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Research on the Challenges and Breakthrough Pathways for reen Transformation in China's Logistics Industry Under the Dual Carbon oals

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Abstract: Chinas progress toward achieving its dual carbon goals has been gener ally stable. This study conducts an in-depth investigation and analysis of the implementation pathways for green transformation in Chinas logistics industry. It reveals that while initial achievements have been attained in policy support, facility upgrading, and pilot applications of green technologies, numerous systemic issues remain unresolved. These challenges are primarily manifested in four dimensions: First, the sectors overall carbon emissions remain high, with fossil fuels still dominating energy consumption. Second, there exists a disconnection between the R&D and practical application of green and low-carbon technologies, leading to insufficient innovation momentum and low efficiency in transforming technological achievements into actual production capacity. Third, policy implementation remains relatively homogeneous, with cross-departmental and cross-regional collaborative governance mechanisms yet to be fully established. Fourth, the benefits of green investments have not been effectively exploited, and the allocation of resources between regions lacks scientific rigor. To address these challenges, this study proposes a multidimensional, collaborative implementation framework. This framework focuses on five key directions: clean energy substitution, smart technology empowerment, integrated policy implementation, targeted investment support, and alignment with international standards. Its purpose is to guide Chinas logistics industry in achieving the dual objectives of emission reduction and carbon mitigation while improving quality and efficiency, thereby facilitating its smooth transition toward high-quality green development.

Keywords: Dual Carbon Goals; Logistics industry; Green transition; Challenges; Breakthrough pathways.

1. Introduction

The Central Economic Work Conference held in 2025 explicitly stated that among the eight core tasks for economic development in 2026, a key priority is “promoting comprehensive green transformation with dual carbon goals as the guiding principle.” Currently in a critical phase of launching the implementation of the 15th Five-Year Plan, this strategic deployment clearly signals Chinas policy orientation: the commitment to advancing green and low-carbon development remains unwavering, and the intensity of implementation will not diminish. Industry experts interviewed emphasized that the green transition centered on carbon neutrality and carbon peaking constitutes a profound systemic transformation. This transformation is anchored in energy sector innovation, contingent upon industrial system upgrading, and supported by regulatory frameworks for guidance and advancement. Meanwhile, it represents a critical strategic choice for China to achieve high-quality economic development and secure the initiative in future growth.

The logistics industry serves as a vital pillar for the efficient operation of the national economy. With its continuous expansion in scale and complex operational processes, it has become a major contributor to energy consumption and carbon emissions. Relevant statistics indicate that the logistics sector currently accounts for 8.51% of Chinas total energy consumption and ranks among the top contributors to carbon emissions nationwide. At present, it demonstrates development characteristics characterized by “high energy consumption, high emissions, and high losses.” This development model not only restricts the sustainable upgrading of the logistics industry itself but also poses a core challenge to the timely achievement of the nations dual carbon goals.

Against this backdrop, green logistics has emerged as a new model covering the entire process, integrating environmentally friendly principles into every stage of logistics operations. It reduces pollution emissions, optimizes resource allocation, and improves recycling efficiency. In addition to delivering significant ecological benefits, it serves as a vital pathway to enhance the quality and efficiency of the logistics sector while driving industrial upgrading and sustainable development. The “14th Five-Year Plan for Modern Logistics Development” explicitly requires the integration of green and eco-friendly concepts throughout the entire logistics chain, comprehensively promoting the industrys transition toward low -carbon and circular practices. However, the logistics sector is currently confronted with a series of practical challenges in the process of its green transformation. These include inconsistent policy implementation across regions, difficulties in adapting green technologies to specific scenarios, inadequate coordination in infrastructure development, and insufficient incentives for enterprises to proactively pursue transformation. The cumulative impact of these issues collectively impedes progress. Therefore, comprehensively analyzing the in-depth obstacles to the logistics industrys green transformation and identifying practical advancement strategies are of great theoretical significance for promoting high-quality industrial development and effectively implementing the national “dual carbon” strategy.

Guided by the “dual carbon” goals and green development principles, this paper focuses on the process of green transformation in the logistics sector. Its objective is to identify the primary challenges facing the industry and propose comprehensive countermeasures from multiple dimensions—including energy structure, technological innovation, policy coordination, and market mechanisms. This study aims to provide practical and valuable references for Chinas logistics industry to steadily move toward more efficient operational models, lower-emission environmental standards, and a more sustainable long-term development path.

2. Literature Review

With the increasing national emphasis on environmental issues and the rising public awareness of environmental protection, more scholars have focused on the green transformation of Chinas logistics industry. Following the introduction of the “dual carbon” goals, academic understanding of green logistics has been deepened. Against this backdrop, Yan Shuli selected 203 listed companies in the retail and wholesale sectors over a 10-year period as research samples. She conducted an empirical analysis of these enterprises operational performance and proposed corresponding countermeasures. Empirical results indicate that green logistics improves corporate performance. The achievement of the “dual carbon” goals is contingent upon establishing green logistics distribution systems, intensifying the adoption of digital logistics technologies, and constructing modern logistics information platforms. Only through these measures can new pathways for the sustainable development of distribution enterprises be developed[1]. Quan Chunguang et al. investigated the green development issues of Chinas logistics enterprises, proposing that companies must implement green initiatives throughout all logistics stages—resource allocation, reverse logistics, packaging, transportation, and warehousing. This approach drives the industry-wide green transformation, aligns with national policy orientations, and promotes the high-quality development of the logistics industry[2]. Li Luqian et al. found a positive correlation between carbon emissions trading and green technological innovation[3]. Xi Chongbin contends that optimizing the transportation structure is paramount to achieving the dual carbon goals. The National Comprehensive Three-dimensional Transportation Network Planning Outline explicitly mandates shifting away from the current road freight-dominated transport pattern and reducing carbon emissions from logistics vehicles—a requirement critical to realizing carbon neutrality[4]. Further research by Wang Lin et al. reveals synergistic effects between endogenous and exogenous drivers in the green transformation of resource-based enterprises. Endogenous drivers include economic benefits and competitive advantages, while exogenous drivers comprise government incentives/penalties and public oversight[5].

Against the backdrop of the steady advancement of the dual carbon strategy, academia has conducted in-depth research and exploration on the green transformation of Chinas logistics industry from various perspectives. Among existing studies, most research findings suggest that green logistics can exert a positive impact on both the environmental performance and operational efficiency of enterprises. Researchers have proposed corresponding implementation measures from multiple dimensions, including corporate social responsibility, logistics process optimization, technology deployment, and transportation structure adjustment. Furthermore, related research has gradually expanded into areas such as policy coordination, internal and external drivers, and market operation mechanisms. These research findings not only provide theoretical support for understanding the green transformation of the logistics industry but also offer crucial reference points for exploring the industrys practical challenges and investigating pathways for systemic breakthroughs.

3. Research on the Current Status of Green Transformation in the Logistics Industry

3.1. Elevated Carbon Emissions and Heavy Reliance on Fossil Fuels in Energy Structure

Currently, the logistics industry is confronted with two prominent issues: first, its overall carbon emissions remain relatively high; second, its energy structure has long been dependent on fossil fuels. Research data demonstrates that Chinas logistics sector accounts for approximately 9% of the nations total carbon emissions, second only to the power and industrial sectors. This renders it a critical area requiring attention in national carbon reduction initiatives. A detailed analysis of its emissions composition reveals that over 95% of carbon emissions originate from fossil fuel consumption in core operational activities such as freight transport, warehousing, loading/unloading, and transportation. This underscores the industrys persistent structural reliance on traditional high-carbon energy sources.

While the government has been actively promoting energy structure optimization through policy instruments and encouraging the adoption of renewable energy, the high-carbon characteristics of energy consumption in logistics remain prominent. Although clean energy sources such as wind and solar power are gradually increasing their share in the national electricity mix, their direct utilization in the actual energy consumption of the entire logistics process remains low, failing to effectively substitute for fossil fuels. The core reason for this phenomenon lies in the high demands of logistics operations for continuous and stable energy supply, which conflicts with the inherent intermittent and fluctuating nature of renewable energy. Additionally, issues such as high infrastructure retrofitting costs, insufficient technological compatibility, and limited application scenarios further consolidate the industrys reliance on the current fossil fuel-based model.

It is crucial to note that relevant studies indicate that while reducing fossil fuel consumption through technological and management approaches can generate significant environmental benefits in the short term, it often results in increased energy expenditures and reduced resource utilization efficiency. This reflects the inherent tension between the immediate objectives of “emission reduction” and “efficiency enhancement.” Consequently, breaking through the high-carbon constraints of the energy structure and gradually reducing carbon intensity while ensuring the efficient operation of logistics systems has become the core structural challenge in the industrys green transformation.

3.2. Slow Technological Advancement and Insufficient Innovation-Driven Support

The green transformation of the logistics industry hinges on technological advancement. However, the sector currently faces numerous technical challenges, including gaps in key technologies, difficulties in implementing innovative solutions, and low digitalization levels among small and medium-sized enterprises. These accumulated issues hinder improvements in overall energy efficiency and keep carbon emissions intensity at elevated levels. Among these, the core green technologies present a particularly acute dilemma between performance and cost. In the field of new energy commercial vehicles, power batteries suffer from insufficient energy density, failing to meet the demands of heavy-duty trucks for long-haul trunk transportation. In cold northern climates, they also experience reduced range and slower charging speeds. Hydrogen fuel cell trucks, meanwhile, face barriers to large-scale adoption due to prohibitively high purchase and operational costs, coupled with the slow development of hydrogen refueling infrastructure.

The application of intelligent technologies faces two challenges: insufficient depth of implementation and inadequate data interoperability. While technologies like artificial intelligence and big data are gradually being adopted in areas such as route optimization and dispatch management, many small and medium-sized logistics enterprises remain constrained by funding, talent shortages, and limited digital infrastructure, continuing to rely primarily on traditional manual operations. Simultaneously, the absence of unified data standards and information-sharing mechanisms among shippers, logistics platforms, and transport companies creates "data silos" due to information fragmentation. This prevents intelligent dispatch systems from fully realizing their energy-saving and emission-reduction potential across the entire logistics chain, thereby undermining the core value of smart technologies.

The driving system for green technological innovation in the logistics industry has yet to be fully established, hindering the widespread adoption and implementation of technological achievements. Merely investing capital does little to enhance the efficiency of logistics enterprises. Without integrating business models, organizational management, and operational processes, such investments may lead to inefficient expansion and resource wastage. In practical operations, most small and medium-sized enterprises lack systematic innovation capabilities, while large enterprises R&D efforts often remain disconnected from frontline business scenarios. This disconnect confines many advanced technologies to pilot demonstration phases, hindering their large-scale commercial application. Evidently, the green technology transformation in logistics is no longer a question of whether to pursue it, but has reached a critical stage of how to execute it effectively. Only by establishing a pathway from technological R&D to coordinated application across the entire industrial chain can innovation outcomes be transformed into a sustainable driving force for enhancing industry efficiency and advancing green transformation.

3.3. Limited Policy Toolkit and Insufficient Multi-Party Synergy

The policy framework driving green transformation in the logistics sector faces practical challenges in tool implementation and cross-departmental coordination, which undermine the overall effectiveness of these measures. Current policy initiatives primarily focus on direct financial support, such as purchase subsidies and tax breaks. While this approach provides some guidance, the substantial investment required for green technologies and their extended payback periods result in limited long-term impact, narrow coverage, and potential regional development disparities. Take the Yangtze River Delta and Northwest China as examples: the former provides subsidies for green logistics that are three times higher than the latter. This imbalance not only widens regional gaps in green transition but also undermines the fairness and coordination of the national unified market.

Another critical issue is the lack of coordination among various policies. The low-carbon transformation of the logistics industry involves multiple sectors including energy, transportation, environmental protection, and industry, each managed by different departments. Currently, however, most policies are formulated and implemented without adequate coordination. For instance, when promoting vehicle electrification, if supporting infrastructure planning and operational right-of-way guarantees are not advanced synchronously, the actual transition costs for enterprises become prohibitively high. Furthermore, core policy tools relying on market mechanisms—such as carbon taxes and emissions trading—have yet to be fully leveraged in the logistics sector. This failure has prevented the establishment of efficient external cost constraint mechanisms and the formation of incentive systems capable of driving sustained corporate innovation.

3.4. Low Investment Efficiency and Structural Imbalances in Resource Allocation

The green and low-carbon transformation of the logistics industry is constrained by imbalances in investment structure and inefficient resource allocation. While capital investment in the sector has continued to grow, it lacks systematic planning and precise guidance. New capital injections fail to effectively translate into technological upgrades and economies of scale. Instead, redundant construction and extensive expansion increase energy consumption, dragging down the industrys overall operational efficiency. From an investment structure perspective, funding for green technologies remains severely inadequate. Fixed-asset investments are predominantly concentrated in traditional infrastructure sectors, with limited support for critical areas like new energy equipment and digital upgrades. Small and medium-sized enterprises (SMEs), constrained by capital shortages, have slow adoption rates for new energy transport fleets, while the phase-out of high-emission transport capacity also proceeds at a sluggish pace. In 2023, diesel consumption still accounted for 44.6% of the logistics sectors energy mix—a figure that directly reflects how insufficient green investment is slowing the energy transition process.

Imbalances in regional resource allocation have widened development gaps across areas, representing a core issue within the investment framework. Regions like the Yangtze River Delta in eastern China provide approximately three times more support funds for green logistics than northwestern regions. Central and western regions face different challenges: constrained by funding and technological limitations, the coverage rate of new energy charging and swapping equipment in these areas remains less than 40% of that in eastern regions. This creates a scenario where eastern regions develop rapidly while central and western regions lag behind, preventing the consolidation of nationwide efforts to advance green development. Concurrently, investments in green logistics exhibit pronounced characteristics of extensive growth, with limited alignment with technological innovation and policy guidance. Merely expanding investment scale offers little benefit for enhancing ecological efficiency and may even result in inefficient capacity slowing progress. Some logistics parks, while expanding storage capacity, failed to build corresponding energy-saving facilities. Consequently, energy consumption per unit area in these parks not only failed to decrease but actually increased. In 2023, total carbon emissions in the green logistics sector remained at a high range of 580 to 630 million tons. This situation also indicates that the current investment model cannot efficiently drive carbon reduction efforts.The root cause of these issues in logistics investment and resource allocation lies in the absence of a comprehensive green investment promotion mechanism spanning the entire supply chain. Most investment decisions focus solely on short-term cost-benefit analysis, neglecting the integrated consideration of long-term environmental benefits.

The core reason for various issues in investment and resource allocation within the logistics industry lies in the failure to establish a comprehensive green investment incentive system covering the entire process. Most investment decisions focus solely on short-term cost inputs and return on investment, neglecting to holistically consider long-term environmental benefits.

4. Research on Pathways to Overcome Challenges in the Green Transformation of the Logistics Industry

In light of the challenges emerging in Chinas logistics development, the following recommendations are proposed to advance the green transformation of the national logistics industry.

4.1. Optimizing Energy Structure to Build a Green Logistics System

To achieve a green transition, the logistics sector must urgently reduce its reliance on fossil fuels. Currently, diesel consumption still accounts for a significant 44.6% of the industrys energy mix, indicating a slow pace of energy transition. Moving forward, we must accelerate the shift in energy supply methods, transitioning from a primary reliance on diesel to cleaner alternatives like electricity, hydrogen, and natural gas. This will enable various clean energy sources to better adapt to the demands of different logistics scenarios. Concurrently, we must expedite the electrification and hydrogenation of transportation vehicles. In short-distance, fixed-route scenarios such as urban delivery and port feeder services, the large-scale adoption of pure electric trucks should be promoted, alongside the rapid establishment of an intelligent, orderly network of charging and rapid battery-swapping infrastructure. For long-haul trunk transportation, addressing the limitations of new energy heavy-duty trucks—such as low battery energy density and poor low-temperature performance—we will first promote liquefied natural gas (LNG) heavy-duty trucks as a transitional solution. Simultaneously, we will advance the commercial demonstration of hydrogen fuel cell heavy-duty trucks. We must concentrate efforts on overcoming key core technologies like hydrogen fuel cell stacks and high-pressure hydrogen storage, while scientifically and rationally planning and constructing hydrogen refueling infrastructure. Building on this foundation, we must develop green warehousing and hub facilities that integrate production and consumption. At national logistics hubs and key logistics parks, large-scale rooftop distributed photovoltaic power stations should be constructed, equipped with energy storage devices to form integrated microgrid systems combining “photovoltaic generation, storage, charging, and discharge.” This will achieve self-sufficiency in energy consumption through photovoltaic power generation and storage, with surplus electricity fed into the grid for transmission, creating “near-zero carbon” benchmark parks. Additionally, we must structurally enhance multimodal transport and electrification levels. We should actively and steadily advance the shift from road to rail and water transport, significantly increasing the proportion of bulk cargo transported by rail and waterways, as well as the coverage of shore power facilities at major ports. We should promote the electrification of mainline railways to reduce emissions from mobile pollution sources during transportation, forming a green intermodal model of “mainline rail and water transport + new energy last-mile delivery.”

4.2. Enhancing Technological Support to Improve Smart and Green Operational Efficiency

To enhance the efficiency of logistics systems and unlock emission reduction potential, technological advancement is key. Currently, the industrys level of informatization remains low, with only about 40% of enterprises equipped with information systems, and the issue of “data silos” is particularly prominent. To address these challenges, we must promote the deep integration of digital technologies with the real economy to achieve intelligent decision-making. We must further advance the digital and intelligent application across the entire logistics chain. Leveraging technologies such as the Internet of Things (IoT), 5G, and BeiDou, we should implement real-time monitoring of vehicles, cargo, and logistics facilities throughout the entire process for precise management. Utilizing big data and artificial intelligence algorithms, we can dynamically optimize transportation routes, loading plans, and warehouse layouts. This will systematically reduce vehicle empty-run rates, inventory turnover time, and inefficient energy consumption. A national multimodal transport public information platform should be established with unified data standards to overcome data silos across rail, road, water, and air sectors, facilitating cross-modal and cross-enterprise collaboration. Additionally, resources must be pooled to achieve breakthroughs in critical green technologies. A dedicated green logistics technology fund should be created to encourage collaborative innovation among governments, enterprises, universities, research institutions, and end-users. Research priorities should focus on next-generation high-energy-density solid-state batteries and long-life, low-cost hydrogen fuel cells. Attention should also be given to frontier areas such as carbon capture, utilization, and storage (CCUS) technologies suitable for logistics scenarios, and lightweight recyclable packaging materials. These represent reserve technologies for the industrys long-term, deep decarbonization. Furthermore, leveraging the enabling capabilities and service procurement of public platforms will help small and medium-sized enterprises overcome digital barriers, enabling their participation in the technological transformation.

4.3. Strengthening Policy Synergy to Enhance Collaborative Governance Effectiveness

The effectiveness of relying solely on a single policy tool is relatively limited. Relevant studies indicate that depending solely on carbon taxes or environmental taxes has little impact on enhancing the green efficiency of the logistics industry. However, policies that subsidize CCUS technology can yield significant improvements exceeding 10%. We need to establish a policy combination model that employs both incentives and penalties, balancing short-term and long-term objectives. This requires creating an economic policy framework that incorporates both incentives and constraints. Implementing a "subsidy + tax" approach should provide targeted fiscal subsidies or tax breaks for key areas such as CCUS technology adoption, new energy vehicle purchase and operation, and green warehouse construction. Concurrently, research should be conducted to develop carbon tax policies for the logistics sector, to be rolled out at an appropriate time. This would internalize the external costs of carbon emissions into corporate costs, creating a market-driven model where "emission reductions yield benefits while carbon emissions incur costs." Furthermore, green finance and market mechanisms must be enhanced. Actively develop financial products like green loans, low-carbon bonds, and green insurance. Support establishing industry-wide carbon footprint monitoring, reporting, and verification systems, while exploring inclusion of major logistics enterprises in the national carbon emissions trading market to unlock the value of corporate carbon assets. Additionally, promote regional policy coordination and unified standards. Address the up to threefold disparity in subsidy levels between eastern and western regions by establishing technology transfer and ecological compensation mechanisms. Accelerate the development of unified national standards and certification systems for green warehouses and green distribution. Simultaneously, encourage large enterprises to disclose environmental, social, and governance (ESG) information to strengthen the industrys green development orientation.

It is noteworthy that with the advancement of the national carbon market and the refinement of the green finance system, China has established the worlds largest carbon market. It covers four key industries—power generation, steel, cement, and aluminum smelting—accounting for over 60% of the countrys total carbon dioxide emissions. The policy space for leveraging market mechanisms and economic instruments to drive emissions reductions in the logistics sector is continuously expanding. The key to future policy reform lies in establishing a combined policy system that integrates incentives with constraints, coordinates central and local efforts, and complements administrative measures with market mechanisms. This will facilitate a shift from breakthroughs in individual segments to comprehensive system-wide advancement.

4.4. Guide Targeted Investment to Optimize Resource Allocation Efficiency

To address the current issues of inefficient capital allocation and structural imbalances, the first approach involves accurately identifying sectors with strong technological driving force and significant carbon reduction potential. We must redirect social capital and government investment away from traditional, scale-expansion-oriented infrastructure projects toward critical areas such as new energy equipment manufacturing, smart logistics information hubs, low-carbon technology R&D and application, and circular logistics system development. Simultaneously, we must strictly control redundant construction projects with low technological standards and inefficient energy utilization. The second approach involves establishing diversified green investment and financing innovation models. It is recommended to establish national and local green upgrade guidance funds for the logistics industry, supporting innovative projects through equity investment and risk compensation mechanisms. Adopting incentive-based subsidies and post-project carbon reduction performance-based grants will tightly link fiscal support with enterprises actual carbon reduction outcomes, thereby genuinely enhancing the efficiency and leverage effect of public funds.

Only by establishing an integrated investment system encompassing green technology R&D, infrastructure upgrades, and policy incentives—one that comprehensively balances short-term returns with long-term environmental benefits and removes barriers to investment coordination across all stages—can we fundamentally resolve the industrys issues of inefficient capital utilization and irrational resource allocation.

4.5. Deepening International Cooperation to Advance Standard Alignment

The global supply chain is undergoing gradual adjustments, and low-carbon regulations are being refined at an accelerated pace. In this context, Chinas logistics sector must proactively integrate into the international green governance framework to enhance its global adaptability and influence. We must not only actively participate but also take the lead in establishing international green logistics standards and rules. We must closely monitor the emission reduction strategies and technical requirements proposed by organizations such as the International Maritime Organization (IMO) and the International Civil Aviation Organization (ICAO). Chinas advanced practices in smart logistics, green packaging, and multimodal transport documentation should be transformed into international or regional standards, continuously enhancing Chinas global influence. Simultaneously, cooperation on cross-border logistics carbon emission accounting and reduction must be strengthened. In collaboration with major trading partners, explore establishing cross-border green logistics corridors to promote mutual recognition and interoperability of transport modes and fuel standards. Additionally, assist enterprises in addressing emerging trade barriers like the EU Carbon Border Adjustment Mechanism (CBAM), develop internationally compatible carbon accounting tools, and tangibly enhance the international competitiveness and environmental compliance capabilities of Chinas logistics services.

5. Conclusion and Outlook

The logistics industry is at a critical juncture of the simultaneous green and digital transformation. This phase presents significant opportunities for the sector leveraging technological empowerment and model innovation can realize cost reduction, efficiency improvement, carbon emission reduction, and energy conservation. Yet it also imposes higher requirements, necessitating the industry to address multifaceted challenges including energy structure optimization, technological synergy implementation, policy system adaptation, and capital utilization efficiency improvement. Operators and relevant institutions within the logistics sector must proactively adapt to the trend of in-depth integration between green and digital development, formulate comprehensive strategies, and actively promote innovation and transformation. Only through coordinated advancement across the entire process and multiple dimensions—establishing sustainable upgrade pathways and industrial ecosystems—can the logistics industry achieve high-quality development while serving the new development paradigm and supporting the “dual carbon” strategy. This will also provide robust support for the comprehensive green transformation of the socio-economic system.

Conflicts of Interest

The authors declare that they have no conflict of interest.

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