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Overview of the Development of China's New Energy Vehicle Power Battery Gradient Utilization

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Abstract

In recent years, the development of new energy vehicles in China has been rapid, and the production volume of new energy vehicles accounts for about half of the global production volume. At the same time, the power battery, which is the core component of new energy vehicles, is about to reach the climax of retirement. Therefore, promoting the secondary utilization of retired power batteries is of positive significance to the sustainable development of the economy and resources, environmental protection, and energy-saving. This paper mainly summarizes the latest status of power battery recycling in China and related policy documents, discusses and analyzes the main application scenarios of power batteries, the main processes of recycling, and the main technical bottlenecks faced at the current stage, and finally summarizes and outlooks the situation of power battery recycling.

Keywords

New Energy Electric Vehicles; Retired Power Battery; Echelon Utilization.

1. Introduction

After nearly a decade of development, the development of China's new energy electric vehicle industry has become increasingly mature, and the development of various supporting facilities is in full swing, and the public's acceptance of electric vehicles has generally increased. Reflected in China's electric vehicle production from 2010-2020 except the 2019 year by year steadily increasing, as shown in Figure 1 2019 and 2020 China's new energy vehicle production were 1,242,000 and 1,366,000, as of July 2021 production of 1,504,000 units. With the increase in the production of electric vehicles, it is expected that by 2025 the retirement of China's power lithium batteries will reach 730,000 tons.

The Battery system is one of the core components of electric vehicles, and the life span of early batteries is generally 5-8 years, so China will gradually enter the climax of power battery retirement. Generally speaking, when the remaining capacity of the battery is about 80% of that of a new battery, the power battery of an electric vehicle faces retirement. And although the retired power batteries cannot meet the requirements of electric vehicles, they still have great utilization value, and the secondary utilization of retired power batteries at this time can effectively promote resource conservation and environmental protection[1]. The retired batteries are tested and estimated, and after re-matching into groups according to different battery group states, they can be used in various application scenarios such as communication base station backup power, distributed energy storage, low-speed electric vehicle, emergency power rescue vehicle energy storage, oil extraction equipment energy storage, and scenic street light energy storage.

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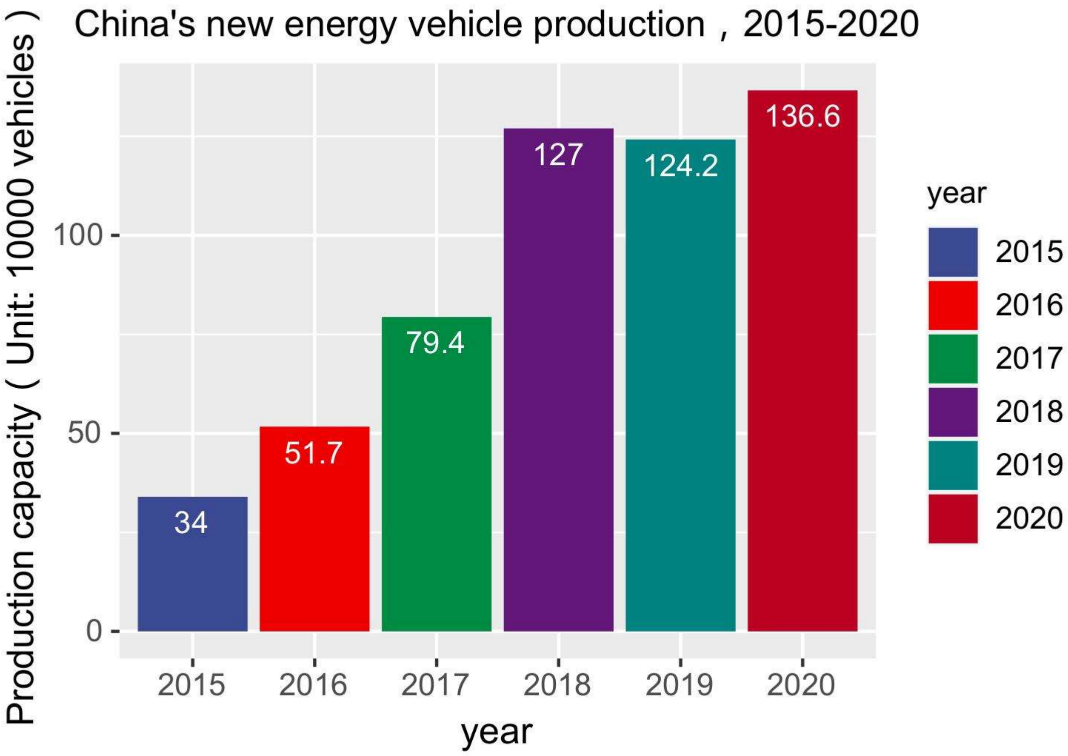

Figure 1. China's new energy vehicle production, 2015-2020

2. The Current Situation of Power Battery Gradient Utilization of New Energy Vehicles

Although China started the research on power battery recycling late, thanks to the vast market in China, the research on retired power battery recycling is in full swing at this stage. Jiangsu Province, Anhui Province, Hunan Province, and Sichuan Province have established power battery recycling industry alliances, which can fully mobilize and integrate various market elements such as talents, technology, and capital, providing strong support for the construction of recycling system. In addition, many gradient utilization projects have been put into use in recent years, For example, in 2017, the 2mwh lithium iron phosphate battery energy storage project of Shanghai Denshi Ba New Energy Technology Co., Ltd, in 2019, the demonstration project of Nanjing Jiangbei energy storage power station, in 2019, the demonstration project of Gansu Province new energy vehicle power battery gradient utilization undertaken by Lanzhou Lan Shi Enli Microgrid Co., Ltd, in 2020, the megawatt-level large-scale PV wind energy integration gradient utilization energy storage power station of Baojun Base developed by SAIC-GM Wuling Organization was officially put into use, and in 2020, Honda subscribed 1% shares of Contemporary Amperex Technology Co., Ltd, and both parties will cooperate in the power battery and its gradient utilization. In terms of power battery ladder utilization, many enterprises have already carried out industrialization layout, but there is still a distance from the large-scale application, around 2010, the State Grid of China followed the pace of foreign research and laid out the technical research on the ladder utilization of electric vehicle power battery. In March 2021, the first gradient battery utilization energy storage project of State Grid Corporation of China Zhejiang Electric Power Company is scheduled to be put into operation. At present, the only large-scale application in China is the communication base station of China Tower Co. China Tower started to layout power battery recovery and recycling in 2015 and organized 9 provincial (city) branches and 10 manufacturers to build 57 test sites in advance, and the geographical scope of test sites covers the main types of base stations in most areas of the country, which really formed the application on a scale [2], and in 2019 China Tower led the establishment of two power battery recycling industry alliances in Hunan and Sichuan. Already in the country about 300,000 base stations about 4GWh secondary batteries for power backup. 2020 China Tower and BYD cooperation in Shandong to establish a power battery recycling center.

In terms of technology.

Li et al. designed a BP-EKF algorithm based on the Kalman filter algorithm and adaptive BP neural network algorithm to estimate the battery SOC, and the estimation accuracy was significantly improved[3].

Gao Siong et al. used a K-means clustering algorithm to regroup retired power batteries and improved the enterprise stepwise utilization of optional grouping technology, and the performance of the grouped battery modules in terms of capacity and consistency was improved[4].

Han et al. established a model based on the economic evaluation of electric vehicle fast-charging stations and determined the optimal capacity configuration of the ladder battery storage system, considering the current situation that a large number of retired power batteries in China are in urgent need of recycling, combined with the ladder battery energy storage system [5].

Liu et al. established a closed-loop supply chain model for power batteries considering the secondary utilization market under four modes: no subsidy, subsidized recycler, subsidized secondary utilization provider, and subsidized manufacturer and studied the effects of the subsidy target, subsidy amount, and scale effect of recycler on the variables and profit distribution of each node of the supply chain[6].

Zhu et al. designed a set of standard containerized gradient utilization battery energy storage system integration schemes, based on the consistency characteristics of the gradient utilization battery, used a unique common bus active equalization design to realize the transfer of energy between any two batteries, and proposed a multi-factor comprehensive evaluation and analysis equalization strategy based on power bus balancing, which provided an important reference for the large-scale application of power batteries in energy storage systems after retirement [7].

Yan et al. applied the adaptive traceless Kalman filter (AUKF) algorithm to estimate the battery SOC and ohmic internal resistance in real-time and estimated the battery SOH in real-time based on the functional correspondence between ohmic internal resistance and battery SOH [8].

Sun et al. analyzed the configuration scale and its economics of the energy storage system of the terraced battery under different recycling costs and compared the capacity configuration and economics of the new battery storage system to conclude that when the recycling price of the terraced battery is 0, 0.2, and 0.4 yuan/Wh, respectively, there is a suitable configuration capacity of the energy storage system to make the net return of the project investment positive, and when the continuous discharge time of the energy storage system is 8 The NPV of the project is the largest when the continuous discharge time of the energy storage system is 8 h, and the highest ROI is when the continuous discharge time of the energy storage system is 3 h; while the net return of the project investment is always negative when the recycling price of the gradient battery is 0.6 Yuan/Wh[9].

Zhou et al. sorted out and summarized the relevant standards of power battery gradient utilization, analyzed the shortcomings of the existing standards, and proposed improvement measures, which are of practical significance and guidance value to improve the overall level of the industry[10].

Li et al. studied the sorting technology in the process of retired battery secondary utilization and proposed an active-passive cooperative equalization strategy considering the correlation of battery parameters to make up for the shortcomings of a single equalization method and further studied the charge state control strategy of retired power battery storage system to help improve the consistent sorting technology of retired battery secondary utilization [11].

Xu et al. studied the integration and application of retired power lithium batteries in optical storage microgrid system, from the perspective of whole pack utilization, checked the appearance, nameplate, open-circuit voltage, and BMS communication of 80 V-60 A-h battery pack for primary selection, completed the secondary selection of battery pack through charge/discharge test, and grouped the batteries according to their capacity, and combined with multi-channel energy storage converter to group the batteries, The results of the application in the optical storage micro-grid system showed that the battery charging and discharging performance after screening and grouping was normal and had the value of secondary utilization[12].

Zhang Meimei et al. designed a blockchain technology-based power battery recycling scheme to establish a whole-life cycle information storage chain with a consensus mechanism for the lack of whole-life cycle traceability of power batteries and unclear residual performance of batteries, which led to high transaction costs of the battery laddering enterprises and could not accurately correspond to the target application scenarios. Simulation results show better economic benefits [13].

3. Policy Research

In order to promote the standardized and efficient development of the new energy vehicle power battery recycling industry, China has issued a number of policy documents, laws and regulations to guide, regulate and promote the development of the retired power battery recycling industry.

In June 2009, in order to regulate the new energy vehicle market, the "New Energy Vehicle Production Enterprises and Product Access Management Rules" were introduced.

In 2012, China's State Council issued the "Energy Conservation and New Energy Vehicle Industry Development Plan (2012-2020)", proposing the establishment of a power battery gradient utilization and recycling management system.

In January 2016, China's National Development and Reform Commission, Ministry of Industry and Information Technology, Ministry of Environmental Protection, Ministry of Commerce, and General Administration of Quality Supervision, Inspection, and Quarantine jointly issued the "Technical Policy on Power Battery Recycling (2015 Edition)".

In February 2018, the Shanghai Municipal Government mentioned in the "Implementation Measures to Encourage the Purchase and Use of New Energy Vehicles" that new energy vehicle manufacturers should fulfill relevant commitments and responsibilities, comply with relevant national and local regulations, and access relevant data on vehicles and power batteries to the public data collection platform designated by Shanghai, so as to jointly maintain a healthy and safe environment for the use of new energy vehicles in Shanghai.

In February 2018, the "New Energy Vehicle Power Battery Recycling Pilot Implementation Plan" was released, making it clear that pilot recycling of new energy vehicle batteries will be carried out in key areas. Support China Tower Company and other enterprises to combine the pilot work in each region, give full play to their own advantages, and carry out the construction of power battery gradient utilization demonstration projects.

In July 2018, the Ministry of Industry and Information Technology officially "released the Interim Regulations on the Management of New Energy Vehicle Power Battery Recycling and Utilization Traceability", requiring the establishment of a "national monitoring and power battery recycling and utilization traceability integrated management platform for new energy vehicles" to monitor the production, sale, use, end-of-life, recycling and utilization of batteries and the fulfillment of recycling responsibilities by the main body of each link.

In April 2019, the “General Office of the Ministry of Industry and Information Technology General Office of the National Development Bank on Accelerating Industrial Energy Conservation and Green Development Notice” was released, clearly supporting the development of retired new energy vehicle power battery gradient utilization.

In 2020, the "New Energy Vehicle Industry Development Plan (2021-2035)" was released to the public, proposing to support the innovative application of power battery gradient products in the fields of energy storage, energy preparation, charging and power exchange based on the sustainable development of new energy vehicles.

In 2021, the Ministry of Industry and Information Technology, the Ministry of Science and Technology, the Ministry of Ecology and Environment, the Ministry of Commerce, the General Administration of Market Regulation, and other five departments jointly formulated the

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"Management Measures for the Gradient Utilization of New Energy Vehicle Power Battery" to encourage gradient utilization enterprises to develop and produce gradient products applicable to base station power backup, energy storage, charging and power exchange, etc.

In September 2021, the National Energy Board issued the "New Energy Storage Project Management Specifications (Interim)", which allows new power battery storage projects, but in principle, no new large-scale power battery storage projects before the key breakthroughs in battery consistency management technology and sound power battery performance monitoring and evaluation system.

China's new energy vehicle production and sales account for about fifty percent of the world, the scale of the recycling of retired power batteries for new energy vehicles is huge, but so far, because the new energy vehicle power battery retirement tide has just begun, the problem of consistency of retired batteries, power battery performance monitoring and evaluation system is not sound, retired power battery recycling system is not complete, more guiding policy documents are needed to guide.

4. Analysis of the Main Application Scenarios of Retired Power Batteries for Energy Vehicles

The capacity of the power battery is still about eighty percent after decommissioning. Compared with traditional lead-acid batteries, lithium-ion batteries have a higher energy density, long service life, can be rapidly charged and discharged, are energy-saving and pollution-free, as shown in Figure 2, and can be applied to a variety of applications scenarios.

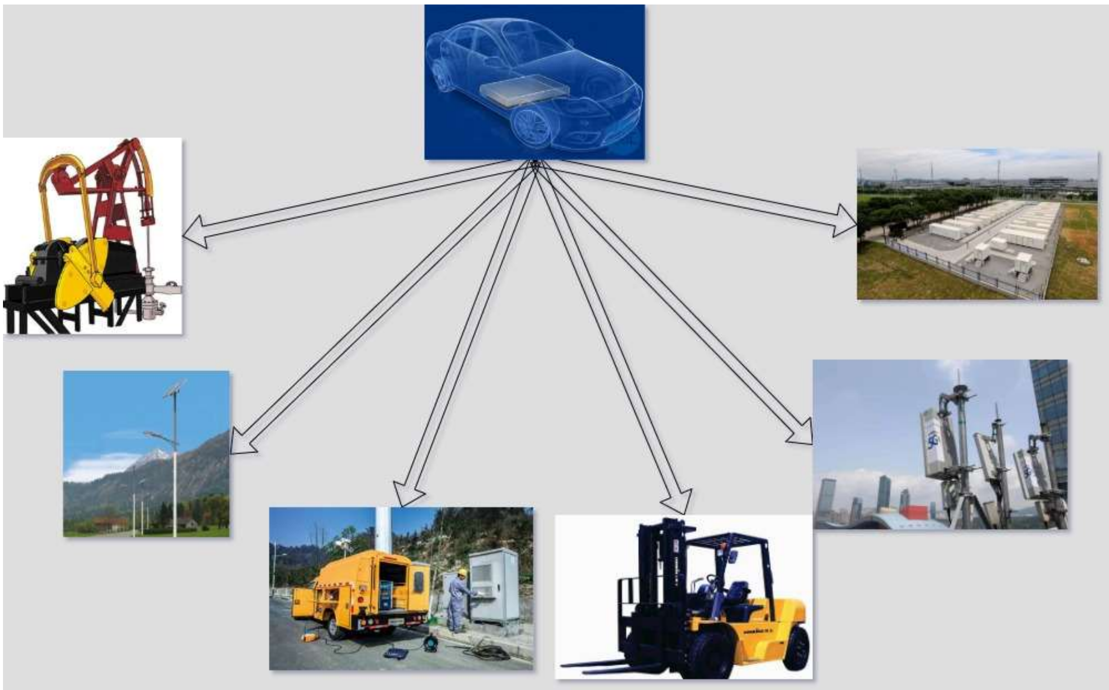

Figure 2. Scenario analysis of ladder utilization

(1) Applied to the energy storage system of the communication base station. Based on the advanced layout of China Tower Company, the energy storage system composed of retired power batteries to replace traditional lead-acid batteries is widely used in the energy storage of communication base stations and has reached a scale application. 2018 China Tower Company signed a strategic partnership agreement with 16 enterprises such as Gotion High-tech Co., Ltd, Chongqing Chang'an, and BYD for the recycling of new energy vehicle power batteries. The retired power batteries of the above enterprises are used to replace traditional lead-acid batteries for communication base station energy storage.

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(2) Application to distributed energy storage. The distributed energy storage system can be divided into three parts: power side, grid side, and user side. It can realize multiple application scenarios such as centralized renewable energy grid connection, combined thermal power frequency regulation; paid peak regulation, independent frequency regulation; peak shaving and valley filling, demand management, power quality optimization, etc., respectively [14]. Like the completion of Nanjing Jiangbei energy storage power station in 2019 on the grid side, which is the first grid-side energy storage power station in China for gradual utilization, the user side like the energy storage project for gradual utilization of retired power batteries in Liyang, Jiangsu, and the Nansha microgrid project on the power station side can realize seamless switching of unscheduled grid-connected to the isolated grid within 50 mm, intelligent switching of four grid-connected/solitary grid operation modes, gradual utilization of retired power batteries, and isolated grid operation capability for one week [15].

(3) Application to low-speed electric vehicles. Electric vehicles have high requirements for power batteries, and generally, when the battery capacity is still about eighty percent, the power battery faces retirement, but at this time the battery still has great economic value, and for low-speed electric vehicles, the requirements for batteries are relatively low, so using retired batteries from new energy electric vehicles for low-speed electric vehicles is also an application scenario. For example, the State Grid Company of China Zhejiang Electric Power Company restructured the retired power batteries of electric vehicles for a 48v electric bicycle power supply [16]. China State Grid Beijing Electric Power Company and Beijing University of Technology and Beijing Pride New Energy Battery Technology Co., Ltd. have used retired power batteries to demonstrate retrofitting on electric field vehicles, electric forklifts, and power substations DC systems for low-speed electric vehicle power sources and grid energy storage.

(4) Application to rail train energy storage power supply. It can be applied to DC side voltage regulation and regenerative braking energy recovery when the train is running. When the DC side voltage is too high, it collects excess energy and stores it, when the train is braking, it can store feedback energy, and when the train starts and is in traction, it can release energy for the train to accelerate.

In addition to the scenarios described above, retired power batteries for new energy vehicles can also be used for power supply for emergency vehicles, energy storage for oil extraction equipment and many other applications.

5. Gradient Utilization Process and Technical Difficulties

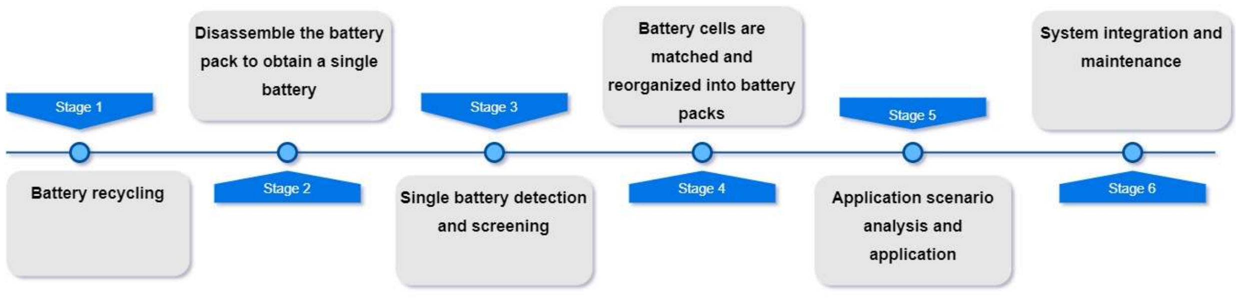

Figure 3. Main steps of laddering

At the current stage, China's retired power battery consistency management technology has not yet made a key breakthrough, and the power battery performance monitoring and evaluation system are not yet sound, still facing many technical problems.

The gradual utilization of retired power batteries usually consists of the following steps.

(1) Battery recycling.

(2) Disassembling the battery pack to obtain the battery monomer.

(3) Battery monomer testing and screening.

(4) Matching and reorganization of battery cells into battery packs.

(5) Application scenario analysis and application.

(6) System integration and operation and maintenance.

In the process of new energy electric vehicle power battery secondary utilization, the testing and screening process is the key, and also the technical bottleneck. We first need to obtain the cell process data, production process data, factory and retired battery surface integrity, factory and retired battery internal structure, factory, use process, and retired battery electrical characteristics data, and so on, and then use the original data and the data measured at this stage to evaluate the SOC, SOH, SOE, SOF and other states of these retired power batteries through data algorithms. Due to the inconsistency between the recovered power battery units, it is necessary to test each battery unit to ensure that the health status and remaining utilization value of each unit are mastered and the specific status of each battery cell is mastered, but in general, battery groups with standard manufacturing, complete coding records and little difference in use scenarios and time can be tested in groups. In addition, because the first batch of power batteries was not designed at the very beginning to consider the problem of gradual utilization after decommissioning, coupled with the imperfect production specification system, resulting in the existence of power battery size is not uniform, uneven models, coding, imperfect records, and other problems. It is impossible to trace the whole life cycle of power batteries, and it is very difficult to detect and screen them.

When conducting usage scenario analysis, it is necessary to analyze each user's performance requirements and price requirements for batteries, establish a data analysis database including cost models, analyze data from various aspects, segment the application scenario market, and achieve the best matching utilization.

The system integration process is faced with the integration of different types of battery cells. The system integration process is divided into three major parts: processing, assembling, and packaging. The individual cells are welded and assembled in series or parallel into a battery pack and matched with the corresponding battery management system. In addition to the above inconsistencies between the cells, the integration process needs to consider the mechanical strength of the entire battery pack, system matching, thermal failure, and other issues, involving thermal management, current control and detection, module assembly design, and computer virtual development and a large number of mature technology cross-collaboration, the operation is more difficult.

The three main technical supports in the design of the BMS battery management system are parameter detection and analysis, SOC initial value estimation, and equalization control design. The working parameter detection covers various aspects, the most important of which is the measurement of the specific value of the elevator battery voltage and its stability analysis, so as to grasp the working state of the battery. In addition to this, accurate estimation of the initial SOC value is needed to lay the foundation for the final equalization control, to ensure the health of the battery with the worst performance, to further ensure the safety of the entire battery pack, and to ensure that the battery is not overcharged and over-discharged, resulting in the risk of thermal failure [17]. After the retired battery is put into use, it needs not only daily monitoring by the BMS system. Battery capacity estimation and health status estimation should also be performed periodically to determine the comprehensive status of the battery.

6. Summary and Outlook

6.1 Summary

As one of China's seven strategic emerging industries, the new energy vehicle industry has great potential for future development. With the continuous development and in-depth research of power battery recycling technology for electric vehicles, and under the guidance of a series of policies and the promotion of the consumer market, China's retired power battery recycling industry will also usher in an unprecedented development. This paper reviews China's research on the gradient utilization of retired power batteries of new energy electric vehicles summarizes some successful application cases of gradient utilization, analyzes the technical difficulties in the process of gradient utilization, and summarizes the research work of scholars. It is of guiding significance for the large-scale engineering application of the gradual utilization of power batteries and provides a basis for the theoretical research of the gradual utilization of batteries. At the same time of the vigorous development of the gradient utilization of retired power batteries, there are also many problems, such as the lack of a perfect gradient utilization system for retired power batteries, most of the specific applications are small-scale applications of pilot type, the monitoring, and evaluation system of power battery performance is not sound, and the key technologies of gradient utilization need to continue to be studied, so there is still much room for progress in the gradient utilization industry of retired power batteries in China.

6.2 Outlook

After ten years of large-scale development, new energy power gradually transitioned from a supplementary power source to the main power source. In the new "14th Five-Year Plan", China solemnly proposed to achieve "carbon peak" by 2030 and "carbon neutral" by 2060. After the goal of "carbon neutrality" is achieved by 2030, the new energy industry will have more sufficient power to develop. In this context, new energy vehicles will become the mainstream of the future automobile industry, and the accompanying retired power battery secondary utilization industry will also usher in a significant development, then, the technology of retired battery secondary utilization of new energy vehicles will be more refined, the secondary utilization system will be more perfect, the utilization efficiency will be further improved, and good economic and social benefits will be generated.

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