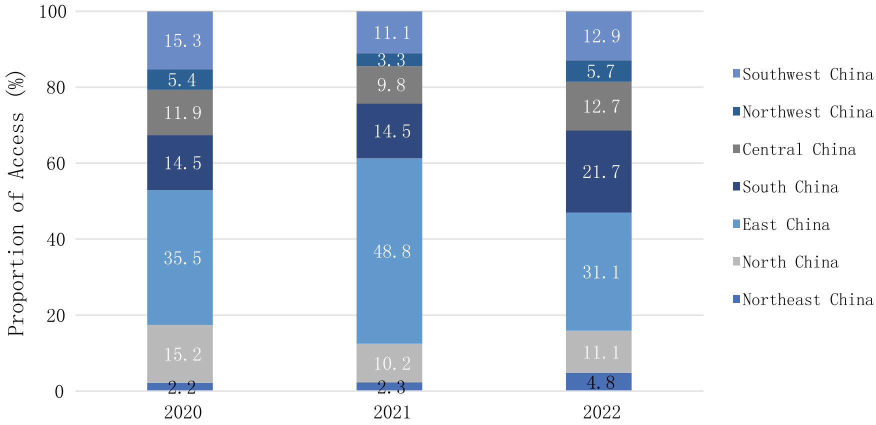


Fig. 8.18 Changes in the proportion of access volume of extended-range electric vehicles across regions over the years

8.3 Operation Characteristics of PHEVs

8.3.1 Online Rate of PHEVs

The online rate of PHEVs remains at a high level, and the usage rate of PHEVs is relatively high.

From the perspective of the online rate of PHEVs in various regions (Fig. 8.19), the average online rate of PHEVs in all regions of China has shown an upward trend in the last three years. Particularly in 2022, the average online rate in all regions of the country exceeded 93%, indicating a high usage rate of PHEVs.

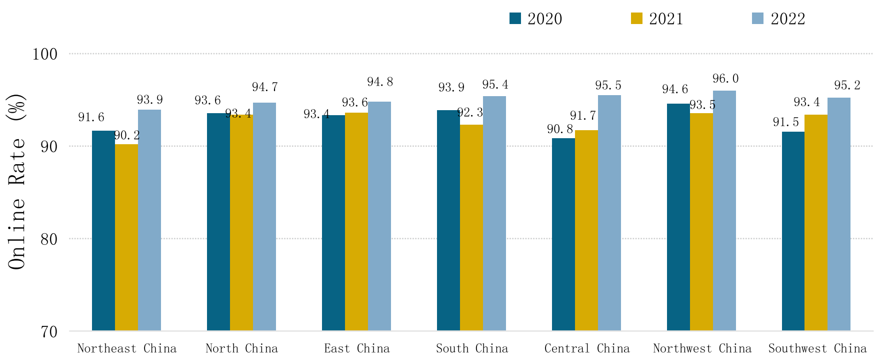


Fig. 8.19 Average monthly online rates of PHEVs in various regions of China

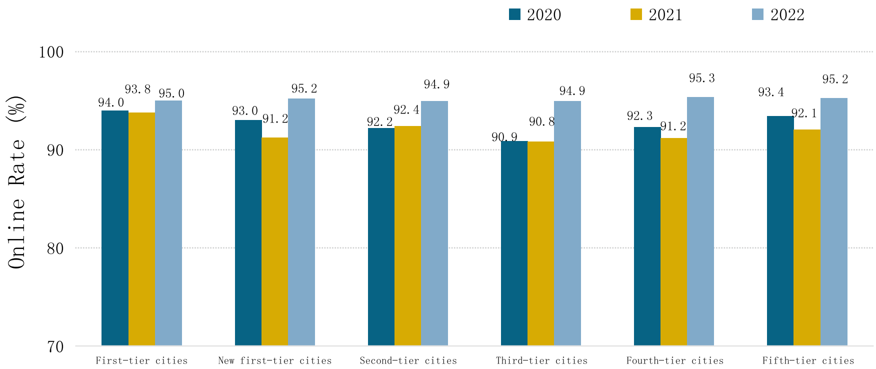


Fig. 8.20 Average monthly online rates of PHEVs in cities of different tiers

From the perspective of the online rate of PHEVs in cities of different tiers (Fig. 8.20), the online rate of PHEVs in cities of different tiers remains above 94%. There are slight differences in vehicle online rates in cities of different tiers.

From the perspective of the online rate of PHEVs by type (Fig. 8.21), the online rate of private cars, e-taxis, taxis, and cars for sharing is generally at a high level, all exceeding 90%. Among them, the average monthly online rate of PHEV-private cars is close to 100%, indicating the normalization of their usage. In the commercial vehicle sector, the online rate of PHEV-buses and PHEV-logistics vehicles in 2022 is slightly lower than that of PHEV-passenger cars, but it has shown a significant year-on-year improvement.

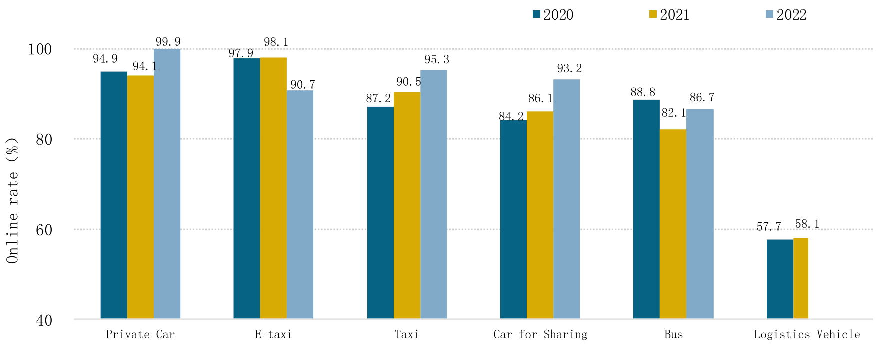


Fig. 8.21 Average monthly online rates of PHEVs in cities of different tiers over the years

8.3.2 Operation Characteristics of PHEVs

The proportion of mileage in electric driving mode is increasing, with a higher usage rate of the electric driving mode in private cars.

The operating modes of PHEVs are divided into electric driving mode, hybrid driving mode, and fuel-powered driving mode. In 2022, the proportion of daily mileage to the total in electric driving mode was 46.2%. From the perspective of different application scenarios, private cars have a significantly higher proportion of daily mileage in electric driving mode compared to other types of vehicles. This can be attributed to the greater convenience of charging, resulting in a higher percentage of mileage covered in electric driving mode. From the perspective of changes over the years, there has been a noticeable increase in the proportion of daily mileage in electric driving mode for private cars, taxis, and cars for sharing in 2022 (Fig. 8.22). Regardless of the vehicle type, the proportion of fuel-powered driving mode is below 10%, indicating that PHEV-passenger cars are environmentally friendly with low carbon emissions compared to vehicles in the same category.

From the proportion distribution of different types of vehicles with different mileages in electric driving mode (Fig. 8.23), it can be seen that the proportion distribution of private cars with different mileages in the electric driving mode is relatively uniform; taxis and cars for sharing with the mileages in the electric driving mode accounting for 40–60% of the total mileage in the electric driving mode are dominated.

Extended-range electric vehicles exhibit a high proportion of mileage in electric driving mode, with those in first-tier cities having a concentrated proportion of mileage in electric driving mode above 50%.

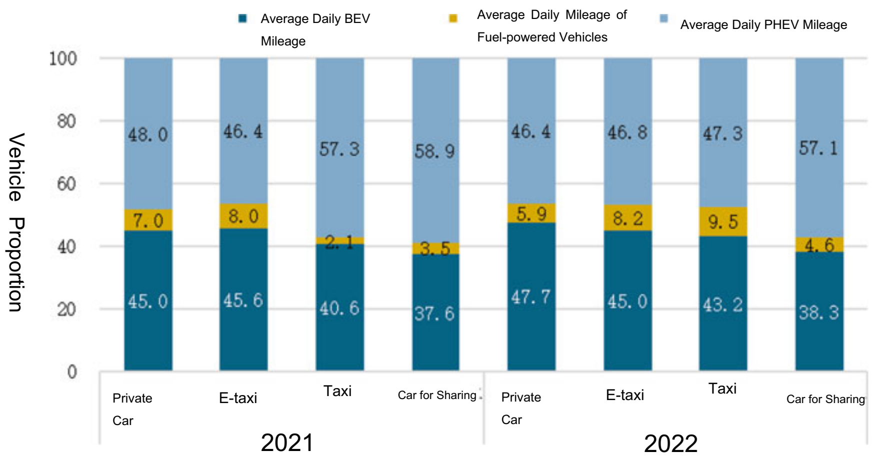


Fig. 8.22 Proportion of average daily mileage of PHEV-passenger cars in different driving modes

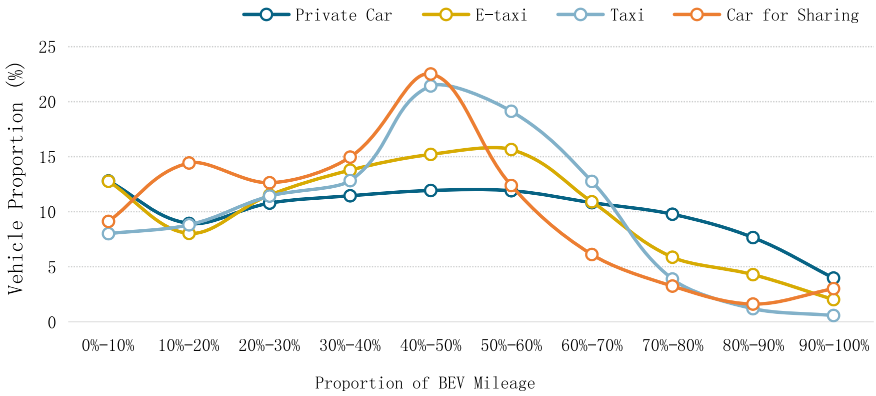


Fig. 8.23 Distribution of PHEV-passenger cars with different mileages in electric driving mode in different scenarios in 2022

In contrast to PHEVs, a higher proportion of extended-range electric vehicles opt for the electric driving mode. As shown in Figs. 8.24 and 8.25, in 2022, 74.8% of extended-range electric vehicles had a mileage proportion in electric driving mode exceeding 60%. As depicted in Fig. 7.26, the proportion of average monthly mileage in electric driving mode for extended-range electric vehicles in first-tier cities is predominantly concentrated above 50%. Among them, Guangzhou and Shenzhen, with lower latitudes, exhibit similar distribution patterns across each month. However, due to colder winter temperatures, extended-range electric vehicles in Beijing show a significantly lower proportion of mileage in electric driving mode compared to other cities during the period from December to February.

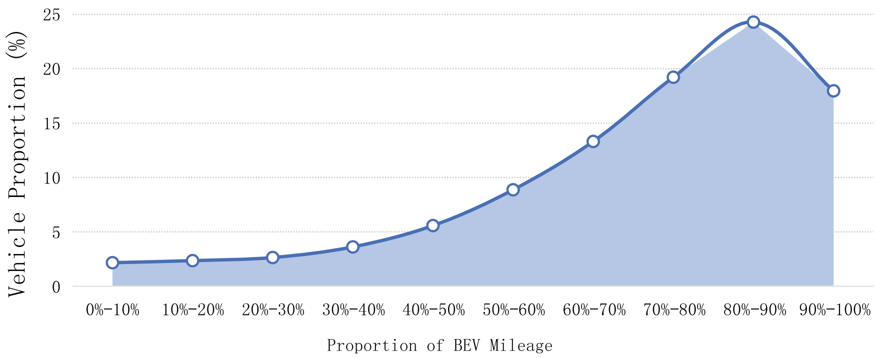


Fig. 8.24 Distribution of extended-range electric vehicles with different mileages in electric driving mode in 2022

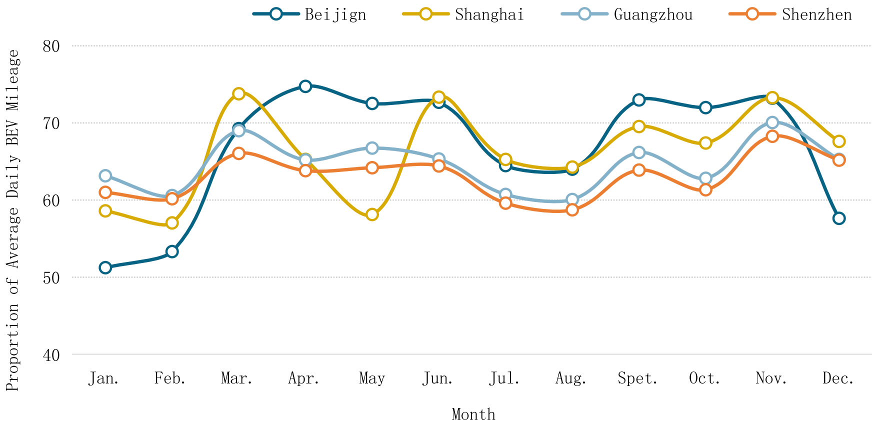


Fig. 8.25 Distribution of average daily mileage for extended-range electric vehicles in electric driving mode in 2022

8.4 PHEV Charging Characteristics

In the field of passenger cars, in Chap. 4—Vehicle Charging, a detailed comparative analysis of the charging characteristics of PHEV-private cars and BEV-private cars has been made. This Chapter will compare the charging characteristics of passenger cars in different application scenarios.

8.4.1 Average Single-Time Charging Characteristics

The average single-time charging duration of PHEV-passenger cars has shown a decreasing trend year by year.

The average single-time charging duration of PHEV-passenger cars has shown a decreasing trend over the years. In 2022, the average single-time charging duration of all types of vehicles was within 3.0 h (Fig. 8.26), which was notably lower compared to the average single-time charging time in 2020. The charging duration of each type of vehicle remained stable in 2022.

In 2022, the average single-time slow charging duration of PHEV-passenger cars was approximately 3 h, while the average single-time fast charging duration was around 1 h.

As seen from the charging methods of vehicles (Fig. 8.27), the fast charging duration of all types of vehicles generally remains around 1 h, while the slow charging duration is around 3 h. In terms of fast charging duration, cars for sharing have a slightly higher duration compared to other types of vehicles. As for slow charging, private cars, taxis, and cars for sharing have similar durations, with an average single-time slow charging time of 3.2 h.

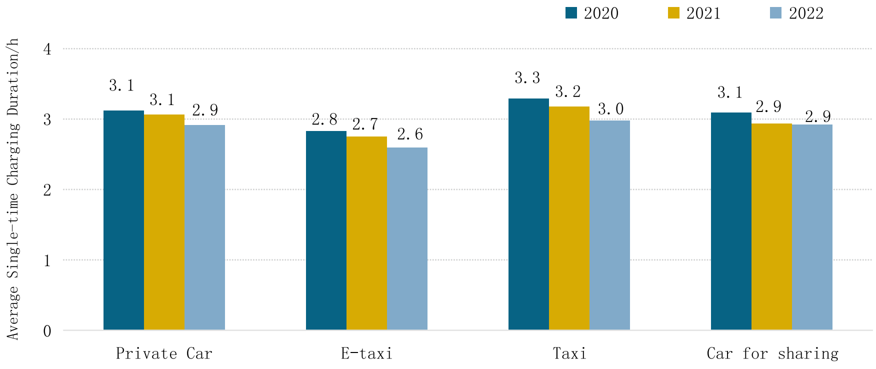


Fig. 8.26 Average single-time charging duration of PHEV-passenger cars over the year—by type of vehicle

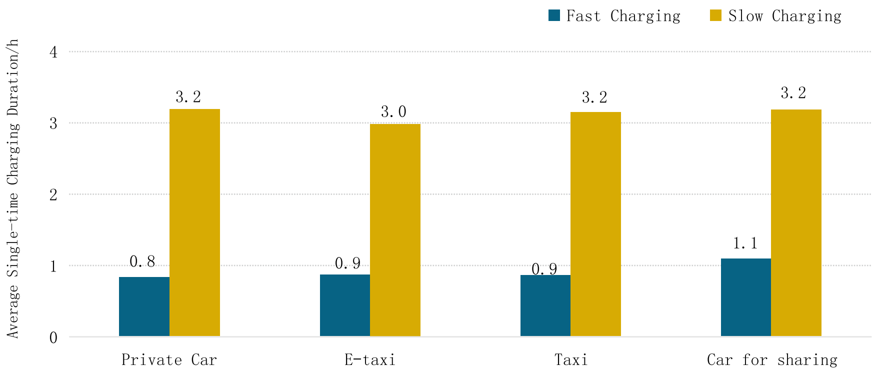


Fig. 8.27 Average single-time charging duration of PHEV-passenger cars in different charging modes in 2022

From the perspective of the distribution of average single-time charging durations of PHEV-passenger cars (Fig. 8.28), it's evident that the average single-time driving duration for each types of vehicle mainly concentrate in the 1–3 h range, with vehicles representing over 50% of all types of vehicles.

In 2022, the average single-time initial SOC of PHEV passenger cars was 30%, and the average single-time end SOC was over 80%.

Compared to other types of vehicles, the average initial SOC of private cars is higher than that of other vehicles, at 32.4%. Whereas operational vehicles like e-taxis, taxis, and cars for sharing maintain a consistent average initial SOC of around 25% (Fig. 8.29). When it comes to the end SOC, all types of vehicles surpass 80%.

From the distribution of initial SOC (Fig. 8.30), it can be observed that the initial SOCs of various vehicle types are predominantly concentrated between 10 and 40%, with the percentage of vehicles within this range exceeding 70%. In the segment with a low initial SOC between 0 and 10%, there are more e-taxis and cars for

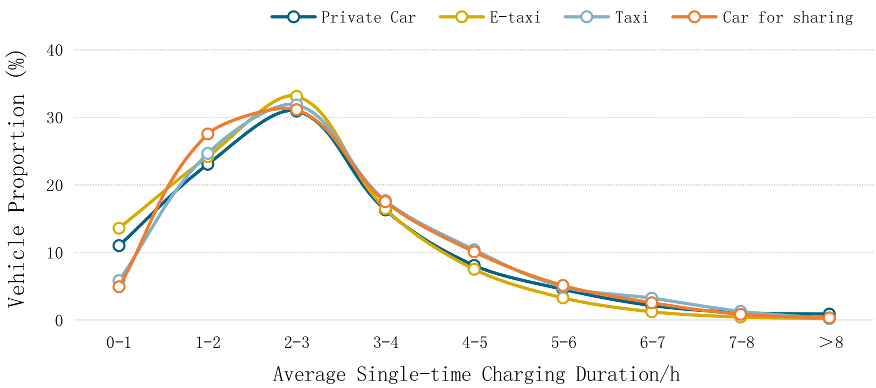


Fig. 8.28 Proportion of PHEV-passenger cars with different average single-time charging durations to all types of vehicles in 2022

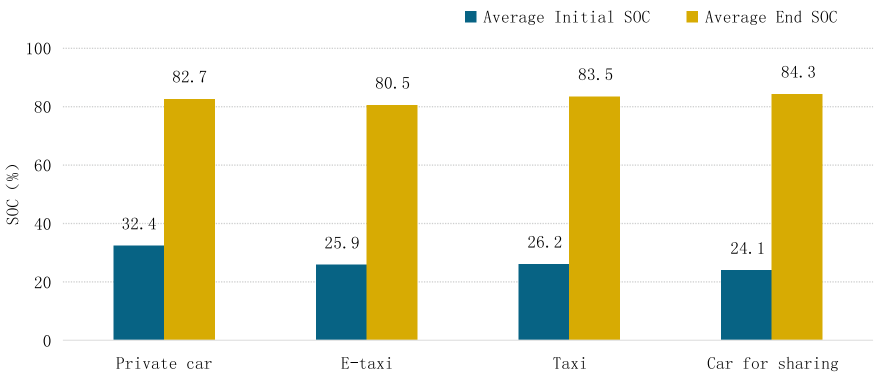


Fig. 8.29 Average single-time initial and end SOC values for PHEV-passenger cars in 2022—by type

sharing than other types of vehicles. Meanwhile, private cars show a significantly higher percentage than other types of vehicles in the segments with the initial SOC ranges of 30–40%, 40–50%, and 50–60%, indicating a more frequent occurrence of charging as per demand.

As seen from the distribution of vehicles by end SOC (Fig. 8.31), private cars, taxis, and cars for sharing in the end SOC segment of 90–100% are significantly higher compared to other types of vehicles, accounting for over 45%. E-taxis exhibits a relatively even distribution across the 70–100% end SOC range.

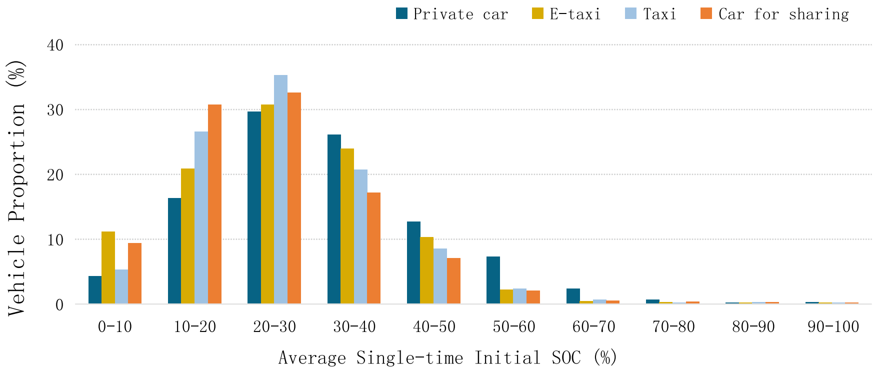


Fig. 8.30 Distribution of PHEV-passenger cars in terms of the average single-time initial SOC in 2022—by type

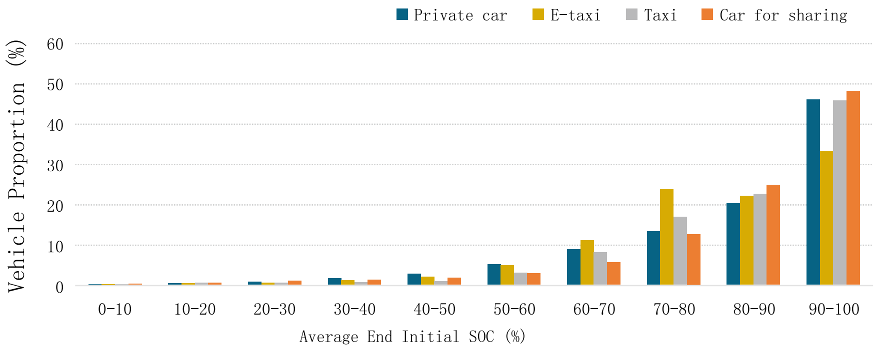


Fig. 8.31 Distribution of PHEV-passenger cars in terms of the average single-time end SOC in 2022—by type

8.4.2 Characteristics of Average Monthly Charging

The average monthly charging frequency of PHEV-passenger cars in 2022 was significantly lower than the two previous years.

The average monthly charging frequency of PHEV-passenger cars in 2022 was 6, with a decrease compared with 2020 and 2021 (Table 8.4). The main reasons for the decrease in average monthly charging frequency for PHEV-passenger cars can be attributed to two factors. Firstly, several best-selling PHEV models, including BYD Song PLUS DM-i, BYD Qin PLUS DM-i, BYD Han DM, BYD Tang DM, and BYD Destroyer 05 high-end variant, have a driving range exceeding 100 km, resulting in an increase in mileage in electric driving mode for these vehicles. The second factor contributing to the decline is the high proportion of access volume of private cars among PHEV-passenger cars. However, in 2022, the average daily mileage of private cars was only 46.6 km, indicating a relatively low mileage. This lower mileage translates to fewer monthly charging sessions, leading to an overall lower average monthly charging frequency for PHEV-passenger cars.

By type of vehicle (Fig. 8.32), it is evident that e-taxis has a significantly higher average monthly charging frequency compared to other types of vehicles. In 2022, e-taxis had an average monthly charging frequency of 12 times. Taxi and cars for sharing also showed a noticeable increase in their average monthly charging frequency, reaching 9.5 times and 7.1 times respectively in 2022. On the other hand, private cars had a relatively lower average monthly charging frequency, with only 4.8 times in 2022, significantly lower than in 2020 and 2021.

PHEV-passenger cars primarily rely on slow charging, but the proportion of fast charging sessions has been increasing annually.

PHEV-passenger cars tend to have a higher frequency of charging using slow charging methods. From the perspective of charging methods (Fig. 8.33), the proportion of slow charging sessions for all types of PHEV-passenger cars is above 65%. However, private cars have a higher proportion of slow charging sessions, reaching 80.2%. When examining the changes in the proportion of charging methods over the years, there is a gradual increase in the proportion of fast charging sessions. When considering the average monthly charging frequency of various types of PHEV-passenger cars (Fig. 8.34), e-taxis stands out with a greater number of charging sessions. Specifically, they have an average of 3.9 fast charging sessions and 8.1 slow charging sessions per month. Due to the greater need for on-the-go charging, e-taxis has a slightly higher average monthly number of charging sessions compared to other vehicle types.

From the distribution of average monthly charging frequency (Fig. 8.35), vehicles with average monthly charging frequency of less than 5 times account for over 50%

Table 8.4 Average monthly charging frequency of PHEV-passenger cars

Year	2020	2021	2022
Average monthly charging frequency of PHEV-passenger cars (times)	7.2	7.5	6

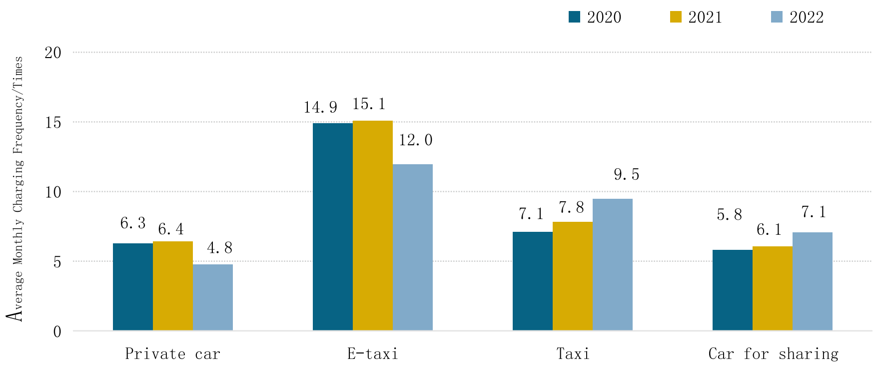


Fig. 8.32 Average monthly charging frequency of PHEV-passenger cars over the years—by type

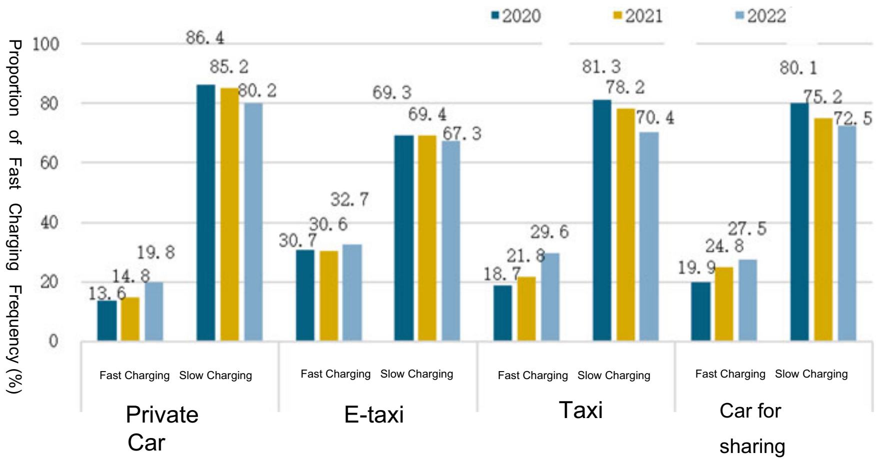


Fig. 8.33 Distribution of average monthly charging frequency of PHEV-passenger cars with different charging methods

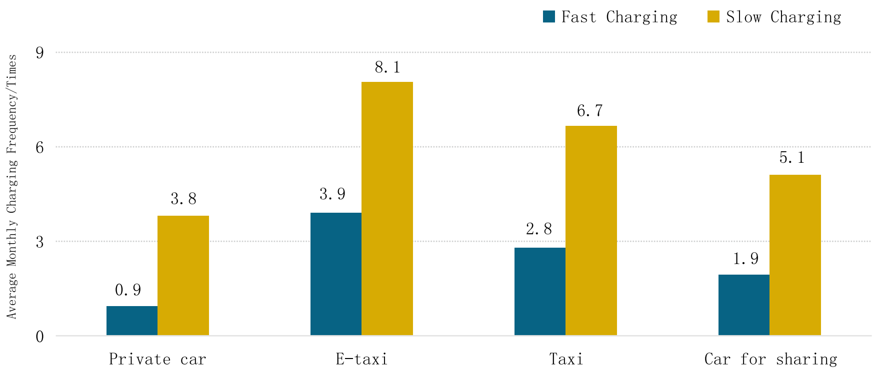


Fig. 8.34 Average monthly charging frequency of PHEV-passenger cars in different charging modes in 2022

across all vehicle types. Specifically, the proportion of private cars with an average monthly charging frequency of less than 5 times is higher, reaching 69.3%; whereas the proportion of cars for sharing with an average monthly charging frequency of more than 20 times is significantly higher than other vehicle types, reaching 27.2%. This indicates that PHEV-cars for sharing have entered a stage of regular operation.

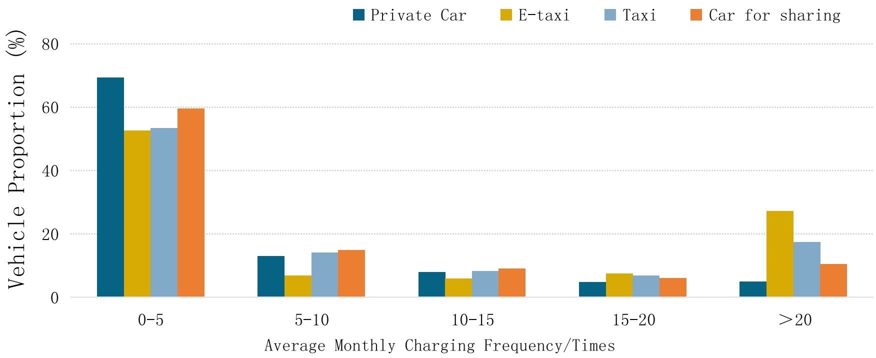


Fig. 8.35 Proportion of PHEV-passenger cars with different average monthly charging frequencies in 2022—by type

8.5 Summary

Plug-in Hybrid Electric Vehicles (PHEVs) have played a crucial role in the automotive industry by swiftly replacing conventional fuel-powered models and driving energy efficiency and carbon reduction. Drawing on the access characteristics, operation characteristics, and charging characteristics of PHEVs on the National Monitoring and Management Platform, this study summarizes the distinctive growth trends in the market demand for PHEVs in China, along with the patterns of PHEV operation and charging. Here are the key research findings:

PHEVs are well-suited to meet the varied needs of consumers, and the market is witnessing a rapid expansion phase, with proprietary brands firmly positioned at the top. Amidst the backdrop of persistently high oil prices, PHEVs exhibit significant advantages, offering a blend of benefits from conventional fuel vehicles and BEVs, thereby fueling sustained explosive growth in market demand. By December 31, 2022, the National Monitoring and Management Platform had successfully seen a cumulative access of 2.298 million PHEVs. Notably, there were 1.191 million new PHEVs added in 2022, marking a substantial year-on-year growth of 147.8%. The market for PHEVs has experienced a substantial growth in consumer demand, as more and more consumers are willing to choose PHEV models. Key Chinese OEMs are ramping up their presence in the hybrid field, with brands like BYD, Great Wall Motor, Geely, GAC Motor, Chery, and Chang'an Automobile expediting the introduction of hybrid systems. The hybrid vehicle offerings from proprietary brands are becoming more refined, spanning across different price ranges and vehicle models, thereby catering to the diverse selection needs of consumers in various market segments. Proprietary brands hold a dominant position in the PHEV market. In 2022, all of the top 5 best-selling PHEV models are from domestic proprietary brands, with foreign brands trailing behind in terms of catching up.

The consumer landscape in the market is undergoing a shift, with a rising focus on lower-tier cities, and the demand is transitioning from license-driven to

encompassing economic factors. Based on the data of the characteristics of PHEV access over the years on the National Monitoring and Management Platform, the share of PHEVs in first-tier cities decreased from 37.1% in 2020 to 21.5% in 2022, witnessing a decline of 15.6 percentage points. In contrast, the proportion of annual access of PHEVs in second-tier and lower cities increased from 34.2% in 2020 to 47.4% in 2022. Furthermore, there is a gradual shift in market demand for PHEVs towards cities not subject to purchase restrictions, as the proportion of access volume in these cities rose from 37.8% in 2020 to 69.3% in 2022. Against the backdrop of persistently high fuel prices, PHEVs hold significant advantages over conventional fuel-powered vehicles in terms of both convenience and acquisition costs, gradually showcasing their comprehensive competitive edge.

The combined economic factors determine the gradual expansion of the proportion of mileage covered in electric driving mode for PHEVs. Taking into account the proportion of mileage covered in different driving modes for different types of PHEVs over the past two years, there is an increasing trend in the proportion of mileage covered in electric driving mode. In 2022, the proportion of average daily mileage covered in electric driving mode for private cars, taxis, and cars for sharing notably increased compared to the previous year (Fig. 7.22). Irrespective of the vehicle type, the percentage of fuel-powered driving mode remains below 10%, highlighting the low-carbon and environmentally-friendly attributes of PHEV-passenger cars among vehicles in the same category. Compared to PHEVs, a greater number of extended-range electric vehicles opt for electric driving mode. According to the statistical data on vehicle travel characteristics from the National Monitoring and Management Platform, in 2022, 74.8% of extended-range electric vehicles had a proportion of mileage covered in electric driving mode of over 60%.

The majority of PHEVs use slow charging methods, but the proportion of vehicles adopting fast charging methods is expanding year by year. According to the statistical data on charging methods for PHEVs from the National Monitoring and Management Platform, it is revealed that in various application scenarios, the proportion of slow charging sessions exceeds 65% for PHEV-passenger cars. Slow charging remains the primary choice for vehicle charging. Furthermore, when examining the average monthly charging sessions over the years, it is evident that there is a year-on-year increase in the proportion of fast charging sessions for PHEVs.

Chapter 9
Promotion and Application in Typical Regions and Cities

This study examines the promotion and application of new energy vehicles (NEVs) in Beijing, Shanghai, Guangzhou, Shenzhen, Liuzhou, Foshan, and cold regions. It outlines the development features of the NEV industry in each typical city and region, offering valuable references for local governments and relevant enterprises in advancing the NEV industry.

9.1 Application in First-Tier Cities

(1) **The remarkable success in promoting NEVs in Beijing, Shanghai, Guangzhou, and Shenzhen has expedited the process of vehicle electrification.**

From the perspective of the promotion of NEVs in Beijing, Shanghai, Guangzhou, and Shenzhen (Fig. 9.1), as of the end of 2022, Shanghai led with the highest proportion of cumulative access volume of NEVs in China. The total number of accessed NEVs in Shanghai stands at 846,000, accounting for 7% of the total in the country. From the historical electric vehicle adoption rates in first-tier cities, it can be observed that the electric vehicle adoption rates in these cities have experienced varying degrees of improvement in 2022. Shenzhen City has consistently led in electric vehicle adoption rates over the years. By the end of 2022, the electric vehicle adoption rate in Shenzhen reached 18.4%, reflecting a 5.37 percentage point increase from the end of 2021.

From the perspective of the NEV accesses in Beijing, Shanghai, Guangzhou, and Shenzhen over the years (Fig. 9.2), it can be observed that over the past three years, there has been a steady annual increase in the access volume of NEVs in first-tier

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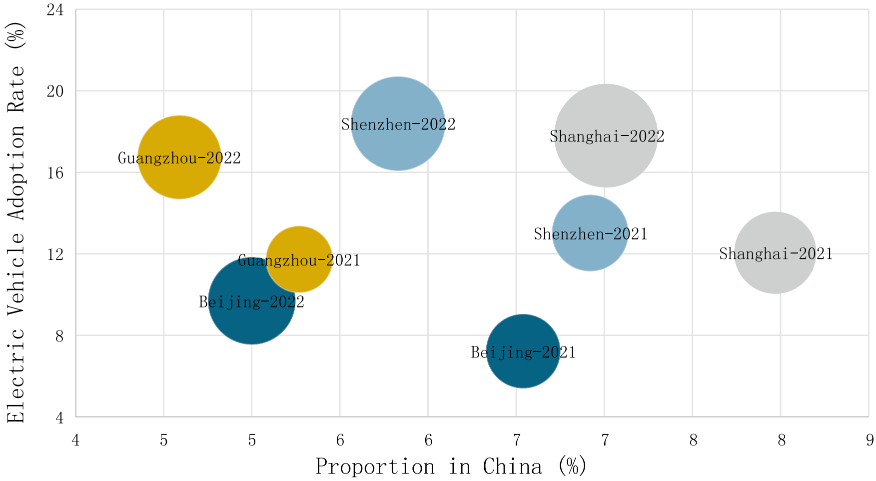


Fig. 9.1 Electric vehicle adoption in first-tier cities in 2022. *Note* ① The size of each bubble indicates the degree of cumulative access volume of NEVs to the National Monitoring and Management Platform as of the end of 2022. ② The electric vehicle adoption rate reflects the proportion of cumulative NEV access volume to the total number of vehicle holding in each city. ③ The data on vehicle holding is derived from the Ministry of Public Security's 2022 statistics on vehicle holding

cities. In particular, Shanghai recorded NEV access volume of 266,000 and 314,000 in 2021 and 2022, respectively, surpassing other cities by a significant margin.

(2) **NEVs in Shanghai, Liuzhou, and Foshan boast generally high online rates, reflecting a high level of vehicle usage.**

Comparing the NEV online rates among major cities, Shanghai, Liuzhou, and Foshan exhibit a higher level of vehicle usage (Fig. 9.3). In 2022, the overall NEV online rate exceeded 90%. When it comes to the online rates by vehicle type, PHEVs

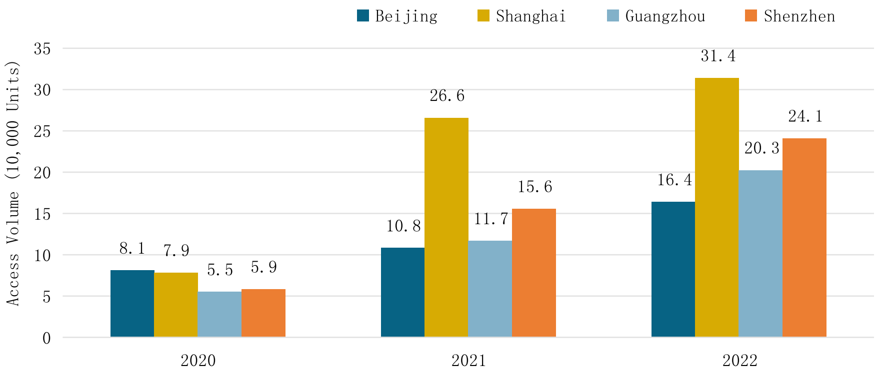


Fig. 9.2 Accesses of NEVs in first-tier cities over the years

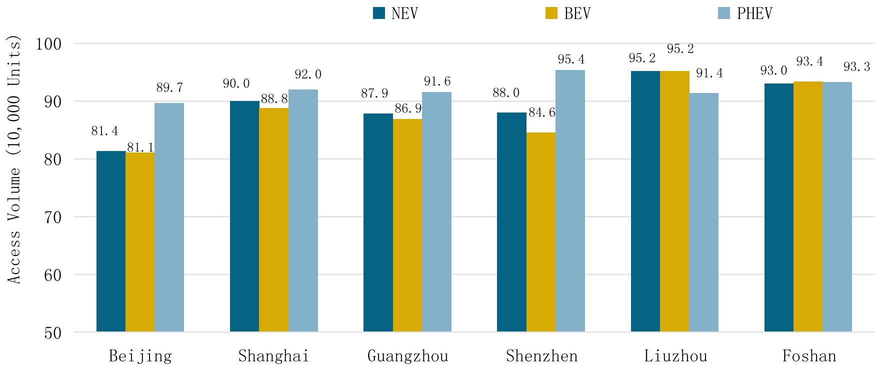


Fig. 9.3 Comparison of the average monthly online rates of NEVs in typical cities in 2022

have a generally higher online rate than BEVs. The online rates of BEVs and PHEVs vary greatly among Beijing, Guangzhou, and Shenzhen.

9.2 Application of NEVs in Cold Regions

9.2.1 Development Status of NEVs in Cold Regions

The continuous progress in the diversification of NEVs and advancements in low-temperature durability technology is elevating consumer acceptance towards NEVs. By the end of 2022, the cumulative number of NEVs accessed in Northeast China, North China, and Northwest China reached 2.252 million, representing 18.6% of the total in the country (Figs. 9.4 and 9.5). In the past three years, the number of NEVs accessed annually in cold regions has shown an upward trend. Notably, North China showed remarkable performance, with an annual access of 466,000 BEVs and 137,000 PHEVs in 2022.

The year 2022 saw a substantial surge in the access volume of NEVs across cities in extremely cold regions. This report divides the extremely cold regions into the provinces of Heilongjiang, Jilin, Liaoning, and the Inner Mongolia Autonomous Region. In 2022, the year-on-year growth rate of NEV accesses in major cities in extremely cold regions was more than double the national average year-on-year growth rate (Fig. 9.6), significantly surpassing the national average (1 time). Notably, Siping City, Tonghua City, and Tieling City saw an increase in access volume in 2022 that was over four times higher than the same period in 2021.

In cold regions primarily favor the widespread adoption of BEVs, while PHEVs have a relatively higher share in Northeast China and Northwest China. In contrast to the structural distribution of cumulative NEV accesses in China, North China stands out with a higher proportion of BEVs in its NEV promotion

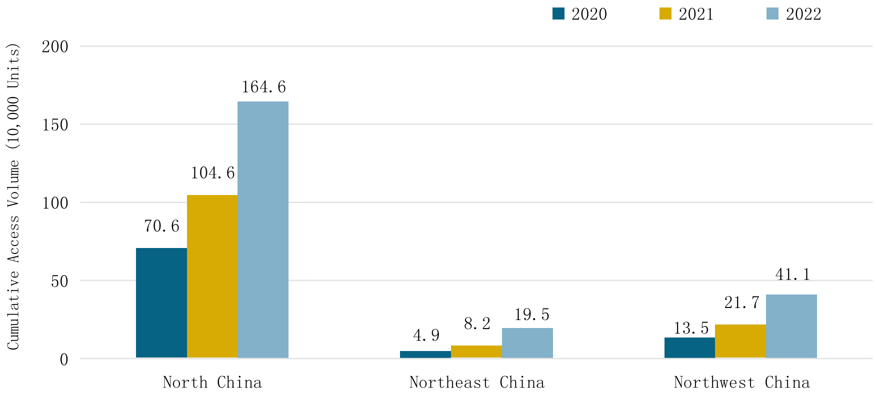
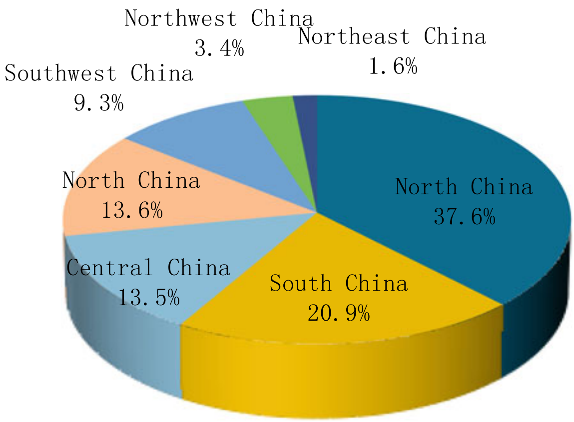


Fig. 9.4 Cumulative access volume of NEVs in cold regions over the years

Fig. 9.5 Structural distribution of cumulative access volume of NEVs across all regions of China



scale, reaching 84.7% due to Beijing's policy mandating the purchase of BEV-buses (Fig. 9.7). In Northeast China and Northwest China, the proportion of BEVs is notably lower than the national average, while PHEVs account for 36.5% and 29.2% of the cumulative access volume, respectively, surpassing the national level. These findings highlight the coexistence of multiple technological roadmaps in the current promotion of NEVs in cold regions.

9.2.2 *Operation Characteristics of NEVs in Cold Regions*

(1) **Online rate of NEVs**

Over the past three years, there has been a consistent increase in the online rate of BEVs in cold regions. The average annual online rate in Northeast China,

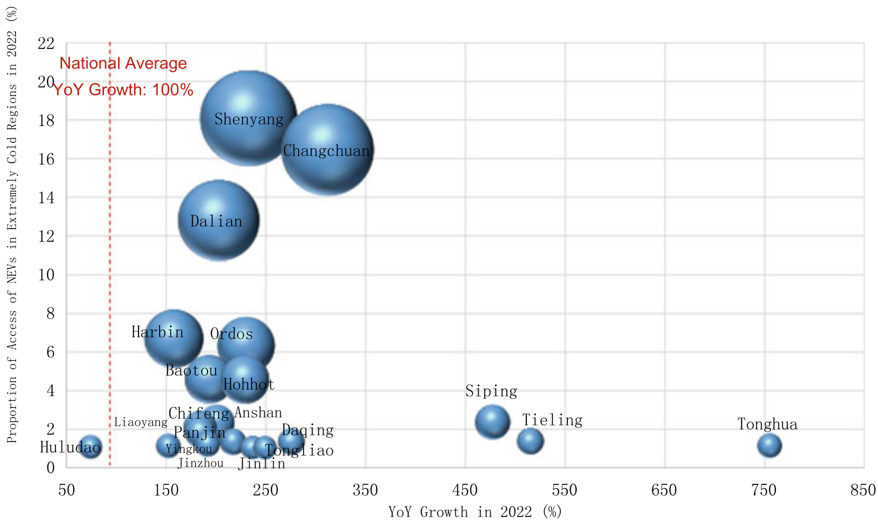


Fig. 9.6 Growth of NEV accesses in the top 20 cities across the extremely cold regions in 2022. *Note* The size of the bubbles represents the degree of annual access volume of NEVs in each city in 2022

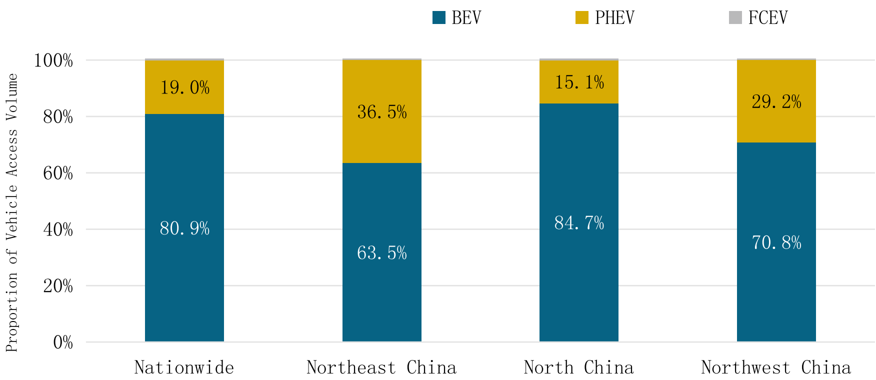


Fig. 9.7 Proportion of cumulative access volume of NEVs with different hybrid system in cold regions in winter

North China, and Northwest China exceeded 80% in 2022 (Fig. 9.8). The average annual online rate of BEVs in Northeast China by region has been slightly higher than that in North China and Northwest China. One contributing factor is the higher proportion of access volume of operational buses in Northeast China (Fig. 9.9).

During 2022, the monthly online rate in cold regions surpassed the levels seen in previous years for the same time period. Examining the monthly online rate distribution of BEVs in cold regions over the past three years (Fig. 9.10), it is evident that, except for the beginning of 2020, the monthly online travel of BEVs

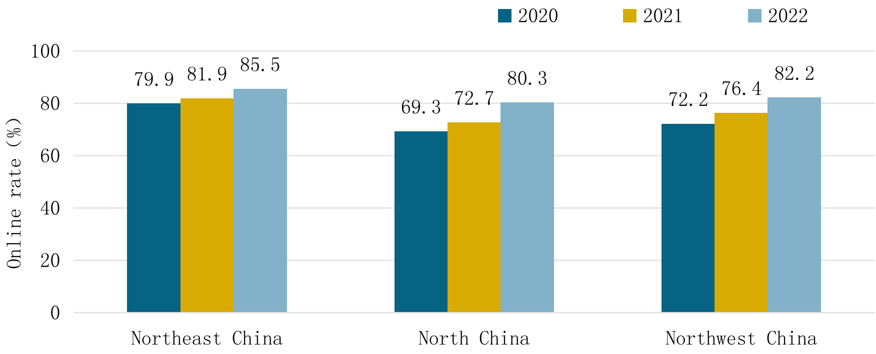


Fig. 9.8 Average online rates of BEVs in cold regions over the past three years

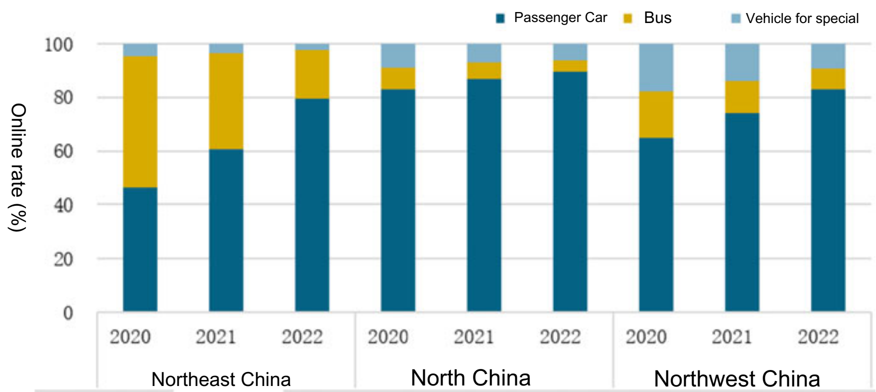


Fig. 9.9 Proportion of access volume of BEVs in cold regions over the years

in cold regions has been favorable and has demonstrated a year-on-year growth trend. During February 2020, the online rate of BEVs was comparatively low. This can be attributed to the initial phase of the COVID-19 outbreak, where authorities advocated for minimizing gatherings and travel, resulting in a lower overall online rate of vehicles.

(2) **Reliability of Mileage**

There is a strong correlation between the reliability of mileage covered in cities across cold regions during winter and latitude. As latitude increases, the reliability of mileage decreases. Temperature plays a crucial role in determining the reliability of mileage in BEVs. In cold regions during winter, the overall reliability of mileage is influenced by temperature. The reliability of mileage covered in typical cities ranges from 0.6 to 0.7 (Fig. 9.11). During winter, cities such as Beijing, Tianjin, Xi'an, Taiyuan, and Shijiazhuang have fewer severe cold weather conditions, leading to higher reliability of vehicle mileage compared to the average (0.648) in cold

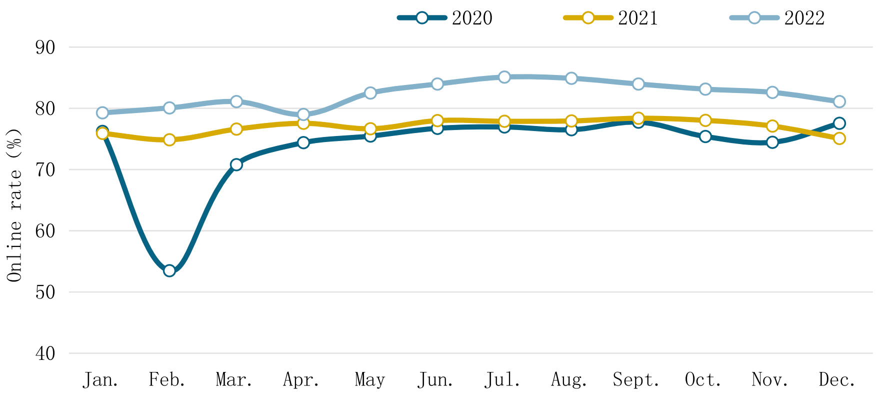


Fig. 9.10 Monthly online rates of BEVs in cold regions over the past three years

regions. On the other hand, cities like Harbin and Changchun, affected by higher latitudes, experience lower temperatures and thus have lower reliability of mileage during winter.

In 2022, the reliability of mileage in cold regions has shown improvement compared to the previous year. In January 2022, the reliability of mileage for BEVs in Northwest China was recorded at 0.677, demonstrating a 3.26% year-on-year growth. Furthermore, both North China and Northeast China experienced a slight improvement in the reliability of mileage for BEVs in 2022 compared to the preceding year (Fig. 9.12). The test evaluation results conducted by DCar in extremely cold regions reveal that from late November to early December 2022, over

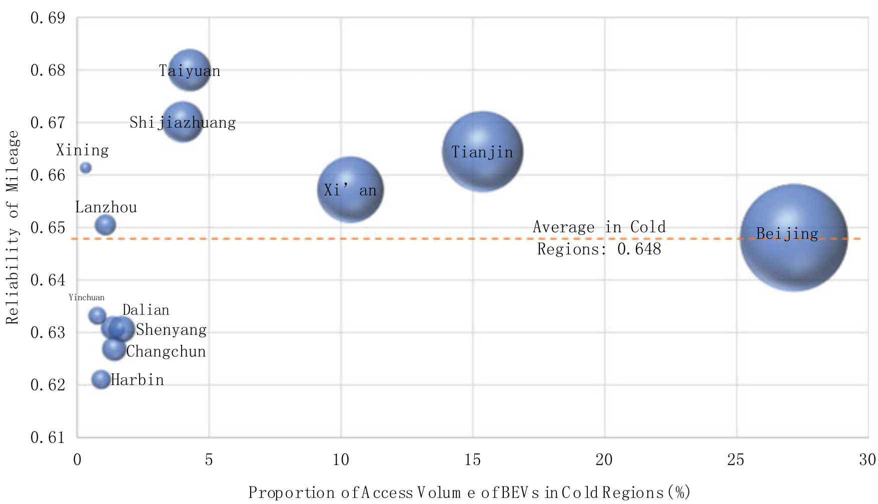


Fig. 9.11 Reliability of mileage of BEVs in typical cities across cold regions in January 2022. *Note* The size of the bubbles represents the level of annual access volume of NEVs in each city

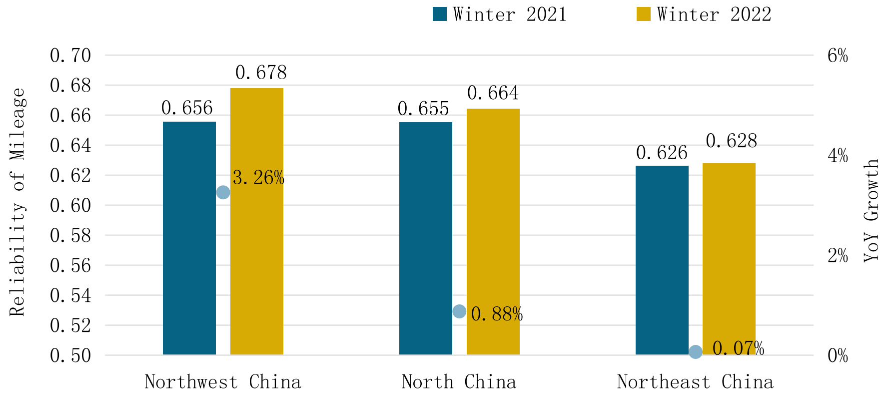


Fig. 9.12 Comparison of the reliability of mileage of BEVs in cold regions during winter over the past two years

60 mainstream models from 34 brands were evaluated. The average range achievement rate for NEVs was 48.5%, with an average driving range of 268 km. These figures represent a 4% and 14% improvement respectively compared to DCar's winter evaluation results in 2021. Notably, domestically produced vehicle models achieved an average range achievement rate of 49.1%, securing the top three places, while the average range achievement rate for joint-venture brand vehicle models stood at 45.8%. Regarding the charging duration, domestically produced vehicle models have an average fast charging duration to reach full capacity of 107.1 min, while joint-venture vehicle models take 162.3 min, showcasing the noticeable advantage of domestically produced electric vehicles.

The reliability of monthly mileage for vehicles of all segments exhibits a "M" shaped distribution, with small cars performing well. The colder winter temperatures result in lower reliability of mileage for vehicles of all segments in cold regions. The overall reliability of mileage remains below 0.7 (Fig. 9.13). Analyzing vehicle models across all segments, the A00 + A0 segment consistently exhibits significantly higher reliability of monthly mileage compared to other segments. Notably, in the months of April, May, and September, the reliability of mileage surpasses 0.9. When compared to larger vehicles, small cars demonstrate superior reliability of mileage due to their lower curb weight. This attribute results in reduced energy consumption for electric accessories, battery heating, and insulation, translating into lower levels of mileage degradation.

(3) **Operation characteristics of BEVs in low-temperature environments**

The mileage per unit SOC for BEVs in cold regions has been steadily increasing year by year. The analysis of data on newly accessed BEVs over the years (Fig. 9.14) reveals a progressive rise in the average mileage per unit SOC for different types of BEVs during winter. Among them, BEV-passenger cars and BEV-Vehicle for special purpose s display noticeable growth, with BEV-passenger cars experiencing a 5% increase from 2020 to 2022.

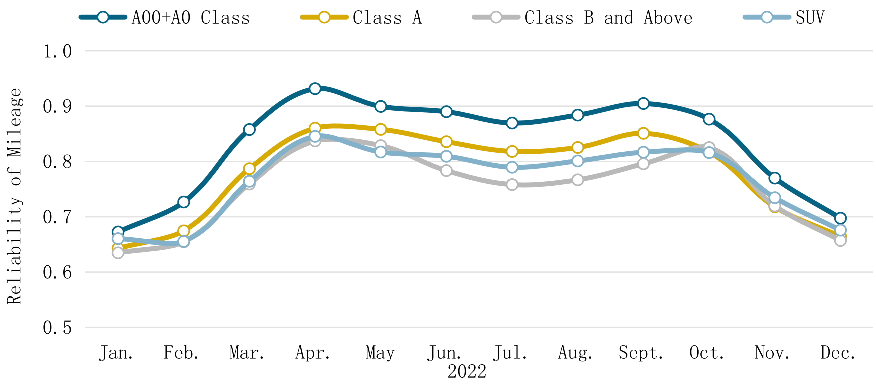


Fig. 9.13 Comparison of the reliability of monthly mileage of BEV models in cold regions—by vehicle segment

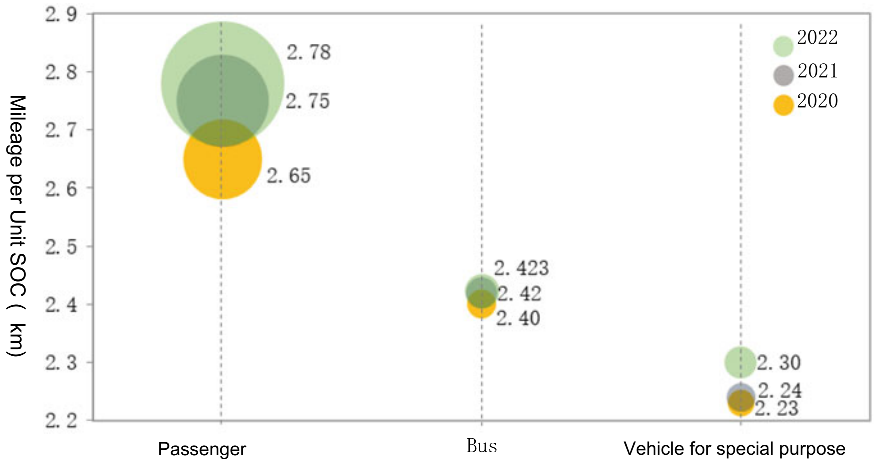


Fig. 9.14 Average mileages per unit SOC of BEVs in cold regions during winter over the years. *Note* The size of the bubbles represents the degree of access volume of BEVs by type in cold regions over the years

The mileage between two charging sessions for BEVs in cold regions during winter exhibits an upward trend, with each passing year. Among them, the mileage covered between two charging cycles for BEV-passenger cars in 2022 witnesses a 27.2% improvement compared to 2020, while BEV-Vehicle for special purpose s show a significant increase of 50.8%. BEV-buses demonstrate a modest growth (Fig. 9.15). The increase in the mileage covered between two consecutive charging sessions for BEVs suggests an improvement in power battery and the integrated cold-weather adaptability technology of the vehicle.

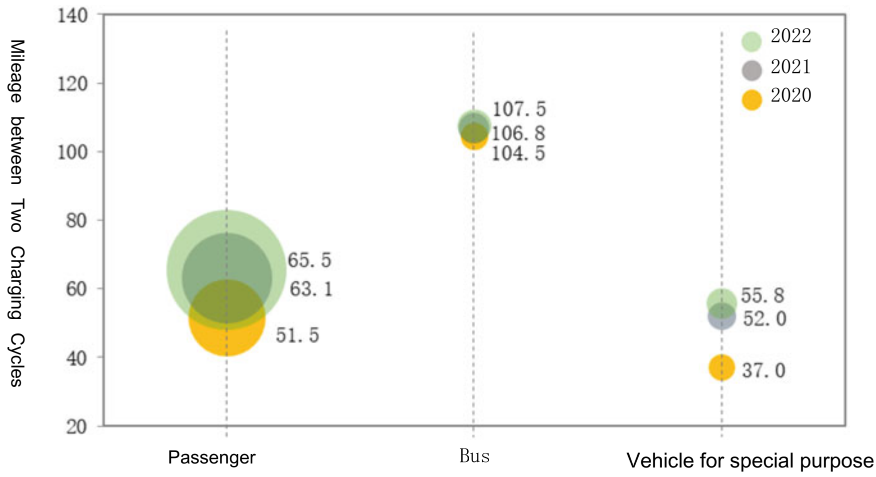


Fig. 9.15 Average mileages covered between two charging sessions for BEVs in cold regions during winter over the years. *Note* The size of the bubbles represents the degree of access volume of BEVs by type in cold regions over the years

The usage rate of BEV-passenger cars in cold regions remains strong overall, with a slight dip observed during the winter months. The monthly usage rate of BEV-passenger cars in cold regions shows promising performance overall, with a slight decrease during the winter season. However, the vehicle usage rates remain steady and maintain levels above 80% throughout the remaining months. When considering different scenarios, the usage rate of private cars is somewhat influenced during the winter season. However, the usage rate of operational cars for sharing remains largely unaffected, maintaining a monthly rate of roughly 90%. This plays a vital role in expediting the comprehensive electric vehicle adoption in the public domain and achieving terminal energy consumption electrification and cleanliness (Fig. 9.16).

(4) **Charging characteristics of BEVs in low-temperature environments**

In cold regions, the initial SOC for the winter charging of BEVs is slightly higher than other seasons. By type of vehicle, the initial SOC for average single-time charging of BEV-buses and BEV-Vehicle for special purpose s remains consistent across seasons, as depicted in Figs. 9.17 and 9.18. Operational vehicles primarily charge at fixed times and locations. In contrast, there is a noticeable seasonal difference in the initial SOC for the average single-time charging of BEV-passenger cars. During winter, the average initial SOC for charging is around 39%, which is approximately 4 percentage points higher than the initial SOC for average single-time charging during summer. In the winter season, BEV batteries experience decreased activity, which leads to a decline in charging and discharging performance and subsequently results in a certain reduction in driving range. This situation often results in noticeable range concerns among users.

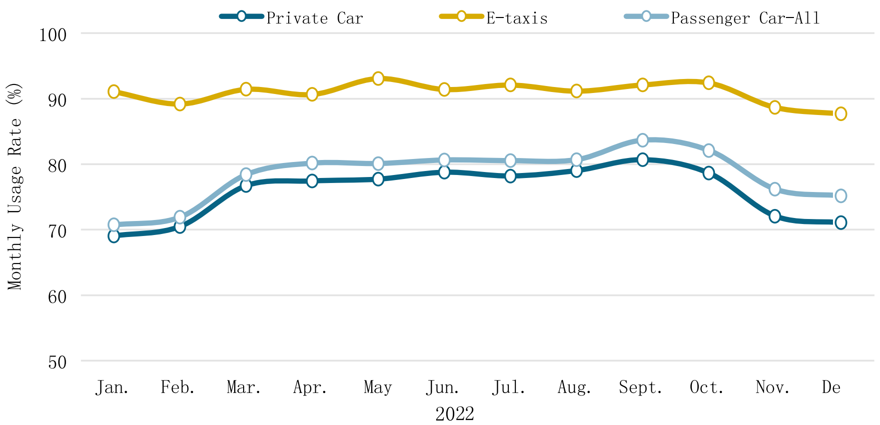


Fig. 9.16 Average monthly usage rates of BEV-passenger cars in cold regions in 2022

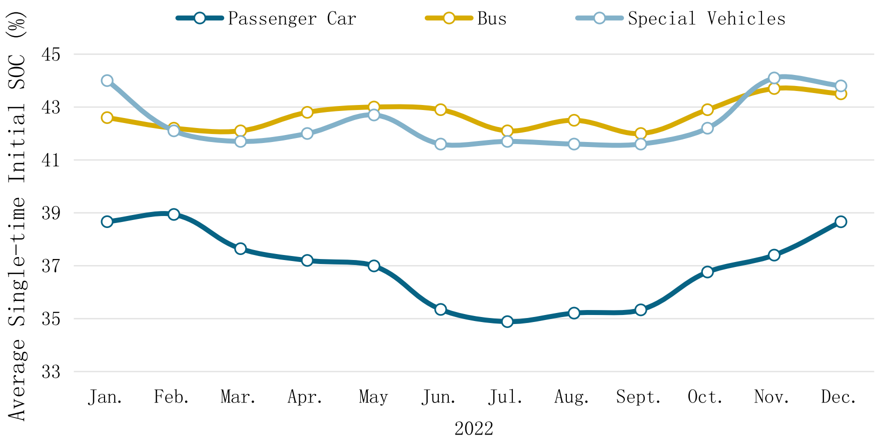


Fig. 9.17 Initial SOC for average monthly single-time charging of BEVs in cold regions in 2022—by type

In winter, BEVs tend to have longer average single-time charging duration, with BEV-passenger cars being particularly affected. Slow charging is often favored for BEV-passenger cars, resulting in an average single-time charging duration of about 4.5 h during the winter season, which is significantly longer than the 3.8-h charging duration in summer. BEV-Vehicle for special purpose s also experience notable seasonal influences, with a difference of around 0.5 h in average single-time charging duration between winter and other seasons. However, BEV-buses are less impacted due to their fixed operating schedules, leading to more consistent charging durations (Fig. 9.18). Decreased power battery activity is observed in low-temperature settings, prompting certain vehicles' battery management systems to activate heating features. This, in turn, partially extends the charging duration.

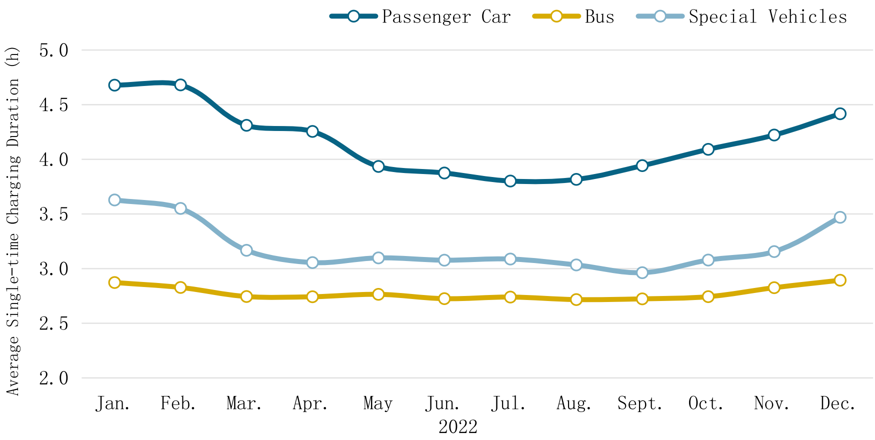


Fig. 9.18 Average monthly single-time charging duration of BEVs in cold regions in 2022

In cold regions, winter sees a higher weekly frequency of charging for BEVs compared to other seasons. The monthly distribution of weekly charging frequencies for BEVs in 2022 shows a carryover effect, as depicted in Fig. 9.19. In January, February, and December, there is a notable increase in weekly charging frequency. This can be primarily attributed to the impact of low temperatures on the vehicles, which affects their actual driving range and necessitates more frequent charging. Cars for sharing, buses, and logistics vehicles in the operational field are known for covering longer mileage during the week. In the winter season, they typically require an average of 8–10 charging sessions per week, which is higher compared to private cars. BEV-private cars tend to have a higher frequency of weekly charging during the winter season, with an average of 3.2 charging sessions per week. This is significantly higher than the average of 2.5 charging sessions per week observed during other seasons.

The promotion and adoption of NEVs in cold regions have witnessed a steady expansion. This growth can be attributed to the ever-evolving diversity of products and advancements in cold-weather durability technology, which have contributed to an enhanced user perception and acceptance. The diminished practical driving range of BEVs in cold regions has consistently hindered the seamless user experience of vehicle usage. In recent years, the growing recognition of NEVs among users in cold regions can be attributed to the expanding variety of product offerings and ongoing improvements in cold-weather durability technology. The cumulative access volume of NEVs in cold regions reached 2.252 million by the end of 2022, accounting for 18.6% of the total in China. From the perspective of the operation of BEVs in cold regions, the online rate of BEVs has shown a steady increase over the past three years. In 2022, the average monthly online rate of BEVs in low-temperature areas surpassed the levels of previous years, indicating a gradual move towards regular and stable usage of BEVs.

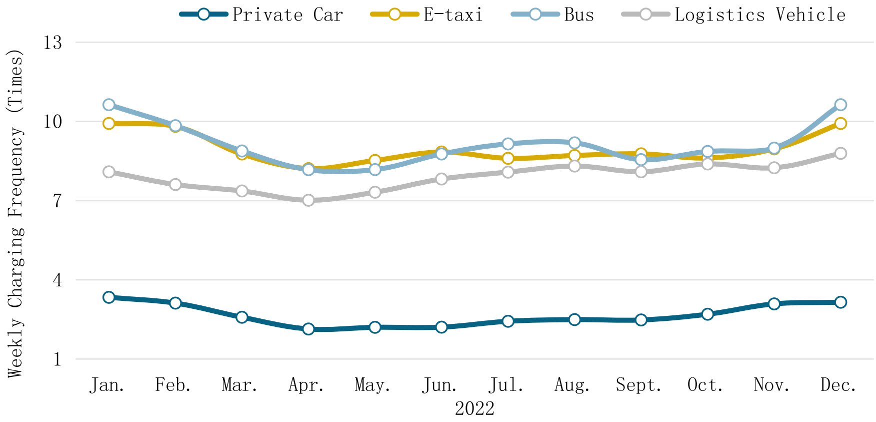


Fig. 9.19 Weekly charging frequencies per month of BEV-passenger cars in cold regions in 2022

The decline in driving range under low-temperature conditions remains a problem that requires urgent solutions. It is also a primary focus for OEMs as they prioritize technological advancements to overcome this challenge. While it is inevitable to encounter battery degradation in low-temperature conditions, automotive companies have made notable progress in tackling this issue through technological advancements in recent years. According to the big data analysis of the reliability of BEV mileage, the results indicate that in 2022, the reliability of BEV mileage during winter has seen minor improvements in Northeast China, North China, and Northwest China compared to 2021. Based on the real-world testing results of mainstream vehicle models, there has been a 4% year-on-year improvement in the average range achievement rate of NEVs in extremely cold climate conditions in 2022. Both from the perspective of the big data on reliability of mileage of NEVs and actual evaluations conducted by institutions, the credibility of NEV mileage has improved in 2022 compared to 2021. Within the industry, OEMs place significant emphasis on addressing the winter range issue in cold regions. Breakthroughs in vehicle thermal management technologies have been continuously made and applied. Notably, the IPB regenerative braking system and the wide-temperature range high-efficiency heat pump system are increasingly being utilized, leading to advancements in the reliability and cold-weather performance of NEVs.

Appendix
Explanation of Key Metrics in This Book

(1) **Key metrics for vehicle promotion and application**

New Energy Vehicle Access Volume: The quantity of new energy vehicles accessed to the National Monitoring and Management Platform. The access volume over the years represents the number of new energy vehicles accessed to the platform in a given year, while the cumulative access volume indicates the total quantity of new energy vehicles accessed to the platform as of a specific moment.

Cumulative New Energy Vehicle Access Rate: The ratio of the total quantity of new energy vehicles accessed to the National Monitoring and Management Platform until a specific moment to the overall new energy vehicle holding.

Market Penetration Rate of New Energy Vehicles: The ratio of current new energy vehicle sales to total vehicle sales in the market.

Electric Vehicle Adoption Rate: The ratio of new energy vehicle holding to vehicle holding as of a specific point in time.

(2) **Key metrics for vehicle operation characteristics**

Vehicle Online Rate: The ratio of the quantity of active new energy vehicles in the current period to the cumulative new energy vehicles accessed to the National Monitoring and Management Platform. The daily online rate reflects the ratio of the daily active new energy vehicle count to the cumulative access volume, while the monthly online rate indicates the ratio of the monthly active new energy vehicle count to the cumulative access volume. The daily and monthly online rates provide insights into the utilization of new energy vehicles from different time perspectives.

Average Vehicle Speed per Trip: The average speed of a vehicle for a single trip, obtained by dividing the distance covered during the trip by the duration of the trip. The average vehicle speed per trip is calculated by taking the weighted average of the trip speeds of all vehicles of the same type, considering the number of vehicles in that type.

Average Travel Duration per Trip: The average duration of a vehicle's travel from the start to the end of a single trip. The average travel duration per trip is obtained by calculating the weighted average of the travel durations of all vehicles of the same type, taking into account the number of vehicles in that type.

Z. Wang, *Annual Report on the Big Data of New Energy Vehicle in China (2023)*,
https://doi.org/10.1007/978-981-97-4840-2

Average Single-time Mileage: The average distance covered by a vehicle from the start to the end of a single trip. The average single-time mileage is calculated as the weighted average of the travel distances of all vehicles of the same type, considering the number of vehicles in that type.

Average Single-time Initial State of Charge (SOC): The average SOC of a vehicle at the start of each trip. The average single-time initial SOC is calculated as the weighted average of the initial SOC values of all vehicles of the same type, considering the number of vehicles in that type.

Average Single-time End State of Charge (SOC): The average SOC of a vehicle at the end of each trip over a period of time. The average single-time end SOC is calculated as the weighted average of the end SOC values of all vehicles of the same type, considering the number of vehicles in that type.

Vehicle Travel Time Distribution: The ratio of the number of vehicles traveling during each time period to the cumulative quantity of vehicles of the same type accessed to the National Monitoring and Management Platform within that time period.

Average Daily Travel Duration: The weighted average of the travel durations of all vehicles of the same type within a single day, considering the number of vehicles in that type.

Average Daily Mileage: The weighted average of the travel distances of all vehicles of the same type within a single day, considering the number of vehicles in that type.

Average Monthly Travel Days: The weighted average of the number of days that vehicles of the same type are in operation within a single month, considering the number of vehicles in that type.

Average Monthly Mileage: The weighted average of the travel distances covered by vehicles of a specific type within a single month, taking into account the number of vehicles in that type.

(3) **Metrics for vehicle charging and battery swapping (hydrogen refueling) characteristics**

Average Single-time Charging Duration: The duration from the start to the end of a single charging session for a vehicle. The average single-time charging duration is calculated as the weighted average of the durations of charging sessions for vehicles of that type.

Average Single-time Fast Charging Duration: The duration from the start to the end of a single fast charging session for a vehicle. The average single-time fast charging duration is calculated as the weighted average of the durations of fast charging sessions for vehicles of that type.

Average Single-time Slow Charging Duration: The duration from the start to the end of a single slow charging session for a vehicle. The average single-time slow charging duration is calculated as the weighted average of the durations of slow charging sessions for vehicles of that type.

Single-time Initial State of Charge (SOC): The weighted average of the initial SOC for charging sessions of all vehicles of that type, considering the number of charging sessions.

Single-time End State of Charge (SOC): The weighted average of the end SOC for charging sessions of all vehicles, considering the number of charging sessions.

Vehicle Charging Time Distribution: The ratio of the number of vehicles charging during each time period to the total number of vehicles accessed to the National Monitoring and Management Platform during that period, for the entire day.

Average Monthly Charging Frequency: The weighted average of the number of charging sessions per vehicle in a single month, considering the total number of vehicles of that type.

Average Monthly Fast Charging Frequency: The weighted average of the number of fast charging sessions per vehicle in a single month, considering the total number of vehicles of that type.

Average Monthly Slow Charging Frequency: The weighted average of the number of slow charging sessions per vehicle in a single month, considering the total number of vehicles of that type.

Average Monthly Charging Capacity: The weighted average of the charging capacity per vehicle in a single month, considering the total number of vehicles of that type.

Charge Rate: The current value required to discharge the rated capacity of a power battery. It is numerically equal to the multiple of the battery's rated capacity, denoted by the letter C. In this context, the charge rate is used as a measure of the fast/slow charging method. Typically, a vehicle is considered fast-charging if its charge rate is $\geq$0.33C, while a vehicle is deemed slow-charging if its charge rate is <0.33C.

Charging Station Turnover Rate: The number of vehicles serviced by a single charging station within a given time frame.

Proportion of Fast Charging Frequency: The ratio of charging sessions with a charge rate $\geq$0.33C to the total number of charging sessions during a certain period. The proportion of monthly fast charging frequency indicates the average proportion of fast charging sessions across different months of the year.

Proportion of Slow Charging Frequency: The ratio of charging sessions with a charge rate <0.33C to the total number of charging sessions during a certain period. The proportion of monthly slow charging frequency indicates the average proportion of slow charging sessions across different months of the year.

Battery Swap Behavior Identification: Battery swap behavior is identified when a vehicle goes from being turned off to being restarted without any charging activity. In this context, a battery swap behavior is recognized when the difference between the State of Charge (SOC) at vehicle shutdown and SOC at vehicle restart is equal to or greater than 40%, and the time interval between two consecutive shutdown-restart events is less than 10 min. An interval of vehicle parking satisfying all three aforementioned criteria is marked as a battery swap behavior.

Actual Battery Swap Rate: The actual battery swap rate is the ratio of the number of battery electric vehicles with battery swap behavior during a specific period to the total number of battery electric vehicles with battery swap capability accessed to the National Monitoring and Management Platform.

Average Monthly Battery Swap Frequency per Vehicle: The average number of battery swap behaviors per vehicle across each month of the year.

Mileage Covered Between Consecutive Energy Refills: The mileage covered by a vehicle between the previous and current instances of energy refilling. Relevant technical terms used in this text encompass "mileage between two charging cycles," "mileage between two battery swapping cycles," and "mileage between two hydrogen refueling cycles."

Average Single-time Hydrogen Refueling Duration per Vehicle: The time taken from the start to the completion of a single hydrogen refueling session for a hydrogen fuel cell electric vehicle. The average single-time hydrogen refueling duration per vehicle is calculated as the weighted average of the refueling durations of individual vehicles, considering the number of vehicles of that type.