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International Journal of Global Economics and Management
ISSN: 3005-9690 (Print), ISSN: 3005-8090 (Online) | Volume 10, Number 5, Year 2026
DOI: https://doi.org/10.62051/ijgem.v10n5.05
Journal homepage: https://ijgem.org

Green Reverse Logistics for Closed-Loop Supply Chains of NEV Power Batteries: A Case Study of BYD

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ABSTRACT

Grounded in green logistics and reverse logistics theories, and incorporating the framework of closed-loop supply chain (CLSC) theory, this study systematically examines the current state of green reverse logistics management within China’s power battery recycling system for new energy vehicles. Taking BYD Auto as a case study, it provides an in-depth analysis of critical challenges related to recycling network efficiency, hazardous material logistics safety, and the collaborative functioning of the CLSC. The findings reveal that a fragmented recycling network layout, pronounced safety risks in logistics operations, and the limited processing capacity of single-brand closed-loop systems severely constrain both recycling efficiency and environmental performance. In response, this paper proposes a set of optimization strategies: the construction of a three-tier collection network comprising “community collection points, centralized recycling centers, and regional treatment bases”; the promotion of low-carbon practices in packaging, transportation, and warehousing; and the establishment of cross-brand battery recycling alliances. The study aims to enhance the operational efficiency and safety of green reverse logistics, facilitate the resource-based circular utilization of power batteries, and provide both theoretical support and practical guidance for developing a highly efficient, environmentally sound, and sustainable closed-loop recycling system for the NEV industry.

KEYWORDS

New energy vehicles; Power batteries; Green logistics; Reverse logistics; Closed-loop supply chain; Recycling network

1. INTRODUCTION

1.1. Research Background

In recent years, the new energy vehicle (NEV) industry has experienced robust growth and has become a national strategic emerging industry. According to data from the China Association of Automobile Manufacturers (CAAM), China’s NEV production and sales have ranked first globally for several consecutive years. As of 2023, the total number of NEVs in operation had exceeded 20 million units, marking the industry’s official entry into a new phase of large-scale development. Against the backdrop of global efforts to combat climate change and promote energy structure transformation, the electrification revolution in the NEV sector has become an irreversible trend. Moreover, with continuous advancements and improvements in domestic NEV technologies, China has gradually emerged as a key leader in this revolution.

However, while the explosive growth of the industry has brought significant environmental benefits (e.g., reduced emissions during vehicle operation), it also presents a substantial challenge: the aging of power batteries. As the core component of NEVs, power batteries typically have an effective service life of five to eight years. Based on this estimate, the first wave of power batteries marketed at scale beginning in 2015 is now entering a period of mass end-of-life. Industry authorities project that by 2025, China's cumulative volume of retired power batteries will approach 800,000 metric tons. If improperly handled, battery components such as electrolytes and heavy metals may cause severe contamination of soil and water bodies, and may even trigger safety incidents. Therefore, establishing a scientific and efficient recycling and reuse system to enable power batteries to move "from end-of-life to second life" has become an imperative for the sustainable development of the industry.

Within the construction of such a system, green logistics plays a pivotal bridging role. The recycling process for retired batteries is, in essence, a complex issue of reverse logistics and closed-loop supply chain management. It involves safely and economically collecting end-of-life batteries from millions of dispersed end-users, and then subjecting them to sorting, packaging, warehousing, and transport via optimized networks to treatment centers, where they ultimately undergo refined reuse.

Currently, this logistics system faces several critical challenges. The layout of the recycling network remains incomplete, resulting in low collection rates through formal channels and a substantial volume of batteries flowing into informal treatment channels. Retired batteries are classified as hazardous Class 9 goods, and there are gaps in the enforcement of safety and environmental regulations in their transportation and storage. Furthermore, the boundaries of responsibility among stakeholders across the industrial chain (i.e., vehicle manufacturers, battery producers, and recycling enterprises) are ambiguous, and information is fragmented. These issues lead to high logistics costs, difficulties in corporate traceability management, and low coordination efficiency.

In view of the dual impact of green reverse logistics management for NEV power batteries on both enterprises and the environment, in-depth research into its management and optimization strategies is of urgent practical significance. Such research would not only help improve the economic performance of individual enterprises but also promote the development of the entire NEV industry and contribute to the global transformation of energy structures.

1.2. Research Purpose

Against the backdrop of rapid development in the new energy vehicle (NEV) industry, the recycling challenges arising from the aging of a large number of power batteries are, in essence, a green reverse logistics problem. At present, a substantial volume of batteries is being recycled through informal channels. The pollution generated during dismantling processes, together with safety issues in transportation and storage, has created severe environmental and safety hazards, directly contradicting the core principles of green logistics—namely, environmental friendliness and process safety. Therefore, establishing a comprehensive green reverse logistics system—employing measures such as green packaging, new energy transport vehicles, low-carbon warehousing, and full-process management—is not only an essential pathway toward the resource-oriented and non-hazardous circular utilization of end-of-life batteries but also the key to transforming the potential environmental burden at the end of the industrial chain into closed-loop economic value. How to design and operate a battery recycling system that truly achieves the integration of environmental benefits and operational efficiency has thus become a central proposition for promoting the sustainable development of the NEV industry.

1.3. Research Significance

This study enriches the application of green reverse logistics theory within the specific domain of new energy vehicles (NEVs). Compared with traditional reverse logistics problems, NEV power batteries exhibit complex characteristics—including the need for systematic safety management, process optimization, and the simultaneous pursuit of safe, efficient, and low-carbon transformation—which pose numerous new challenges for green reverse logistics management. By systematically examining the features, problems, and optimization pathways associated with these batteries, this study adds a new case and analytical framework to the theoretical system of green reverse logistics, expands the boundaries of theoretical research, and renders the theory more adaptable to diverse practical scenarios.

Besides, This study focuses on the green reverse logistics management of NEV power batteries and holds significant practical value. By conducting an in-depth analysis of the problems existing in the battery recycling processes of automotive enterprises through case studies, and by proposing targeted optimization strategies, this research can help enterprises improve the efficiency and effectiveness of reverse logistics, reduce costs, enhance international market competitiveness, solidify their global market position, and strengthen brand influence. At the same time, the research findings provide other enterprises of the same type with referable management optimization ideas and methods, contribute to elevating the level of green reverse logistics management across the industry, promote the healthy and orderly development of the NEV sector, and support the global transition toward more sustainable energy structures.

2. AN OVERVIEW OF THE GREEN REVERSE LOGISTICS THEORY FOR THE CLOSED-LOOP SUPPLY CHAIN SYSTEM OF NEW ENERGY VEHICLE POWER BATTERIES

2.1. Theories of Green Logistics

Green logistics research originated in Western academic contexts and spans multiple disciplines, including sustainable development theory, ecological economics, and environmental ethics, and has been widely discussed worldwide [1]. In a broad sense, green logistics refers to the suppression of environmental harm caused by logistics activities while simultaneously purifying the logistics environment and achieving the full utilization of logistics resources [2]. In a narrow sense, green logistics entails the use of advanced logistics technologies to achieve green operations across processes such as transportation, warehousing, loading and unloading, materials handling, circulation processing, packaging, and distribution, thereby reducing environmental pollution and resource consumption throughout the entire operational process [3]. In essence, the fundamental objective of green logistics is to ensure that logistics operations overcome temporal and spatial barriers to meet human needs, while at the same time greening the environment through which goods flow during circulation, thereby achieving sustainable development [4].

2.2. Theories of Reverse Logistics

American scholar Stock first proposed the concept of "reverse logistics" in 1992, and it was documented in a research report of the Council of Logistics Management (now the Council of Supply Chain Management Professionals). Subsequently, scholars in the logistics field worldwide began conducting research on reverse logistics. In China, exploration of reverse logistics started later than international research in this area. Chinese scholars represented by Zhou Chui, based on a synthesis of definitions from various countries, proposed a relatively comprehensive definition of reverse logistics that emphasizes the purposefulness of value acquisition [5].

In a traditional forward supply chain, products flow from suppliers to manufacturers, then to distributors and retailers, ultimately reaching consumers. Reverse logistics, in contrast, involves the flow of products from consumers back to the upstream stages of the supply chain, encompassing movements from end-users to retailers, distributors, recycling centers, processing facilities, and raw material suppliers. Therefore, this study defines reverse logistics as the process through which products return from consumers to the upstream stages of the supply chain, covering multiple activities including product recycling, returns management, and remanufacturing.

2.3. Theoretical Research on the Closed-Loop Supply Chain for Power Batteries in New Energy Vehicles

With the continuous increase in domestic production and sales of new energy vehicles, coupled with the arrival of the first peak period for power battery recycling in 2025, many scholars both domestically and internationally have begun shifting their research focus toward closed-loop supply chains (CLSC) that encompass the recycling and reuse of power batteries [6]. The recycling and reuse of electric vehicle power batteries are closely intertwined with the management of CLSC. A closed-loop supply chain builds upon the traditional supply chain by introducing the concept of a reverse supply chain, which includes processes such as collection, inspection, reprocessing, treatment, and redistribution. Through case analyses of the remanufacturing processes of different types of enterprises, it has been found that the remanufacturing process within a CLSC exhibits different characteristics under different environmental conditions.

Internationally, research on CLSC that include power battery recycling generally falls into three major streams: the selection of recycling channels, the formulation of recycling strategies, and the role of government regulations and subsidies [7]. This paper focuses on the formulation of CLSC recycling strategies and conducts a literature review accordingly. Gu and Ieromonachou [8] analyzed a CLSC for power battery recycling consisting of manufacturers and remanufacturers, finding that the recycling price plays a decisive role in the volume of power batteries collected. Liu and Gong [9] modeled and simulated the electric vehicle power battery recycling process using an agent-based approach and analyzed the factors influencing recycling, concluding that the battery refurbishment rate significantly affects the simulation outcomes. Li and Mu [10] constructed mathematical models with and without government-regulated recycling rates and explored the impact of introducing price discount contracts into the forward supply chain. Their results indicate that the combination of mandatory and incentive policies can improve recycling levels.

3. ANALYSIS OF THE CURRENT STATUS OF GREEN REVERSE LOGISTICS MANAGEMENT IN THE RECYCLING SYSTEM FOR POWER BATTERIES OF NEW ENERGY VEHICLES

3.1. Current Status of Green Reverse Logistics Management in the Power Battery Recycling System for New Energy Vehicle Manufacturers

Driven by the sustained development of the new energy vehicle industry, the first batch of power batteries has entered a phase of large-scale retirement, propelling China's battery recycling market from its initial exploratory stage into a period of rapid growth. According to industry statistics, the total volume of retired power batteries nationwide exceeded 500,000 tons in 2023, with cumulative retirement volumes projected to approach 800,000 tons by 2025. This corresponds to a market size expected to surpass the 100-billion-yuan mark, signifying the gradual formation of a market system with distinct industrial characteristics in this sector. Throughout this process, market participants have become increasingly diverse, with three dominant forces emerging: vehicle manufacturers, battery producers, and third-party specialized recycling and regeneration enterprises. These players engage in the market through differentiated approaches—including channel management, technological closed-loop systems, and large-scale processing capabilities—thus establishing an industry landscape characterized by both competition and coexistence.

From the perspective of green reverse logistics, the industry currently exhibits three representative pathways, each with its own features and implementation challenges. The vehicle manufacturer-led model, exemplified by BYD and NIO, relies on their dealer and after-sales service networks to establish recycling systems. While this model offers advantages in channel controllability and customer reach, it also faces cost pressures arising from insufficient storage conditions at collection points and the dispersed nature of upfront collection. The dominant model among battery manufacturers is exemplified by closed-loop strategies such as the "Battery Bank" implemented by CATL and Gotion High-Tech, which leverage technological synergies to achieve targeted material recycling. However, this model requires the independent construction of recycling networks, entailing substantial infrastructure investment and limited end-user coverage. The third-party specialized recycling enterprise model, typified by GEM and Guanghua Technology, focuses on large-scale processing and material regeneration, diluting costs through cross-source collection. Nevertheless, the operational stability of this model is highly dependent on long-term collaborative relationships established with upstream manufacturers, and the capacity for supply chain integration directly affects system sustainability.

Overall, each model faces varying degrees of challenges in terms of network construction, cost control, and collaboration mechanisms, reflecting that the current battery recycling logistics system remains at a critical stage of standardization and integrated development.

3.2. Existing Problems and Challenges

Chinese new energy vehicle (NEV) enterprises still face numerous problems in the green reverse logistics management of power batteries. In terms of recycling network construction, the layout of formal collection points remains sparse and lacks convenience, making it difficult to effectively cover dispersed end-users. Meanwhile, informal recycling channels encroach on the market through flexible collection methods and price advantages, resulting in a situation where the compliant recycling system encounters significant difficulties in battery collection, and the efficiency of the "last mile" of reverse logistics is notably constrained.

At the logistics operations level, retired batteries, classified as hazardous Class 9 goods, still exhibit clear deficiencies in safety management across packaging, transportation, and storage. Non-standardized packaging, non-specialized transport vehicles, and temporary storage facilities lacking adequate protection are relatively common, severely threatening the safety and environmental integrity of the logistics chain.

Furthermore, the numerous environmental protection requirements and high standards associated with green logistics lead to elevated logistics costs. These costs—arising from standardized packaging, standardized transportation, standardized storage, and safe, non-hazardous cleaning—result in price instability for recycled materials. This makes it difficult to maintain the cost structure and sustainable operation of formal recycling channels, thereby significantly undermining the economic competitiveness and operational sustainability of the compliant recycling system. As a consequence, it becomes challenging for formal channels to establish a cost advantage in competition with informal alternatives.

4. PROBLEMS IN THE GREEN REVERSE LOGISTICS MANAGEMENT OF BYD'S AUTOMOTIVE POWER BATTERY RECYCLING SYSTEM

4.1. The Issue of Low Efficiency in Logistics Recovery Networks

BYD has established its primary recycling channel by leveraging its extensively distributed dealer network, which offers significant advantages in fulfilling the extended producer responsibility (EPR) system and ensuring channel controllability. However, this model also presents notable problems: the dispersed recycling nodes are overall inefficient.

In terms of spatial coverage, the formal recycling network suffers from an uneven geographical distribution, with insufficient coverage in small and medium-sized cities as well as rural areas. Coupled with the relatively high costs incurred by users in returning batteries—across various dimensions—this suppresses their willingness to participate. In terms of reverse logistics, to comply with hazardous materials temporary storage regulations, each recycling outlet must invest capital in constructing dedicated storage areas equipped with safety protections. However, the daily volume of end-of-life batteries recovered at a single outlet is low and unstable. This characteristic leads to high unit storage costs for batteries prior to centralized transportation, making it difficult to achieve large-scale full-vehicle shipments. Consequently, the "last mile" reverse logistics cost from collection points to regional processing centers remains persistently high, and economies of scale are difficult to realize.

4.2. Safety Issues in the Logistics of Hazardous Materials

Retired power batteries are classified as hazardous Class 9 goods, and their logistics are subject to stringent safety requirements across all stages, including packaging, transportation, and warehousing. Although BYD has successfully applied innovative models such as "separate-case shipping" in its forward export logistics to mitigate risks, the recycling process involves multiple non-specialized actors, including vehicle owners, numerous dispersed 4S dealerships, and third-party carriers. This makes the implementation of uniform safety standards exceedingly difficult. In practice, issues such as non-standard temporary packaging, mixed loading and transportation with non-hazardous goods, and substandard conditions in transit warehousing occur frequently, posing potential risks to public safety and the environment.

4.3. The Limitations of Closed-Loop Systems

The closed-loop supply chain system established by BYD primarily serves the recycling of its own brand batteries, playing a positive role in clarifying responsibility boundaries and ensuring material closed-loop management. However, this model excludes the massive volume of retired batteries from other brands outside the system. Facing the future industry-wide wave of retired batteries on a million-ton scale, a single-brand closed-loop system may face challenges due to limited processing capacity. Moreover, current collaborations with third-party professional recycling companies like GEM remain largely at the level of business outsourcing, with no breakthroughs achieved in industrial synergy mechanisms such as deep integration of recycling networks, sharing of core technologies, or value-chain-based benefit distribution, thereby hindering the formation of a socialized and highly efficient large-scale industry recycling system.

5. CONSTRUCTION OF A GREEN RECYCLING AND LOGISTICS SYSTEM FOR POWER BATTERIES IN NEW ENERGY VEHICLES

5.1. Construction of a Multi-level Recycling Network

To address the problems of dispersed recycling collection points and high collection costs, it is necessary to modify the existing inefficient logistics network structure. Accordingly, this study constructs a three-tier gradient network model comprising "community collection points, centralized recycling centers, and regional treatment bases."

The core concept of this model is to achieve logistics operations through a hierarchical spatial structure: at the top tier, a small number of regional technology-intensive treatment bases are established to serve as centers for centralized inspection, cascading utilization, and cascading regeneration; at the middle tier, a limited number of regional centralized recycling centers are established to function as regional consolidation hubs, sorting centers, and pretreatment centers; at the bottom tier, a large number of social collection points are deployed to serve as community collection points, acting as regional receiving and temporary storage centers. Regarding the location and capacity of network facilities, the number, location, and service area of facilities are determined by comprehensively considering factors such as battery retirement volume, transportation costs, and environmental carrying capacity, so as to satisfy overall route cost and efficiency requirements, thereby achieving minimization of total supply chain costs and maximization of efficiency.

5.2. Low-carbon Operations Within A Closed-Loop Supply Chain System

To realize the principles of green logistics, this scheme constructs a low-carbon operations system centered on the three core links of packaging, transportation, and warehousing. Specifically, through the research, development, and promotion of transport equipment featuring leak-proof, insulating, fire-resistant, and condition-monitoring functionalities, and through the establishment of an information-sharing dispatching system, packaging waste and safety incidents can be eliminated. In the transportation link, dedicated routes for the collection of power batteries from new energy vehicle (NEV) recycling are planned, and real-time monitoring and prediction of transport routes are enabled via Internet of Things (IoT) technology to achieve risk management and control. In the warehousing link, smart warehousing centers are constructed in accordance with the highest fire protection and environmental standards, incorporating environmental control systems, hazardous gas monitoring, and automatic fire suppression systems to maximize operational safety.

5.3. Establish a Battery Recycling Cooperation Alliance

While preserving the advantages of its own brand's closed-loop supply chain, this approach upgrades the enterprise's self-built brand-specific closed-loop system into a shared, industry-wide circular system through mechanisms innovation and technological empowerment. By breaking brand boundaries and sharing infrastructure and services, enterprise self-built battery recycling is integrated into a legitimate recycling system. A battery recycling platform is established, led by backbone enterprises such as BYD and CATL, operating through cooperative construction and shared use, to provide standardized recycling, inspection, and warehousing services for batteries of all brands. Third-party partners (e.g., GEM) are transformed from service subcontractors into strategic partners, with whom core technologies and long-term benefits are shared, and a technology cooperation company is formed focusing on material regeneration technologies. BYD contributes battery data, design standards, and distribution channels, while partners contribute recycling technologies and processing capacity, with intellectual property rights and profits shared jointly.

6. SUMMARY

6.1. Summary

This paper primarily investigates green reverse logistics management within the closed-loop supply chain system for new energy vehicle (NEV) power batteries, using BYD Auto as a case study. It examines the concepts and characteristics of green reverse logistics, as well as reverse logistics processes and models. The study comprehensively analyzes the logistics management problems in BYD's battery recycling process and proposes corresponding optimization strategies in a targeted manner.

The findings indicate that BYD's NEV power battery recycling faces problems in overall recycling efficiency, hazardous waste logistics safety, and the limitations of the closed-loop system. Specific deficiencies include the low overall efficiency of dispersed recycling collection points, disorder in transportation, packaging, and warehousing operations, and limited processing scale of the closed-loop system. These issues severely affect recycling efficiency and safety, hindering enterprise development. Therefore, this paper proposes optimization strategies including the establishment of a multi-tier recycling network, low-carbon operations in the closed-loop supply chain system, and the formation of battery recycling cooperation alliances. These strategies aim to improve the efficiency of green reverse logistics, ensure safety across all stages, and enhance enterprise competitiveness.

6.2. Shortcomings and Prospects

With the rise and development of automotive power battery recycling and reuse, green reverse logistics management has gradually evolved from a supportive supplementary measure into a foundational strategy for ensuring resource and environmental security and promoting the development of a circular economy. In the future, this field will exhibit multiple trends, including technological integration, value concept integration, and international integration. Management systems will gradually evolve toward being smart, lean, and global in nature.

Green reverse logistics management will become increasingly important. On the one hand, the future proliferation of technologies such as big data, artificial intelligence (AI), and the Internet of Things (IoT) will provide greater technical support for green logistics management, enabling functions such as tracking and management of recycling routes, deployment of recycling equipment, and improvements in reverse logistics efficiency and safety. On the other hand, as consumer awareness of environmental protection and sustainability deepens in the future, green logistics represents an inevitable trend, with increasing emphasis on environmentally friendly recycling and treatment processes, reduction of environmental impact, and realization of value-added benefits. Furthermore, the globalization of automotive power battery recycling will prompt enterprises to place greater emphasis on international cooperation and collaboration in green reverse logistics management, strengthening communication and coordination with partners—including suppliers and logistics service providers—across different countries and regions. Together, they will address various challenges in logistics activities and promote the healthy and sustainable development of the industry.

REFERENCES

[1] Cao R, Ji XF, Chen F, et al. Theoretical framework and research progress of green logistics at home and abroad. Logistics Research, 2025(2): 7-17. [in Chinese]

[2] Liu ZX. Modern Logistics Handbook. Beijing: China Logistics Publishing House, 2001. [in Chinese]

[3] Chen HY, Chang LY. Analysis of green development of modern logistics in China. Traffic Enterprise Management, 2024, 39(1): 90-93. [in Chinese]

[4] Wang J, Zhao DQ. Development status of green logistics at home and abroad and its enlightenment to China. Logistics Technology, 2018, 37(2): 20-25. [in Chinese]

[5] Liu J, Zhao QQ. Review and future prospect of reverse logistics research. Journal of Commercial Economics, 2020(1): 66-70. [in Chinese]

[6] Fleischmann M, Krikke HR, Dekker R, et al. A characterisation of logistics networks for product recovery. Omega, 2000, 28(6): 653-666.

[7] Wang ZW, Yin Q, Pang Y, et al. Research progress on recycling issues in remanufacturing closed-loop supply chains. Computer Integrated Manufacturing Systems, 2019: 1-25. [in Chinese]

[8] Gu X, Ieromonachou P, Zhou L, et al. Developing pricing strategy to optimise total profits in an electric vehicle battery closed loop supply chain. Journal of Cleaner Production, 2018, 203: 376-385.

[9] Liu S, Gong D. Modelling and simulation on recycling of electric vehicle batteries – using agent approach. International Journal of Simulation Modelling, 2014, 13(1): 79-92.

[10] Li X, Mu D. Research on pricing and coordination mechanism of closed-loop supply chain for power batteries. Soft Science, 2018, 32(11): 124-129. [in Chinese]