Discussion on the recycling ecological chain and commercial model of decommissioned batteries

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Abstract. When the battery capacity is reduced to less than 80%, it is no longer suitable for electric vehicles, if the decommissioned batteries directly scrapped treatment, it will cause a great waste of resources, and even cause environmental pollution. The reuse mode of lithium battery can be divided into two modes: Cascade utilization and recovery. This dissertation introduces these two methods, summarizes the current situation of power battery reuse, draws on the successful experience domestic and foreign, and combines the actual situation of domestic enterprises to improve the reuse ecosystem and business model of decommissioned batteries. The paper puts forward the business model of ‘Internet + Recycling Network + specialization processing’, and constructs the closed-loop network of retired power battery recovery, which integrates government supervision, enterprise operation and consumer participation.

1. Introduction

In recent years, with the rapid development of electric vehicle industry in China, power batteries as the core component have become a research hotspot in the industry. With excellent characteristics and mature technologies, lithium batteries have snatched a huge share of commercial market in its application on new-energy vehicles[1]. The sales of new-energy vehicles and shipment of lithium batteries are shown in Figure 1. According to the battery industry development target put forward in the ‘Action Plan for Promoting Development of Automobile Power Battery Industry’ issued in March 2017, the total capacity of the power battery industry will exceed 100 GWh by 2020. The large-scale production, sales and utilization of power batteries will definitely result in large-scale scrapping and recycling. When the capacity of a power battery attenuates to below 80% of that when it is initially used, it will fail to meet the standards for use by electric vehicles. This requires recycling and reuse of decommissioned power batteries[2]. Estimation of decommissioning of lithium power battery is shown in Figure 2.

Under the situation that the recycling market has not yet fully developed, an enormous quantity of decommissioned batteries will bring about a series of sever problems. On the one hand, the gap in the recycling market makes it impossible to stack decommissioned batteries in fixed places. Randomly throwing or stacking of batteries tends to cause cracking of the battery shells in worse environmental conditions. This will expose the anode and cathode and the electrolyte in the outside world, causing chemical reaction and resulting in such environmental pollution as heavy metal pollution and high alkali concentration of soil[3,4]. On the other hand, decommissioned power batteries still have 70~80% capacity. The remaining capacity and power can be used to satisfy requirements lower than that in the
new-energy vehicles. Direct scrapping will be a huge waste of the remaining value of power batteries. If their value of a full life cycle can be utilized, its cost-efficiency can be effectively improved[5]. Moreover, since the battery-driven system forms 30%~45% of the total cost of electric vehicles and power batteries 75~85% of the total cost of the battery-driven system, the lack of a recycling system for decommissioned batteries is not conducive to lowering the cost and sales price of new-energy vehicles and will seriously hinder the development of the new-energy vehicle industry. Therefore, cascade utilization and recycling of batteries will be an effective solution to the problem related to decommissioned batteries and the technologies involved therein will play a key role in forming a closed loop of new-energy vehicle industrial chains[6].

Figure 1. Sales of New-energy Vehicles and Shipment of Power Batteries

Figure 2. Estimation of Decommissioning of Lithium Power Battery

At present, China has unveiled various policies guiding the establishment of a market for recycling of decommissioned lithium batteries. The ‘Technical Policy for Recycling Power Batteries of Electric Vehicles’ (2015 Revision) acts as a guidance for enterprises in reasonably carrying out design, production and recycling of power batteries for electric vehicles for the purpose of building a power battery recycling system with both upstream and downstream enterprises involved. In the same year, the Ministry of Industry and Information Technology released the ‘Requirements of the Industry Standards for the Comprehensive Utilization’ which puts forward requirements for scaled, standard, professional and comprehensive use of power batteries. The Extended Producer Responsibility System defines power battery producers as the responsible bodies for power battery recycling. According to industrial analysis,
the lithium battery recycling market is reckoned to reach a scale of RMB 15.6 billions by 2020 and the compound growth rate from 2018 to 2020 will be 40.84%. In this dissertation, regarding decommissioned batteries, and issues of how to take up a highly valuable market and how to actively and correctly respond to national policies, the basis for dividing the recycling system and ecosphere is explored, and a new commercial model for reference by industry is proposed.

2. Ecosystem for Recycling of Decommissioned Lithium Battery

In the current stage, it is urgent to systematize and commercialize the recycling ecosystem. Major problems faced by the green battery recycling industry of China include: 1) Difficulty in battery recycling; It is estimated that 2018 will witness a peak period of power battery decommissioning. However, there is yet no specialized battery recycling network in China and no mandatory or incentive policy requiring or encouraging customers to spontaneously return decommissioned batteries. The scattered and extensive way of recycling will undoubtedly cause environmental pollution and even disorder of the industry. 2) Certain risks to be borne by enterprises; According to national laws and regulations, only enterprises with the permit of handling dangerous waste are allowed to carry out recycling and disposal activities. With no sound market and difficulty in negotiating benefit distribution, enterprises of certain scale and meeting the conditions are not willing to engage in the lithium battery recycling business. Worse still, some small enterprises directly scrap the batteries recycled or use them as power banks, which not only disturbs the market order, but also brings environmental and safety hazards. In this section, the current industrial ecosystem is analyzed based on cascade utilization and disassembling for recycling of batteries, putting forward suggestions on standard industrial layout.

2.1. Cascade Utilization

Cascade utilization generally refers to the process in which a battery with capacity attenuates to below 80% after being used by new-energy vehicles is used again in such places as energy storage stations of commercial residential buildings and telecom base stations, and then scrapped and recycled after its capacity becomes too low. Power batteries on the market are mostly made of lithium iron phosphate (LFP) and ternary compounds. According to comparison of these two kinds of batteries discharging under 1C discharge rate, with the increase of the number of cycles, the capacity of the ternary battery attenuates rapidly while that of the lithium iron phosphate battery still remains at above 50% after 1,000 times [7]. Therefore, LFP batteries are more suitable for cascade utilization.

For cascade utilization considering battery safety and capacity, power batteries, according to their multilevel structures, can be used in different scenarios in the form of battery packs, modules, cells and so on. Currently, such scenarios for cascade utilization include telecom base stations, battery charging (swapping) stations, household energy storage, portable power sources and so on. Among them, base stations promise a huge market and are the most suitable application scenarios. China Tower Corporation Limited is a model in terms of the scale of cascade utilization. It has made more than 3,000 base stations models for cascade utilization in 12 provinces of China. These base stations have been in good operation so far with profits constantly increasing.

2.2. Disassembling for Recycling

Disassembling for recycling is a way of turning power batteries into resources to realize high-efficiency cyclic utilization of battery materials and valuable metals. Waste batteries with low safety and having gone through cascade utilization shall be disassembled for recycling, to keep valuable resources. In this case, the scarcity of upstream raw materials and the price fluctuation can be alleviated in a certain degree. Power batteries are disassembled into shells, anode and cathode, diaphragms and electrolyte after such pretreatment procedures as discharging, disassembling, crashing and separation, and are then subject to different recycling procedures to get valuable materials. Battery recycling processes generally include the dry process, wet process and biological process. The dry process can be further divided into physical separation and high-temperature pyrolysis while the wet process includes acid - alkali leaching, organic
solvent extraction and ion exchange [8]. The recycling methods adopted by technically leading domestic recycling enterprises are shown in Table 1.

Table 1. Resource Recycling Methods of Technically Leading Domestic Recycling Enterprises

| Enterprise                          | Recycling Method       | Main Product                                      |
|-------------------------------------|------------------------|---------------------------------------------------|
| GEM Co., Ltd                        | Dry and wet processes  | Spherical cobalt powder                           |
| Guangdong Brunp Recycling Technology Co., Ltd. | Dry and wet processes  | Battery-level cobaltosic oxide and Ni-Co lithium manganate |
| Ganfeng Lithium                     | Dry and wet processes  | Lithium carbonate and battery-level lithium chloride |

2.3. Industrial Layout Analysis

Two principles need to be followed during building of the recycling ecosystem according to the mode of utilization of waste batteries: ① Since batteries are dangerous, safety insurance is required during transportation for recycling and treatment to avoid battery damage. National standards, codes and safety rules shall be observed; ② Since cascade utilization is mostly for wind power, PV power and energy storage applications, research on geological factors is required during selection of the site for battery’s industrial ecosphere with priority given to areas where the recycling industry is mature and cascade utilization is feasible. In addition, the principle of ‘consumption nearby’ also needs to be considered. Upstream and downstream enterprises in the battery industry are closely related. The upstream industry involves battery material manufacturers and battery manufacturers that shall consider the actual needs of downstream new-energy vehicle manufacturers. The downstream industry involves vehicle manufacturers, automobile dealers and battery recycling enterprises that shall also share the responsibility of manufacturers in tackling battery pollution. On July 26, 2018, the Ministry of Industry and Information Technology released a list of enterprises qualified for recycling of waste power batteries. Among them are Huayou Cobalt, Highpower International, GEM, Brunp Recycling Technology and Guanghua Sci-tech. From various perspectives, battery recycling industrial layout and building of reuse ecosphere mainly focus on the Yangtze River delta, Pearl River Delta and surrounding cities of Beijing where relevant industries are rapidly developing. In such areas, it is easy to realize regional integration, carry out battery recycling and reuse, and alleviate the government supervision pressure. Meanwhile, with large number of registered electric vehicles and various recycling methods, emphasis shall be placed on developing such cities into green recycling cities to form a complete industrial chain comprising battery’s key material production, manufacturing equipment, sales channels and recycling and reuse with battery technological innovation as the core, so as to create an ecosphere for cluster industrial development.

3. Commercial Mode

Relevant policies related to battery reuse have been released in recent years, constantly driving market and commercial mode adjustment. With experience at home and abroad and according to the Extended Producer Responsibility System, a new commercial mode of ‘Internet + recycling network + specialized disposal’ is put forward. Under this mode, the responsibility body is made clear and a reuse network driven by a profit chain with clear division of work is built and the Internet is used as a tool for optimization to form an efficient and standard management mode.

3.1. Recycling Network

The recycling network is key to the full-life-cycle ecosphere, and is also the basis for realizing healthy industrial cycles from battery decommissioning from new-energy vehicles, to battery material recycling and battery re-production. Based on different orientations, the power battery recycling network is divided into two types: producer-oriented recycling network and recycling network oriented at a professional third party. Huayou Cobalt, Ganfeng Lithium and other battery material enterprises possess rich mineral resources and advanced production and recycling technologies, and boast recycling industry layout both
at home and abroad. Domestic power battery and vehicle manufacturers such as CATL and BYD with key battery manufacturing technologies and channel advantages realize low-cost recycling and reuse in energy-storage, low-speed vehicle and other cascade utilization scenarios, forming a producer-oriented recycling network.

Domestic professional third-party recycling enterprises are mostly engaged in traditional battery recycling or comprehensive reutilization of relevant waste resources. Through market expanding, they have entered the lithium battery recycling field and accumulated certain operating experience. Nevertheless, a large quantity of manpower and material resources are still needed to establish new recycling networks and logistics channels. GEM, Ganzhou Highpower Technology and Brunp Recycling Technology as the third-party recycling enterprises have been deeply rooted in the recycling field for many years, making them the first batch of model enterprises for recycling of waste batteries. With relatively mature traditional battery and lithium battery recycling technologies and qualification in treatment of dangerous wastes, they have built a business-to-business battery full-life-cycle industrial chain. Through cooperation with the middle and down streams and expansion of the recycling network based on regional division by the enterprises themselves, they can make up for the shortage of recycling channels and alleviate the pressure from building a huge recycling network. For example, through cooperation between GEM and BYD, a production line for processing waste battery materials has been built with the annual quantity of cobalt resources recycled being more than 4,000 t. A recycling network has been built by Ganzhou Highpower Technology and BAIC BJEV together, dedicating to recycling, disposal and reuse of battery renewable resources.

In terms of setting of recycling stations, convenience for customers shall be taken as a starting point in the design of recycling station layout to solve the difficulty in vehicle’s waste battery handling. In addition to fixed recycling points at the dealers, streets and bus companies, online booking service for recycling may be provided for large-capacity batteries not easy to recycle. Customers upload battery numbers and pictures to provide battery information for the recycling suppliers, for regular arrangement of personnel for battery recycling door to door. Considering cascade utilization mostly happens at base stations and communities, special recycling points are required, to satisfy recycling needs and realize online and offline collaborative operation.

3.2. Recycling System

To promote healthy circulation of battery recycling ecosphere, identification and coding systems as well as the deposit refund system may be put into full use. The National Development and Reform Commission, Ministry of Industry and Information Technology, Ministry of Ecology and Environment, Ministry of Commerce and General Administration of Quality Supervision, Inspection and Quarantine co-issued the ‘Technical Policy for Recycling Power Batteries of Electric Vehicles (2015)’ which clearly specifies establishment of the power battery coding system to form a waste battery traceability system. When handling relevant expenses related to waste battery recycling and disposal, battery manufacturers need to stick unified company information labels and permanent codes on their products to facilitate battery recycling and defining of responsible bodies. The battery coding system enables the government to better supervise the market, making waste battery recycling a necessity and punishing irresponsible enterprises.

Moreover, to arouse the initiative of customers in battery recycling and prevent environmental problems caused by random throwing of lithium batteries, customers may be required to pay a deposit when buying new batteries or products with batteries in a unified manner and they can get a refund of the deposit when returning the used batteries. The deposit refund system can promote battery recycling. For reference, the amount of deposit may be 1%–2% of the vehicle price. In addition, vehicle enterprises shall take responsibility for battery-caused pollution, and shall make certain payment to the foundations established by the government or a third-party organization as industrial subsidy. When the third-party enterprises finish recycling and disposal, they may get certain amount of subsidy for battery disposal [9].
3.3. Commercial Mode of 'Internet + Recycling Network + Specialized Disposal'

Under the new trend of 'Internet +', the combination of 'recycling network + specialized disposal' enables flowing of massive data. The battery databases can be established through identification and coding, for real-time tracking of the battery status; by virtue of big data, the third-party enterprises can constantly improve the battery recycling efficiency; by retrieving battery disposal information, the government can easily supervise the recycling market. Meanwhile, customers can get access to relevant battery information via APP or web pages, quickly and conveniently estimating the value of waste batteries, thus quickly placing orders or applying for battery recycling through the Internet [10]. A closed-loop battery recycling network formed based on the mode of 'Internet + recycling network + specialized disposal' is shown in Figure 3.

![Figure 3. Recycling Network Based on the Mode of 'Internet + Recycling Network + Specialized Disposal']()

4. Summary

The recycling industry of decommissioned battery in China is at the stage of development, with an urgent need of sophisticated recycling enterprises to dispose a large scale of waste batteries. Therefore, a series of relevant policies from Chinese government are required to promote an orderly market development. Such two principles as 'Safety and Consumption Nearby' shall be adhered for establishment of a recycling ecosystem. Since battery-related industries are mostly distributed in Beijing and the Yangtze River delta, layout of the ecosphere in such areas is promotive for building industrial parks of battery recycling, thus promoting development of the power battery recycling industry. Under the trend of 'Internet +' and based on the extended producer responsibility system, the closed-loop commercial mode of 'Internet + recycling network + specialized disposal' is put forward with recycling network, recycling system and fund flowing mode as the bases. Therefore, government supervision, enterprise running and customer participation are integrated, with coordinated development under the precondition of respecting the interests of all parties.

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