China's Development on New Energy Vehicle Battery Industry: Based on Market and Bibliometrics

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Abstract. The continuous deterioration of environmental problems and the energy crisis has prompted countries and regions to increase research and development and support for new energy vehicles (NEV). NEV’s battery as the core components play an essential role in the cruising range and manufacturing cost in terms of energy, specific power, new materials, and battery safety. In order to know the development of NEV’s batteries, as well as research hotspots and technology trends, this paper analyses the market performance and technology trend of China NEV’s battery industry. Firstly, this paper analyses the policy and market, then clarify the macro environment of China's NEV battery industry development. Secondly, this paper uses CITESPACE software to analyze the scientific knowledge of the literature data, such as research hotspots, research institutions, and technology development trends. In the end, this paper proposes policy recommendations for the future development of China's NEV’s battery industry from the perspectives of technology, market, and industrial chain.

1. Introduction
With the continuous advancement of global industrialization, the energy crisis and environmental pollution problems have become more and more serious, and various countries are actively seeking alternatives to non-renewable energy.[1] In the automotive industry, most countries and regions around the world are promoting new energy vehicles (NEV) such as battery electric vehicles (BEV), Plug-in hybrid electric vehicle (PHEV), and fuel cell vehicles that use renewable energy as their main source of power. It hopes that it will gradually replace traditional fuel-powered vehicles and reduce dependence on non-renewable energy sources.
Moreover, some countries and regions have issued timetables for terminating the sale or registration of new internal combustion engine vehicles: Norway, 2025; Ireland, Netherlands, Slovenia, 2030; Scotland, 2032; France, Sri Lanka, UK, 2040; Sweden, 2045. According to the statistics of EV Sales, by the end of 2018, the global sales of NEV totaled 2.0182 million. The top five are Tesla, BYD, BAIC New Energy, BMW, and Nissan, and China's NEV sales account for the highest proportion in the global NEV market. [2]
In China, the government implemented a double-point policy and subsidy standards to promote mileage upgrades in 2018. These policies have promoted NEV's technological developments, such as improved cruising range and achieved sustained growth in NEV sales. This trend shows that society's acceptance of new energy vehicles is gradually increasing. According to the statistics of the China Passenger Cars Association (CPCA), the sales volume of China's NEV was 993,000 units in 2018, increase 90.43%. Among them, the sales of BEV reached 750 million units, an increase of 79.48% over the same period of last year, accounting for 3/4 of the annual sales of NEV.
Compared with the sales volume of China's fuel vehicle market in 2018, the market share of new energy vehicles is still insufficient. The reasons why users are not accepting high-energy vehicles...
(especially pure electric vehicles) are mainly affected by factors such as low cruising range and long charging time. At the same time, although the battery price has dropped from 1,000 €/kWh in 2010 to about 200 €/kWh [2], the cost of battery replacement is still an important reason why consumers do not buy new energy vehicles.

Therefore, how to improve the performance of NEV’s battery and cruising range, how to reduce the cost of batteries, and shorten the battery charging cost has become a hot research topic.

In order to clarify NEV’s battery current technology and future development trends, this paper uses CITESPACE for bibliometrics and visual analysis, such as research hotspots, cooperation between research institutions, and technological development trends. Through the analysis of bibliometrics and industrial policies, this paper finally provides policy recommendations for the development of China's NEV battery industry.

2. Literature review

Nowadays, NEV’s batteries are mainly composed of lithium batteries, phosphates battery, titanites battery, nickel-metal hydride, and nickel-hydrogen batteries [3]. According to the electrolyte state of the lithium battery, it can be divided into a liquid lithium battery, semi-solid lithium battery, and all solid lithium-ion battery. As the degree of curing of the lithium-ion battery electrolyte is increased, the safety of the lithium-ion battery is also higher, but the technical difficulty and manufacturing cost are also higher [4]. The research mainly focuses on the following aspects.

About the technological development, most scholars have focused technical analysis from the history of BEV’s batteries, such as specific energy, density, specific power, and cycle life of NEV batteries, from the perspective of the critical role of BEV battery development. Some scholars analyzed the current situation of BEV’s battery installed capacity, policies, battery advantages, and disadvantages, and proposed that the enterprises should be rationally arranged to strengthen industrial cooperation and development. [5]

On the research of technology trends, most scholars have conducted in-depth research on NEV’s battery core technologies, such as new materials for power batteries, diaphragms, charge balancing problems, SOC estimation, etc., as well as battery recycling technology and safety issues. Besides, some scholars conducted a comparative analysis of new NEV batteries, such as new lithium-ion batteries, solid-state batteries, magnesium-ion batteries, metal-air batteries, and lithium-sulfur batteries. They are committed to clarifying the technological development trend of NEV’s batteries and realizing the leap-forward development of the NEV industry. [6]

For the replacement of NEV batteries after 5-8 years, in order to improve the economic in BEV’s battery life cycle and maximize the utilization of resources, scholars have carried out multi-angle analysis on used NEV’s battery[7,8], such as battery performance analysis, recycling risks, safety technologies, and also focus on the commercial value, business model, and project feasibility [9, 10]. At the same time, a large number of scholars conducted trend analysis on battery literature and patents, and analyzed the development of BEV batteries in technology, industry, and market.

Therefore, this paper comprehensively uses qualitative and quantitative analysis to conduct market and Bibliometrics analysis on the trend of NEV’s battery industry. Through analysis, we will deeply understand the characteristics and development trends of NEV’s battery industry and provide policy recommendations.

3. NEV’s battery industry market

In addition to technological innovation, the market development of China's emerging industries cannot be separated from the strong support of national policies, as is the NEV industry. The battery is the core element of NEV, and its development has been strongly supported by the central and local governments in China. A series of industrial policies promulgated play an essential role in promoting healthy development and improving the industrial chain of the NEV’s battery industry.[11]

Since 2001, China has launched the National “863” Plan for Electric Vehicle Major Project, which has determined the technological development route of three vertical and three horizontal of NEV, and clarified the importance of batteries in the development of the NEV industry. In 2009, the state officially launched a three-year Ten Cities and Thousand Vehicles promotion project, which goals to
promote 10 new cities and 1,000 new energy vehicles for each city every year. Since then, China's NEV industry has entered a period of rapid development. The development of the NEV industry has greatly promoted the market growth of the battery industry, just like Figure 1 shows.

![Figure 1. NEV Sales and Battery Installed Capacity](image1)

About NEV’s battery industry, the global NEV’s battery installed capacity was 92.5GWh in 2018, an increase of 45.8%. The top ten battery companies are CATL, Panasonic, BYD, LG Chem, AESC, Samsung SDI, Guoxuan, Lishen, Fu Neng, and Bick. The installed capacity is shown in figure 2.

![Figure 2. Global Battery Companies Installed Capacity in 2018](image2)

Figure 2 shows that in 2018, the world's top ten NEV battery companies are from China, Japan, and South Korea. Among the top 10 companies, the installed capacity of China's NEV battery companies accounted for 47.42% of the global installed capacity of power batteries in 2018.
From the perspective of the Chinese market, the top 10 NEV battery installed enterprises are mainly distributed in the eastern coastal areas such as Guangdong, Fuzhou, Jiangxi, Hefei, Beijing-Tianjin-Hebei and the Yangtze River Delta. At the same time, China's NEV battery companies are clearly ranked, such as CATL ranked first with 23.54GWh installed capacity, accounting for 41.31% of China's NEV battery installed capacity in 2018, accounting for about a quarter of the global market. Except for CATL and BYD's NEV battery installed capacity of more than 10GWh, the rest battery manufacturers have a relatively small market share, that is, they have not formed a good market competitive advantage. However, with the advancement of the NEV industry policy, the development of China's NEV battery industry will form a more solid industrial foundation.

It should not be overlooked that compared with the internationally renowned NEV companies such as the United States, Germany, Japan, etc., the development of China's NEV battery industry still has many problems: ①In the upstream: over-reliance on foreign raw material suppliers, the development of the industry is subject to the supply of core raw materials. Restrictions. ②In the midstream: low input and output of technology, high cost hinders consumers' enthusiasm for purchase. ③ In the downstream: the industry has not established a complete system of sales, after-sales maintenance, recycling, and reuse.[12]

Therefore, the market development of China's NEV battery industry still needs to continue its efforts in policy, capital, technology, personnel, and industrial support.

4. Bibliometrics analysis
The marketization analysis of China's NEV battery industry makes us to better understand the development of China's NEV battery industry In order to know the technical status and trends of China's NEV battery industry, and this part will analyze the literature of the NEV battery industry. This paper first selects "New Energy Vehicle Battery" as the topic search keyword, and then searches the core database of Web of Science (WOS). Among them, the data retrieval period is all period, and the search time is October 24, 2019. At the same time, this paper selects the widely used CITESPACE software to conduct bibliometrics analysis on the collected related literature. Through the literature search of the WOS database, we searched 11610 articles were searched. Its annual distribution is shown in Figure 4.

![Figure 3. Annual distribution of literature](image)

Due to the time error of the publication of journal articles, the literature data for 2019 is not shown in Figure 4. As we can be seen from figure 4, before 2008, NEV battery related literature was relatively small, and the growth was flat. Since 2009, NEV battery related literature has increased significantly, and it is still showing an upward trend.

The distribution of countries in the relevant literature is shown in Figure 5.
Figure 4. National Distribution of Authors

As can be seen from Figure 5, China has the largest number of related works of literature on NEV batteries, accounting for 24.27%. It is followed by the United States, Germany, and Canada, accounting for 23.351%, 6.391%, 5.073%. This also shows that scholars from countries such as China, the United States, and Germany are paying more attention to the NEV battery industry.

In order to clarify the research hotspots of current scholars, this paper uses CITESPACE software for visual analysis (Figure 6) and further clarifies the development trend of the NEV battery industry.

Figure 5. NEV battery related literature research hotspot

It can be seen from Fig. 6 that the research of NEV batteries mainly focuses on lithium-ion batteries, lithium iron phosphate batteries, thermal management systems, battery safety, battery internal resistance, and electric vehicle vehicles. In the field of lithium-ion batteries, the main focus is on its electrolyte, membrane, electrochemical performance, SOC estimation, rate performance, and cycle life. In the field of lithium iron phosphate batteries, research on thermal runaway, cathode materials, and
waste battery treatment is mainly carried out. Regarding the electric vehicles, scholars mainly focus on
the power system, electrolyte and control strategy, namely battery and electronic control.
At the same time, since 2008, the main research focus of NEV battery has gradually shifted from pure
technology such as SOC estimation, internal resistance, and battery management system to battery
materials and commercial application of batteries. Research on new NEV batteries, such as sodium-
sulfur batteries and solid-state batteries, has also been strengthened.

5. Conclusion
China's NEV battery industry has been rapidly developed under the policy encouragement, laying a
solid foundation for the transformation of the national automobile industry. Moreover, with the
implementation of the new energy vehicle development strategy, research on NEV batteries will
continue to deepen.
However, while China's NEV battery industry is overgrowing, there are still many problems, such as
lack of patented technology and low-end overcapacity. Whether China's new energy automobile
industry can sustainably develop and maintain the international parallel and leading advantages of the
industry depend primarily on the development of the power battery industry.
In the future industrialization development and marketization promotion process, on the one hand, we
cannot simply pursue high energy density, long life, low cost, etc., and should focus on consumer
demand to ensure the safety and reliability of electric vehicles. Eliminate consumer buying concerns.
On the other hand, it is necessary to enhance the ability of collaborative innovation, integration, and
innovation among enterprises, and enhance the innovation capability and industrial competitiveness of
the entire industry chain.
Finally, because of some weak links in the current power battery industry chain, such as upstream
materials and equipment and downstream recycling, strengthen these weak links and constraints, and
promote synergy innovation in the industry chain to control the core technology. Only in this way can
China's new energy vehicle and battery industry maintain a relatively fast and rapid development.

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