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Suggestions on Speeding up Recycling of Power Battery for New Energy Vehicles in China

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Abstract: Under the guidance and support of national policies, the new energy vehicle industry in China is developing rapidly. It is estimated that the number of new energy vehicles will exceed five million by 2020. The ensuing battery recycling problem of the new energy vehicle has become a major issue. Power batteries without effective recycling will result in serious environmental pollution and a waste of resources. The United States, Germany, Japan, and other developed countries have planned for power battery recycling. After extensively analyzing the existing problems of power battery recycling, this study proposes concrete suggestions for accelerating the development of power batteries for new energy vehicles.
Keywords: new energy vehicle; power battery; recycling

1 Introduction

China has proposed a national strategy for vigorously developing new energy vehicles to protect the national energy security, ease the contradiction between fuel supply and demand, reduce exhaust emissions, and improve the atmosphere [1]. China's new energy vehicle market has been rapidly developing in the recent years.

The sales of new energy vehicles in China have reached 777 000 units in 2016. The cumulative promotion of new energy vehicles has exceeded 1.7 million units, accounting for more than 50% of the stock of the global new energy vehicle market. As such, China is the global leader in the new energy vehicle market. The rapid development of new energy vehicles has also caused some new problems. It is predicted that the power battery scrap in 2020 will exceed 2.48×10^5 t, which is approximately 20 times that in 2016. China's power batteries will usher in a "scrap tide."

The resulting resource and environmental issues will become increasingly prominent. On the one hand, chemical elements such as nickel, cobalt, and lithium required for the manufacture of power batteries are rare worldwide and difficult to extract. On the other hand, the composition of used power batteries is complex; therefore, their improper disposal will cause significant hazards to the environment, thereby threatening human health [2]. Therefore, it is necessary to increase the total lifetime value of power batteries and ensure proper recycling and disposal of used power batteries to avoid "secondary pollution." This has become an important topic in the development of new energy vehicles. Not only can promoting the recycling of power batteries for new energy vehicles help save resources, protect the environment and social safety, but it can also meet the development requirements of China's circular economy. Therefore, it is of great significance to the healthy development of China's new energy vehicle industry and the construction of ecological civilization.

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2 Recycling of power batteries for new energy vehicles in other countries

2.1 The United States: establishing a sound legal framework for power battery recycling

The United States has established a sound legal framework for the recycling of power batteries from the federal, state, and local levels. At the federal level, licenses are used to supervise battery manufacturers and used battery recycling enterprises, and the *Mercury-Containing and Rechargeable Battery Management Act* is used to regulate the production and transportation of used batteries. At the state level, most states adopt the battery recycling laws proposed by the Battery Council International, and use the price mechanisms to encourage retailers, consumers, etc. to participate in the recycling of used batteries. For example, the NYS *Rechargeable Battery Recycling Law* and the California *Rechargeable Battery Recycling Act* impose mandatory requirements for rechargeable battery retailers to recall used rechargeable batteries from consumers for recycling at no cost. At the local level, most U.S. municipalities have established laws for recycling power batteries to reduce the environmental hazards caused by used batteries. The Battery Council International has promulgated a battery product management law. It has set up a battery recycling deposit system to encourage consumers to collect and hand in used batteries. Meanwhile, the United States has actively conducted the research on the cascaded use, recycling technologies, and processes of power batteries. Research has also been conducted on the cascaded use and systematic aspects of on-vehicle power batteries, including the evaluation of the economic benefits of power battery recycling and the promotion of recycling technologies, as shown in Fig. 1.

2.2 Germany: building a sound power battery recycling system

Germany has achieved remarkable results in the legal system, responsibility division, and technical path of power battery recycling. According to the EU *Waste Framework Directive*, *Battery Directive,* and *End of Life Vehicle Directive*, Germany has formulated the circular economy law, battery recycling act, and end-of-life vehicle recycling act. Under the legal framework, clear responsibilities are divided for each link in the recycling system of used power batteries. Manufacturers, consumers, and recycling companies in the industry chain have the corresponding responsibilities and obligations. In addition, Germany emphasizes the extended producer responsibility (EPR) system. New energy vehicle manufacturers such as Volkswagen and BMW have actively implemented the recycling of used power batteries. BMW, together with a power company, plans to establish a peak-valley mechanism to apply used batteries to energy storage. To further analyze the effectiveness of different recycling technologies for power batteries, the German Ministry of Environmental Protection has funded demonstration projects using pyrometallurgical and hydrometallurgical recycling technologies, as shown in Fig. 2.

2.3 Japan: globally leading technology of power battery recycling

Owing to the lack of raw material resources, Japan leads the world in recycling used power batteries. Since 1994, Japan has initiated a power battery recycling program and established a power battery recycling system from production to sales, and then to recycling, and finally to regeneration treatment.

To standardize the development of the recycling of used power batteries for vehicles, Japan has issued the corresponding laws from three levels: basic law, comprehensive law, and special law. These laws have stipulated that new energy vehicle manufacturers are obliged to undertake the recycling and treatment of power batteries, and have encouraged large automobile manufacturers to attach the importance of the research of vehicle power battery recycling technologies. Automobile manufacturers including Toyota, Nissan, and Mitsubishi have actively invested

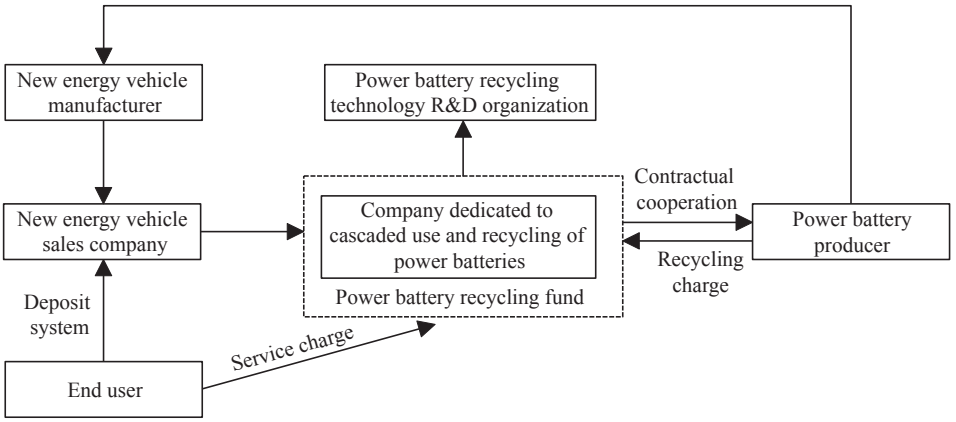

Fig. 1. Power battery recycling system in the United States.

in the R&D of power battery recycling. The frequent occurrence of natural disasters in Japan renders it easier to accept and popularize emergency power supplies. With the help of automobile companies, an increasing number of homes and businesses are using retired new energy vehicle power batteries as emergency power supplies. In Japan, the power battery recycling model led by production companies has enabled new energy automobile manufacturers to attach the importance of power battery recycling, and has driven them to perform original innovations at the product R&D and design stages, thereby increasing the recycling efficiency, as shown in Fig. 3.

3 Issues in recycling power batteries for new energy vehicles in China

3.1 Imperfection of top-level design, and laws and regulations for power battery recycling

First, specific and systematic development plans and top-level designs have not yet been launched in terms of power battery recycling, thus restricting the technological R&D of related companies and hindering the cascaded use of used power batteries. Subsequently, China has no special legislation for the recycling of power batteries for new energy vehicles, and lacks the entry conditions and management measures for recycling companies. Some of the existing power battery recycling plants adopt the extensive development model and outdated technological processes, and have weak environmental awareness, thus limiting the sustainable and healthy development of used power battery recycling [3]. Finally, power batteries have not yet been standardized. The shape, core composition, and shell material of power batteries are all different. This has caused difficulties to recycling, and has also hindered the industrialization of the related companies.

3.2 Lack of a power battery recycling system in China

Currently, China's power battery recycling system is still imperfect. China lacks a system for managing the recycling, transportation, dismantling, and comprehensive utilization of power batteries. Consequently, the competition in the used battery recycling industry is disorderly, and severe environmental pollution and waste of resources are caused during the recycling process, which hinders the development of the industry [4]. In addition, the *Technical Policy for Recycling of Power Batteries for Electric Vehicles* (Edition of 2015) was jointly released by five ministries, i.e., the National Development and Reform Commission, Ministry of Industry and Information Technology, Ministry of Ecology and Environment (formerly the Ministry of Environmental Protection), Ministry of Commerce, and General Ad-

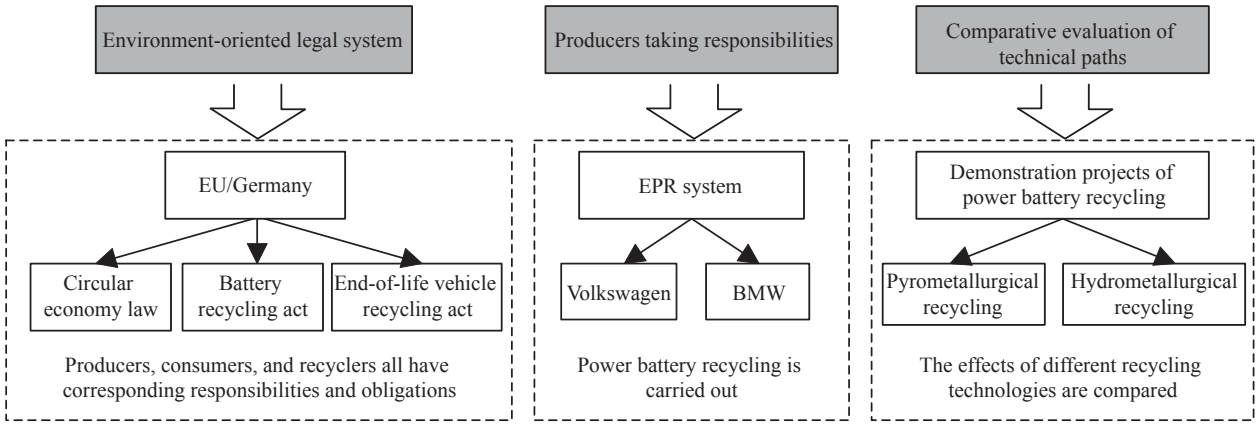

Fig. 2. Power battery recycling system in Germany.

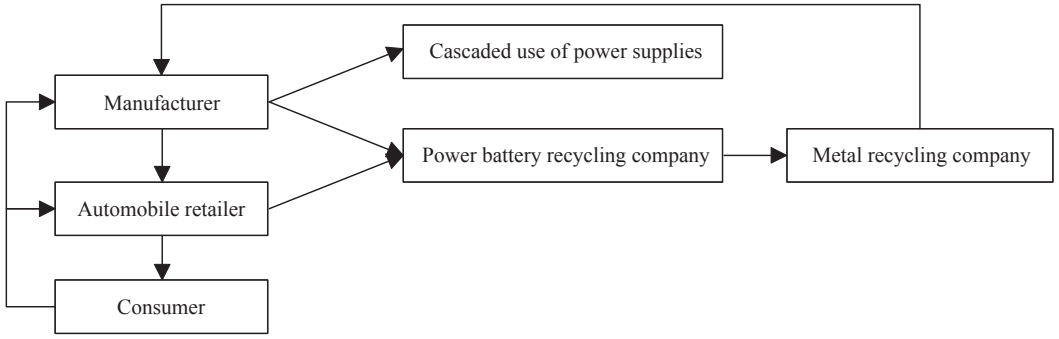

Fig. 3. Power battery recycling system in Japan.

ministration of Quality Supervision, Inspection and Quarantine. Although this policy has clearly defined that electric vehicle and power battery manufacturers are responsible for the recycling of power batteries, it has not been effectively implemented, leaving the entire recycling system in a disordered state. Consequently, the recycling and disposal rates of used power batteries are low in China and a severe waste of resources exists. The shortage of raw materials such as lithium, cobalt, and nickel has exacerbated the price increase and environmental pollution.

3.3 Low level of the power battery recycling technologies and processes

On the one hand, the recycling process route for power batteries is still at the exploratory stage, and recycling technologies aiming at circular manufacturing have not yet been realized [5]. On the other hand, the recycling of power batteries still remains at the waste disposal stage, and the research on resource recycling technologies and lithium-ion battery recycling technologies has not yet been conducted. No specific measures and equipment guarantees exist for the safety and environmental issues involved in the recycling of lithium-ion batteries [6].

3.4 Difficulty in profitability of power battery recycling

First, retired power batteries are directly treated as end-of-life batteries owing to the lack of a cascaded use channel, thus resulting in significant economic loss. Subsequently, the recycling of power batteries includes multiple steps such as discharge, disassembly, smashing, and extraction, requiring great investment in equipment and labor. Therefore, it is difficult for the related companies to garner profits without creating a scale effect. Finally, the structure of power batteries varies greatly among different automobile companies, and the material system of power batteries also differs, thereby increasing the recycling difficulty and recycling costs.

4 Suggestions on recycling of power batteries for new energy vehicles in China

The new energy vehicle power batteries promoted for use at earlier stages are about to enter their end-of-life stage, while the retired power batteries still maintain approximately 80% of the initial energy. Therefore, effectively recycling new energy vehicle power batteries is of great significance for rendering resources intensive, protecting the environment, and increasing the total lifetime value of power batteries.

4.1 Accelerating the top-level design, and law and regulation formulation for the recycling of power batteries

First, the top-level design and prospective layout must be performed excellently in terms of law, regulation, and standard formulation for power battery recycling, and specific demonstration applications for power battery recycling must be deployed. Next, laws and regulations should be formulated for the recycling, transportation, and storage of used power batteries; the standards should be systematically streamlined and stipulated for the structure design, connection methods, process technologies, and integrated installation of power batteries to ensure the consistency, safety, and economy of power batteries during disassembly and testing; industry-related companies should be encouraged to participate in the standard setup. Finally, the power battery coding system and traceability system should be further enforced to ensure the information records of the whole life cycle of the power battery and improve the accuracy and convenience of monitoring and evaluation; this will standardize and guide the large-scale and orderly development of the power battery recycling industry.

4.2 Building a power battery recycling management system

Information technologies such as the Internet of Things and big data should be fully utilized to build a large-scale, highly efficient, and traceable used power battery recycling management system. The management system should primarily include original equipment manufacturers (OEMs), new energy vehicle sales companies, consumers, power battery recycling companies, and power battery manufacturers. The EPR system should be actively implemented. Automobile manufacturers must be responsible for the recycling of batteries when they sell new energy vehicles. The consumers' awareness of recycling of used batteries should be increased through the deposit system as well as publicity and training. Consumers should be actively encouraged to participate in the recycling of power batteries. Power battery recycling should follow the principle of limited cascaded use. Based on the power battery health assessment technology, significant efforts should be conducted to recycle the remaining value of power batteries. Elements with high extraction value should be recycled, thus forming a closed-loop industrial chain of power batteries, maximizing the use of resources, and minimizing environmental pollution.

4.3 Increasing efforts in the R&D of power battery recycling technologies

First, automated dismantling technologies for power battery cells, battery modules, and packs should be developed to achieve low-loss, low-input, high-efficiency, and intelligent dismantling, to improve the physical recycling rate of low-value metals such as copper, iron, and aluminum. Automated dismantling equipment should also be developed for power battery cells, modules, and packs. Next, cathode and anode material recycling technologies should be developed to significantly increase the recycling rates of nickel, cobalt, manganese, and graphite; targeted cycle

technologies for high-value chemical materials such as nickel, cobalt, and manganese should also be developed to form a sustainable circular economy development model. Subsequently, research on lithium-ion battery recycling technology should be conducted to provide safety and environmental protection measures and equipment guarantees for lithium-ion battery production. Finally, a power battery health assessment technology with high accuracy and wide application should be established to accurately assess the service life of power batteries.

4.4 Promoting the commercialization of power battery recycling

First, incentive regulations for the recycling of power batteries should be formulated, and a clear reward-and-punishment mechanism should be established. It is suggested that subsidies and tax preferences be offered to power battery recycling companies based on the battery pack quantity and capacity at the early stages to ensure the economy of the recycling companies. Next, the efficiency of the recycling of power batteries should be assessed. The costs of the power battery assembly technology should be analyzed, as well as the economic and social benefits in reuse scenarios. Based on this analysis, pilot demonstrations of innovative business models should be conducted to promote the development models of a valued circular economy. Subsequently, the scenarios and potential markets of the cascaded use of power batteries should be actively explored, including energy storage, smart grid peak load shaving, distributed power supply in remote areas, backup power supplies for communication base stations, and household power supply regulation. Finally, the power battery recycling channel should be extended. The "Internet + power battery recycling," O2O, APP, WeChat, and other sharing modes should be considered to fully explore the recycling value of used power batteries to achieve the intensive use of resources.

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