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Study of the Development Status and Potential Solutions for Improving the Logistics of Power Battery Reverse Logistics

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Abstract

In recent years, there has been a notable surge in the production and sales of new energy vehicles, driven by a confluence of factors including economic growth, enhanced environmental consciousness, and the growing awareness of the scarcity of natural resources. This growth has been facilitated by the joint efforts of the government and vehicle manufacturers. As a central component of new energy vehicles, the market demand for power batteries is also expanding rapidly. In consideration of the warranty period of automobiles, the peak elimination of power batteries is imminent. In light of the current state of automotive power battery recycling reverse logistics and the associated challenges, this paper presents a series of proposed measures and recommendations with the aim of fostering the advancement of power battery recycling reverse logistics. In the context of the circular economy, these suggestions will assist the power battery recycling industry in achieving a more rational and efficient planning of investment decisions, facility configuration, network layout and human resource allocation. Furthermore, they will provide a basis for the government to introduce encouraging policies.

Keywords

Power Battery; Reverse Logistics; Ladder Utilisation.

1. Introduction

In parallel with the accelerated growth of China's economy and the notable enhancement of the country's overall quality of life, consumers have demonstrated a growing propensity to purchase automobiles, thereby stimulating a surge in demand and extensive expansion within the motor vehicle industry. Nevertheless, the accelerated growth of the motor vehicle industry has also resulted in the emergence of increasingly significant environmental concerns. In order to address the challenges of environmental protection and the finite nature of resources, the government and manufacturers have collaborated to advance the production and sale of new energy vehicles, resulting in a notable expansion of the new energy vehicle market in recent years. Statistical data indicates that the production and sales of new energy vehicles in China in 2023 will reach 9.587 million and 9.495 million, respectively. As the new energy vehicle industry continues to expand at a rapid pace, the recycling and disposal of end-of-life vehicles will inevitably become a significant social and environmental concern.

The growing popularity of new energy vehicles has led to an increase in demand for power batteries, which are a crucial component in these vehicles. As evidenced by the data, by the conclusion of 2023, the aggregate production capacity of power batteries in China had reached 387.7 GWh, representing a year-on-year increase of 31.6%. New energy vehicles are typically covered by a warranty period of between six and eight years or 80,000 and 160,000 kilometres, respectively. In accordance with this standard, a considerable number of new energy vehicles that were promoted between 2015 and 2018 are approaching or have already exceeded the

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standard period of use. Consequently, a significant number of power batteries are nearing the end of their operational lifespan and are therefore due for replacement. The recycling of used power batteries is currently facing a number of challenges, including the lack of an effective recycling system, the necessity for improvements to the recycling model, the relatively low recycling rate and the existence of inconsistent normative standards. These issues have attracted significant attention from governmental and corporate entities. In response to these challenges, in 2018, the Ministry of Industry and Information Technology, in collaboration with seven other government departments, issued the Interim Measures for the Administration of Power Battery Recycling for New Energy Vehicles. The Measures elucidate the extended producer responsibility system, stipulating that automobile manufacturers bear the primary responsibility for power battery recycling and that relevant enterprises assume corresponding responsibilities in all aspects of power battery recycling. This is done in order to ensure that power batteries are effectively utilised and disposed of in an environmentally friendly manner. The implementation of the new policy provides a framework for the advancement of the power battery recycling industry and has the potential to significantly impact public awareness of circular economy and low-carbon environmental protection.

The reverse logistics of recycling power batteries for new energy vehicles is distinctive in that the time, location and quantity of generation are uncertain, and distribution is relatively decentralised. This results in considerable challenges for businesses in terms of operational efficiency and economic benefits. Concurrently, the government and the public must address the environmental pollution and resource waste generated during the battery recycling process with urgency. In light of the prevailing challenges associated with the recycling of power batteries, a series of constructive recommendations have been put forth. These recommendations are designed to assist enterprises in formulating rational power battery recycling strategies and to serve as a point of reference for the government in the development of relevant reverse logistics policies. The objective is to facilitate the sustainable development of the circular economy.

2. The Current Status of Reverse Logistics for Power Batteries

2.1. The Power Battery Reverse Logistics Industry has not Yet Reached a Sufficient Scale

Since 2013, there has been a notable increase in the production and sales volume of electric vehicles in China. As the power batteries of these electric vehicles reach the end of their operational lifespan, the volume of lithium-ion batteries being scrapped has reached 168,000 tonnes, representing a year-on-year increase of 78.3%. This information is drawn from the statistics of 2023. Nevertheless, the extensive geographical distribution of used batteries has resulted in elevated logistics costs, which in turn has impeded the advancement of reverse logistics for power batteries. Presently, China has yet to establish a comprehensive, cost-effective, and efficient recycling network for used power batteries. The responsibility for recycling is not sufficiently clear, and the phenomenon of partial recycling and broken-chain recycling is common, which results in the power battery reverse logistics network developing in a small-scale and disorderly manner. In light of the accelerated expansion of electric vehicle sales in recent years, the current nascent recycling network will likely prove inadequate in responding to the impending surge in retired power batteries. It is therefore imperative to establish an effective recycling system for used power batteries in order to meet the challenges that lie ahead.

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2.2. High Cost and Difficult to Make Profit in Reverse Logistics of Power Battery

The reverse logistics management of power batteries presents a number of significant challenges. The internal flammable and explosive unstable chemical components of these batteries, coupled with their high density and heavy mass per unit volume, necessitate the involvement of specialised personnel and equipment, as well as advanced testing technology, and the use of specialised storage facilities. As a result, the cost of transport for these batteries is significantly higher than that of other, less hazardous materials. Furthermore, the operation of reverse logistics is characterised by a high degree of uncertainty, with a number of variables, including the recycling cycle, quantity, product quality and location, which contribute to an increase in the complexity of the logistics network and a corresponding rise in operational costs. Furthermore, the recycling of power batteries necessitates the involvement of numerous specialized entities, including those engaged in discharge, testing, and classification. These processes demand not only sophisticated technical apparatus but also personnel proficient in the requisite technical and professional competencies. The aforementioned requirements result in elevated capital and operational costs, rendering the investment in power battery reverse logistics a significantly more costly undertaking than that of ordinary logistics. In the absence of economies of scale, it is challenging for enterprises to generate profits in the domain of reverse logistics.

2.3. Incomplete Coverage of Power Battery Reverse Logistics Network

As the peak of power battery end-of-life approaches, the development of reverse logistics in the field of power battery recycling in China is facing significant challenges. In economically developed areas, the presence of numerous precious metals in batteries has led to the proliferation of private recycling outlets. This has resulted in a lack of coordination and coherence in the reverse logistics network of formal recycling enterprises, which has in turn affected the efficiency and effectiveness of the network. Conversely, in less developed regions, the low penetration rate of new energy vehicles has resulted in relatively low recycling profits, which has led to the majority of recycling enterprises failing to establish a comprehensive reverse logistics network. Consequently, a considerable number of end-of-life power batteries lack formal recycling channels. The unequal distribution of this reverse logistics network not only impedes the healthy development of the new energy vehicle industry, but also poses a significant environmental risk, which is contrary to the original intention of promoting new energy vehicles. It is therefore necessary to reinforce the construction and optimisation of the reverse logistics network in order to guarantee the effective management of the recycling of power batteries and thus promote the sustainable development of the new energy vehicle industry.

3. The Problems of Reverse Logistics in the Context of Power Batteries

3.1. Inadequate Recycling and Regulatory Systems for Power Batteries

China's power battery recycling system is still in its infancy, with the relevant supervision and management systems for the recovery, transport, dismantling and comprehensive utilisation of power batteries still underdeveloped. This has resulted in a lack of consumer awareness regarding the appropriate channels for the disposal of power batteries, coupled with a relatively weak legal awareness among the primary recycling entities. Furthermore, instances of informal recycling channels utilising broken-chain transport are commonplace. Consequently, the actual recycling volume of formal specialised enterprises is considerably below the designed demand, which has a detrimental impact on the healthy development of the industry.

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Despite the fact that numerous policies and regulations have been enacted at the state level, their implementation in practice has been inadequate. The reverse logistics industry of waste power battery recycling continues to exhibit a diffuse developmental state, which gives rise to a series of issues, including elevated costs, diminished efficiency, low utilisation and disposal rates in the context of waste power battery recycling in China.

3.2. The Configuration of Reverse Logistics Network Nodes is Untenable

3.2.1. The Unregulated Proliferation of Recycling Outlets

Recycling outlets represent the initial stage of the reverse logistics process for power batteries. They are directly engaged with consumers and exert a significant influence. The optimal configuration of these outlets is of critical importance in facilitating the growth of both the number and scale of recycling operations. Furthermore, the recycling network serves as a pivotal nexus for the exchange and dissemination of information between the upstream and downstream segments of the power battery industry.

Despite the establishment of numerous recycling points in the Chinese power battery recycling market, the overall layout remains dispersed and haphazard, devoid of rational planning and resulting in incomplete coverage of the area. This situation has resulted in two extreme phenomena. Firstly, some formal recycling points are unable to fulfil their intended function due to a lack of available goods. Secondly, a significant number of used power batteries are being dismantled illegally by small private workshops or individuals. The majority of these private recycling facilities are not within the operational scope of formal recycling and logistics enterprises, thereby exacerbating market confusion.

3.2.2. Inefficient Planning of Recycling Centre

In the reverse logistics system of power batteries, the recycling centre plays a pivotal role, primarily responsible for collecting batteries from its recycling outlets and undertaking pivotal processes such as testing and classification, which represents the core node in the reverse logistics network. One of the primary causes of the elevated logistics and transportation expenses associated with power battery recycling in China, coupled with the notable disparity in the utilisation rate compared to that of developed countries, can be attributed to the suboptimal planning of recycling centres.

Firstly, the location of the recycling centre is not optimally selected, with the distance from some recycling outlets being relatively far. This not only reduces the enthusiasm of the recycling outlets to take the initiative to send the batteries to the recycling centre, but also increases the distance of the unit goods transported by the logistics vehicles in the recycling centre, which in turn raises the transport cost of the reverse logistics. Secondly, the functional design of the recycling centre is also flawed. The centre is deficient in professional logistics facilities and information technology equipment, as well as insufficient testing equipment for power batteries. This significantly impedes the efficiency of logistics operations and affects the screening ratio of gradient-usable batteries. It is therefore evident that optimising the planning layout and functional design of the recycling centre represents a significant opportunity for enhancing the overall efficiency of power battery recycling in China.

3.2.3. Absence of Upstream and Downstream Links in the Processing Centre

In China, the end node of power battery reverse logistics – the processing centre – bears the significant responsibility of dismantling and treating chemical pollutants on end-of-life power batteries that cannot be used in a gradual manner. Such facilities are capable of extracting recyclable metal resources and polyethylene materials, thereby providing valuable raw materials for the production of new batteries. Nevertheless, there is currently a significant deficit of such facilities in China. The existing processing centres are relatively isolated within the recycling market and lack integration with the logistics channels of upstream recycling

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outlets and recycling centres. This has resulted in the inefficient dissemination of information regarding logistics, products, and other pertinent matters, thereby placing these centres in a predicament characterised by the dual challenges of an excess of supply and the lack of demand for their products.

3.3. Insufficient Specialised Resources for Reverse Logistics of Power Batteries

In the field of power battery recycling, the necessity for diverse talent arises from the differences in the stability and detection methods of various types of power batteries. These differences require that different types of batteries be handled in a manner that reflects their specific characteristics. The reverse logistics system of recycling enterprises requires a significant number of professionals to effectively coordinate and manage a range of processes, including collection and sorting of waste power batteries, testing, maintenance, treatment, transport, and other activities. The presence of these professionals is essential to ensure the efficiency and safety of logistics operations. Nevertheless, the requisite technology and management mode remain in a state of infancy, and the return on investment of power battery recycling is less than that of the traditional logistics industry. This situation gives rise to a relative paucity of investment in professional equipment and talent by the majority of recycling enterprises. This situation has a markedly detrimental impact on the healthy development of the reverse logistics system.

4. Suggestions for the Development of Power Battery Reverse Logistics

4.1. Optimise The Layout of Network Nodes and Establish a Perfect Reverse Logistics System for Power Battery

The reverse logistics network system of waste power batteries comprises a complex network architecture, interwoven by logistics nodes and transport routes. The configuration of the nodes is a primary determinant of the network's radiation range, while the transportation route between nodes represents a critical aspect of network efficiency and complexity. In order to enhance the overall efficiency of the network, it is essential to optimise the layout of the nodes in order to establish a comprehensive reverse logistics network that encompasses the entire region.

In the construction of nodes, particular attention should be paid to the planning of large-scale professional nodes, such as recycling centres and processing centres. This necessitates a scientific determination of the number of nodes, the hierarchical structure of the network, and the carrying capacity of each node in accordance with the actual development requirements. The implementation of such a plan will result in a notable reduction in the complexity of the reverse logistics network for used power batteries, an enhancement in logistics efficiency, the attainment of economies of scale, and, ultimately, a reduction in logistics costs. Such an optimisation strategy not only enhances the professionalism of the logistics system but also provides a robust guarantee for the recycling and treatment of waste power batteries in China.

4.2. Establish Scientific Supervision and Management Mechanism to Guide the Healthy Development of Power Battery Reverse Logistics

Despite the rapid growth of the new energy automobile industry in China, the recycling and supervision system for waste power batteries remains inadequate. This has resulted in the dismantling of batteries by unlicensed small workshops, which not only pollutes the environment but also wastes resources. It is therefore imperative to reinforce the supervision and management of reverse power battery logistics. It is imperative that the government assumes a pioneering role, in collaboration with industry associations, enterprises and customers, to establish a robust quality supervision and management mechanism. It is imperative that comprehensive supervision and inspection of all aspects of reverse logistics be

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conducted in order to ensure the effective implementation of relevant regulations and standards. Specifically, the government should reinforce its supervisory role, industry associations should facilitate inter-organizational collaboration, enterprises should assume social responsibility for advancing recycling technology, and consumers should engage in monitoring to safeguard their rights and environmental protection. It is anticipated that the implementation of these measures will facilitate the establishment of a more comprehensive and efficient reverse logistics system, thereby contributing to the sustainable development of China's power battery industry.

4.3. Improve Reverse Logistics Infrastructure Construction, Better Integration Of Modern Logistics Information Technology

In the advancement of reverse logistics for waste power batteries, it is essential to progressively enhance the construction of recycling networks, sorting centres, distribution centres and processing centres. This necessitates the investment in additional professional recycling facilities, transportation tools and waste power battery testing equipment to guarantee the continued availability of waste batteries and recycling channels. Furthermore, attention should be paid to the following aspects:

Firstly, the advantages of the Internet must be fully exploited in order to construct an efficient information platform which will bring together the logistics information resources of various types of waste power batteries. The optimal allocation of logistics resources can be achieved through the integration of transport, warehousing and distribution information. Secondly, the utilisation of the Internet of Things, wireless radio frequency and other sophisticated technologies to facilitate the reverse logistics process of power battery information and network management. These technologies are characterised by the capacity to track information, perform comprehensive sensing, facilitate unlimited transmission, enable real-time monitoring and intelligent processing. They can therefore assist in the establishment of an interoperability system for the sharing of logistics information, thereby promoting the development of an 'Internet + efficient logistics' system. Furthermore, the collection of pertinent data, including the type, composition, and service life of used power batteries, should be enhanced to facilitate the expedient and precise assessment of their residual value. This can lead to a notable enhancement in the utilisation of power batteries, thereby creating greater social value. In essence, through the aforementioned measures, we can guarantee that the reverse logistics system for waste power batteries is more comprehensive, thus contributing to the sustainable development of China's power battery industry.

4.4. Establish a Reasonable Agitation and Benefit Distribution Mechanism to Improve the Participating Parties' Enthusiasm

In the entire power battery reverse logistics network system, consumers, new energy vehicle sales and maintenance, manufacturers, power battery manufacturers and battery raw material suppliers, and other links play an indispensable role. These subjects are not only the generators of used power batteries, but also the key stakeholders in the recycling process. Their participation is therefore crucial for improving the effectiveness of power battery recycling, optimising the operational efficiency of reverse logistics and reducing operational costs.

In light of the aforementioned considerations, it is recommended that the government implement a comprehensive assessment and auditing system to evaluate the quality of battery reverse logistics development. In recognition of their responsiveness to the national green development policy and their exemplary contributions to technological innovation, management optimisation, model innovation and standardisation in the field of reverse logistics, it is recommended that the government provide the necessary financial and policy support. Concurrently, the government must devise a series of scientific benefit distribution

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programmes, establish reasonable benefit distribution principles, and address pivotal elements such as distribution ratios and incentive and constraint strategies. By monitoring the actual inputs and outputs, as well as the performance evaluation results of the relevant enterprises, the government should implement continuous adjustments to the distribution scheme, with the aim of more effectively motivating all parties to actively participate in the standardised and regulated reverse logistics network for power batteries. This approach would result in a notable improvement in operational effectiveness and efficiency in this field.

5. Conclusion

Presently, the reverse logistics of power battery recycling is in a developmental phase, with numerous links requiring improvement. This creates new opportunities for development, as well as corresponding challenges. In the context of the circular economy, the reverse logistics of power battery recycling not only aims to achieve economic benefits but also places a greater emphasis on resource conservation and environmental protection. Advances in this area are becoming a crucial element in the implementation of the 'double-wheel drive' strategy, which aims to advance economic and social development while simultaneously protecting the environment. Ultimately, this approach seeks to achieve a harmonious coexistence and sustainable development of the economy, society, and the environment. In conjunction with the exponential growth of the new energy vehicle industry, the peak of power battery end-of-life is imminent. It is therefore imperative to accelerate the improvement of the power battery recycling system, promote the optimisation of the reverse logistics recycling model and strengthen the construction of infrastructure and intelligent information platforms. It is imperative to continuously enhance the organisation and standardisation of reverse logistics in power battery recycling. This is not only a contemporary trend in logistics development, but also a pivotal approach to optimising industrial structure, transforming economic development models and advancing the sustainable growth of the region.

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