Infrastructure Development for the Management and Optimization of New Energy Vehicle Battery Reverse Logistics Network Information

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Abstract. Due to the extreme lack of environmental capacity and energy, new energy vehicles have developed rapidly in China. The waste battery recycling in new energy vehicles has become the focus of social concerns. No matter in what field, the waste battery without the timely treatment will cause pollution. Therefore, building a scientific reverse recycling logistics network is the primary task. The amount of power battery contains a huge amount of resources, including nickel, cobalt, manganese, lithium, copper, aluminum, iron and plastic, which increased from 0.08 million tons in 2009 to 1.214 million tons in 2019. According to the future development simulation analysis, it is estimated that the power battery resource stock will reach 22.6666 million tons. In order to ensure the reasonable recycling of batteries, the logistics network and information management are designed by combining the recycling rate of renewable resources with the energy consumption, material consumption and global warming potential (GWP) coefficient of the corresponding production process of primary resources. The purpose is to get the optimal reverse logistics network and improve the management level.

Keywords: new energy; car battery; reverse logistics; network info management
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1 INTRODUCTION

In view of the pollution caused by the battery recycling of new energy vehicles, it is necessary to build a reasonable reverse recycling network. According to the stock and potential of power battery resources, a model of power battery resource availability analysis is further established. From three dimensions of material flow optimization, resource efficiency regulation and management system design, countermeasures and suggestions for sustainable resource management of new energy vehicle power battery are put forward[20]. The countermeasures and suggestions include developing the stock market of power batteries and building a "stock-flow" closed-loop industrial chain of resources; improving the efficiency of power battery renewable resources and extending the range of cascade utilization; establishing EPR-based power battery stock control mechanism, innovating power battery recycling system, and further improving the whole life cycle management system. The results of the model are analyzed to solve the problems of reverse logistics network layout, construct a more scientific structure, and ensure the quality of management [22].

2 LITERATURE REVIEW

In recent years, with the continuous improvement of China's national economic level and automobile manufacturing level, automobiles are rapidly popularized across the country and consumer demand is strong. The data show that China is in a leading position in the world in both the sales volume and the number of motor vehicles, and has been at the top for ten consecutive years. However, although the automobile brings great convenience to the national life, the energy crisis and environmental pollution caused by it can not be ignored. Under the background of advocating energy conservation, emission reduction and low-carbon economy, new energy electric vehicles have gradually become the development trend of China's and the world's automobile industry due to their advantages of resource-saving and environmental-friendliness. With the rapid development of electric vehicle industry, the production and use quantity of power lithium battery also appears the trend of rapid development[7]. Lithium ion battery has significant advantages in the operating temperature range, cycle life and low environmental pollution. It is the most widely used power battery in the electric vehicle industry. In 2020, China's power battery production reached 83.4GWh and the market size reached 65 billion yuan. In the next few years, with the implementation of various preferential systems for electric vehicles in China and the measures taken by European and American countries to accelerate the electrification of vehicles, power lithium batteries will continue to maintain a high growth trend[19]. The data show that it is expected that by 2025, the output of global power lithium ion battery will reach 668GWh, and the compound annual growth rate will reach 15.8% in the next five years. The shipment statistics and growth of global power lithium ion battery market from 2015 to 2025 are shown in Figure 1.

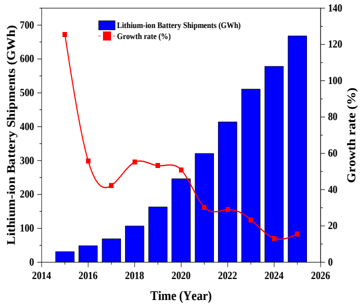

Figure 1: Shipment statistics and growth of global power lithium ion battery market from 2015 to 2025.

Compared with the domestic research, the foreign waste battery recycling system starts earlier, which has a relatively mature system[3]. Different from the existing multi-objective closed-loop supply chain network design model, which was usually oriented by cost or profit, a new objective was also considered, namely "maximize the collection of recycled batteries covered by the open facility"[10]. In recent years, the recycling of waste batteries has been widely concerned by scholars in China. Based on the experience and lessons of European and American countries, reasonable suggestions are put forward for the construction of waste battery recycling system in China. A reasonable recovery network is proposed.

1. A set of power battery resource stock calculation method considering cascade utilization is established to provide scientific basis for the sustainable environmental management of power battery. In the quantitative scenario analysis of the stock of power battery resources, the change and influence of the growth trend of China's new energy vehicles and the development direction of power battery technology are considered comprehensively. The benchmark scenario, ternary lithium battery dominant scenario and lithium iron phosphate battery dominant scenario are set up to make the simulation analysis results more realistic,As shown in Figure 2[5].

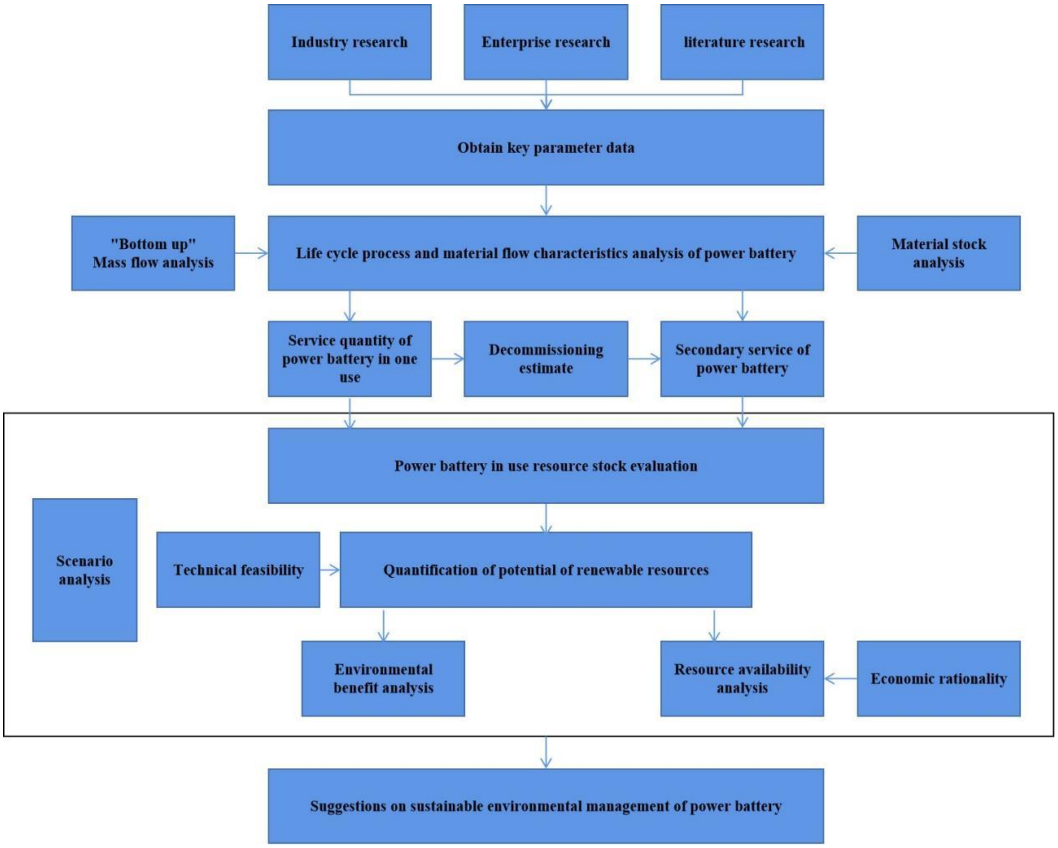

Figure 2: Technology road map.

2. The power battery resource availability analysis model is constructed based on economic rationality, and the cost and discount rate of power battery recycling are comprehensively considered. The cash flow discount method is used to solve the available prices of different resources under the market price, so as to analyze the availability of power battery resources.

3 NEW ENERGY VEHICLE BATTERY REVERSE LOGISTICS STATUS AND PROBLEM ANALYSIS

The relevant data show that around 2020, China's power battery came to the scrap peak, the cumulative scrap amount would reach 120,000-170,000 tons, and the actual amount of dismantling and recycling was less than 10,000 tons in 2016. By the end of 2019, the cumulative recovery rate of waste new energy vehicle batteries was only 10%(Figure 3). The problems of small scale and low recycling efficiency exist in the battery recycling of new energy vehicles in China, mainly due to the following aspects[11].

1. The forward logistics network of new energy vehicle batteries is complex, resulting in the difficulty of reverse logistics. First of all, the positive logistics of the battery of new energy vehicles involves many subjects. Due to the large number of participants and the low degree of informatization of the participants, information fault is prone to occur in the process of operation[4]. In addition, the flow of batteries is gradually dispersed. New energy vehicle manufacturers have a low degree of control over the final flow of batteries(Figure 4), which invisibly increases the difficulty of reverse logistics of batteries. Secondly, each subject pursues the maximization of their own interests in the process of participating in the network construction, which leads to the unclear division of responsible subjects in the network. Finally, due to the imperfect disposal methods of scrapped batteries and unclear channel information, consumers are not very motivated to hand over batteries to designated recycling manufacturers.

2. The guidance of relevant policies and enterprise systems is not enough. At present, there is a lack of regulations on the reverse logistics of new energy vehicle batteries at the national level in our country. The recycling of new energy vehicle batteries has become a bottleneck restricting the development of our country's new energy vehicle industry[18].

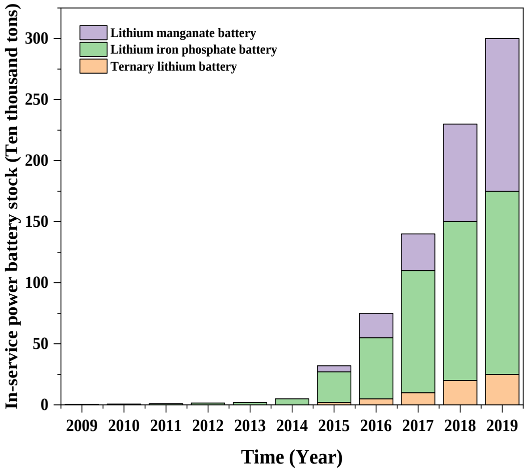

Figure 3: Electric vehicle battery stock in use from 2009 to 2019.

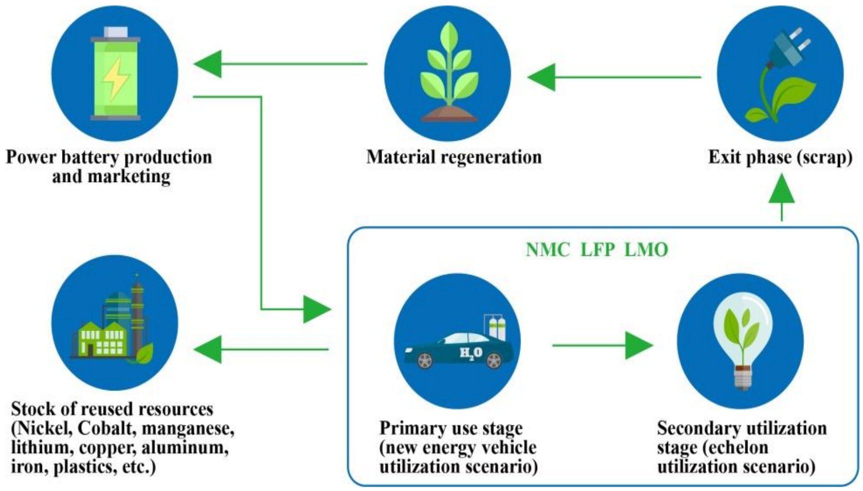

Figure 4: The life cycle process of new energy vehicle power battery.

4 RELATED CONCEPTS AND THEORETICAL BASIS

4.1 Concepts Related to Reverse Logistics

4.1.1 The driving factors

Forward logistics is also known as reverse logistics. It is based on information technology. It is customer and market-oriented. Through supply chain channel members, the items that need to be recycled are returned from consumers to manufacturers or the third-party outsourcing recycling companies[12]. The main processes are the recall of substandard products, consumer returns, recycling of waste products, remanufacturing, harmless disposal of waste, etc. These processes can ensure that waste products are properly disposed of and regain value. Countries around the world are paying more and more attention to environmental protection issues and resource recycling issues, and companies are also paying more and more attention to the economic benefits and good corporate image brought by reverse logistics. In general, the main driving factors that promote the development of reverse logistics at home and abroad are government regulations and policies related to environmental protection, the shortened life cycle due to the accelerated product iteration, the diversification of channels, and the power conversion of different entities in the supply chain.

4.1.2 Characteristics of reverse logistics

1. Reverse nature of reverse logistics

The operation direction of traditional forward logistics is from upstream manufacturers to downstream consumers. While the operation direction of reverse logistics is the opposite, from downstream to upstream[21]. In the reverse logistics network, whether it is the circulation of scrapped products or the transmission of information, they are caused by consumers at the end of the supply chain.

2. Uncertainty and dispersion of reverse logistics

The starting point of consumer returns can be scattered in any corner of the country. The time and place cannot be predicted in advance, and the quality and quantity of discarded products cannot be guaranteed, which leads to a high degree of uncertainty in the supply of reverse logistics, and the consumption field is not reverse logistics[13]. The only way to produce it is that in the process of production and circulation, there will also be other situations where the product quality is not up to standard or the product needs to be recalled, so there is a high degree of dispersion.

3. Slowness of reverse logistics

The number of recycled items is small and involves a wide variety of items. Large-scale transportation and warehousing can only be formed after collection, and before they are put into the second-hand market or the raw materials are recycled, there are still links such as classification, processing, and remanufacturing. This is a complex and long process determines the slowness of reverse logistics.

4. The complexity of reverse logistics

In the process of reverse logistics, due to the high uncertainty of quality and quantity, the returned items are usually mixed together with different qualities and different quantities, which requires the manual detection and classification. It is impossible to carry out unified logistics transportation in the same batch like forward logistics. And the subsequent processing steps for different types and different quality of returned goods are different, so different processing should be performed to ensure the maximum recovery efficiency, resulting in the complexity of reverse logistics management.

5. The high processing cost of reverse logistics

Because end consumers do not have standard and unified packaging capabilities, the returned items often do not have standardized packaging. The uncertainty is high and it is difficult to form economies of scale in the process of transportation and warehousing. It needs to go through the manual detection, classification and other processes to enter the correct processing process. The efficiency is low and the labor cost increases accordingly[9].

6. Decreasing and increasing value of reverse logistics

In the reverse logistics process of product recycling, it may go through some or all of the links such as logistics transportation, warehousing management, manual inspection, and recycling and reuse. There will be corresponding expenses in these links, resulting in a reduction in the value of the returned product itself. However, some return products that have no use value for consumers are given new value after being recycled or remanufactured through reverse logistics. Therefore, reverse logistics increases the value of the return products.

4.2 Reverse Logistics Network Design Model

Reverse logistics network design refers to the planning and layout of the entire channel from the point of consumption to the recycling point of renewable resources, or waste products, or an appropriate disposal site, including the location, quantity, and scale decisions of reverse logistics nodes, as well as the common decision of logistics network design, such as the distribution of reverse logistics flow among logistics nodes. Reverse logistics network design is a strategic decision, which plays a decisive role in the overall operation efficiency of the entire reverse logistics network. It is the primary task in reverse logistics management[14].

4.2.1 Common models

At present, in the existing research on reverse logistics network design, the most used models are mixed integer programming model, stochastic integer programming model and integer programming

model. The mixed integer programming method is selected in the research. The scene is modeled, and the lingo software can be used to solve the model.
The details are as follows.
Model assumptions:

(1)The location and scale of logistics node i are known, and the alternative location and scale of logistics node j are also known. It is necessary to select the location of logistics node j in the alternative points.
(2)If there is no inventory capacity at logistics node i, it will all be shipped to logistics node j.
(3)The total number of waste products received by logistics node j cannot exceed its processing capacity limit.

Symbol Description:
aj: The maximum processing capacity of logistics node j;
bj : The logistics flow received by logistics node j;
ej : The unit cost of daily operation of logistics node j;
Cij : The unit transportation cost of waste from logistics node i to logistics node j;
Xij: The reverse logistics flow of waste between logistics node i and logistics node j;
fj: The fixed cost of logistics node j, generally the fixed construction cost;
yj : 0-1 variable, indicating whether logistics node j is selected.

Objective function: In $\min F = \sum_{i=1}^{I}\sum_{j=1}^{J} C_{ij} \cdot X_{ij} + \sum_{j=1}^{J} f_j \cdot y_j + \sum_{i=1}^{I}\sum_{j=1}^{J} e_j \cdot X_{ij}$, F is the total cost, and from left to right are transportation costs, fixed costs and operating costs.
Constraints:

$$\sum_{i=1}^{I}\sum_{j=1}^{J} X_{ij} \le a_j y_j, \ \forall j (1)$$

$$\sum_{i=1}^{I}\sum_{j=1}^{J} X_{ij} \ge b_j, \ \forall_j (2)$$

$$X_{ij} \ge 0 (3)$$

$$y_j = \begin{cases} 1, & select \\ 0, & otherwise \end{cases} (4)$$

,

According to the
formula, when the demand constraints of Formula (2) are satisfied, Formula (3) is a non-negative constraint, and Formula (4) is a variable of 0-1.

4.2.2 Basic theory

Stanford model theory is a model to predict the waste quantity of a particular product according to its annual sales, product life cycle and product life distribution ratio. For Stanford model, when the product life cycle ends, not all products will be abandoned, and not all products will be used to the end of the life cycle. A certain percentage of the products will be abandoned before the end of the life cycle. The annual sales of products by the use of different consumer level and habits are different, obeying different life distributions. That is to say, after the product is sold to the consumer, the probability of being scrapped or eliminated after the 1nth, 2nth... ,mnth year is 1P, 2P... , mP, where mn is equal to or more than the product design life cycle L. And P1+P2+…+Pm=1, and then the

future scrap volume can be estimated through the sales volume or output of the product over the years[15].
According to the principle of the model, the product scrap quantity estimation model is $S = \sum_{t}^{T} Q_t * P_t$, where S is the scrap quantity (group) of the product in the year, T is the design life cycle of the product, Qt is the output of power battery before t years from that year, Pt is the probability that the product produced before t years will be scrapped after t years.

5 POWER BATTERY REVERSE LOGISTICS NETWORK DESIGN AND MODEL EXPERIMENT

5.1 Development Overview

T Company, founded in 2003, is an electric vehicle and energy company. Its main business is producing and selling electric vehicles, solar panels and energy storage equipment. It officially entered the Chinese market in December 2013. Since its entry into the Chinese market, the sales volume of electric vehicles has been increasing year by year. The sales model of T Company is different from that of traditional automobile enterprises. Traditional automobile sales channels are through 4S shops or dealers. However, T Company adopts the direct sales model and builds its own global marketing network without selling through authorized dealers. Company T adopts the model of ordering reproduction, and sells new cars mainly through online direct sales and offline experience stores. The sales process is shown in Figure 5. In the forward supply chain of T Company's electric vehicles, the battery supplier of T Company provides supporting power batteries for the production of T Company's electric vehicles, and then consumers buy the whole vehicle from the offline experience store directly owned by T Company to complete the whole forward circulation process of power batteries.

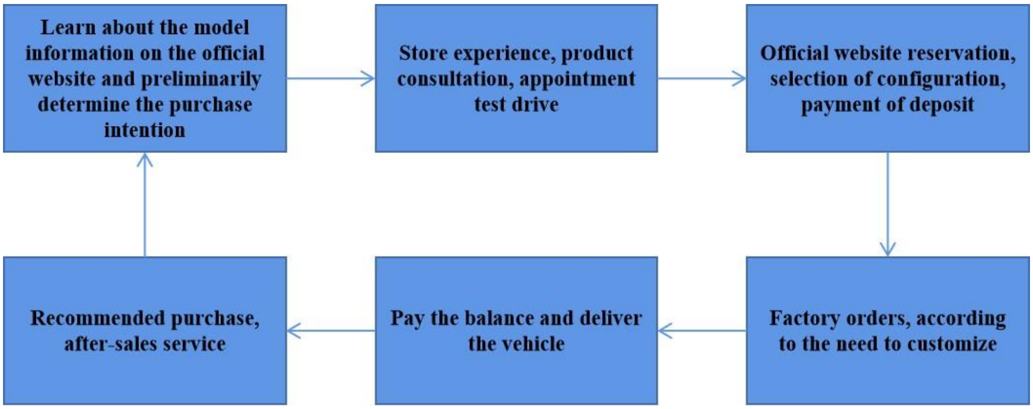

Figure 5: Flow chart of sales.

The service scope has covered to north China, east China, south China and west China. It has built up a user-centered intelligence service system(Figure 6).

Figure 6: Flow chart of after-sales service.

5.2 Analysis of operation mode of reverse logistics network of waste batteries

5.2.1 Reverse logistics network

At present, there are three recycling modes of waste power battery in China, which are the self-run mode of electric vehicle manufacturer, the recycling mode of electric vehicle industry alliance and the third-party outsourcing recycling mode[1]. The self-run recycling process is that electric vehicle manufacturers recycle consumers' discarded batteries through their sales networks. The specific process is shown in Figure 7.

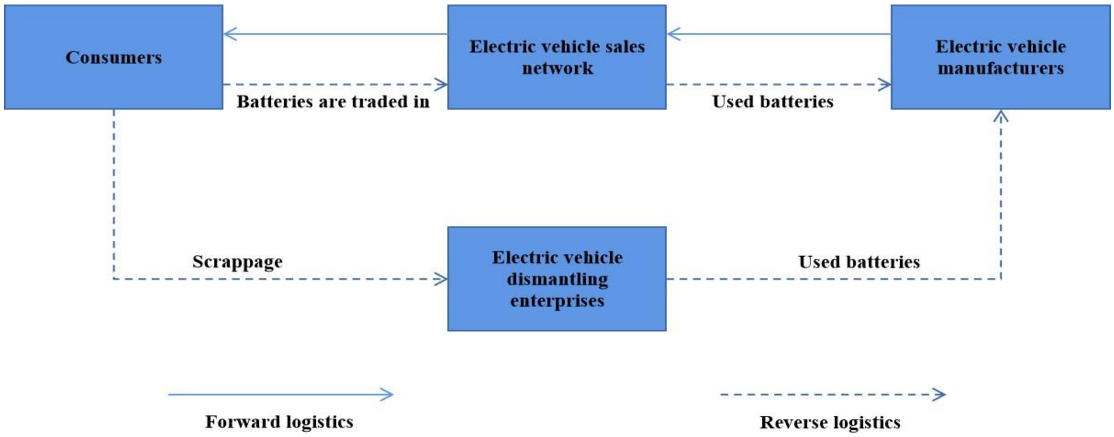

Figure 7: Flow chart of self-run mode of electric vehicle manufacturers.

The main components of industrial joint organizations are power battery manufacturers, new energy electric vehicle manufacturers or third-party battery leasing companies, which cooperate to build recycling channels. This mode can also reasonably promote industrial transformation and upgrading. The organization can jointly build a high degree of professional processing center, so that the recycling of waste batteries can be used in steps or other reasonable treatment. Under the recycling mode of industry joint venture, consumers will return the discarded batteries through the distribution outlets of the member enterprises of the alliance. And the waste batteries collected from consumers will be sent to the waste battery treatment center for professional treatment. Its recycling mode is shown in Figure 8.

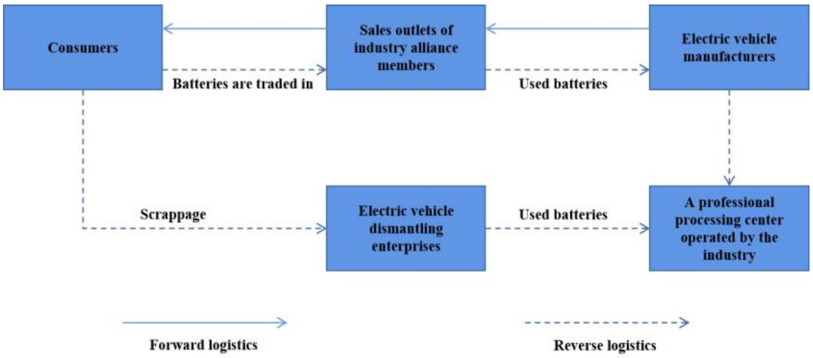

Figure 8: Flow chart of joint-venture recycling mode in electric vehicle industry.

The scale and comprehensive strength of domestic power battery manufacturers and electric vehicle manufacturers are not the same, and there are also differences in business strategies of enterprises. Some manufacturers do not have the ability to independently build self-run mode reverse logistics network, and are unwilling to join the industry recycling alliance for strategic consideration. At this time, many enterprises will outsource the reverse logistics of power battery recycling to professional third-party battery recycling enterprises (Figure 9).

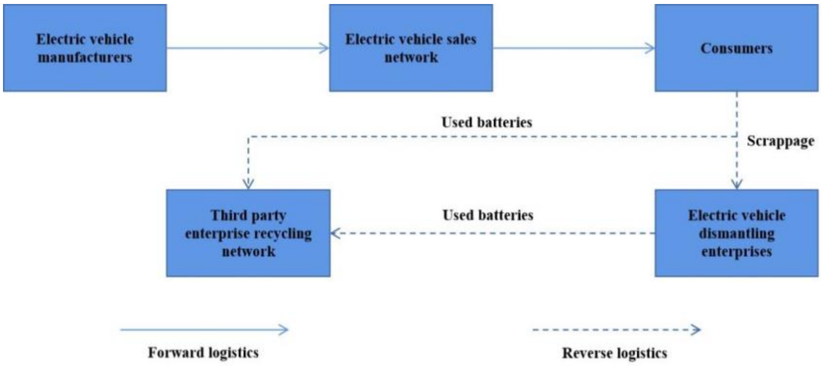

Figure 9: Flow chart of third-party outsourcing recycling mode.

5.2.2 The operation mode of reverse logistics network

According to Table 1 with the introduction of the three kinds of recycling mode, the three mainstreams of the electric car manufacturers proprietary mode, the electric car industry associated recycling recycling model and third party outsourcing each have advantages and disadvantages[16]. Enterprises should choose according to their specific situation and industry situation suitable operation model. The comparison of specific advantages and disadvantages of the three models are shown in table below. According to the comparison of different logistics network operation modes, it can be found that although self-run mode has relatively high short-term investment, it has significant advantages in information security, information feedback, influence on corporate image and promotion of technological innovation. Therefore, the design of reverse logistics network for waste power battery recovery based on self-run mode is investigated.As shown in Figure 10.

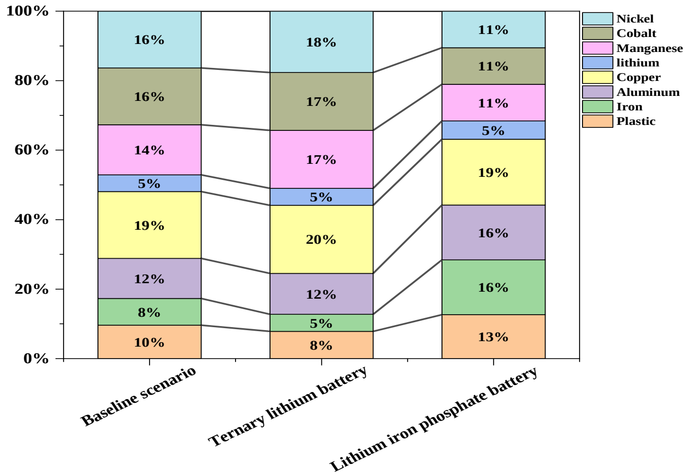

Figure 10: Power battery resource stock ratio under different scenarios.

	Self-run mode	*Industry alliance model*	*Third-party outsourcing model*
Investment and operating costs	*High*	*Medium*	*Low*
Information security	*Powerful*	*Weak*	*Weak*
Information feedback	*Fast*	*General*	*Slow*
Recovery efficiency	*Low*	*Medium*	*High*
A professional degree	*Medium*	*High*	*High*
Corporate Image Impact	*Good*	*General*	*Medium*
Promoting technological innovation	*Powerful*	*General*	*Weak*

Table 1: Comparison of advantages and disadvantages of different recycling modes.

5.2.3 Reverse logistics network design and analysis of battery recovery

According to the analysis and comparison results of operation modes, based on the design principles of economy in reverse logistics network design and integration with forward logistics network, and combined with the domestic policy requirements of extended producer responsibility system for power battery recycling, the self-operated network structure of forward logistics and reverse logistics integration for new energy electric vehicle power battery is designed for T Company. Network node mainly includes after-sales service center (waste battery recycling point), recycling waste metal processing plant, testing center, processing center, its operation process include classification, dismantling, recycling, transportation, testing and manufacturing and waste disposal, etc[2]. The flow diagram of old power battery recycling reverse logistics based on the T Company is shown in Figure 11.

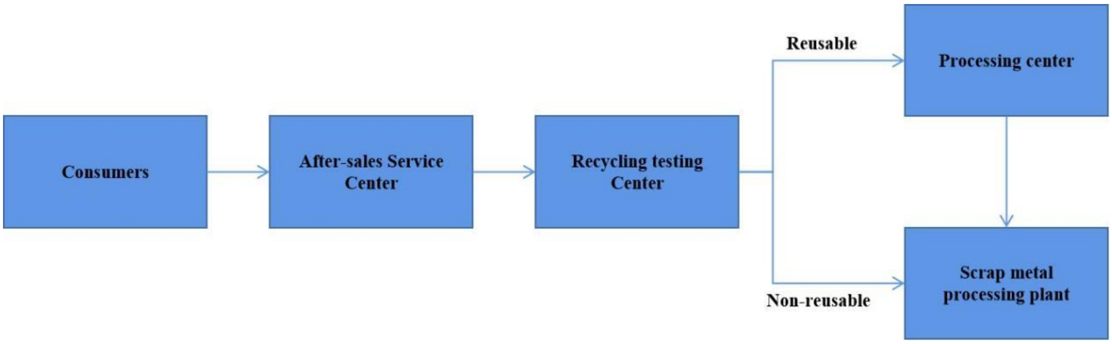

Figure 11: Flow chart of waste battery recovery reverse logistics network.

From the above section on the T Company flow diagram of the power battery reverse logistics network, T Company power battery reverse recovery of the network takes consumers as a starting point, through the T Company offline service center, testing center, ultimately gets to the supply chain upstream of the scrap metal processing plant power battery supplier or a third party. Among them, the geographical location of the power battery supplier and the third-party waste metal recycling center is fixed. Therefore, the main factor affecting the cost of T Company's reverse logistics recycling network is the location of the recycling detection center. Therefore, according to the analysis of the reverse logistics network process of waste power battery recovery, the node diagram of the reverse logistics network of waste power battery of T Company can be obtained by splitting the reverse logistics process.

5.3 Power Battery Reverse Logistics Network Design Model

5.3.1 Problem description

When planning the reverse logistics network for waste battery recycling, the following issues need to be considered (Figure 12).
1. In which candidate locations are recycling testing centers built, and what is the storage size?
2. In which candidate locations will waste battery treatment centers be built, and what is the scale of the treatment?
3. How to distribute the reverse logistics flow of waste power battery between nodes at all levels?

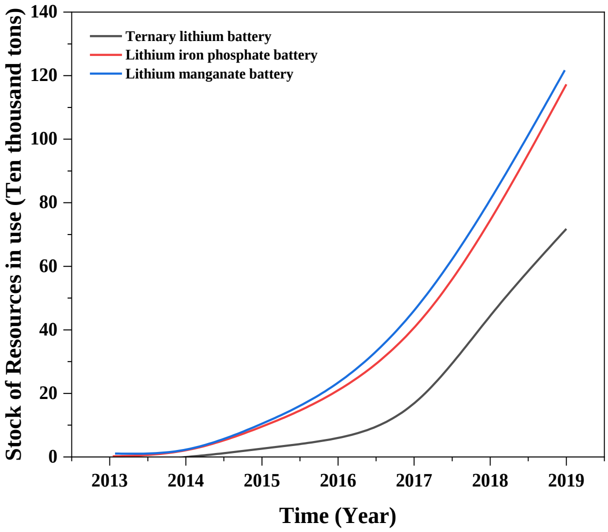

Figure 12: Inventory of resources in use for different types of power batteries.

5.3.2 Model hypothesis and symbol description

1. In this model, the case of single cycle and single product is only considered.
2. Only the after-sales service center can accept the discarded batteries of consumers, and consumers cannot directly send the discarded batteries to the second-level node recycling and testing center, the third-level node waste battery processing center and the waste metal treatment plant.
3. The waste batteries in the reverse logistics network can only reach the waste battery treatment center after the recycling and detection center, and the nodes of the same level cannot transfer the waste batteries to each other.
4. Transportation cost only considers the distance of known roads between nodes, and does not consider other factors such as road conditions[8].
5. Only the site selection of recycling testing center, waste battery treatment center and waste metal treatment plant is considered among the candidate sites. The investment and construction cost, processing capacity limitation and unit operating cost of logistics facilities of each node are known, while the unit cost of transportation between nodes is the same and known.
6. The after-sales service center has no inventory capacity. All the waste batteries recovered will be transported to the recycling and detection center.
7. The number of waste batteries arriving at the recycling and testing center and the waste battery treatment center should not exceed its maximum processing capacity.
8. There is no limit to the maximum processing capacity of waste metal processing plants.

5.3.3 Model construction

Based on the assumptions of the model, the reverse logistics network model of single-cycle power battery is constructed with the goal of minimizing the total cost and the negative utility of residents.

The objective function of minimizing the total cost of reverse logistics network of waste power battery recovery is shown as follows.

$$\min E(F) = F_1 + E(F_2) + F_3$$

$$F_1 = \sum_{j=1}^{J} FJ_j \cdot YJ_j + \sum_{r=1}^{R} FR_r \cdot YR_r$$

$$F_2 = \sum_{k=1}^{K}\sum_{j=1}^{J} XKJ_{kj} \cdot DKJ_{kj} \cdot v + \sum_{j=1}^{J}\sum_{r=1}^{R} XJR_{jr} \cdot DJR_{jr} \cdot v$$

$$F_3 = \sum_{k=1}^{K}\sum_{j=1}^{J} XKJ_{kj} \cdot EJ_j \cdot v + \sum_{j=1}^{J}\sum_{r=1}^{R} XJR_{jr} \cdot ER_r$$

In the formula, F1 is the total investment and construction cost of node facilities of reverse logistics network, F2 is the transportation and logistics cost between nodes, F3 is the operation cost of node facilities. The waste power lithium batteries of new energy electric vehicles belong to the nine categories of dangerous goods, which may have a negative impact on the nearby residential areas. Therefore, in the model construction, not only the lowest cost is considered, but also the negative utility of residents is taken into account as the objective function. The influence of the reverse logistics network on the surrounding residents mainly includes the influence on the residents during the operation of the reverse logistics node facilities. The objective function of reducing the negative utility of the residents in the waste reverse logistics network can be expressed as follows.

$$\min P$$

$$P = \sum_{k=1}^{K}\sum_{j=1}^{J} \frac{XKJ_{kj}}{(GJ_j)^{\gamma}} + \sum_{j=1}^{J}\sum_{r=1}^{R} \frac{XJR_{jr}}{(GR_r)^{\gamma}}$$

Model solution: $\sum_{j=1}^{J} XKJ_{kj} \cdot YJ_j = \tilde{z}_k, \ \forall k$; $\sum_{k=1}^{K} XKJ_{kj} \leq QJ_j \cdot YJ_j, \ \forall j$;

$$XKJ_{kj},\ XJR_{jr},\ XJL_{jl},\ XRL_{rl} \geq 0$$

5.4 Power Prediction

Based on the current development level of domestic power battery technology, the actual life cycle of the power battery supporting the electric vehicles produced by T Company can be divided into four grades, namely 7 years, 5 years, 3 years and 1 year. That is, the probability of scrap battery after 7 years, 5 years, 3 years and 1 year are 7P, 5P, 3P, 1P respectively. Due to the limitation of technical level, the actual life cycle of the power battery produced from 2014 to 2018 is 5 years. After 2018, the performance of the power battery is improved, and the longest life cycle reaches 7 years. It is known that the power battery used by T Company weighs 500kg. Table 2 shows the electric vehicle sales and power battery usage of T Company. According to the Stanford scrap model, the power battery scrap volume of T Company in 2021 can be estimated as shown in the table[6].

Year	Electric vehicle Sales volume (Unit)	Power battery usage (Ton)
2015	122	26.5
2016	425	212.5
2017	983	491.5
2018	1842	932
2019	1971	955.2
2020	6033	3016.5
2021	19867	9723.1

Table 2: Electric vehicle sales and power battery usage.

According to the battery usage, the amount of discarded batteries is predicted, and the results are shown in Table 3.

Year	Sales	Power battery life distribution (%)			
		P1	P2	P3	P4
2015	53	4	49	47	/
2016	427	5	49	46	/
2017	983	6	46	48	/
2018	1852	5	44	52	0
2019	1911	4	27	38	30
2020	6033	5	27	40	28
2021	18275	4	24	36	36

Table 3: Prediction of scrapped battery quantity of electric vehicles.

Compared with forward logistics network, a significant characteristic of reverse logistics network is its uncertainty, namely the quantity and quality of recycling are highly uncertain [17]. In order to construct a scientific and efficient reverse logistics of power battery recovery, the scrap quantity of power battery must be estimated scientifically and reasonably. Whether the government formulates relevant laws and regulations on power battery recycling, or the reverse logistics system and network layout with enterprises as the main body for efficient operation, the quantity scale and development trend of power battery scrap quantity estimated have a very important role.

6 CONCLUSIONS

New energy electric vehicles are rapidly popularized in the world. Driven by electric vehicle terminals, the output and sales of power lithium batteries will maintain a high growth trend. Recycling of waste batteries has become one of the hot issues of social concern in recent years. In the future, there will be large scale scrapped power batteries, which will cause the waste of resources and environmental pollution. At present, China's electric vehicle industry has been market-oriented for a short time, and power batteries have not entered the large-scale scrap stage, so China lacks a scientific and efficient waste battery recycling system, and how to build a reasonable and effective reverse logistics recycling network is still being explored. The status quo, driving factors and structural characteristics of reverse logistics for recycling waste batteries of electric vehicles are analyzed, and the strategic significance of recycling waste batteries of electric vehicles is expounded. And waste battery recycling can bring huge economic and social benefits for enterprises, which is the key to achieve the sustainable development of electric vehicle industry.infrastructure development should also focus on optimizing the logistics operations involved in the reverse logistics network, considering factors such as transportation costs, storage facilities, and processing capabilities.

The construction of the reverse logistics network is a wide-ranging and complicated research subject. In the research, the total cost of logistics and the residents disutility two factors are only considered. But in real life scenarios, there are many other factors are likely to affect the construction of the reverse logistics network. So the results in the research has some limitations in practical applications. In the future, the influence of government energy subsidies and social environmental awareness on the reverse logistics network of waste battery recycling can be further considered, and the reverse logistics network of waste battery recycling based on the influence of government or social behavior can be further discussed. The model constructed in the research is only discussed from the single cycle and static level, ignoring that in the actual production of enterprises. The reasonable logistics operation plan is based on multiple cycles and has dynamic changes, which needs to be improved and continuously optimized in the research.

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