The Issues and Development of New Energy Vehicle Batteries

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Abstract. This paper conducts research on the core value, key issues, and development prospects of batteries in new energy vehicles. Under the deepening global climate governance and the "dual carbon" goals, power batteries, as the core component of new energy vehicles, have multiple values at the vehicle end, industrial and social ends, and are of crucial importance. The research employed data collection and case analysis methods. Firstly, it deeply explored the comprehensive value of batteries in terms of technology, economy, and ecology, clearly identifying their core role in the energy transition. Then, it identified the key bottlenecks restricting the development of the industry, including shortcomings in the technical and usage standards systems, lagging detection equipment, and risks of waste battery pollution in the industrial and environmental ends. Finally, it prospectively analyzed the future evolution trend and industrialization prospects of battery technology, providing ideas and decision-making references for the industry to break through troubles and achieve high-quality and sustainable development.

1 Introduction

Due to population growth, the transformation of times, and the gradual depletion of fossil fuel resources, the demand for new energy sources is continuously increasing [1]. The new energy vehicle industry has entered the market-oriented development stage since the policy-supported period and has become a key factor in building the global energy structure and transportation system. As the new energy industry continues to develop, the power battery, as the "heart" of new energy vehicles, has become more important than just a component, and has become a key point in national competition. It is crucial for determining the vehicle's range, safety performance, and user experience, and is also the hub connecting renewable energy power generation and intelligent transportation networks. New energy vehicles have made rapid progress in China's new industries [2]. In 2022, 6.887 million new energy vehicles were sold in China, driven by both market and policy factors [2].

Currently, China's power battery industry has achieved remarkable achievements, with global installed capacity exceeding 89.4 GWh in 2024, forming the most complete industrial chain in the world. However, the rapid development of the industry is also accompanied by deep-seated contradictions, which constitute the core issue domain of this study. Firstly, at the core value level, batteries not only carry technical value, but also contain huge economic

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value and ecological value. Secondly, in terms of core issues, the industry is facing multiple challenges. For example, the high dependence on key mineral resources such as lithium, cobalt, and nickel in the upstream has brought supply chain security risks. With the implementation of the "strictest safety order", the inherent contradiction between high energy density and high safety has become increasingly prominent, and the risk of thermal runaway still exists, constantly threatening safety. In addition, due to the large-scale retirement of early installed batteries, the unimproved recycling system and the lack of standards for secondary utilization, the industry's green closed loop and resource security are under threat.

Based on the aforementioned industrial background and current challenges, the core of this study is to conduct a systematic analysis of the core value, bottlenecks, and development trends of new energy vehicle power batteries. The specific research tasks can be summarized into three aspects: Firstly, from multiple levels such as technical, economic, and ecological dimensions, analyze the comprehensive value of batteries, clarify their key positioning in the energy transition strategy. Then, accurately identify and decompose the core pain points that restrict the advancement of the industry, focusing on prominent obstacles such as resource supply security, battery safety, and cycle cycle safety. Forward-lookingly, predict the iteration direction of battery technology, explore the breakthrough routes and industrialization prospects of new generation energy storage technologies such as solid-state batteries, in order to provide feasible references and decision support for the industry to break through development bottlenecks and promote high-quality and sustainable development.

2 The value of new energy vehicle batteries

2.1 Vehicle-side Value

The battery of new energy vehicles is the core energy carrier of the vehicle, directly determining the range, acceleration performance, and charging efficiency. Its capacity, energy density and charge-discharge rate are the key factors for power performance. The battery accounts for a considerable proportion of the vehicle's cost, and 40% of the cost of new energy vehicles comes from the battery. When the raw material supply is poor, it may account for 60% [3]. The technical route directly determines the product pricing and market competitive advantage. The battery thermal management scheme and structural design level directly affect the vehicle's crash safety and thermal runaway prevention effect, while the cell degradation characteristics determine the actual experience of users over the long term. In addition, the battery health status is the core basis for the valuation of used vehicles, and batteries beyond their service life can be extended through secondary utilization, further enhancing the comprehensive benefits of the entire battery life cycle.

2.2 Industry and social value

New energy battery power supplies are the core components of new energy vehicles, accounting for approximately 40% of the vehicle's cost. The technical level directly determines the industrial competitiveness. In recent years, with the improvement in energy density, extension of cycle life and popularization of fast charging technology, the range of mainstream models has exceeded 500 kilometers, and the fast charging time has been reduced to within 20 minutes, effectively alleviating "range anxiety" and promoting the increase in market penetration rate.

The phosphorus iron battery system jointly developed by CATL and Yutong Bus has been widely used in electric buses in Zhengzhou. This system has a cycle life of over 4,000 times, supports dual-gun fast charging, and can be charged to 80% in 15 minutes. By the end of

2025, the proportion of new energy buses in Zhengzhou will reach 100%, with an average annual carbon reduction of 120,000 tons, driving employment in the upstream and downstream industries to over 20,000 people, and becoming a typical sample of coordinated development.

The acceleration of domestic battery production has formed a complete industrial chain from lithium mining to recycling and reuse, creating a large number of high-quality jobs. The technology for secondary utilization of retired batteries is mature, reducing the reliance on key metals and reducing ecological damage; combined with V2G technology, electric vehicles can reverse power transmission, improving the stability of the power system, promoting the consumption of clean energy, and helping to achieve the "carbon neutrality" goal and the green and low-carbon transformation.

3 The core issue of new energy batteries

3.1 Issues related to technology and usage

The standard system for battery power inspection and testing has significant shortcomings. Currently, various standards are fragmented and lagging behind. There are gaps and conflicts between different levels of standards. This situation seriously undermines the uniformity and authority of the test results and also raises the compliance costs for enterprises.

The further expansion of the gap in new battery testing standards has exacerbated the system's deficiencies. The corresponding testing standards for emerging technologies such as solid-state batteries and sodium-ion batteries are still incomplete, making it difficult to provide strong technical support for industrial development. It is notable that China's participation in international battery standards formulation has always been low. In the process of promoting global battery safety standards through the United Nations World Vehicle Regulations Coordination Forum (WP.29), the participation rate of Chinese enterprises was only about 15%, and the core technology proposals were always firmly dominated by European and American enterprises. At the 2024 Solid-State Battery Standards Seminar, the "ceramic separator puncture test" proposal submitted by China was not recognized. This result directly led to the need for additional compliance requirements for related products when exported to the EU, artificially creating technical trade barriers.

Although the commercialization level of lithium batteries is relatively high, the recycling process is relatively backward [4]. 95% of lithium batteries are buried after reaching their service life, but they are not recycled [4]. The construction of the recycling system in the life cycle is still relatively lagging, and the overall level of resource utilization is relatively low.

3.2 Industry and environmental issues

The focus of public concern is how to recycle new energy batteries in an environmentally friendly manner, which is also a problem in the new energy vehicle industry [5]. The disposal of battery waste is the core system of environmental risk prevention in the new energy industry. If the waste batteries are not subject to standardized recycling and disposal, the toxic and harmful substances they contain will enter the atmosphere, soil, water bodies, and sediment through evaporation, leakage, etc. thereby polluting groundwater and surface water resources, triggering ecological toxicity and biological toxicity effects, and posing a direct threat to human health and the stability of the water ecosystem [6]. Even if a recycling system is established, problems such as insufficient maturity of recycling technology and non-standard execution of disposal processes can still cause dangerous substances to leak, further increasing the regional environmental load, and becoming a key bottleneck restricting the green and sustainable development of the new energy industry.

The cathode materials contain heavy metal compounds such as cobalt, manganese, and nickel. Once they come into contact with water, acids, or strong oxidants, they will undergo intense reactions, releasing harmful metal oxides, causing significant fluctuations in environmental pH values, and triggering heavy metal pollution, which has long-term damage to the soil and water ecosystem. The anode materials are mainly carbon materials or graphite, and their dust has flammable and explosive properties. When reacting with acids and bases, they will burn and release carbon monoxide and solid particles, directly polluting the atmospheric environment.

The main component of the electrolyte is lithium salt, which is highly corrosive and easily decomposes when exposed to water, generating toxic hydrogen fluoride (HF) and other toxic substances. It not only causes fluorine pollution and changes the environmental acidity, but can also be inhaled through skin contact and the respiratory tract, directly causing irritation to the human body. The solvents and separators of the electrolyte mostly belong to organic compounds. During hydrolysis or combustion processes, they will generate acids, ethers, carbon monoxide, and aldehydes, forming organic pollution. The fluoropolymer contained in the adhesive is prone to decomposition under high temperatures or strong corrosive conditions, generating hydrogen fluoride, further increasing the risk of fluorine pollution.

The incident of "underground battery dismantling village" in Yichun, Jiangxi Province is a typical example of the pollution caused by new energy batteries. Local villagers illegally dismantled retired lithium batteries using primitive methods and randomly dumped electrolytes containing lithium hexafluorophosphate, cobalt, nickel, etc. which caused excessive lead content in the surrounding soil, and the concentrations of nickel, cobalt, etc. were far beyond safety limits. The groundwater in some areas is no longer drinkable. The informal dismantling method not only results in a resource recovery rate of less than 30%, but also causes irreversible long-term damage to the ecological environment. Local residents have been living in a polluted environment for a long time, and have successively experienced symptoms such as skin allergies and respiratory irritation. The proportion of children with elevated blood lead levels is also significantly higher. This reality profoundly highlights the environmental and health risks hidden in the informal recycling process of new energy batteries.

4 Current development of new energy technologies

Lithium ternary has significant roles in the low-altitude economy and robotics sectors. Lithium iron phosphate can be used in cost-effective and safe household vehicles. The implementation of both solutions is necessary to meet a wider range of market demands and ensure the foundation of the industry's energy. These two approaches are not mutually exclusive but rather complementary and symbiotic developments. They precisely match the core requirements of different scenarios based on their respective material characteristics and technological advantages, and mutually promote and learn from each other in the process of technological iteration, driving the improvement and upgrading of the entire value chain, including cathode materials, cell processes, and battery management systems.

With the advancement of lithium battery technology, lithium batteries are widely used in new energy vehicles, including pure electric vehicles and hybrid vehicles [7].

The team of Cui Guanglei from the Chinese Academy of Sciences abandoned traditional binders and used thermoplastic polyamide to build an elastic network through hot pressing, breaking through the bottleneck of wet processing technology, and preparing a 12 μm ultra-thin film with excellent room-temperature ionic conductivity and a surface resistance as low as $0.69\ \Omega \cdot cm^2$. The assembled battery can work stably at high loads for 10,000 hours, cycles more than 3,000 times, and has an energy density of 390Wh/kg, far exceeding that of traditional liquid batteries. The team adopted the path of "extreme scenario technology driving civilian innovation" from the polymer battery technology that provides support for deep-sea exploration vessels to its application and service in the civilian market. The battery industrialization process is accelerating [8].

The team of Hu Wenbin from Tianjin University achieved a key technological breakthrough in the field of lithium metal batteries, proposing the core concept of "localized electrolyte" and innovatively establishing an unordered micro-environment system, precisely balancing the ion transmission efficiency and interface stability performance, effectively improving the electrochemical characteristics of the lithium metal electrode interface, and fundamentally solving the core problems of intense interfacial side reactions and ion transmission imbalance in traditional lithium metal batteries.

Based on this innovative concept, the lithium metal battery pouch cell developed by the team has an energy density that is stable within the range of 604.2-618.2Wh/kg, and the corresponding battery module energy density has climbed to 480.9Wh/kg, achieving a 2 to 3 times leapfrog improvement in comprehensive performance compared to traditional lithium-ion batteries. Moreover, the battery cycle life has been significantly extended by more than 50%, and even after long-term charging and discharging cycles, it can still maintain excellent stability and safety, successfully breaking the industry's predicament of being unable to achieve both high energy density and long cycle life.

This team's original technological breakthrough has overcome the core bottlenecks in the lithium-based battery field, providing solid technical support for industrial transformation and upgrading, and enabling China's lithium-based battery industry to rank at the leading level in global competition.

5 The future development prospects of new energy batteries

Driven by the global "dual carbon" goals and the energy transition wave, the new energy battery industry will enter a period of rapid growth driven by policies and the market, with broad development prospects. According to statistics, from 2023 to 2028, the global market size of new energy battery power will increase from 218.164 billion US dollars to 1088.487 billion US dollars, with a compound annual growth rate of over 30%, showing a high development trend.

The commercialization of all-solid-state batteries is accelerating: in 2027, electric vehicles equipped with all-solid-state batteries will be planned by Toyota, with a range of up to 1200 kilometers, and the charging time will be shortened to 10 minutes [9].

From the perspective of market size, the continuous expansion of the new energy vehicle market has brought huge development space for the battery industry [10]. As consumers' acceptance of new energy vehicles continues to increase, more and more consumers start to choose new energy vehicles as their means of transportation [10].

6 Conclusion

From the perspectives of both the overall performance of the vehicles at the terminal stage and the national low-carbon strategy, the batteries of new energy vehicles have always been at the core of the new energy vehicle industry. They are also the key leverage for China to promote the transformation of the energy structure and implement the "dual carbon" goals. Their core value is transmitted in a hierarchical manner: directly determining the core performance such as vehicle range and fast charging, and connecting the upstream and downstream materials, production, and operation and maintenance for collaboration.

Moreover, at the macro level, they lay a fundamental foundation for the green and low-carbon development of society. However, the industrial scale expansion still faces many practical constraints, such as incomplete standard unification, uneliminated safety hazards, and variable supply of key minerals. The battery recycling and utilization system also urgently needs to be improved.

This research is based on the actual industrial landscape, systematically sorts out the layout of the battery industry and the logic of value transmission, clarifies its core role in both the industrial efficiency and social value dimensions, reveals the practical dilemmas intertwined by multiple factors such as technological iteration and safety control, and the research results can provide practical guidance for the high-quality upgrade of the industry, offer feasible paths for ensuring resource supply security and maintaining ecological stability, and possess significant practical value.

Looking forward, with the breakthroughs in solid-state battery technology and the increasingly standardized recycling system, the battery industry will resolve the inherent contradictions between safety and performance, break through the application boundaries of vehicles, and expand into multiple fields such as energy storage, becoming the core support for China to lead global energy transformation and participate in international industrial competition.

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