

Article

Development of New-Energy Vehicles under the Carbon Peaking and Carbon Neutrality Strategy in China

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Abstract: China regards the development of new energy vehicles (NEVs) as an important breakthrough to achieve the periodic goals of carbon peaking and carbon neutrality. After decades of development, China's NEVs industry has made significant progress, especially in the past 20 years, where the industry has transformed from a follower to a leader. This article reviews the development background of NEVs in China and reflects the development status of NEVs in different periods of China. The development of NEVs in China was analyzed through data, reflecting the current development status and trends. Combined with the policy background of carbon peaking and carbon neutrality, the position of NEV industry in China's automobile submarket, domestic market, and international market is analyzed. Based on the analysis and discussion, the main issues faced by the development of NEVs in China were proposed, including the impact of subsidy policy withdrawal on car companies and consumers, the construction and development of infrastructure, the research and development of core technologies and components, and the construction of a clean energy system based on sustainable development. It is proposed that the future development direction of China's NEV industry can follow the directions of electrification, intelligence, lightweight, and sustainable development.



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1. Introduction

Global climate change has put forward low-carbon requirements for all countries in the world [1]. As the world's second-largest carbon emission industry, the transportation industry has more than one fifth of the world's total carbon emissions [2]. In addition, the transportation industry consumes a large amount of energy. In 2020, about 60% of the world's petroleum was consumed in the transportation field. Among them, automobiles are the main means of land transportation, accounting for the largest proportion of land transportation and even overall transportation [3]. In order to solve the increasingly prominent contradiction between fuel supply and demand and environmental pollution, new energy vehicles (NEVs) have become an inevitable trend in the development of the automobile industry. NEVs refer to vehicles that use unconventional vehicle fuels as their power source (or conventional vehicle fuels or new on-board power devices), including passenger cars and commercial vehicles, integrate advanced technologies in vehicle power control and driving, and form advanced technical principles, new technologies, and new structures. NEVs include pure electric vehicles, extended-range electric vehicles, hybrid electric vehicles, fuel cell electric vehicles, hydrogen engine vehicles, etc. An increasing number of governments are setting objectives for EV deployment, providing signals to manufacturers and other industry stakeholders, building confidence based on policy frameworks, and mobilizing investment [4]. The major automobile producing countries in the

world have taken the promotion of NEVs as a national strategy for the development of low-carbon transportation [5–7].

The history of NEVs dates back over a century and a half, predating the development of internal combustion engines. In 1807, Isaac de Rivas manufactured the first hydrogen internal combustion vehicle. Although the design was not successful. Even now, hydrogen-fueled vehicles are still a research hotspot, but due to cost, storage, safety, and other factors, they have not yet occupied a dominant position in the market compared with electric vehicles. Thomas Parker, an English inventor, built the world's first electric vehicle in 1834 [8]. This was followed by the appearance of several disposable battery-powered electric vehicles. In 1881, French engineer G. Trouve made history by assembling the world's first rechargeable battery-powered electric vehicle. During the following decades, electric vehicles rapidly developed in countries such as the United States, Germany, France, and Britain. Despite its rapid progress, the development of NEVs has experienced ups and downs in the competition with oil-powered vehicles. However, with increased concerns over energy security and environmental protection, the research and development of electric vehicles entered a new phase of activity in the 1990s. This was marked by Sony Corporation of Japan's development of the world's first rechargeable lithium battery. The advancements in battery technology have greatly improved the performance of electric vehicles in terms of endurance and speed. Additionally, alternative NEVs such as solar-powered, hydrogen-powered, and plug-in hybrid electric vehicles are also emerging. Today, NEVs are rapidly developing and receiving growing support and recognition worldwide. China, Japan, the United States (U.S.), Germany, South Korea, and other countries have introduced a number of policies to develop the NEVs industry at all levels [9]. Concerns about carbon emissions and energy security are driving a shift in the transportation area from traditional fuels to alternative fuels and electric vehicle (EV) propulsion systems [10]. Many countries have worked out subsidy policies for NEVs to encourage consumers to switch to NEVs to reduce air pollution [11]. The Chinese government has also provided strong support for the shift from traditional fuel vehicles to NEVs from a policy perspective [12]. The fast-growing light-duty plug-in electric vehicle (PEV) market in China has important implications for both the global vehicle market and energy policies [13]. Germany and the EU promote the development of NEVs through government policies to further reduce carbon dioxide emissions from road transportation [14].

In the past 40 years, the problems of petroleum shortages and environmental pollution caused by China's rapid industrialization have been particularly prominent. China recognizes the importance of NEVs in addressing the challenges posed by petroleum shortages and environmental pollution and is taking proactive measures to support the growth of this industry. China is taking active steps to promote the development and widespread adoption of NEVs, such as electric vehicles (EVs), plug-in hybrid electric vehicles (PHEVs), and fuel cell vehicles (FCVs). The Chinese government has introduced a series of policies and incentives to support the growth of the NEV industry, such as subsidies, tax breaks, and preferential treatment for EV owners. China's efforts to promote the development of NEVs have led to significant progress in recent years, and the country is poised to play a major role in shaping the future of the global transportation industry [15–17]. In 2021, pure electric vehicles accounted for the largest proportion of China's segmented production of NEVs, reaching 2.942 million, accounting for 82.9% of the total production of NEVs. In addition, the production of PHEVs reached 601,000, accounting for 17% of the total production of NEVs. The production of FCVs reached 1777, accounting for less than 0.05% of the total production of NEVs. Despite significant progress in the research and development of fuel cell vehicle technology in recent years, the proportion is still very small, so this article focuses mainly on electric vehicle development.

China's NEVs are developing rapidly, both in terms of technology and market. Especially in the context of the dual carbon policy, NEVs experienced explosive growth from 2020 to 2022. Scholars' exploration of NEVs in China focuses more on technical details, government strategies, etc. Macro reporting data tends to be outdated, and there is less

coverage of their development status and data in recent years. This study is based on the latest data on the development of NEVs in China, attempting to provide the latest information to domestic and foreign observers.

This paper is dedicated to elaborating on the development and evolution of China's NEV industry and exploring the sustainable development of the automobile industry in the context of carbon neutrality. Based on the analysis of data on the development of NEVs in China in recent years, problems existed in the industry development process, and the future development trends of NEVs in China were proposed, providing reference information for industry researchers and decision-makers.

The remaining parts of this manuscript are organized as follows: Section 2 elaborates on the development background and process of NEVs in China, especially the analysis of production, sales, and ownership in recent years. Section 3 analyzes the development status of NEVs in the context of the dual carbon policy and explores the development trend in China based on statistical data on the segmented market and domestic and international market share of NEVs in China. Section 4 provides a general discussion of the problems in the development of NEVs in China. Section 5 summarizes the main conclusions.

2. Development of NEVs in China

China established its first automobile manufacturing plant in 1949, which completed the transformation of China's automobile industry from scratch. After decades of development, the scale of China's automobile industry has been considerable, but it is "large but not strong" [18], and there is still a large gap between China and western countries. The scale of China's automobile industry has gradually expanded since 2000, and electric vehicles have been listed as one of the 12 major projects of the "863" plan [19,20]. In order to support the development of China's NEV market, in 2005, the state clearly required that the market share of NEVs account for more than 50% of the vehicle market [21]. China's NEV industry began in 2006. Under the guidance of the national energy conservation and emission reduction policy, the Ministry of Science and Technology launched the "863" Plan's major energy conservation and NEVs projects and established the "Three Horizontal and Three Vertical" NEVs industry development strategy. In 2007, the National Development and Reform Commission officially listed NEVs in the directory of encouraged industries in the Guiding Catalogue for Industrial Restructuring (2007 edition) issued by the National Development and Reform Commission. From then on, the development of the NEV industry began to be on track. In March 2009, the State Council issued the Plan for the Adjustment and Revitalization of the Automobile Industry, which proposed the goal of large-scale development of NEVs for the first time. At the executive meeting of the State Council held on 8 September 2010, the State Council deliberated and adopted in principle the Decision of the State Council on Accelerating the Cultivation and Development of Strategic Emerging Industries, officially listing NEVs as one of the seven strategic emerging industries [22–24]. After 2011, with the increasing investment of government departments and relevant enterprises, NEVs have achieved significant breakthroughs in product quality and technology, and the speed of industrial development has significantly accelerated [25]. According to the economic operation data of the automobile industry from 2015 to 2022, as shown in Figure 1, the production and sales of NEVs in China reached about 340,000 and 331,000, respectively, in 2015, with a year-on-year increase of more than three times, surpassing the United States, and becoming the country with the highest production and sales of NEVs in the world for the first time.

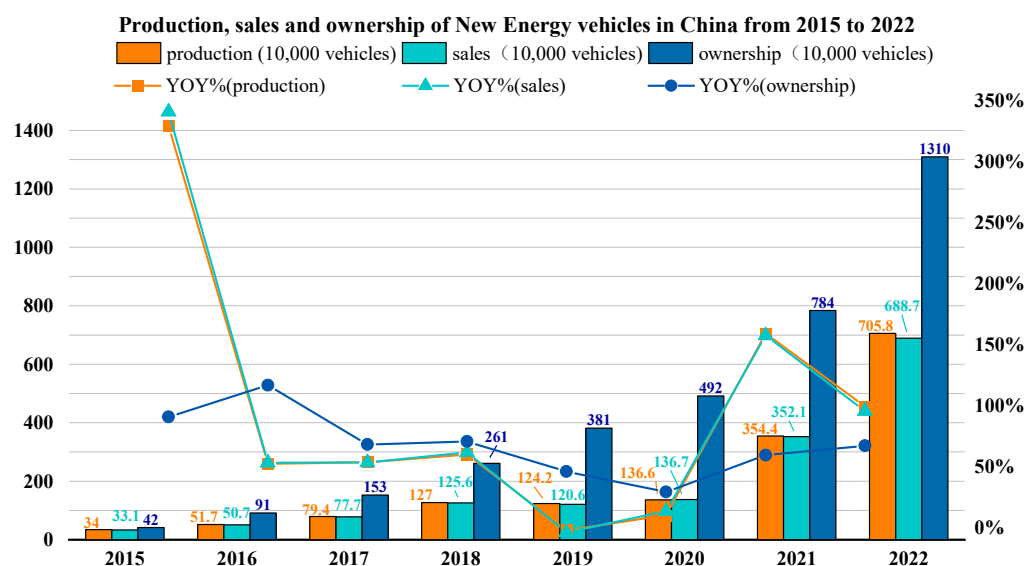


Figure 1. Production, sales, and ownership of NEVs in China from 2015 to 2022.

The production and sales of NEVs continued to develop rapidly in the next three years, with an annual growth rate of more than 50%, and remained the first in the global production and sales of NEVs. The production and sales of NEVs in China exceeded 1 million for the first time in 2018, reaching 1.27 million and 1.256 million, respectively, accounting for more than 50% of the global production and sales of NEVs and becoming the world's largest production base and sales market for NEVs [26]. At the same time, on the basis of the laws and regulations of European and American countries on NEVs, China introduced a "Double Credit Policy" in combination with the actual situation, and the subsidy policy gradually withdrew from the stage of history. In 2019, due to the decline of subsidies, the production and sales of NEVs in China fell for the first time, and the development prospects were overshadowed. The outbreak of COVID-19 in 2020 and the complexity of the international situation make the development situation of China's NEVs industry more severe. With the joint efforts of all participants in the industry, the production and sales of NEVs in China will stop falling and increase in 2020, reaching 1.366 million and 1.367 million, both exceeding 1.3 million, creating a new record of production and sales [27,28]. In November 2020, the State Council issued the New Energy Vehicle Industry Development Plan (2021–2035), which clearly stated that we should continue to vigorously develop the NEV industry. In the context of continuous favorable policies and increasingly improved supporting facilities, China's NEVs production and sales have again exploded: in 2021, China's NEVs production and sales were 3.544 million and 3.521 million, respectively, reaching a new record with a year-on-year increase of 159.5% and 157.5%, the highest growth rate in six years. China's NEVs ranked first in global production and sales of NEVs for seven consecutive years. According to relevant data, by the end of 2022, the number of NEVs in China reached 13.1 million, the highest in the world with more than half of the global number of NEVs, and China's pure electric buses account for more than 95% of the global market share, which is almost monopolistic. Looking around the world, from 2015 to 2022, China has become the world's largest NEV market for eight consecutive years. Today, the new energy automobile industry is the most competitive emerging industry in China, and China has become the development center of the world's new energy automobile industry.

3. Data and Descriptive Analysis

3.1. Development of China's NEVs Sub-Market

In order to cope with climate change, on 22 September 2020, China formally proposed the dual-carbon goals of achieving carbon peaking by 2030 and carbon neutrality by 2060

at the 75th United Nations General Assembly. To achieve this goal, the government has issued stimulus policies in the transportation sector, such as industrial support policies, car purchase subsidy plans, green licenses (green license plate cars do not need to comply with traffic restrictions.), etc., which have led to explosive growth in the production and sales of NEVs after 2020, as shown in Figures 2 and 3. With China's emphasis on environmental protection and the promotion of the dual-carbon policy, China's share of NEVs in the overall automobile market has increased year by year, and their types have also diversified, mainly including pure electric vehicles, plug-in hybrid vehicles, and fuel cell electric vehicles [29]. In the past few years, China's NEV industry has been taking pure electric vehicles as the main development direction, and the production and sales of pure electric vehicles have always occupied the absolute dominant position. As shown in Figure 2, the overall sales of pure electric vehicles in China showed an upward trend from 2017 to 2022, with a breakthrough of 5.365 million vehicles in 2022, an increase of 81.6% year on year, and a market share of more than 80% in NEVs for three consecutive years. Similarly, in recent years, the sales of hybrid vehicles in China have also shown a continuous growth trend. According to the statistics of the China Association of Automobile Manufacturers, the sales of hybrid vehicles in China exceeded 1.5 million in 2022, with a year-on-year increase of 152%. However, the overall scale of the hybrid vehicle market is still small. According to the "Road Map 2.0 of Energy Saving and New Energy Vehicle Technology" released in China, the penetration rate of hybrid passenger vehicles will reach 50% by 2025. It can be seen that there is still a huge space for hybrid vehicles to increase. Compared with the first two kinds of NEVs, China's hydrogen fuel vehicle industry is developing slowly at present, mainly due to high battery costs, few hydrogen stations, and difficulties in hydrogen production. At present, commercial vehicles are the main application field for fuel cell vehicles in China. However, with the introduction of more and more relevant hydrogen energy industry plans and the implementation of subsidy policies, hydrogen fuel cell vehicles will usher in a stable linear growth period in the future.

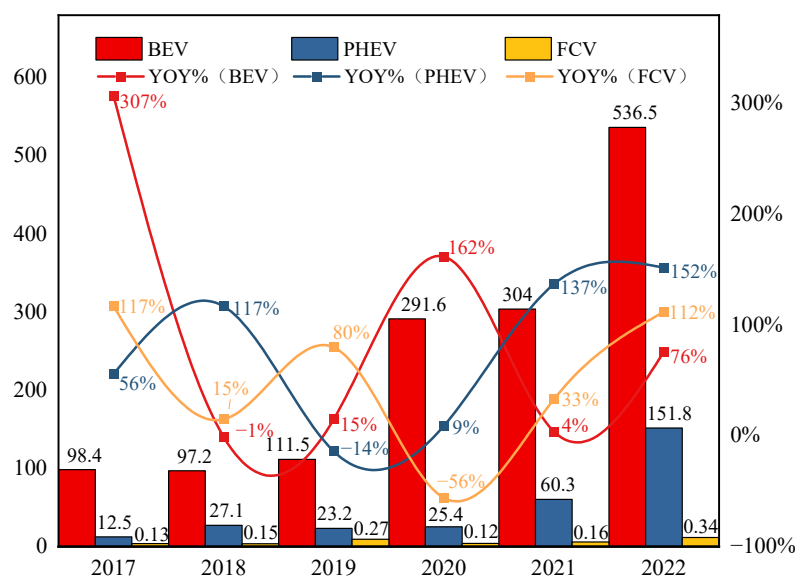


Figure 2. Sales chart of different types of NEVs in China from 2017 to 2022.

New energy vehicles can be divided into new energy passenger vehicles and new energy commercial vehicles according to the application market classification. Among NEVs, passenger cars are the main products on the market. From the 2017 to 2022 sales chart of new energy commercial vehicles and passenger vehicles, as shown in Figure 3, it can be seen that the sales of new energy passenger vehicles have increased explosively in the past two years, with nearly double growth compared with the previous year. In 2022, the retail sales of passenger vehicles exceeded 5.647 million, and the penetration rate in the NEV market exceeded 80%. Compared with the new energy passenger vehicle

market, the market scale of new energy commercial vehicles is relatively smaller, and the market share is lower. After 2020, driven by the carbon peaking and carbon neutrality goals, the opening of the right-of-way for new energy commercial vehicles, and the rise of the electricity exchange model, the growth rate of new energy commercial vehicles will continue to rise. The growth rate in 2022 reached 82.7%, and the future development prospects are very promising.

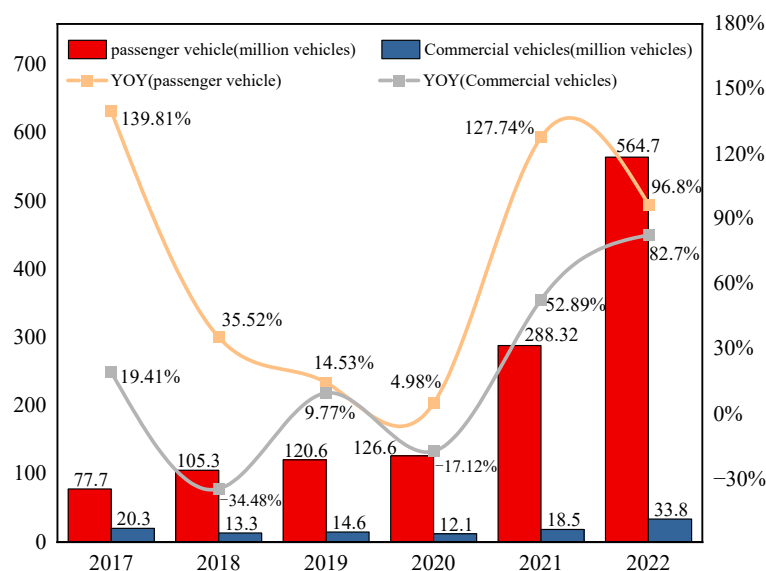


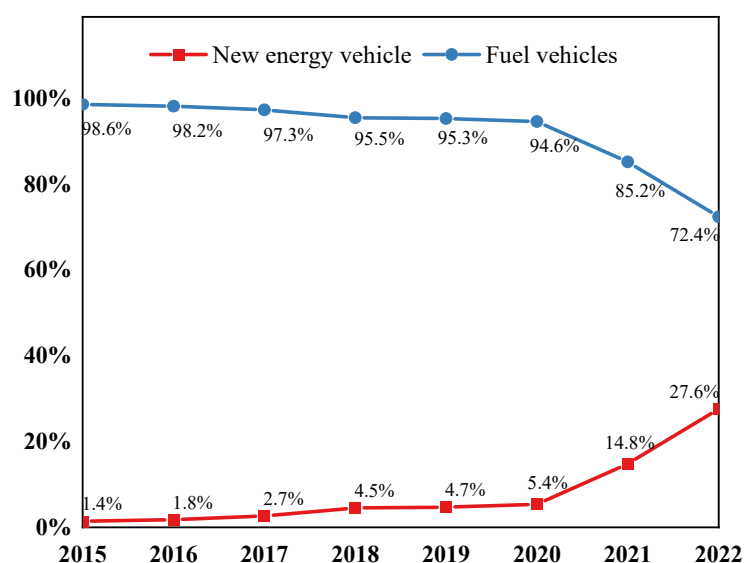
Figure 3. Sales volume and growth rate of new energy passenger vehicles and commercial vehicles in China from 2017 to 2022.

3.2. Domestic Market Development of NEVs

The change in oil price is an important variable factor that affects consumers' choice of NEVs [30–32]. At present, due to the large price difference between oil and electricity, NEVs have obvious advantages in vehicle costs. With the help of the national energy structure adjustment policy, the sales of NEVs have soared in recent years, and the process of replacing traditional fuel vehicles has been accelerating. It can be seen from Table 1 that the sales of traditional fuel vehicles have continued to decline in the past five years, and the NEVs have stopped the triple decline in the total sales of vehicles from 2018 to 2020 by their own efforts. An analysis of the market penetration of NEVs and fuel vehicles in 2015–2022 (Figure 4) shows that the market penetration of NEVs has increased from 1.4% in 2015 to 27.6% in 2022, while the market penetration of fuel vehicles has dropped to 72.4%. The replacement effect of NEVs on traditional fuel vehicles has become increasingly obvious. With the increasing penetration of NEVs, the energy use structure of the automobile market will change, and the supply of new materials such as batteries and motors will reach a new balance, forming an important guaranteed capacity for supply. At the same time, the supporting environment for NEVs is becoming more and more perfect. By the end of 2022, China had built 5.21 million charging piles, 1973 power stations, and built a fast charging network covering 176 cities and more than 50,000 km of expressways. The construction of charging and replacing infrastructure has been significantly accelerated, and more than 10,000 power battery recycling service outlets have been established in total, basically realizing nearby recycling.

Table 1. Comparison of sales volume and growth rate between NEVs and traditional fuel vehicles from 2018 to 2022.

	New Energy Vehicles (10,000 Vehicles)	YOY% (New Energy Vehicles)	Fuel Vehicle (10,000 Vehicles)	YOY% (Fuel Vehicle)	Total	YOY%
2018	125.6	116.8%	2222.9	−6.0%	2348.5	−3.85%
2019	120.6	−3.98%	1963.8	−11.7%	2084.4	−11.25%
2020	136.7	13.35%	1818	−7.4%	1954.7	−6.22%
2021	352.1	157.6%	1717	−5.6%	2069.1	5.85%
2022	688.7	95.6%	1488	−16.67%	2176.7	5.20%

**Figure 4.** Comparison of penetration rates between NEVs and traditional fuel vehicles in China from 2015 to 2022.

3.3. International Market Development of NEVs in China

China's NEV industry is playing an increasingly important role in the international market. Figure 5 shows the share of the global NEV market in 2022. In 2022, the global total sales of new cars fell by 1%, to only 80.6 million, of which the sales in the United States fell by 8% and the sales in Europe fell by 7%. However, sales in China rose by 2.1% against the trend, partially offsetting the decline in Europe and the United States. The rapid growth in the sales of NEVs made an important contribution to offsetting the decline in car sales. According to the data in the White Paper on the Development of China's New Energy Automobile Industry (2023), the main contribution of global automobile sales comes from China. In 2022, the global sales of NEVs reached 10.824 million, with a year-on-year increase of 61.6%. The sales of NEVs in China reached 6.884 million, with a global market share of 63.6%. The strong growth of China's NEVs is inseparable from the support of national policies and the long-term accumulation and construction of the industrial chain. With the further improvement of NEV technology, the improvement of the industrial service system, and the further enhancement of consumer confidence, China's NEVs will release greater consumption growth potential.

China's NEVs have demonstrated impressive performance in the global export market. In 2022, China's total automobile exports reached 3.111 million, marking a significant 54.4% YoY increase. NEV exports also demonstrated strong growth, reaching 679,000 units, a YoY increase of 1.2 times, and accounting for 21.8% of total automobile exports. This robust growth indicates that China's NEVs offer high cost performance, which is recognized not only by domestic consumers but also by international buyers, driving the overall level of China's automobile exports. With the gradual relaxation of epidemic control in China, the

export market for NEVs is poised to expand, and sales volumes are expected to continue increasing in 2023.

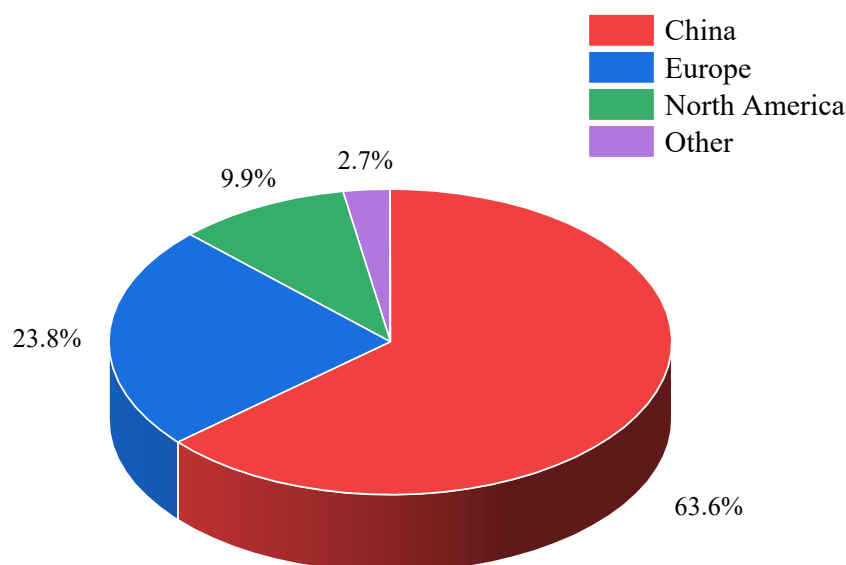


Figure 5. Share of the global NEV market by region in 2022.

4. Discussion

In 2022, China's NEVs market entered a new stage of large-scale and rapid development, but the development of the NEVs industry still faces multiple pressures and challenges. Looking forward to the new year, the withdrawal of government subsidies from the market, the difficulty of charging, and the rapid growth of the price of battery raw materials will become three major challenges for China's NEV industry.

In order to speed up the popularization of NEVs, the government has implemented many supporting policies. Under the support of various policies, the NEV industry has developed rapidly. However, this subsidy policy is not permanent. Since 1 January 2023, the government has officially cancelled the subsidies for NEVs, which will affect both automobile enterprises and consumers. After the cancellation of subsidies for NEVs, the price of new energy products will rise, which may lead many consumers to give up buying NEVs, especially with the new forces in car manufacturing. Currently, most of the new forces in car manufacturing are basically in a state of loss. Once the subsidies are cancelled, it will be a serious blow to them. If enterprises can make breakthroughs in technological innovation and reduce the production cost of NEVs through technological innovation, they will effectively cope with the financial pressure brought by the cancellation of state subsidies.

With the rapid increase in the number of NEVs in recent years, the contradiction between the number of NEVs and the charging pile has become increasingly prominent. Only by solving the problem of charging difficulty can we fundamentally promote the healthy, sustainable, and stable development of the NEV industry. On the basis of matching the number of charging outlets with the number of NEVs held by users as much as possible, reasonably plan the regional layout of charging stations, build smart vehicle networking, fully realize the interaction between NEVs and the power grid, optimize the charging path, realize the reasonable allocation of resources, and establish a more intelligent charging and changing mode. In addition, it is also an important way to solve the problem of charging difficulty, tackle the key problems of charging and replacement technology, shorten the charging time, and improve the turnover rate of charging piles.

The battery is a core component of NEVs, and the rising prices of raw materials for power batteries have had a serious impact on the development of the automotive industry [33]. Currently, the rate of increase in raw material production is not keeping pace with

the growth of NEVs. Shortages and price hikes for lithium batteries, chips, and other components have created supply-demand imbalances, hindering the development of China's NEVs. In the future, improving the supply of battery materials will require development and management efforts, focusing on technological innovation through resource extraction, refining, battery technology R&D, and recycling system construction. In particular, developing low-nickel, low-cobalt, or cobalt-free batteries should be a research focus. At the same time, it is necessary to manage the lithium and other raw material trading markets, strengthen international cooperation in areas such as optimizing international logistics channels and trade processes, and ensure the global supply of power battery materials.

5. Conclusions

After years of development, China's NEVs industry has taken a leading position in technology, market, and promotion and has gained some influence in the international market. China has become the world's largest production base and sales market for NEVs.

However, in the process of rapid development, there are also many urgent problems that need to be solved:

(1) In 2023, the national new energy policy subsidies were officially withdrawn, and the sales of NEVs immediately faced challenges. For NEV companies, whether to maintain profits or sales will be a common challenge in the coming years.

(2) Infrastructure is the basis for the development of NEVs. If the NEVs market is to develop healthily, such as the speed of charging pile construction, it must show exponential growth so as to avoid worries about the development of the NEVs industry.

(3) The lack of core technology. At present, key core technologies are still greatly constrained, especially in areas such as batteries, electronic controls, and motors, which are still lagging behind. In terms of core technologies such as batteries, there is a lack of safety and reliability.

(4) The construction of a clean energy system based on sustainable development. Sustainable development issues should be considered from the perspective of the entire product lifecycle.

The development trend of China's NEVs industry in the future will be the following:

(1) Electrification: With the continuous progress of technology, the performance and range of electric vehicles will continue to improve, and the cost will also continue to decrease.

(2) Intelligentization: With the development of artificial intelligence and the Internet of Things technology, NEVs will continue to become intelligent, enabling functions such as autonomous driving and intelligent charging. Future NEVs will be interconnected with other intelligent devices to form an intelligent transportation network.

(3) Lightweight: Lightweight is a trend in the development of NEVs in the future. By using lighter materials, the weight of the vehicle body can be reduced, and the range and performance can be improved.

(4) Sustainable development: The development of NEVs will increasingly focus on environmental protection and sustainable development. In the future, NEVs will pay more attention to the use of low-carbon, environmentally friendly, and renewable energy to reduce their impact on the environment.

It is undeniable that our analysis has some limitations, such as: Can NEVs effectively reduce carbon emissions? Taking electric vehicles as an example, carbon emissions throughout their entire lifecycle have always been a topic of discussion. Although their total carbon emissions during use are very low, carbon emissions are generated in processes such as body manufacturing, upstream and downstream of battery manufacturing, and disposal of discarded batteries. To achieve effective control of carbon emissions, building a clean energy system based on sustainable development is the ultimate solution. Another challenge is that the production cycle for NEVs is shorter than the production cycle for new sustainable components of the infrastructure. Should policies be implemented to slow

production and sales of NEVs until the infrastructure is improved? That requires more systematic research to draw better conclusions.

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