Analysis on Echelon Utilization Status of New Energy Vehicles Batteries

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Keywords: new energy vehicles, traction battery, echelon using, industry status.

1. Introduction
In recent years, new energy vehicles have become the main direction of the transformation and development of the global automobile industry. Developed countries in the automobile industry have strengthened strategic planning and policy support, and multinational automobile enterprises have increased investment in R&D and improved the industrial layout. Since 2009, China started to promote new energy vehicles in 10 cities, and began to promote and apply new energy vehicles on a large scale after 2013, which has established a certain first-Mover advantage. In 2019, the output of new energy vehicles in China was 1.147 million, ranking first in the world for the fifth consecutive year. In 2020, new energy vehicles were produced nationwide, and the supporting capacity of power batteries exceeded 236.8GWh (about 2.05 million tons).

With the long-term use of some new energy vehicles in China gradually entering the stage of decommissioning or scrapping, the problem of recycling and disposal of their power batteries after decommissioning has become increasingly serious. According to industry estimates, by the end of 2020, the cumulative decommissioning of power batteries will exceed 200,000 tons; By 2025, it will accumulate over 780,000 tons [1]. Improper disposal and random disposal of retired batteries will not only endanger the environment and public safety, threaten human health, but also cause waste of resources. After decommissioning, power batteries still have a certain amount of surplus energy, which can meet other application fields with lower performance requirements. After being tested and reorganized, some decommissioned batteries can be used in the fields with lower performance requirements such as energy storage and power backup, and then scrapped and disassembled to extract valuable metals such as lithium, nickel and cobalt, so as to maximize the utilization value [2].
2. Status quo of decommissioning and recycling of power batteries

According to the calculation of industry organizations, about 70% of retired batteries have the value of ladder utilization. It is estimated that by the end of 2020, the cumulative utilization of retired batteries will reach 140,000 tons, and by 2025, the cumulative utilization will exceed 550,000 tons (see Figure 1) [1]. With good market prospects and development potential, the cascade utilization of power batteries has attracted wide attention from the industry.

![Figure 1. Prediction of decommissioning and cascade utilization of power batteries in China](image)

At present, the power storage battery has begun to enter the large-scale decommissioning period. According to the sales statistics of China Automotive Data Terminal (based on the situation that vehicles cannot enjoy preferential treatment if the compulsory insurance is overdue for 3 months, we assume that vehicles will be decommissioned if the compulsory insurance is overdue for 90 days), as of the end of March 2020, a total of 408,000 new energy vehicles have been decommissioned or scrapped, and it is estimated that 15.6 GWh (109,000 tons) of decommissioned batteries will be generated (see Figure 2). Among them, the decommissioning amount in the first quarter of 2020 was 7.1 GWh (44,000 tons), which increased by 419% compared with the average level in the quarter of 2019. Retired batteries are mainly concentrated in Guangdong, Zhejiang, Shandong and other cities with strong promotion of new energy vehicles, and the retired batteries in the above three provinces account for 22%, 10% and 7% of the national total respectively (see Figure 3).
Figure 2. Discontinuation of New Energy Vehicles and Supporting Power Batteries in China

From the composition of waste batteries recovered by enterprises, the main source has changed from waste batteries produced by R&D, test and production or test in the early stage to retired batteries of new energy vehicles. According to incomplete statistics, about 35,000 tons of used batteries were recovered and disposed of by major comprehensive utilization enterprises in 2019, of which about 53%
originated from the retirement of new energy vehicles and 42% originated from R&D, production or testing (see Figure 4).

![Recycling of used batteries in major comprehensive utilization enterprises in 2019](image)

**Figure 4.** Recycling of used batteries in major comprehensive utilization enterprises in 2019

3. Development status of cascade utilization industry

With the gradual increase of decommissioning of power batteries, the number of enterprises engaged in cascade utilization is increasing, and the industrial development is speeding up.

3.1. Industrial scale and distribution

In terms of industrial scale, there are more than 40 enterprises that have used their existing production capacity in cascade, and a number of typical enterprises represented by BYD, Langu Wisdom, Lishen Power and Zhongtian Hongli have formed a certain scale of cascade utilization capacity, with the built production capacity exceeding 30GWh/year (about 270,000 tons/year). Driven by market prospects and interests, the scale of investment in cascade utilization industry is still expanding, and the planned production capacity of known enterprises exceeds 860,000 tons/year. Because the cascade utilization links are mostly manual operations, enterprises can flexibly adjust production capacity and resource allocation according to market conditions, and the risk of overcapacity is relatively small.

From the industrial distribution point of view, because the cascade utilization enterprises are sensitive to resource elements such as battery decommissioning amount, operating cost, talents and technology, the enterprises are mainly concentrated in the first-tier cities in Beijing-Tianjin-Hebei, Yangtze River Delta, Pearl River Delta and other regions with high battery decommissioning amount and concentrated talents, capital and technology, or small and medium-sized cities with good foundation. Among them, the total production capacity of cascade utilization enterprises in Guangdong Province and Jiangsu Province exceeds 50% of the national total production capacity (see Figure 5).
3.2. Main types of participating enterprises

At present, there are a wide range of enterprises participating in the cascade utilization, including enterprises in the upstream and downstream of the industrial chain and energy storage and other related fields: First, new energy vehicle manufacturers (about 11%), such as BYD, Beiqi New Energy, Zhengzhou Yutong, etc., in order to tap the residual value of the retired batteries of vehicles produced by this enterprise, and use them in photovoltaic energy storage, charging (changing) power stations and other fields; Second, power battery manufacturers (about 22%), such as Lishen Power, Guoxuan Hi-Tech, etc., use the R&D and production technology foundation of their power batteries to extend to the field of cascade utilization; Third, electrochemical energy storage enterprises (about 37%), such as Puland, Jiangsu Huineng Source, etc., use their business advantages in the field of battery energy storage to develop cascade energy storage products; Fourth, comprehensive utilization enterprises (about 26%), such as GEM, Huayou Cobalt Co., Ltd, etc., have certain technical bases such as customer resources and dismantling, and expand from recycling to cascade utilization; Fifthly, the enterprises applying echelon products (about 4%), such as China Tower, State Grid, etc., have great demand for echelon products, and have accumulated a certain technical reserve in the process of applying echelon products, and cooperated with other enterprises to develop echelon products suitable for their own use.

3.3. Enterprise output and ranking

According to incomplete statistics, in 2019, 13,000 tons of used batteries were recycled and processed by 18 major cascade utilization enterprises such as BYD, and 809MWh (about 9,700 tons) of cascade products were produced, with a total output value of about 600 million yuan (see Figure 6). Due to the small number of retired batteries and limited supply of raw materials in the current market, the utilization rate of enterprise cascade utilization capacity is less than 12%. In terms of output distribution, Shenzhen BYD, Langu Wisdom, Lishen Power, Shanghai BYD and Zhongtian Hongli have a total output of 521MWh, accounting for 65% of the total output. Among them, BYD makes use of the advantages of new energy vehicles and battery production to ensure the recycling of retired batteries and R&D and production of echelon products. The total output of its Shanghai and Shenzhen factories is 237MWh, accounting for 29% of the total output, ranking first in the industry.

Figure 5. Distribution of cascade utilization capacity by region
3.4. Technical process

At present, the development of disassembly, reorganization and utilization technology in the industry is relatively mature, and about 95% of enterprises mainly use battery modules or monomer level, and accelerate the exploration of whole package utilization of batteries. More than 50% of enterprises carry out multi-level cascade utilization in parallel with various technical routes, such as Langu Wisdom and Quzhou Huayou. Give priority to the utilization of the whole package of batteries. If the performance of the whole package of batteries does not meet the requirements, it will be disassembled into modules and monomers step by step, and then sorted and reassembled into echelon products.

The automatic production degree of cascade utilization industry is not high. About 90% of enterprises adopt semi-automatic production lines with automatic handling and manual disassembly and reorganization. Because of the variety, structure and model of retired batteries, the automatic disassembly line cannot meet the diversified disassembly requirements. Huayou Cobalt Co., Ltd. has developed a fully automatic production line, which can realize the automatic disassembly and reorganization of retired batteries with specific model structure. However, there are still some problems such as insufficient compatibility and low practicability. Enterprises are speeding up the research of flexible disassembly technology with high compatibility. At the same time, some enterprises such as Henan Liwei and Jiangsu Smart Energy are throwing all-manual production lines.

![Figure 6. The top ten echelon utilization enterprises in 2019](image)

4. Characteristics and market application fields of echelon products

The market of echelon utilization shows diversified development trend, and echelon products are used in scenarios such as standby power, energy storage and low-speed power of communication base stations. Among them, the field of base station standby power and low-speed power has been preliminarily commercialized.

4.1. Product features

At present, retired lithium iron phosphate battery is the main step-by-step utilization. Among the echelon products produced in 2019, lithium iron phosphate battery products accounted for 79%, and ternary battery products accounted for 18%. The main ways of cascade utilization are as follows: First, the whole package level cascade utilization is mainly used for power storage and industrial level standby power; Second, module-level cascade utilization is mainly used for base station power backup, household energy storage, electric tricycles or motorcycles, etc. In addition, there are a few enterprises...
that use dismantled single batteries for consumer electronic products, such as mobile power supplies and toys.

![Figure 7. Application distribution of echelon products](image)

### 4.2. Application field
From the application field, it is still mainly in the field of base station power preparation and energy storage. About 50% of the echelon products produced in 2019 are used in the field of base station power supply, 30% in the field of energy storage, 16% in the field of low-speed power and 4% in consumer electronic products (see Figure 7).

#### 4.2.1. Field of base station power preparation

| Table 1. Comparison of power backup schemes for communication base stations |
|-----------------------------|-----------------|-----------------|-----------------|
|                | Lead acid battery | New lithium iron phosphate battery | Lithium iron phosphate ladder products |
| Available capacity (kWh) | 3.6              | 3.6              | 3.6             |
| Total system power (kWh) | 5.5              | 4.0              | 4.2             |
| Depth of discharge (DOD) | 65%              | 90%              | 85%             |
| Charge and discharge rate (c) | 0.1-0.2        | 0.5-1            | 0.5-1           |
| Unit price of battery pack (yuan /Wh) | 0.5          | 0.85             | 0.65            |
| Total price of battery pack (yuan) | 2769         | 3400             | 2753            |
| Service life (years) | 3-5              | 10               | 5-8             |

The standby power of communication base station has low requirements on battery consistency, cyclic charging and discharging, and low safety risk, which is the largest and most mature application scenario of echelon products. Compared with traditional lead-acid batteries, ladder products have obvious advantages in environmental pollution, cycle life and fast charge and discharge [3], and the cost is equal (see Table 1). China Tower Company stopped purchasing lead-acid batteries in 2018 and
purchased ladder batteries from 20 companies including Shenzhen BYD. By the end of March 2020, about 380,000 base stations in China had used 5.5GWh of ladder batteries, which had replaced about 20% of lead-acid batteries, and there was still room for replacement of over 21GWh in the future. According to the forecast of the industry, in 2020, the reserve power demand of newly built and renovated 5G base stations will exceed 10GWh, which will help to further expand the market scale of echelon products [4].

4.2.2. Energy storage field. The energy storage system uses a large number of battery modules, and runs under the working condition of high current and rapid charge and discharge for a long time, which requires high performance such as battery cell consistency, cycle life and safety [5], which is a high value-added application field of cascade products. In recent years, the transformation of China's energy structure has driven the rapid growth of electrochemical energy storage market. By the end of 2019, the cumulative capacity of electrochemical energy storage in China reached 2.84GWh; According to the conservative forecast of the industry, it will exceed 15 GWh by 2024 [6]. The cascade utilization is beneficial to reduce the energy storage cost and has a good market prospect.

At present, 13 enterprises including State Grid, BYD and Beijing Puulaid have built a number of representative demonstration projects for cascade utilization of energy storage at user side and grid side [7], with a cumulative use of 243MWh of cascade products and a total consumption of more than 3,000 tons of retired batteries. The implementation of these projects has accumulated key data and verified technical solutions for the application of echelon products in the field of energy storage, and transformed from demonstration to commercial operation.

Due to the large investment and long return period of energy storage projects, the economic feasibility and safety of cascade utilization of energy storage systems are the focus of industry debate, which needs further evaluation after long-term practice. Taking a 1MW/5MWh user-side cascade utilization energy storage system built in Suzhou as a scenario, and combining with the actual engineering case and experimental data of Shenzhen Eriswat New Energy Co., Ltd., we found that: The investment of the project is about 5.5 million yuan, and the system is charged and discharged twice a day, which can save 1.19-1.36 million yuan in electricity charges every year, and the investment return period is up to 5 years (see Table 2).

| Total power (kW) | Basic information of energy storage system by cascade utilization | System cost (yuan /KWh) | The total investment of the project | Charge and discharge rate | Charge and discharge strategy | Accumulated project income |
|-----------------|---------------------------------------------------------------|------------------------|------------------------------------|--------------------------|-----------------------------|--------------------------|
| 1000            | System cost (yuan /KWh)                                       | ¥1,100                 | ¥5,500,000                         | 0.25C                    | 350 days/year, two charges and two discharges every day |                         |
| 5000            | Total capacity (kWh)                                          | 80%                    | Charge and discharge rate          |                          |                             |                         |
| 86.0%           | Depth of discharge dod                                        |                        | Charge and discharge strategy      |                          |                             |                         |
| Cumulative number of cycles | Time                  | Total income of single-year project | Battery attenuation coefficient | 0                       | Accumulated project income |                         |
| 0               | 0                                                               | ¥0                     | 1                                  | -                        |                             |                         |
| 700             | 1                                                               | ¥1,362,665             | 0.9467                             | -5,500,000               | -4,137,335                  |                         |
| 1400            | 2                                                               | ¥1,317,438             | 0.9153                             | -2,819,896               |                             |                         |
| 2100            | 3                                                               | ¥1,280,333             | 0.8895                             | -1,539,563               | -1,539,563                  |                         |
| 2800            | 4                                                               | ¥1,254,566             | 0.8716                             | -2,84,997                |                             |                         |
| 3500            | 5                                                               | ¥1,234,361             | 0.8576                             | 949,364                  |                             |                         |
| 4200            | 6                                                               | ¥1,216,963             | 0.8455                             | 2,166,327                |                             |                         |
| 4900            | 7                                                               | ¥1,202,256             | 0.8353                             | 3,368,583                |                             |                         |
| 5600            | 8                                                               | ¥1,188,935             | 0.8260                             | 4,557,518                |                             |                         |
4.2.3. Low speed power field. Low-speed power cars need less battery capacity, have lower requirements on battery unit consistency, multiplying power and other performance, and are easy to control safety risks. It is one of the mainstream development fields of cascade utilization after the use scenarios such as base station power backup and energy storage. At present, the share of lead-acid batteries in domestic electric bicycles is about 90%. With the gradual replacement of traditional lead-acid batteries, the industry expects that the market demand will exceed 17GWh in 2022. If 70% of the 250 million electric bicycles in China use echelon products, the total market demand is expected to exceed 100GWh [8]. At present, xingheng power supply, Hangzhou yiyuan technology, Zhongtian Hongli and other enterprises have cooperated with logistics express, sanitation, meituan, Ele Me, etc. all over the country to replace lead-acid batteries of electric bicycles, electric tricycles and low-speed four-wheeled vehicles with ladder products [9]. Among them, Zhongtianhongli has promoted 55MWh ladder products in more than 60 cities across the country through the mode of "selling for rent", providing services for more than 28,000 low-speed vehicles and ensuring the recycling of scrapped ladder products.

5. Development status of foreign cascade utilization industry.
At present, there is no foreign management policy specifically for the recycling of power batteries for new energy vehicles. However, developed countries such as Europe, the United States, and Japan started early in the recycling of lead-acid batteries and consumer lithium batteries, and established a relatively complete recycling system. Therefore, the previous recycling experience has been basically followed for the recycling of power batteries, and a producer responsibility derivation mechanism has been formed, in which battery manufacturers bear the main responsibility for battery recycling. At the same time, the United States began to carry out certification management for the whole process of ladder utilization in 2018 to ensure the quality and safety of ladder products.

In terms of industry development, the research on the cascade utilization of retired batteries started earlier in European Union, America, Japan and other countries. Among them, the South Germany group started to participate in the echelon utilization research project in 2010, and established an energy storage application demonstration project in Berlin, Germany; The energy storage system of 2MW/2MWh large-scale photovoltaic power station built in Berlin by Bosch Group, BMW and Watenfu has been put into use; FreeWire Company of the United States has developed new energy vehicle charging treasure products by using retired batteries, providing mobile charging services for new energy vehicles in office buildings and other working areas; Japan's 4R Energy Co., Ltd. has developed a series of household and commercial energy storage products with nominal power of 12-96kW by using the retired batteries of Nissan Leaf cars sold or leased, and obtained the first UL 1974 certification in the world in 2019 [10].

6. Conclusion
Generally speaking, the European Union, the United States, Japan and other countries have built some engineering and commercial demonstration projects for the cascade utilization of retired batteries, but the application volume is small, and the application scenarios are all concentrated in the field of energy storage, while the application exploration in other fields is less. In addition, the retired power batteries in foreign countries are still small and lack of scale effect, so the research work remains at the experimental and demonstration application stage. Most of the existing projects are mainly implemented by automobile manufacturers and battery manufacturers, while comprehensive utilization enterprises are less involved, and the development of cascade utilization industry has not yet fully started. Comparatively speaking, China has only started the related research and demonstration projects in recent years. Because of the relatively large decommissioning amount of power batteries in China and the huge market space for cascade utilization, government departments, scientific research institutions and enterprises have paid close attention to it. With the active participation of many enterprises, the industry has developed rapidly, and has formed a certain scale of production capacity. It has actively explored many application fields such as base station power backup, energy storage and low-speed power, and established a demonstration project and commercial operation projects. The industry has entered the
initial stage of commercial operation. However, there is no clear management system for power battery cascade utilization in China, and the cascade products lack relevant safety certification, which will hinder the further development of domestic power battery cascade utilization industry in the later stage.

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