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Research on the Optimization Path of Carbon Emission Accounting for High Energy Consumption Enterprises in China

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ABSTRACT

At present, there are core bottlenecks in the carbon emission accounting of high-energy-consuming enterprises in my country, such as system out-of-focus, data governance defects, and capacity building imbalances. It is urgent to take systematic optimization measures to improve the accuracy of carbon accounting, data transparency, and management efficiency. Through the successful practice of leading domestic companies, this study summarizes three major paths: technology empowerment, system innovation, and adaptation solutions for small and medium-sized enterprises, providing realistic and feasible solutions to solve carbon accounting problems.

KEYWORDS

Carbon Emission Accounting; High Energy Consumption Enterprises; Green Transformation

1. RESEARCH BACKGROUND AND SIGNIFICANCE

1.1. Research Background

In recent years, my country has a high degree of carbon emission management. The national carbon market will be officially launched in 2021. By the end of 2023, the cumulative transaction volume of carbon emission allowances in the national carbon emission trading market will be 442 million tons, with a cumulative transaction volume of 24.919 billion yuan. However, despite the continuous improvement of the policy framework, carbon emission accounting is still an insurmountable "heart disease" in high-energy-consuming industries-enterprises have shortcomings in carbon accounting, data governance, personnel capabilities, etc., which leads to limited carbon management decisions and even affects emission reduction. Implementation of actions. Especially in high-energy-consuming industries such as steel, chemical industry, electric power, and cement, where carbon emissions are large and production processes are complex, issues such as the adaptability of the accounting system, data accuracy, and regulatory effectiveness have become major obstacles to the low-carbon transformation of enterprises. Therefore, it is urgent to take systematic optimization measures to improve the accuracy of carbon accounting, data transparency and management efficiency.

1.2. Literature Review

In recent years, international research has mainly focused on the optimization of carbon accounting, the application of intelligent technology, and the improvement of carbon market mechanisms. Artificial intelligence (AI), blockchain, big data and other technologies are widely used in carbon emission accounting. Haoyue Peng et al. (2024) use the LSTM deep learning model to improve the

accuracy of carbon emission prediction [1], Gongduan Fan, Qiaoling Xu et al. (2024) Multi-objective optimization model and system dynamics (SD) model [2], while Chao Wu et al. (2024) combine deep reinforcement learning (DRL) to optimize carbon trading strategies, indicating that intelligent technology can reduce the uncertainty of the carbon market [3], Hongcheng Li et al. (2025) established a hybrid carbon source accounting model [4]. Loke Kok Foong et al. (2024) optimization algorithms SHO, MFO and GOA combined with four machine learning Gaussian processes, linear regression, MLP and random forests are applied to carbon dioxide emission prediction [4].

In terms of carbon emission system and carbon responsibility accounting, Wei Gao et al. (2025) built a predictive composite full life cycle carbon emission accounting system to more accurately predict the carbon emissions and impact of wind power projects during their service life [6]. Chunli Wang et al. (2025) realized the carbon emission responsibility accounting of each link of the power system [7]. In addition, mature carbon markets such as the EU ETS are also promoting carbon digitization and improving data consistency.

However, international research still faces challenges, such as the compatibility of carbon accounting in different countries, data privacy and sharing problems, which also affect my country's carbon market. Therefore, my country needs to learn from the international market and combine the characteristics of local enterprises to promote the intelligent transformation of carbon accounting, and at the same time build a data governance and market supervision system that adapts to national conditions.

2. CARBON EMISSION ACCOUNTING OPTIMIZATION CASES

Through typical cases, this study proposes the following three optimization paths: technology empowerment, system innovation and SME adaptation solutions, the specific optimization path is as follows.

2.1. Technology Empowerment: Application of Digital Accounting Tools

2.1.1. Case: Shandong Weiqiao Aluminum and Electricity Real-time Monitoring System

Shandong Weiqiao Aluminum and Electricity is a benchmark enterprise in the domestic electrolytic aluminum industry. Its production process involves a large amount of power consumption, and the accuracy of carbon emission management directly affects the cost of corporate carbon market compliance. The company took the lead in deploying a real-time carbon emission monitoring system. Through edge computing and Internet of Things sensor technology, it fully covers all aspects of electrolytic aluminum production and realizes high-precision collection and intelligence of carbon data.

When we walked into the Shandong Weiqiao Aluminum Power Plant area for the first time, we saw that smart sensors were installed in almost every production link in the factory area. The staff told us: "This system is equivalent to installing a" carbon monitoring camera "for the entire factory. Real-time monitoring of emissions." Compared with manual reporting, this intelligent accounting has increased the efficiency of data collection by 70%. When asked if this system has encountered resistance to promotion, the person in charge of the company admitted frankly that this system is relatively expensive, but without this system, the company may spend millions more every year on carbon market compliance.

2.1.2. Technology Path: Edge Computing Internet of Things Sensors

Edge computing: Deploy computing units at process nodes close to data sources, delay data transmission, and realize localized real-time computing.

Internet of Things sensors: Smart sensors are deployed at key points such as aluminum electrolysis cells, electrolytic flue gas outlets, and waste heat recovery equipment to automatically collect CO_2 emission data.

Intelligent system: Combined with production process parameters, intelligent comparison and abnormal identification of carbon emission data are carried out to improve accounting accuracy.

2.1.3. Promotion effectiveness: improve data accuracy and calculate costs

The efficiency of carbon emission data collection has been increased by 70%, and second-level updates have been achieved. The carbon accounting error rate has been reduced from 8.5% to 2.3%, which is required by the international carbon market. The accounting cost is 30%, and the manual entry is wrong, which improves the carbon asset management capabilities of enterprises.

2.1.4. Interview: Technical Director of a National Supercomputing Center

In order to optimize the processing efficiency of carbon emission data, this study investigated a national supercomputing center, which has cooperated with a number of large enterprises to provide carbon accounting and calculation support. Its technical director said: "Enterprise carbon accounting relies on local servers, and it may take hours to calculate carbon emission models, but through the parallel computing architecture of the supercomputing center, the computing time can be shortened to a few minutes." Through comparison, we found that:

The supercomputing center can greatly improve the carbon data processing capability-after a power company uses the supercomputing center to calculate carbon emissions, its carbon emission data processing time.

The supercomputing center can optimize the accuracy of carbon emission prediction-using machine learning supercomputing to predict carbon emission trends, and its error rate ratio statistics.

The supercomputing center can support dynamic carbon accounting modeling-a chemical company realized automatic calculation of carbon emissions based on real-time data in a pilot project, which improved the accuracy of carbon quota trading.

2.2. Institutional Innovation: Construction of Cross-industry Collaboration Platform

2.2.1. Case: Yangtze River Delta Iron and Steel-Chemical Carbon Accounting Alliance

The iron and steel industry and the chemical industry have a carbon emission coupling relationship. The coke oven gas and waste gas waste heat of iron and steel enterprises can be used as raw materials for chemical enterprises to realize cascade utilization of energy. The Yangtze River Delta region took the lead in establishing the "Steel-Chemical Carbon Accounting Alliance" to optimize carbon quota management and corporate carbon costs through cross-industry data sharing and collaborative emission reduction mechanisms.

2.2.2. Mechanism: Supply chain carbon data sharing coke oven gas recycling

Data sharing platform: Establish a unified carbon emission accounting database to realize real-time interoperability of carbon data between iron and steel enterprises and chemical enterprises.

Coke oven gas recycling: Coke oven gas from iron and steel enterprises is transported to chemical enterprises through the pipeline network for synthetic ammonia, methanol and other chemical products and fossil fuel use.

Supply chain collaborative accounting: When fulfilling the carbon market contract, chemical companies can reward additional carbon allowances based on the low-carbon attributes of coke oven gas.

2.2.3. Promotion effectiveness: carbon emission reduction transaction cost optimization

The enterprises participating in the alliance reduce their emissions by 12% annually, which is a large amount of carbon emissions. Collaborative accounting of the supply chain enables enterprises to demand carbon allowances and saves carbon market transaction costs by more than 10 million yuan per year. Promote the coordinated low-carbon transformation of the industrial chain and improve the overall competitiveness of the industry.

The cross-industry coordination mechanism can make up for the shortcomings of the current carbon accounting system, enable enterprises to achieve emission reduction gains through resource sharing, and optimize the carbon market transaction structure.

2.3. SME Adaptation Solution: Lightweight Toolkit

2.3.1. Case: Zhejiang Building Materials Industry "Carbon Ledger" Mini Program

Small and medium-sized enterprises often face problems such as talent shortage, backward technology, and high management costs in the process of carbon emission accounting. During the team's investigation, he saw the whole process of carbon emission accounting in a building materials company in Zhejiang. Originally, the company needed to manually fill in dozens of carbon emission data every month, and the calculation process was cumbersome and error-prone. However, after the introduction of the "Carbon Ledger" applet, the person in charge tapped the mobile phone a few times, and the system automatically generated an accounting report. "How do we understand those complicated calculations? Now we can just lose a few numbers." The person in charge sighed.

2.3.2. Function: one-click accounting, adapting to industry characteristics

Intelligent accounting algorithm: Based on the industry database, it automatically calculates the carbon emissions of enterprises.

One-click report generation: supports direct generation of carbon emission reports that meet the requirements, and enterprises manually calculate costs.

Industry customized model: For kiln process, integrate energy consumption model to optimize carbon accounting accuracy.

2.3.3. Promotion effectiveness: Improving the accounting capabilities of small and medium-sized enterprises

300 small and medium-sized enterprises are connected, and the carbon accounting threshold is large. The data error rate is controlled within 5%, and the carbon market complies with the requirements. Through automated accounting, each enterprise invests an average of 50 hours/year of labor and operating costs. Lightweight accounting tools provide small and medium-sized enterprises with low-cost, easy-to-operate carbon management solutions, and improve the overall carbon accounting efficiency and compliance of the industry.

3. OPTIMIZING THE CARBON ACCOUNTING SYSTEM

In view of the reality of carbon emission accounting, this paper summarizes three effective optimization paths:

Table 1. Path to Optimize Carbon Accounting System

Optimized path	Case	Corresponding object	Innovation	Realize the effect
Technology Empowerment	Shandong Weiqiao Aluminum and Electricity Real-time Monitoring System	Large-scale high-energy-consuming enterprises	Edge Computing	Carbon emission data collection efficiency increased by 70%
			Layout of IoT sensors	Carbon accounting error rate reduced from 8.5% to 2.3%
			Adoption of intelligent systems	Accounting cost30%
	Interview with the technical director of a supercomputing center	supercomputing center	Combination of Carbon Accounting System and Supercomputing Center	Promote enterprises to achieve more efficient and accurate carbon data processing, and optimize the carbon market compliance mechanism
Institutional innovation	Yangtze River Delta Iron and Steel-Chemical Carbon Accounting Alliance	Industry alliances	Establish a unified carbon emission accounting database	Enterprises participating in the alliance reduce emissions by an average of 12% per year
			Coke oven gas recycling	Save carbon market transaction costs by more than 10 million yuan/year
			Collaborative accounting of supply chain	Promote the coordinated low-carbon transformation of the industrial chain and improve the competitiveness of the industry
SME Adaptation Scheme	Zhejiang Building Materials Industry "Carbon Ledger" Mini Program	SMEs	Adopt intelligent accounting algorithm	300 small and medium-sized enterprises access
			Supporting the generation of compliant carbon emission reports	The data error rate is controlled within 5%
			Integrated industry customization model	The average labor input of each enterprise is 50 hours/year

In order to improve the accuracy and traceability of carbon data, the research team is currently developing an intelligent carbon accounting system based on the Python blockchain AI algorithm, using Internet of Things sensors, edge computing, blockchain certificate storage and other technologies to realize real-time collection, trusted certificate storage and intelligence of carbon emission data.

The technical architecture design is as follows:

(1) Data collection layer: Collect carbon emission data through industrial Internet of Things devices, and preprocess it at edge computing nodes, delay data transmission, and improve data integrity.

(2) Data storage layer: Carbon data is stored in the Hyperledger Fabric blockchain in the form of hashes to ensure that the data cannot be tampered with, and is synchronously stored in the MongoDB database to support subsequent.

(3) Data calculation layer: Use the LSTM deep learning model to predict carbon emission trends, combine regression to optimize the carbon accounting calculation model, and improve data accuracy.

(4) Data application layer: Web-based SaaS carbon management platform, providing services such as enterprise carbon accounting, carbon footprint tracking, and carbon quota optimization, and opening API interfaces to support third-party system integration.

The dual support of technology and policy will significantly improve the efficiency of corporate carbon management, promote the green and low-carbon transformation of the industry, and lay a solid foundation for the realization of the "dual carbon" goal. Through cross-field collaboration and integration of multiple resources, the system will realize the full life cycle management of carbon emissions, enhance corporate environmental protection awareness, promote green technology

innovation, and eventually form a virtuous circle, contributing Chinese wisdom to global climate governance.

4. CONCLUSION

Through the successful practice of leading domestic enterprises, this study summarizes three major paths: technology empowerment, system innovation, and small and medium-sized enterprise adaptation solutions. These three are suitable for large-scale high-energy-consuming enterprises, industry alliances, and small and medium-sized enterprises, providing different types of enterprises with Operable carbon accounting optimization solutions are provided. In the future, policy makers should further promote digital accounting tools, improve the supply chain collaborative emission reduction mechanism, and promote the popularization of carbon management tools to improve the carbon accounting capabilities of enterprises and help achieve the "double carbon" goal.

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