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Research on the Development Path of Cold Chain Logistics in the Context of Low-Carbon Economy

Xiping Xu[1,a,*], Xiaohua Cai[1,b]

[1]*School of Economics and Trade, Haojing College of Shaanxi University of Science & Technology, Xianyang City, Shaanxi Province, China*
[a]*2542028851@qq.com*, [b]*383040125@qq.com*
[*]*Corresponding author*

Abstract: *With the vigorous development of the global low-carbon economy, cold chain logistics, as a crucial link in safeguarding the quality of perishable products, is confronted with pressing challenges in energy conservation and emission reduction, as well as valuable opportunities for transformation and upgrading. This paper focuses on the field of cold chain logistics, conducting a comprehensive analysis of its current development status amidst the wave of low-carbon trends. It delves deeply into the numerous difficulties encountered, such as constraints from technological bottlenecks, shortcomings in infrastructure, the burden of high operational costs, and the absence of policy standards. Targeted development pathways are proposed from multiple dimensions, including technological innovation, facility optimization, operational improvement, and policy support, striving to propel cold chain logistics towards a low-carbon, efficient, and sustainable direction. The paper aims to provide powerful guidance for industry practices and offer insights for policy formulation.*

Keywords: *Low-Carbon; Cold Chain Logistics; Development Path*

1. Research Background

Against the backdrop of global warming attracting significant attention from all sectors, the low-carbon economy has emerged as a core development strategy pursued by countries worldwide. The cold chain logistics industry, with its special mission of ensuring product quality and safety in key areas such as food and pharmaceuticals, inevitably involves substantial energy consumption, and the use of refrigerants poses many hidden risks of greenhouse gas emissions, thus being placed at the forefront of the low-carbon transformation [1]. From the significant electricity consumption in cold storage refrigeration to the continuous fuel consumption of refrigerated transport vehicles, to the potential greenhouse effect of refrigerants, every aspect of cold chain logistics urgently requires green upgrades to meet the increasingly stringent requirements of the low-carbon era [2].

2. Analysis of the Current Status of Cold Chain Logistics Development in the Context of Low Carbon

2.1 Industry Scale and Growth Trends

In recent years, the global cold chain logistics market has shown a strong trend of continuous expansion, with the Asia-Pacific region leading the charge and experiencing rapid growth. With the wave of consumption upgrades, fresh food e-commerce has sprung up like bamboo shoots after a rain, and the demand for pharmaceutical cold chains has also shown a surge. The annual growth rate of the cold chain logistics market easily exceeds 15%, as shown in Figure 1. As a country with a large population and consumption, China's potential in the cold chain market is gradually being unleashed [3]. Cold storage capacity and the number of refrigerated vehicles are steadily increasing, initially establishing a framework for a cold chain logistics network covering both urban and rural areas, which, although still nascent, is taking shape.

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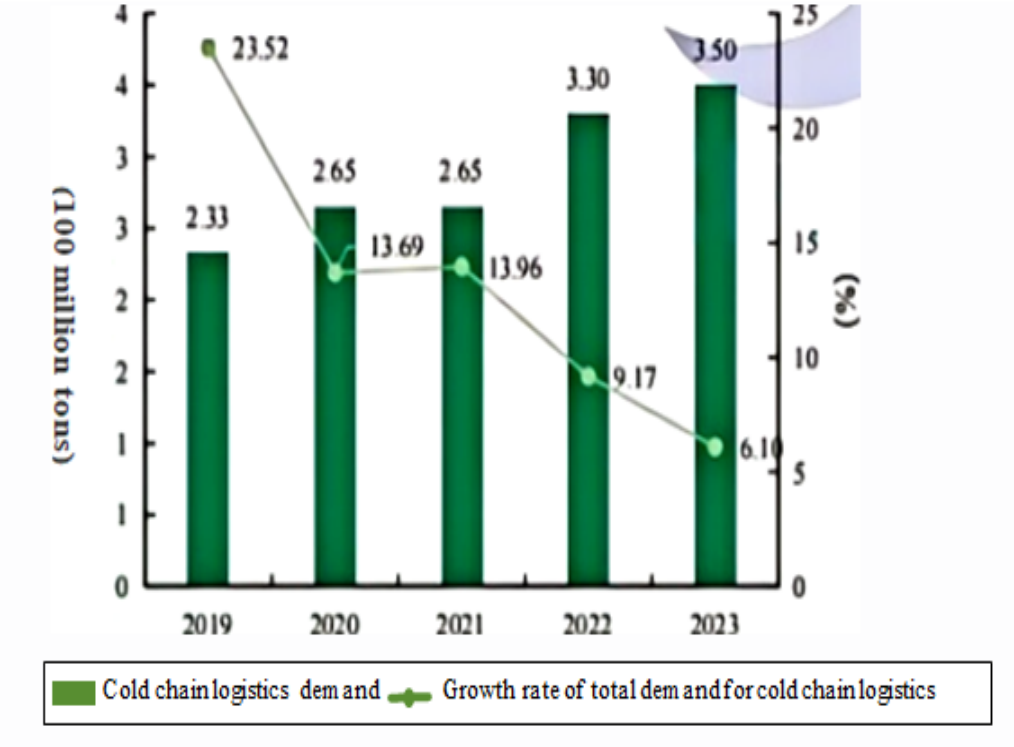

Data source: China IoT Cold Chain Committee

Figure 1. Cold chain logistics demand

2.2 Application of Low-Carbon Technologies

2.2.1 Refrigeration Technology Innovation

New refrigeration technologies, such as carbon dioxide refrigeration and ammonia refrigeration, are gradually replacing traditional Freon refrigeration methods. This change not only significantly reduces the risk of damage to the ozone layer but also achieves a qualitative leap in refrigeration efficiency [4]. Some advanced cold storages at the forefront have cleverly introduced intelligent variable frequency refrigeration systems, which can automatically and precisely adjust refrigeration power based on the actual quantity of stored goods and ambient temperature, achieving remarkable energy-saving effects and setting a benchmark for green development in the industry [5].

2.2.2 Renewable Energy Transportation Equipment

Electric refrigerated vehicles and hydrogen fuel cell refrigerated vehicles have embarked on pilot promotion tours [6]. Compared with traditional fuel vehicles, their zero-emission advantage is evident in urban distribution, and they operate with low noise, perfectly aligning with the concept of green logistics. Notably, some innovative companies have also ingenuity equipped vehicles with solar auxiliary power supply devices, which can replenish energy for the on-board temperature control system during vehicle operation, effectively extending driving range and adding a significant stroke to the low-carbonization process of cold chain transportation.

2.3 Policy and Regulatory Environment

Governments worldwide have introduced a series of policies closely related to the low-carbon development of cold chain logistics. The European Union is known for its strictness, having formulated extremely stringent energy efficiency standards for the cold chain, imposing heavy fines on non-compliant enterprises without mercy. The United States takes a different approach, encouraging enterprises to boldly innovate low-carbon technologies through generous policies such as tax credits and R&D subsidies. Naturally, China is not lagging behind, having successively issued cold chain logistics plans, emphasizing the orientation towards green development, and piloted favorable policies such as subsidies for the purchase of new energy refrigerated vehicles and rewards for energy-saving retrofits of cold storages in some regions, carefully creating a warm and suitable policy "incubator" for

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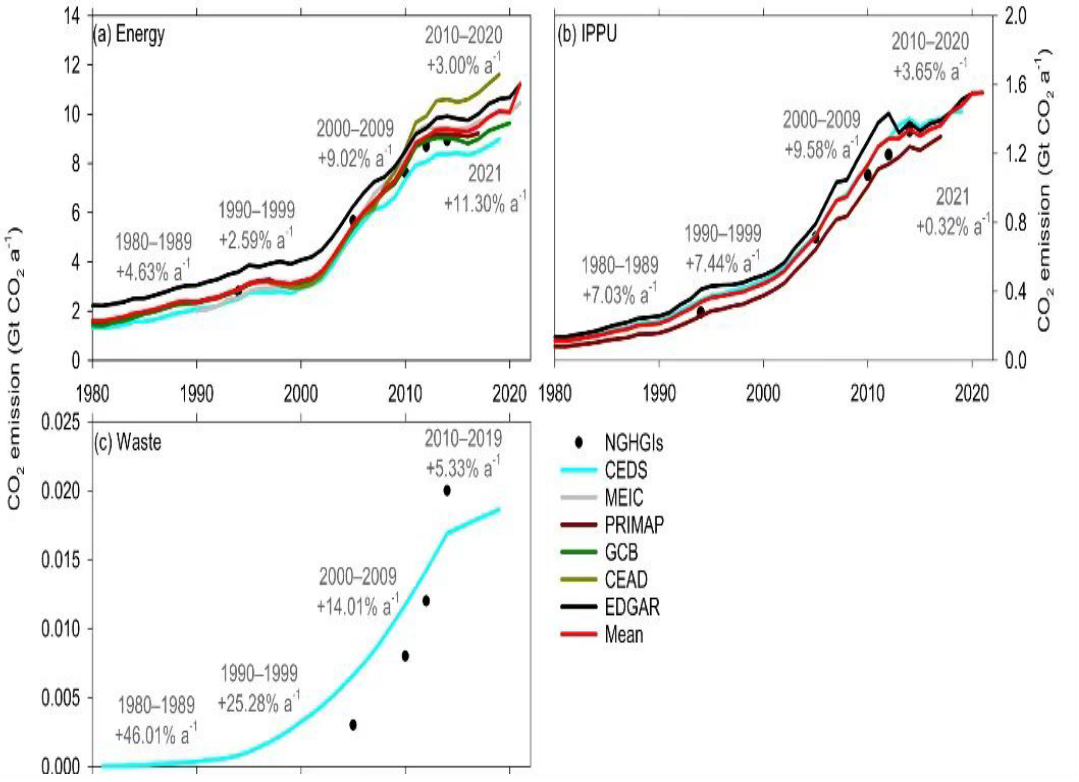
the low-carbon transformation of the cold chain logistics industry.

3. Challenges Faced by the Low-Carbon Development of Cold Chain Logistics

3.1 Technological Innovation Bottlenecks

Many core technologies in the field of cold chain logistics, such as ultra-low temperature refrigeration and precise temperature control chips, are still heavily reliant on imports due to China's current weak independent R&D capabilities. This not only subjects enterprises to high cost pressures but also makes them highly susceptible to international political and economic fluctuations, often lagging behind in technology iterations, severely restricting the industry's progress towards high-end development and becoming a "hard hurdle" on the development path, as shown in Figure 2, the emissions of carbon dioxide in recent years [7].



Data source: National Greenhouse Gas Inventory (NGHGIs)

Figure 2. Long term changes in carbon dioxide emissions in the energy sector (a), industrial processes and product use (IPPU, b), and waste sector (c)

3.2 Infrastructure Shortcomings

On the one hand, the construction and distribution of cold storages are uneven. The total number of cold storages is still insufficient to meet the explosive growth in cold chain demand. In the production areas of perishable products, the construction of cold storages lags significantly, resulting in heavy losses of agricultural products due to the lack of proper refrigerated conditions. On the other hand, there is a risk of "cold chain disruption" in cold chain transportation. Issues abound in the cold chain transportation segment, with varying insulation performance among vehicles [8]. Some outdated vehicles experience drastic temperature fluctuations during transportation, akin to a "roller coaster," while temperature control during loading and unloading is nearly non-existent, leading to frequent "cold chain disruptions."

3.3 Operational Cost Pressures on Enterprises

In the context of volatile energy prices, the long-term electricity consumption required for the

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operation of cold storages and the fuel consumption of refrigerated vehicles are like two heavy burdens on enterprises, making them unbearable. Moreover, with the continuous improvement of cold chain service standards, the accuracy of temperature control is becoming increasingly stringent to ensure flawless product quality, which further pushes up energy consumption costs and makes enterprise operations increasingly difficult.

3.4 Imperfect Policies and Standards

Cold chain logistics lacks unified and clear standards in key areas such as carbon emission accounting, low-carbon technical specifications, and service quality grading. Regulatory authorities, facing this chaos, are like "choosing vegetables without a basket," struggling to scientifically evaluate and effectively supervise the low-carbon performance of enterprises, leading to a mixed market where "bad money drives out good" occurs frequently, severely disrupting market order.

4. Exploration of Development Paths for Cold Chain Logistics in the Context of Low Carbon

4.1 Increase Independent R&D Investment

The government should decisively intervene by establishing special R&D funds for cold chain logistics, injecting a "shot in the arm" for industry development, guiding enterprises, universities, and research institutions to collaborate, focusing their gaze on frontier key technology research areas such as ultra-low temperature energy storage, intelligent temperature-controlled IoT, and high-efficiency insulation materials, fully cultivating independent intellectual property rights, gradually reducing dependence on foreign technologies, and grasping the initiative in industry development.

4.2 Optimize Infrastructure Construction

Firstly, this study makes overall planning and layout of cold storage, makes full use of advanced technologies such as big data and geographic information system, and carries out high-level planning for cold storage construction according to the distribution of agricultural production areas and the layout characteristics of consumption hub cities. In agricultural produce areas, pre-cooling and preservation storages should be built according to local conditions to nip agricultural product post-harvest losses in the bud.

Secondly, this study strengthens the continuity of cold chain transportation, timely formulates the technical standards of cold chain transportation vehicles, vigorously eliminates backward vehicles, and vigorously promotes the application of high-performance thermal insulation materials and intelligent temperature control equipment. This study ensures stable temperature during transportation and prevents "roller coaster" temperature fluctuations [9]. At the same time, this study speeds up the construction of cold chain logistics park, and carefully improves the comprehensive functions of loading and unloading docks, cold chain warehousing, distribution and transfer.

4.3 Implement Joint Distribution and Multimodal Transportation

Within cities, multiple cold chain enterprises should abandon the old mindset of going it alone and jointly carry out joint distribution, optimizing delivery routes and increasing vehicle load factors to achieve resource sharing and mutual benefit. In the scenario of long-distance transportation, this study makes use of the advantages of large volume and low energy consumption of railways and waterways, combined with the flexibility of road transportation, to carefully build a cold chain logistics multimodal transport system combining roads, railways and waterways, comprehensively reduce the overall transportation cost and energy consumption, and open up a new path for the development of cold chain logistics.

4.4 Improve Industry Standards and Regulatory Mechanisms

This study carefully formulates a series of standards for the low-carbon development of cold chain logistics, such as carbon emission measurement, equipment energy efficiency labeling, and service quality evaluation, to establish a clear "benchmark" for the development of the industry.

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5. Conclusion and Outlook

In the grand context of low-carbon development, the path of cold chain logistics is fraught with challenges yet brimming with opportunities. Through concerted efforts to overcome technological innovation hurdles, address infrastructure deficiencies, optimize business operation models, and perfect policy and standard systems, cold chain logistics stands a promising chance to successfully achieve green and low-carbon transformation. While ensuring the quality and safety of perishable products, it will also contribute significantly to the global efforts in addressing climate change. Looking ahead, as technological advancements continue unabated, policy landscapes improve consistently, and societal awareness of environmental protection grows steadily, cold chain logistics is poised to gradually establish a new, low-carbon, efficient, and intelligent ecosystem [10]. This will serve as a powerful engine driving sustainable economic development and help pave the way for a brighter future for humanity.

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References

[1] Guo Xiaolong; Zhang Wei; Liu Bingbing. Low-carbon routing for cold-chain logistics considering the time-dependent effects of traffic congestion[J]. Transportation Research Part, 2022, 8(1):4-6.

[2] Yujie Yang; Jinde Jiang; Rong Wang; Guoyin Xu; Jing Gu. Study on the Application of Activity-Based Costing in Cold Chain Logistics Enterprises under Low Carbon Environment[J]. Sustainability, 2023, 4(18): 5-10.

[3] Wang Lulu; Chen Leyi; Li Yushuang. Digital economy and urban low-carbon sustainable development: the role of innovation factor mobility in China[J]. Environmental science and pollution research international, 2022, 15(18): 56-61.

[4] Li F, Tao J, Wang Q, et al.Simulation and optimization of cold chain logistics system towards lower carbon emission: a state-of-the-art review[J].Carbon Research, 2025, 4(1):22-24.

[5] Chunrong N, Katarzyna D .Research on Optimization of Agricultural Products Cold Chain Logistics Distribution System Based on Low Carbon Perspective[J].International Journal of Information Systems and Supply Chain Management (IJISSCM), 2024, 17(1):1-14.

[6] GuoL, LiuM .Optimization of low‐carbon cold chain logistics distribution path for agricultural products based on two‐stage algorithm [J].Advanced Control for Applications: Engineering and Industrial Systems, 2023, 6(4):176-178.

[7] Yang Y, Jiang J, Wang R, et al.Study on the Application of Activity-Based Costing in Cold Chain Logistics Enterprises under Low Carbon Environment[J].Sustainability, 2023, 15(18)

[8] Jingjie W, Xiaoshuan Z, Xiang W, et al.A Data-Driven Packaging Efficiency Optimization Method for a Low Carbon System in Agri-Products Cold Chain[J].Sustainability, 2022, 14(2):858-859.

[9] Wang Y .Study on the Path Selection of Low-carbon Distribution in Cold Chain Based on Multi-objective Programming[C]//IEEE Beijing Section, Global Union Academy of Science and Technology, Chongqing Global Union Academy of Science and Technology. Proceedings of 2017 IEEE 2nd Information Technology, Networking, Electronic and Automation Control Conference (ITNEC 2017). School of Management, Shanghai University; 2017:5.

[10] Yu J, Zhang S .Research on the Measurement of Low-Carbon Competitiveness of Regional Cold Chain Logistics Capacity Based on Triangular Fuzzy Evaluation Rating–Gray Correlation Analysis[J]. Sustainability, 2024, 16(2):926-928.