

Research on Lithium Battery Recycling and Utilization

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ABSTRACT

With the rapid development of new energy, lithium batteries, as one of the key technologies in the field of energy storage, play an important role. However, with the widespread application of lithium batteries, the problem of their disposal has become increasingly prominent, which not only affects the environment but also wastes precious resources. This article analyzes the domestic new energy lithium battery market situation and finds that domestic new energy is developing rapidly and the lithium battery market has huge potential. In terms of lithium battery recycling and utilization, comparison shows that foreign lithium battery recycling technology is relatively mature, but there are certain challenges in adapting to domestic actual conditions and cost control. Although there are some advanced recycling technologies in China, the overall level still needs to be improved.

KEYWORDS

New energy; Lithium batteries; Recycling and utilization; Domestic situation; Technology comparison; Learning and innovation

1. INTRODUCTION

As the global demand for renewable energy continues to grow, the development of new energy technologies has become the key to solving energy and environmental problems. Among new energy technologies, lithium batteries have attracted much attention due to their high energy density, long life and environmentally friendly properties, and are widely used in electric vehicles, energy storage systems, mobile devices and other fields. However, with the large-scale application of lithium batteries, their disposal problems have become increasingly prominent, posing serious challenges to the environment and resources. In the past, due to a lack of environmental awareness and limited knowledge, people often disposed of used lithium-ion batteries by directly discarding or burying them. However, this approach may cause serious pollution to the environment. The cathode materials and electrolytes of used lithium-ion batteries contain a large amount of heavy metals. These heavy metals may enter the food chain through various channels, accumulate toxins, and cause harm to humans and other organisms. Correct disposal of lithium batteries can not only improve the environment, but lithium batteries contain a large amount of heavy metals and have rich recycling value [1].

This article aims to discuss the recycling and utilization of new energy lithium batteries, paying special attention to the domestic situation and conducting a comparative analysis of domestic and foreign recycling technologies. First, we will introduce the importance and development prospects of new energy lithium batteries in the field of energy storage, emphasizing their key role in promoting the development of the renewable energy industry. Next, we will analyze the situation of the domestic new energy lithium battery market, including market size, development trends, and assessment of the current status of recycling and utilization. Subsequently, we will compare the maturity, advantages

and disadvantages of domestic and foreign lithium battery recycling technologies, and explore what can be learned and innovated. Finally, we will put forward some suggestions to promote the development of domestic lithium battery recycling and utilization technology, with a view to promoting the sustainable development of the new energy industry.

2. IMPORTANCE AND DEVELOPMENT OF LITHIUM BATTERIES

2.1. The role and Prospects of New Energy Lithium Batteries in the Field of Energy Storage

With the continuous growth of energy demand and the development of renewable energy, new energy lithium batteries, as an efficient and environmentally friendly energy storage technology, are becoming one of the key technologies in the energy field. New energy lithium batteries can efficiently store renewable energy such as solar energy and wind energy, and release energy when needed to achieve stability and sustainability of energy supply. With the rapid development of new energy electric vehicles, energy storage systems and other fields, the market demand for new energy lithium batteries has shown a continued growth trend. Therefore, the research and development of new energy lithium battery technology is of great significance and plays an important role in promoting energy transformation and sustainable development.

2.2. Types and Structures of Lithium Batteries

In the field of new energy lithium batteries, common types include lithium-ion batteries (Li-ion) and lithium polymer batteries (Li-Polymer). Lithium-ion batteries realize charge and discharge by the reciprocating movement of lithium ions between the positive and negative electrodes. They have the advantages of high energy density and long cycle life, and are widely used in electric vehicles, energy storage systems and other fields. In contrast, lithium polymer batteries have higher safety and lighter weight, and are suitable for scenarios that have strict requirements on battery volume and weight.

2.3. Importance and Necessity of Lithium Battery Recycling and Utilization

With the widespread application of new energy lithium batteries, the problem of recycling and utilization of used lithium batteries has become increasingly prominent. Used lithium batteries without proper treatment may cause environmental pollution and waste precious resources. Therefore, the effective recycling and utilization of lithium batteries is of great significance. By recycling useful materials from used lithium batteries, resource consumption can be reduced, environmental pollution can be reduced, and raw materials can be provided for the production of new energy lithium batteries. At the same time, continuous innovation and improvement of recycling technology can reduce recycling costs, improve recycling efficiency, and promote the development of circular economy [2].

In this section, we will discuss the role and prospects of new energy lithium batteries in the field of energy storage, introduce the types and structures of lithium batteries, and discuss the importance and necessity of lithium battery recycling and utilization.

3. ANALYSIS OF DOMESTIC NEW ENERGY LITHIUM BATTERY MARKET SITUATION

3.1. Domestic New Energy Development Situation and Trends

China's new energy vehicle market continues to grow, and the main types of power batteries include nickel-metal hydride batteries, lithium-ion batteries and fuel cells. Lithium-ion batteries are the most widely used due to their high energy density. According to different positive electrode materials,

lithium-ion batteries are mainly divided into lithium iron phosphate, NCM ternary and NCA ternary batteries, among which lithium iron phosphate batteries have the highest market share [3]. China's power battery market is growing rapidly. In 2021, the installed capacity of power batteries reached 154.5GWh.

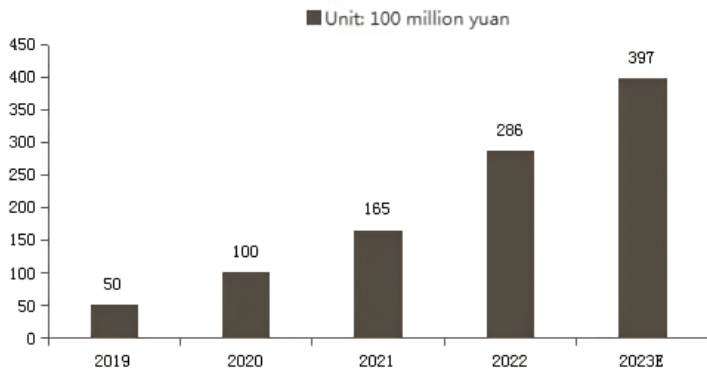


Figure 1. Forecast trend of China's power battery recycling market size from 2019-2023

It is expected that by 2025, China's power battery market will account for about 60% of the world. According to the trend chart, the scale of China's power battery recycling market is expected to reach 39.7 billion yuan in 2023, with a growth rate of 39% . This is mainly affected by the increase in sales of new energy vehicles and the accelerated replacement of power batteries [4].

3.2. Analysis of the Domestic New Energy Lithium Battery Industry Chain

China's power battery industry chain includes lithium, nickel, cobalt, manganese and battery system integrated production. With the continuous development of lithium-ion battery technology, new battery cell and battery system technologies have emerged, such as CTP square batteries and blade batteries, as well as new system structures CTB and CTC. These technologies are expected to improve the energy density and space utilization of power battery systems [3]. While battery technology is advancing, it also faces many problems, such as unstable raw material supply, limited core technology, increased environmental pressure in the production process, unclear division of labor in the industry chain and fierce market competition. Among them, the uncertainty of raw material supply affects production stability, technology is limited to improve product performance, environmental pressure requires green transformation of the industry chain, and unclear division of labor in the industry chain and fierce market competition lead to narrowing profit margins, which restricts the coordinated development of the industry chain.

4. COMPARISON AND ANALYSIS OF LITHIUM BATTERY RECYCLING TECHNOLOGIES AT HOME AND ABROAD

4.1. Overview of Domestic Lithium Battery Recycling Technology

Domestic lithium battery recycling technology covers many fields such as physics, chemistry and engineering .

4.1.1. Chemical methods

Chemical precipitation method : Add a precipitant to the leach solution to convert the metal ions into insoluble (or slightly soluble) metal salts and precipitate them, thereby separating the metal from the system. The key point of chemical precipitation technology lies in the selection of precipitant and pH control ;

Electrochemical method : By applying an external electric field, the electrode material obtains electrons at the cathode, reducing the valence state of the metal ions, thereby increasing the leaching rate. The recycled products obtained by the electrochemical method have high purity and the process is environmentally friendly. The disadvantages are large power consumption, harsh reaction conditions and high cost. It is difficult to achieve industrialized production [4, 5].

Ion exchange method : A method of enriching or removing a specific ion by exchanging ions on the solid ion carrier with free ions in the solution. The main application in the recycling of used lithium-ion batteries is the separation of metals such as Co and Ni [6].

4.1.2. Physical methods

Pyrometallurgy is a common physical method for lithium battery recycling , and its main steps include crushing, roasting, leaching and electrowinning [7]. First, used lithium batteries are crushed to separate the battery casing and internal electrode materials. Next, the separated electrode material is roasted to remove organic matter and volatile components and convert them into oxides. Then, through acid leaching, the oxide is dissolved to obtain a lithium-containing solution. Finally, lithium is precipitated from the solution through electrowinning or other methods to obtain high-purity lithium products [8]. Pyrometallurgical technology has the advantages of simple process, convenient operation, and low cost, but it also has problems such as high energy consumption and environmental pollution, and needs further optimization and improvement [6].

4.2. Overview of Foreign Lithium Battery Recycling Technology

Foreign lithium battery recycling technologies mainly include physical separation, chemical dissolution, smelting extraction and recycling. Physical separation separates battery components through crushing, screening and other steps, while chemical dissolution uses acid-base treatment or solvent extraction to extract valuable metal materials from waste batteries. Smelting extraction converts the extracted metal materials into usable substances through high-temperature treatment. Finally, recycling uses the extracted metal materials to manufacture new batteries or other products to achieve the recycling of resources. These methods complement each other and can efficiently recover useful substances in waste lithium batteries while reducing the impact on the environment.

4.3. Comparative Analysis of Lithium Battery Recycling at Home and Abroad

There are some significant differences and similarities in lithium battery recycling at home and abroad. In China, lithium battery recycling technology is still in the early stages of development and is mainly concentrated in the physical dismantling and simple chemical treatment stages. The technical level is relatively low and the recycling rate is low. In foreign countries, especially in developed countries, lithium battery recycling technology is relatively mature, and in addition to ordinary physical and chemical methods, there is also a complete set of mixed processing methods that pay more attention to environmental protection and resource utilization efficiency [9].

In addition, foreign lithium battery recycling industry chains and policies are more complete, forming a standardized recycling system [8]. for example:

the United States has established corresponding laws and regulations at the federal, state and local levels to guide the development of power vehicles, standardize the recycling of power batteries, adopt a producer responsibility system, and support the association in formulating a deposit system to encourage consumers to voluntarily hand in used batteries. Promote the construction of power battery recycling network. In terms of recycling, professional technology research and development enterprises are equipped to provide corresponding technical specifications for the production, collection, transportation and storage of used batteries; in terms of finance, a special fund is established to support the end-of-life recycling of products, and additional environmental fees are adopted. The United States The International Battery Association has established a battery recycling

foundation to organize and implement a deposit system among professional recycling companies. Professional recycling companies and battery manufacturers ensure the recycling of used batteries through corresponding fees [7].

In Japan, consumers do not need to pay extra fees to any organization when purchasing power battery products, and they can rent power batteries. Power battery manufacturers can use service networks such as retail merchants, car dealers, scrapped car dismantling companies and gas stations to recycle used batteries from consumers for free, and finally hand them over to professional recycling companies for processing. The processed batteries are ultimately Will return to power battery manufacturers to manufacture new power batteries. At this time, the government will provide certain subsidies to battery manufacturers. Japan's orderly and natural recycling model is based on the government's active guidance and encouragement of enterprise development on the one hand, and the deep-rooted concept of circular economy; on the other hand, it comes from the citizens' good awareness of "voluntary efforts" in recycling [7].

Germany has established relatively mature and complete recycling laws, regulations and operating systems for power battery recycling . In the power battery recycling model, the government is the core of the overall recycling. The government legislates, formulates recycling from the source, clarifies the responsibilities of each link in the production chain, and battery manufacturers and importers must register with the government; dealers participate in the construction of the recycling network, cooperate with the government and manufacturers to layout offline recycling outlets, and actively publicize and introduce free battery recycling locations and related policies to consumers; consumers are obliged to hand over used batteries to designated recycling agencies through a fund and deposit system [7].

However, China is still in the growth stage of emerging industries in terms of lithium battery recycling technology, and is constantly improving. Combined with the development of China's new energy vehicles and battery-related policies and existing problems, China's new energy power battery system has gradually changed from guiding policies to specific implementation methods, and battery technology has gradually adapted to the needs of the market and enterprises. This is inseparable from the government's support for research and development and industrial structure, especially the support for safety supervision construction after mass production of power batteries, which guarantees consumption and is conducive to getting rid of the passive development model.

5. WHAT CAN BE LEARNED AND INNOVATED IN LITHIUM BATTERY RECYCLING TECHNOLOGY AT HOME AND ABROAD

5.1. Reference and Learning From Foreign Advanced Recycling Technologies

5.1.1. Learn new technologies

China can learn from the comprehensive application and improvement of recycling technology in foreign countries, establish a more complete recycling system for waste lithium batteries, improve the recycling rate and resource reuse rate, and strengthen technical research and development and policy support to promote the development of China's lithium battery recycling industry. By deeply understanding the principles and application cases of foreign leading technologies, we can master their advanced recycling methods and technical paths. For example, the hybrid technology in foreign lithium battery recycling technology is a technology that comprehensively utilizes multiple recycling methods and process flows, which has not yet been realized in China. We can also obtain the latest research results and technical trends through international conferences, academic journals, professional reports and technical exchanges. At the same time, we need to establish international cooperation relations and attract foreign experts and institutions to participate in domestic scientific

research projects and technical cooperation to jointly promote the innovation and development of lithium battery recycling technology [7].

5.1.2. Learn useful policy experience

the policies and methods of lithium battery recycling in the United States, Japan, and Germany , we can learn from the following:

Establish laws and regulations : At the national, state and local levels, laws and regulations should be adopted to clarify policies, standards and requirements for power battery recycling, including recycling obligations, recycling processes and responsibility allocation for used batteries. Establish a producer responsibility system, require battery manufacturers and importers to assume the responsibility for recycling used batteries, and set up a special regulatory agency to supervise and manage recycling work. Develop industry standards and certification systems, standardize recycling technologies and processes, and improve recycling efficiency and quality. Strengthen publicity and education, increase the public's and enterprises' awareness and attention to power battery recycling, and promote the development of recycling work [7].

Deposit system : The deposit system can encourage consumers to actively participate in the recycling of used batteries, promote the effective recycling and reuse of used batteries, and at the same time constrain the behavior of production and sales companies, encouraging them to establish a sound recycling network and mechanism. The government actively guides enterprises and all sectors of society to participate in the recycling of power batteries through tax incentives, financial subsidies and other measures. At the same time, it strengthens publicity and education, improves public awareness of environmental awareness, and creates an atmosphere in which the whole society pays attention to and supports the recycling of used batteries [7].

National awareness: The cultivation and improvement of national awareness is crucial in power battery recycling work. The government can increase public awareness and emphasis on power battery recycling by carrying out extensive publicity and education activities. This includes using various media platforms for publicity, holding waste battery recycling activities and exhibitions, organizing special lectures and training, etc. At the same time, the government can also formulate relevant laws, regulations and policies, emphasize the environmental protection responsibilities and obligations of citizens, and encourage residents to actively participate in the recycling and processing of used batteries, thereby forming a good atmosphere in which the whole society pays attention to and supports the recycling of power batteries [7].

Improvement through China's national conditions: Improvement through China's national conditions means formulating policies and measures that are more suitable for China's national conditions while taking into account the specific domestic environment and conditions. This includes taking into full account China's industrial structure, resource conditions, technological level, economic development stage and other factors, and formulating corresponding policies and measures to promote the smooth development of power battery recycling. For example, in view of China's economic structure and industrial development status, it is possible to formulate industrial development plans and technological innovation policies to encourage enterprises to increase research and development and investment in power battery recycling technology. At the same time, it is possible to strengthen cooperation between the government and enterprises, establish a sound policy support system and industrial standards, and improve the technical and management levels of power battery recycling. In addition, it is also possible to strengthen international cooperation and exchanges, learn from foreign advanced experience and technology, and promote international cooperation and development in power battery recycling.

5.2. Innovation and Development of Existing Domestic Technologies

5.2.1. Process Optimization

Domestic enterprises have improved the recycling efficiency and resource utilization rate by optimizing and improving the existing recycling process. For example, the process of recovering nickel and cobalt by oxygen-enriched pressure leaching has been successfully applied to the production process of recovering nickel and cobalt from dealuminized slag. Ni and Co are basically leached into the leaching solution, with an average leaching rate of Ni of 99.6% and an average leaching rate of Co of only 98.35%. The Ni content in the leached slag is less than 0.5%, and the Co content is less than 0.0 [8].

5.2.2. Equipment Improvement

Domestic enterprises have developed a series of efficient and environmentally friendly recycling equipment, such as automated sorting equipment, efficient crushing equipment and intelligent separation equipment, etc. These equipment have higher production efficiency and lower energy consumption, and can meet the needs of large-scale lithium battery recycling.

5.2.3. Comprehensive Utilization of Resources

Domestic enterprises are committed to developing diversified comprehensive resource utilization technologies to further process and utilize the valuable materials recovered. For example, recycled metals, plastics, and electrolytes are recycled to produce new materials or chemical products, thus realizing the recycling of resources.

5.2.4. Technological innovation

Domestic enterprises have made a series of technological innovations in the field of lithium battery recycling, such as intelligent recycling systems based on artificial intelligence, automated sorting systems based on machine vision, etc. These innovative technologies have improved the automation and intelligence level of the recycling process and reduced labor costs and operational risks.

5.2.5. Industry Chain Integration

Domestic enterprises have built a complete lithium battery recycling industry chain and formed an integrated recycling system by integrating upstream and downstream industry chain resources. These enterprises not only have perfect recycling processes and equipment, but also have the ability to collect, disassemble, sort and reuse waste batteries, realizing closed-loop management of the entire process from waste batteries to new materials.

6. CONCLUSION AND OUTLOOK

There is huge innovation potential and future development trends in the field of lithium battery recycling technology. Through a comparative analysis of domestic and foreign lithium battery recycling technologies, we found that foreign technologies are relatively mature, but there are still challenges in adapting to domestic actual conditions and cost control. Although there are some advanced technologies in China, the overall level still needs to be improved. Future development directions include intelligence, greenness, efficiency and comprehensiveness to meet market demand and environmental protection requirements. Policy support and market demand are important driving forces for the development of lithium battery recycling technology. The government has introduced a series of supporting policies, and the market demand for lithium battery recycling technology continues to increase. Future development will focus more on technological innovation and comprehensive utilization of resources to achieve efficient extraction and reuse of various valuable materials in used lithium batteries. Based on the above findings and conclusions, it can be concluded that lithium battery recycling technology is an area with huge development potential and market

prospects, and is expected to achieve the dual goals of environmental protection and resource recycling.

With the widespread application of new energy lithium batteries, the demand for their recycling and utilization will continue to increase. In the future, the country can further improve the level of lithium battery recycling and utilization technology through technological innovation and policy support, and achieve efficient use of resources and the development of a circular economy. In order to promote the healthy development of the new energy lithium battery recycling and utilization industry, it is recommended that the government increase investment in related fields, formulate more complete regulations and policies, encourage enterprises to strengthen technology research and development and innovation, and increase recycling and utilization rates. At the same time, strengthen international cooperation and exchanges, learn from advanced foreign experience, and promote the rapid development of my country's new energy lithium battery recycling and utilization technology.

REFERENCES

- [1] Cui, S. (2024). Research on risk management of ZW company's power battery recycling business. Thesis of Henan University of Technology.
- [2] Li, J., Tian, Y., Yang, B., et al. (2023) Current status of research on valuable metal recycling of waste lithium-ion battery cathode materials. *Journal of Chinese Nonferrous Metals*. *Chinese Journal of Nonferrous Metals*, 34.
- [3] Zan, X. (2023). Analysis of the development status and trends of key technologies for domestic new energy vehicles. *Internal Combustion Engines and Accessories*, 17: 112-114.
- [4] Weng, Y., Long, G., Li, Y., et al. (2022). Research progress and development trends of comprehensive recycling of retired power batteries. *Biochemical Engineering*, 06:139-146+152.
- [5] Qi, X., Wen, J., Yang, J. (2023). Progress in recycling technology of cathode materials for new energy vehicle power batteries. *Modern Chemicals*, 03:51-56.
- [6] Pang, Z., He, Y., Wei, N., et al. (2023) Current status of retired lithium-ion battery recycling technology and regeneration technology. *Battery*, 5.
- [7] Liu, H. (2022). Research on waste new energy power battery recycling system. Thesis of Shanghai Second Polytechnic University.
- [8] Peng, X. (2023). Research on new wet recovery process of valuable metals from waste nickel-cobalt-manganese ternary lithium battery cathode materials. Thesis of Kunming University of Science and Technology.
- [9] Sun, M. (2024). Research on the recycling potential and environmental impact assessment of new energy vehicle power batteries in Shandong Province under the dual-carbon background. Thesis of Qilu University of Technology.