

Study on the Utilization Mode of Retired Batteries in New Energy Vehicles

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Abstract: With the increasing sales of new energy vehicles in China, the increasing number of new energy vehicles is driving the rapid growth of power battery installations in the context of "carbon peaking and carbon neutrality". When the battery life of new energy vehicles reaches retirement limit, it is necessary to study how to deal with the retired batteries of new energy vehicles. Based on the cascade utilization function of retired batteries of new energy vehicles, the paper studies how to reuse retired batteries of new energy vehicles, and with reference to data from Hainan Province, China, the paper studies how the recycling and utilization of power batteries can bring huge economic value. Finally, the key implementation path for the recycling and utilization of retired power batteries is provided. It aims to help all regions to complete the major strategic goals for achieving the carbon peaking and carbon neutrality task.

Keywords: Retired Batteries; Carbon Peaking; Carbon Neutrality.

1. Background Analysis

The sales of new energy vehicles in China have reached new highs, and the market penetration rate has significantly increased. In 2022, 7.058 million and 6.887 million new energy vehicles were produced and sold in China, with year-on-year growth of 96.9% and 93.4% respectively, and the sales penetration rate increased to 25.6%. After a certain number of charging and discharging cycles, the capacity of the batteries for new energy vehicles will decay to below 80% of the rated capacity, and many of the battery's performance will be significantly weakened to a certain extent, which is theoretically not suitable for application in electric vehicles. Therefore, the battery needs to be "retired", but mandatory retirement is only required when the capacity drops to 30%. In the range of 80%~30%, the performance of power batteries can still meet the energy needs of other devices, which is the cascade utilization in power battery recycling, also known as the re-exploration of battery energy value. Although China has vast territory and abundant resources, the raw material resources for batteries are still relatively scarce. Recycling and reusing the batteries can fully extend the life cycle of power batteries since the power batteries contain a large amount of precious metals such as cobalt, nickel, manganese, lithium, aluminum, and copper [1-5].

At present, the cascade utilization and recycling of power batteries have been elevated to an unprecedented height, both domestically and internationally. Firstly, the cost pressure on battery companies has increased due to the rising prices of upstream raw materials. Secondly, due to geopolitical conflicts, the supply of raw materials is unstable and prices are constantly fluctuating, making enterprises pay more attention to the re-exploration of the value of power batteries. Thirdly, the recycling and utilization of power batteries are benefited from the continuous development of regeneration technology and can achieve higher economic benefits. Under broad market development prospects, the technology and market for cascade utilization and recycling of power batteries have been booming.

The full life cycle of power batteries includes production,

use, scrapping, decomposition, and recycling. For power batteries with a capacity reduced to less than 80%, their charging and discharging performance cannot meet the needs of car driving and need to be retired. In addition to a decrease in chemical activity, the chemical composition inside the batteries has not changed, so they can be applied in situations with lower electrical energy requirements than cars for proposed utilization. For some power batteries that are severely damaged, have no useful value, have production problems, or have been utilized in cascades, it is necessary to disassemble and recycle them to extract valuable metals and materials, and then apply the recovered metals and materials to the production of cells, modules, and systems, forming a closed loop throughout the life cycle of the power batteries [1-5].

2. Cascade Utilization Scenarios of Retired Batteries

There are three scenarios given for the cascade utilization market of retired batteries: conservative, average, and optimistic. By 2030, 40%, 60%, and 80% of retired lithium iron phosphate batteries (LFP batteries) can be directly or after consistency testing and repair for cascade utilization, and the cascade utilization proportion α_T between 2022 and 2030 is calculated according to the function shown in formula (1). The retired batteries accounting for the proportion of α_T will be recycled after three years of cascade utilization, while the retired LFP batteries accounting for the remaining proportion of $1-\alpha_T$ cannot be involved in cascade utilization due to limitations in market capacity and battery consistency, and will directly enter the recycling process. Formula (1) is the cascade utilization function of retired batteries.

$$\alpha_T = \alpha_{T-1} + (T-2022) \times \beta \quad (1)$$

In the formula, α_T is the cascade utilization ratio of retired LFP batteries in year T; T is the year; β is the coefficient, with values of 0.8%, 1.2%, and 1.6% for conservative, average, and optimistic scenarios, respectively. In addition, according to the research data, the α_{2022} values for conservative, average,

and optimistic scenarios are 4.8%, 7.2%, and 9.6%, respectively. Fig. 1 shows the cascade utilization ratios of retired LFP batteries under three scenarios, in which blue

indicates conservative predictions, brown-yellow indicates average predictions, and gray indicates optimistic predictions.

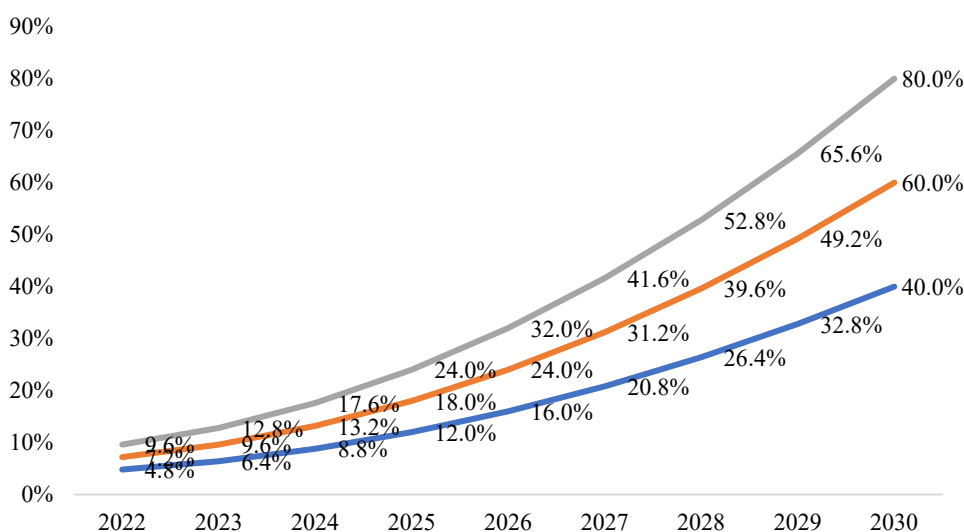


Fig 1. Cascade Utilization Ratio of Retired LFP Batteries under Three Scenarios

Fig. 2 shows the capacity of retired LFP batteries under the three scenarios (conservative, average, and optimistic) after calculations. By 2030, the retired LFP batteries will enter the cascade utilization market with a volume of approximately 1.006GWh under the conservative scenario, or with a volume of approximately 1.509GWh under the average scenario, or

with a volume of approximately 2.012GWh under the optimistic scenario. Fig. 2 shows the capacity of retired LFP batteries under three scenarios, where blue indicates conservative predictions, brown-yellow indicates average predictions, and gray indicates optimistic predictions.

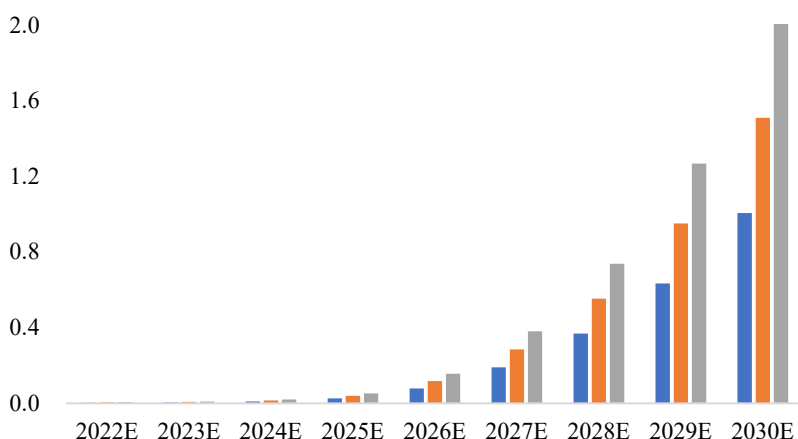


Fig 2. Cascade Utilization of Retired LFP Batteries under Three Scenarios (GWh)

According to market research, the price of batteries after cascade utilization is about 50% to 70% of the price of new batteries. Here, conservative, average, and optimistic scenarios are also selected to assume and calculate the price of batteries after cascade utilization. Under the conservative scenario, the price of batteries after cascade utilization is 50% of the price of new batteries; Under the average scenario, the price of batteries after cascade utilization is 60% of the price of new batteries; Under the optimistic scenario, the price of batteries after cascade utilization is 70% of the price of new batteries. According to the research, the price of new batteries was RMB 1.1 per watt hour in 2020. In 2021 and 2022, as the price of battery raw materials rose due to the COVID-19 pandemic and international trade friction, the price of batteries rose sharply, with an average price of about RMB 1.3 and RMB 1.4 per watt hour. It is expected that with the normalization of COVID-19 pandemic prevention and control, the price of upstream battery raw materials will

gradually become rational. Similarly, with the progress of technology and scale effect, the manufacturing cost of power batteries will decline. Assuming that the battery price in 2022 was at its peak in recent years, it will recover to RMB 1.0 per watt hour by 2024, and then linearly decrease year by year to RMB 0.32 per watt hour in 2030. The price forecast of power batteries over the years and the price changes of batteries under three scenarios of cascade utilization are shown in Fig. 3 and Fig. 4. Fig. 3 shows the forecast graph of power battery prices over the years, while Fig. 4 shows the forecast of battery price changes in three scenarios, where blue indicates conservative predictions, brown-yellow indicates average predictions, and gray indicates optimistic predictions.

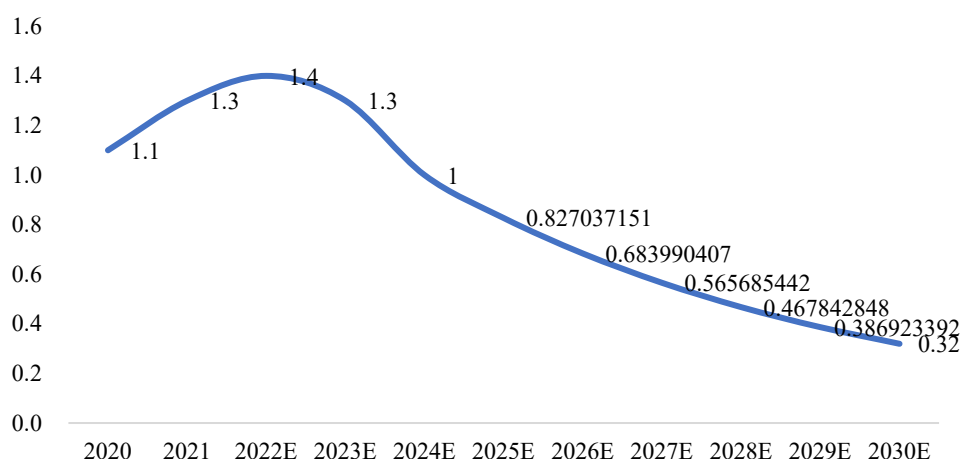


Fig 3. Trends and Forecast Values of New Battery Prices (RMB/Wh)

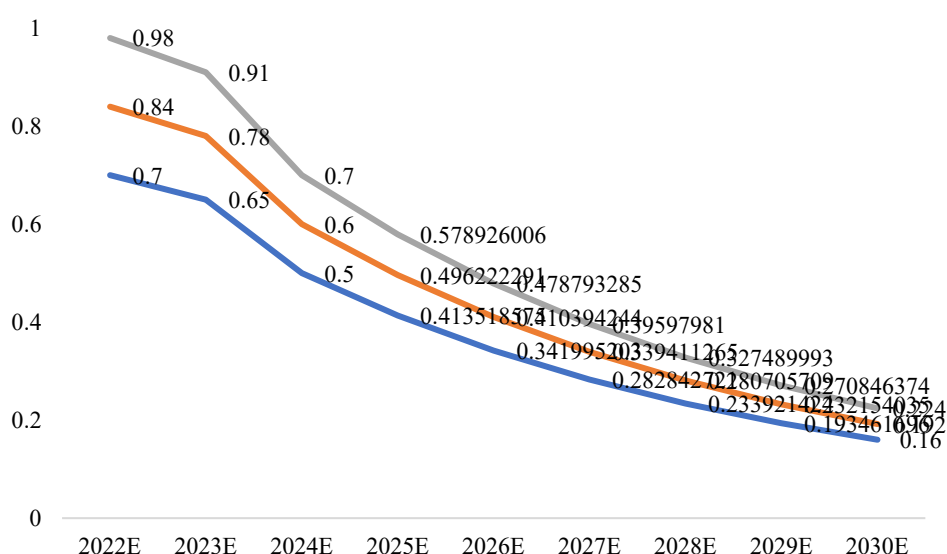


Fig 4. Price Forecast of Batteries after Cascade Utilization in Different Scenarios (RMB/Wh)

It is expected that under the optimistic scenario, the market size of retired LFP batteries for cascade utilization will reach RMB 450 million by 2030. After calculation, nine scenarios are obtained from the three scenarios of cascade utilization (optimistic, average, and conservative) for retired LFP batteries, and three scenarios of retired battery prices (optimistic, average, and conservative), and the market size of cascade utilization for batteries is shown in the table below. Under the optimistic scenarios of price and cascade utilization, the market size of cascade utilization will reach RMB 450 million, while under the average scenarios of price and cascade utilization, the market size of cascade utilization will reach RMB 290 million.

It is expected that under the optimistic scenario, the market

size of retired LFP batteries for cascade utilization will reach RMB 450 million by 2030. After calculation, nine scenarios are obtained from the three scenarios of cascade utilization (optimistic, average, and conservative) for retired LFP batteries, and three scenarios of retired battery prices (optimistic, average, and conservative), and the market size of cascade utilization for batteries is shown in the table below. Under the optimistic scenarios of price and cascade utilization, the market size of cascade utilization will reach over RMB 30 million, while under the average scenarios of price and cascade utilization, the market size of cascade utilization will reach over RMB 19 million. The market size forecast of cascade utilization for batteries in various scenarios is shown in Table 1.

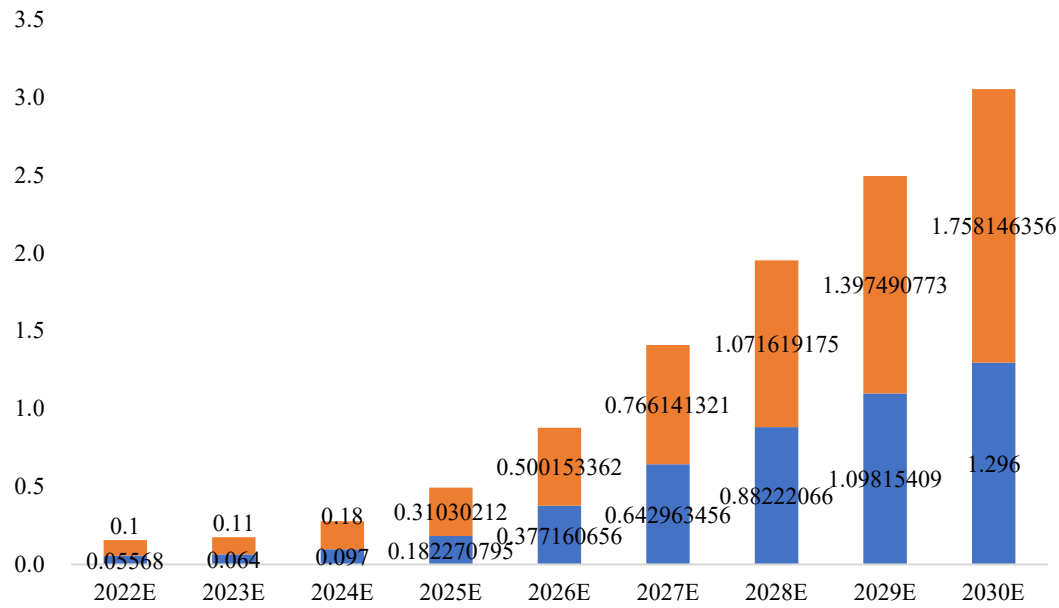
Table 1. Market Size of Cascade Utilization for Batteries in Various Scenarios (RMB 10,000)

	Conservative retirement volume			Average retirement volume			Optimistic retirement volume		
Price	Conservative	Average	Optimistic	Conservative	Average	Optimistic	Conservative	Average	Optimistic
2022E	201.6	241.9	282.2	302.4	362.9	423.4	403.2	483.8	564.5
2023E	291.2	349.4	407.7	436.8	524.2	611.5	582.4	698.9	815.4
2024E	484.0	580.8	677.6	726.0	871.2	1016.4	968.0	1161.6	1355.2
2025E	1076.9	1292.2	1507.6	1615.3	1938.4	2261.4	2153.7	2584.5	3015.2

3. Forecast of Future Investment Scale

It is expected that the market size of recycled batteries will reach 3.1GWh by 2030. The following assumptions are made for the calculation of the recycling market: First, the annual scale of retired LFP batteries is analyzed based on the average retirement volume scenario mentioned above, and the LFP batteries entering the cascade utilization market are recycled three years after the cascade utilization, while batteries that do not enter the cascade utilization market are directly recycled; Second, ternary batteries directly enter the recycling

market after retirement; Third, the impact of retirement of other types of batteries, such as lithium manganese batteries, is ignored due to their small amount. After calculation, the market size of LFP batteries and ternary batteries entering the recycling market over the years is shown in Fig. 5. By 2030, the recycling market size of LFP batteries is about 1.296GWh, the recycling market size of ternary batteries is about 1.758GWh, and the total recycling market size is about 3.054GWh. Fig. 5 shows the capacity prediction of recycled batteries, where blue represents LFP batteries and brown-yellow represents ternary batteries.



Note: The battery capacity is the capacity of retired battery, which is 80% of the new battery capacity
Fig 5. Capacity Prediction of Recycled Batteries

Ternary batteries contain metal elements such as nickel, cobalt, and manganese, making them one of the most valuable types of batteries for recycling. However, due to the different proportions of nickel, cobalt, and manganese metals in the positive electrode materials of ternary batteries, ternary lithium batteries can be divided into four types: NCM111, NCM523, NCM622, and NCM811. Different types of ternary lithium batteries have differences in technical routes and energy density, which also leads to significant differences in

recycling value. With the rise in the prices of cobalt metal materials, the trend of high nickel and low cobalt in the ternary lithium battery industry is obvious, and high-nickel batteries are expected to become the mainstream of the industry in the future [1-5]. Based on the analysis of technical routes, the assumed proportions of the installed capacity of each type of ternary lithium batteries from 2021 to 2025 are obtained. Table 2 provides the predicted proportions of the installed capacity of each type of ternary batteries.

Table 2. Predicted Proportions of Installed Capacity of Different Ternary Batteries

	NCM111	NCM523	NCM622	NCM811
2021E	0%	45%	30%	25%
2022E	0%	25%	25%	50%
2023E	0%	20%	25%	55%
2024E	0%	10%	30%	60%
2025E	0%	10%	30%	60%

Nickel, cobalt, manganese, lithium and other metal elements in retired power batteries have the most recycling value, and the recycling price accounts for about 90% of the income from battery recycling. To further analyze the value of recycling core metal elements of retired power batteries,

the mass of metal elements contained in each type of batteries is obtained through survey questionnaires, as shown in Table 3. Table 3 shows the mass of positive electrode materials and metals contained in each type of batteries.

Table 3. Mass of Positive Electrode Materials and Metals Contained in Different Batteries

Battery type	Mass of 1kWh positive electrode materials	Content of metal elements in 1kWh positive electrode materials (kg)			
		Li	Ni	Co	Mn
Lithium iron phosphate	2.4	0.106	0	0	0
NCM111	1.95	0.143	0.403	0.403	0.376
NCM523	1.85	0.134	0.564	0.226	0.315
NCM622	1.74	0.125	0.634	0.211	0.197
NCM811	1.63	0.117	0.788	0.099	0.092

According to the *Interim Measures for the Administration of the Announcement of Industry Standards for the Comprehensive Utilization of Waste Power Batteries (2019 Version)*, the comprehensive recovery rate of cobalt, nickel and manganese should be no less than 98%, and the recovery rate of lithium should be no less than 85%. In summary, we assume that the industry's recovery rate of nickel, cobalt, and manganese metals is 98%, and the lithium recovery rate is linearly increased by an annual growth rate of 1% from 87%

in 2022 to 95% in 2030. Through calculation, the mass of core metal elements in retired batteries for recycling is obtained and shown in the table below. By 2025, the recovered lithium metal is expected to reach 37.02 tons, the recovered nickel metal to 172.94 tons, the recovered cobalt metal to 72.71 tons, and the recovered manganese metal to 87.76 tons. The prediction of the amount of recovered core metal elements in power batteries for recycling is shown in Table 4.

Table 4. Amount Prediction of Recovered Core Metal Elements in Power Batteries for Recycling (ton)

	LFP battery	Ternary battery			
	Lithium	Lithium	Nickel	Cobalt	Manganese
2022E	5.13	12.22	43.82	34.80	35.12
2023E	5.97	13.37	52.28	34.15	36.58
2024E	9.15	21.66	93.44	48.22	55.47
2025E	17.39	37.02	172.94	72.71	87.76

The battery metal price fluctuates greatly due to the explosive growth of new energy vehicles in recent years, the rising global demand for nickel, cobalt, manganese, lithium and other metal elements year by year and the growing price for bulk consumer goods caused by the pandemic. As of July 25, 2022, the domestic market prices of lithium, nickel, cobalt, and manganese metals were RMB 297, 17.14, 33.80, and 16,300 per ton respectively.

4. Key Implementation Path for Recycling Retired Power Batteries

4.1. The Information Traceability Management System Shall be Established

The registration system for related corporations shall be improved. The primary responsibility of new energy vehicle manufacturers shall be strengthened in the field of power battery recycling, and new and in-use new energy vehicles and their power batteries shall be coded accordingly in accordance with national standards. In addition, information on the complete vehicle, power battery, and owner shall be provided on relevant management platforms to facilitate the source tracing and circulation monitoring of the full life cycle of power batteries [1-5].

Data connection and platform establishment shall be strengthened. All entities engaged in the production and sales of new energy vehicles, comprehensive utilization of waste power batteries and related businesses in Hainan Province shall report the information on power batteries, including the circulation information of power batteries in various links such as production, sales, leasing, personal use, maintenance, and recycling. This information shall be recorded and uploaded into the National Comprehensive Management Platform for Monitoring of New Energy Vehicles and

Recycling Traceability of Power Batteries to ensure the whole life-cycle supervision and traceability of information pertaining to power battery production, sales, use, maintenance, repair, recycling, and utilization [1-5].

A power battery recycling management platform system shall be established in Hainan Province based on the existing local operation monitoring platform of new energy vehicles. Moreover, relevant information shall be uploaded promptly, and data collection and statistics shall be conducted on power batteries of new energy vehicles in Hainan Province, which shall be successfully linked with the applicable national traceability information system. Meanwhile, it is important to collect and release information about battery recycling and utilization on industrial information platforms, corporate websites, etc. so as to provide relevant public information and promote information sharing and circulation.

4.2. The Waste Battery Recycling Management System Shall be Established

The construction of power batteries recycling network shall be carried out. Enterprises engaged in automotive production and sales, power battery production, recycling and disassembly of scrapped vehicles, and comprehensive utilization of recycled power batteries should collaborate to establish a recycling network based on recycling and scrapping channels of end-of-life power batteries, supporting enterprises within the upstream and downstream industry chains to together reconstruct existing recycling channels, link on-line and off-line services, and set up movable recycling stations [1-5].

4.3. The Cascade Utilization and Recycling System Shall be Established

The behavior of enterprises involved in cascade utilization

and recycling shall be regulated. In Hainan Province, a strict "white list" access system shall be established for the industry to issue licenses to enterprises that meet the qualification criteria, supplemented by strict supporting environmental regulations. Enterprises engaged in the cascade utilization and recycling of waste power batteries should turn to the competent authorities for qualification application and work filing as required. Entities such as scrapped vehicle recycling and disassembly enterprises, and repair and maintenance outlets are obligated to disassemble waste power batteries which will be delivered to enterprises for discharge recycling services or comprehensive utilization. Throughout the whole process, corresponding certification documents of waste power batteries should be provided for traceability purposes [1-5].

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