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# Big data and AI empower innovative practices in low-carbon production processes

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***Abstract:*** *This article deeply explores how state-owned metallurgical enterprises use big data and artificial intelligence technology to empower innovative practices in low-carbon production processes in the context of global and Chinese "double carbon" goals[1]. By analyzing the current situation and challenges of state-owned metallurgical enterprises in carbon emission control, the article explains the application value of big data and AI technology in optimizing production processes, improving energy efficiency, and reducing emissions[2]. Through specific case presentations, it is revealed how these technologies can help state-owned metallurgical enterprises achieve green transformation and enhance their competitiveness. Finally, the article summarizes the challenges and response strategies, and looks forward to the continued application of big data and AI technology in the low-carbon transformation of the metallurgical industry in the future.*

***Keywords:*** *big data, artificial intelligence (AI), low-carbon production, state-owned metallurgical enterprises, dual carbon goals, green transformation, technological innovation*

## 1. Introduction

As the serious challenge of global climate change becomes more and more prominent, it has become the consensus of the international community to reduce greenhouse gas emissions and cope with climate warming. Against this backdrop, China, as a responsible big country, has actively responded to the call for global climate governance and put forward the ambitious goal of carbon peaking and carbon neutrality (referred to as "dual carbon")[3]. The goal is to achieve peak carbon dioxide emissions by 2030, and then to achieve carbon neutrality, i.e., net-zero carbon dioxide emissions, by 2060. This goal signifies that China will undergo a comprehensive and profound green and low-carbon transformation in terms of its energy structure, industrial structure and production and lifestyle.

Emphasizing the key role of State-owned metallurgical enterprises in achieving carbon neutrality.

As one of the important basic industries of the national economy, the metallurgical industry's production process is often accompanied by large amounts of energy consumption and carbon emissions. Therefore, the low-carbon transformation of the metallurgical industry is a key link in realizing the national "double-carbon" goal. State-owned metallurgical enterprises, as the mainstay of China's metallurgical industry, not only bear the important responsibility of safeguarding national economic security and promoting industrial upgrading, but also play a crucial role in low-carbon transformation. Through technological innovation, management optimization and other means, state-owned metallurgical enterprises can lead the trend of low-carbon development in the industry and contribute to the realization of the national "double carbon" goal.

Facing the urgent need for low-carbon transformation in the metallurgical industry, the rapid development of big data and artificial intelligence (AI) technology has provided strong technical support for this process. Big data technology can realize the real-time collection, processing and analysis of massive production data, help companies accurately identify energy consumption and emission hot spots in the production process, and provide data support for optimizing production processes and improving energy efficiency. AI technology uses machine learning, deep learning and other algorithms to conduct in-depth mining and analysis of big data, automatically discover potential problems in the production process, put forward optimization suggestions, and even realize intelligent control of the production process. Therefore, the deep integration and application of big data and AI

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technology has become an important driving force for the innovation of low-carbon production processes in state-owned metallurgical enterprises, providing a strong guarantee for the realization of green and low-carbon transformation.

## 2. Status and Challenges of Low-Carbon Production in State-Owned Metallurgical Enterprises

### *2.1 Overview of industry carbon emissions*

As an industrial sector with high energy consumption and high emissions, the metallurgical industry accounts for a significant proportion of total carbon emissions in the world and in China. According to relevant statistics, the carbon emissions of the metallurgical industry occupy an important position in global industrial emissions. As the world's largest producer of metallurgical products, China's carbon emissions of the metallurgical industry remain high. This current situation not only aggravates the severe situation of global climate change, but also poses a huge challenge to China's realization of the "double carbon" goal.

In the metallurgical production process, high carbon emissions exist in many aspects. The first is the raw material preparation stage, such as ore mining, crushing, screening and other processes will produce a large amount of energy consumption and emissions; second is the smelting process, such as blast furnace ironmaking, converter steelmaking and other core links, due to the need for high-temperature operations, energy consumption and carbon emissions are great; and finally is the stage of product processing and energy utilization, such as rolling, heat treatment of steel, as well as the production process of residual heat, residual pressure, and other energy recycling issues The last is the product processing and energy utilization stage, such as steel rolling and heat treatment, as well as the recycling of energy generated in the production process, such as waste heat, waste pressure and so on, which is also directly related to the level of carbon emissions.

### *2.2 Main challenges faced*

#### *2.2.1 The complexity of the production process and the difficulty of reducing emissions*

The production processes in the metallurgical industry are complex and diverse, and the carbon emission characteristics and emission reduction potentials of different processes vary significantly[4].This makes companies face many difficulties when formulating emission reduction strategies, and they need to comprehensively consider factors such as technical feasibility, economic costs, and environmental benefits. At the same time, because many links in the metallurgical production process are interrelated and influence each other, emission reduction measures in a single link are often difficult to achieve the ideal emission reduction effect, and the systematic optimization of the entire production process is required.

#### *2.2.2 Insufficient investment in research and development of low-carbon technologies, and innovation capacity to be upgraded*

Although state-owned metallurgical enterprises have made some progress in the research and development of low-carbon technologies in recent years[5], on the whole, the investment in research and development is still insufficient, and the innovation ability needs to be further improved. On the one hand, due to the metallurgical industry's high technological threshold, long research and development cycle, large investment funds, many enterprises in the technology research and development of the existence of difficult; on the other hand, the maturity of the existing low-carbon technology and the level of commercialization and application of the level of improvement, it is difficult to meet the needs of the actual production of enterprises.

#### *2.2.3 Inadequate carbon emissions data management system and low level of refined management*

Carbon emission data is an important basis for formulating emission reduction strategies and evaluating the effect of emission reduction. However, at present, the carbon emission data management system of many state-owned metallurgical enterprises is not sound, and there are problems such as incomplete data collection, low data quality and insufficient data analysis. This has led to the lack of scientific data support in the formulation of emission reduction targets, decomposition of emission reduction tasks and monitoring of emission reduction effects, making it difficult to realize refined management. In addition, some enterprises still have problems such as low awareness and unclear responsibility in carbon emission data management, which require further strengthening of

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management and supervision.

## 3. The application value of big data and AI in low-carbon production

### *3.1 Data-driven production optimization that*

In low-carbon production, the value of big data application is firstly reflected in the comprehensive optimization of the production process[6]. Through in-depth analysis of energy consumption and emission data in the production process, enterprises can accurately identify the potential for energy saving and emission reduction. These data include, but are not limited to, raw material consumption, energy consumption, waste emissions, etc. Through big data analysis, enterprises can identify bottlenecks and waste points in the production process, so as to develop targeted improvement measures.

1) Energy consumption and emission data analysis: big data analysis tools can process massive production data, identify which links have high energy consumption and high emissions, and then provide data support for energy conservation and emission reduction. For example, in the power system, intelligent algorithms can accurately predict power demand based on historical power consumption data and weather forecasts, so as to rationally arrange power generation plans and reduce unnecessary energy waste and carbon emissions.

2) Real-time monitoring of equipment running status: the combination of big data and Internet of Things technology, so that enterprises can monitor the running status of production equipment in real time. Through the real-time collection and analysis of equipment data, enterprises can find equipment failures and potential problems in a timely manner, and carry out maintenance and repair in advance to avoid production interruptions and increased energy consumption caused by equipment downtime. At the same time, this also helps to improve production efficiency and reduce energy consumption and emissions.

### *3.2 Intelligent decision support*

The application of AI in low-carbon production further enhances the decision-making capabilities of enterprises. With the assistance of AI algorithms, companies can formulate production plans more scientifically and rationally, optimize resource allocation, and achieve the goal of low-carbon production.

1) Production plan optimization: AI algorithms can automatically generate optimal production plans based on various factors such as market demand, production capacity, and equipment status. This can not only improve production efficiency, but also reduce ineffective production capacity, reduce energy consumption and emissions. For example, in manufacturing, AI algorithms can optimize production planning and scheduling to minimize idle time and delivery delays and improve on-time delivery.

2) Market demand forecast: AI technology can predict market demand changes in the future through analysis of market data. Enterprises can adjust product structure and production plans in a timely manner based on these prediction results to avoid waste and emissions caused by over or under production. At the same time, this will also help companies better meet market demands and improve market competitiveness.

### *3.3 R&D and application of low-carbon technologies*

The combination of big data and AI also accelerates the development and application of low-carbon technologies. Through simulation technology and data analysis methods, companies can more efficiently develop low-carbon processes and catalysts, shorten the research and development cycle, and reduce research and development costs.

1) Accelerate the research and development of low-carbon technologies: AI technology can simulate and emulate various conditions in the production process, providing strong support for the research and development of low-carbon technologies. For example, in the chemical industry, AI can help companies develop more environmentally friendly and efficient catalysts and processes by simulating reaction conditions and optimizing reaction parameters.

2) Optimize process flow: Through big data analysis and simulation technology, companies can

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gain an in-depth understanding of each link in the production process, identify links with high energy consumption and large emissions, and optimize them. For example, in the power industry, AI can optimize power generation plans and dispatch strategies based on information such as grid load conditions and weather forecasts, reducing unnecessary energy waste and carbon emissions. At the same time, by optimizing the process flow and parameter settings, companies can also reduce the consumption of raw materials and the generation of waste, and achieve the goal of low-carbon production.

To sum up, the application value of big data and AI in low-carbon production is reflected in many aspects. Through data-driven production optimization, intelligent decision support, and low-carbon technology R&D and application, companies can conduct production activities more efficiently and environmentally, and contribute to achieving sustainable development goals.

## 4. Innovative practical cases of big data and AI empowering low-carbon production processes

### *4.1 Case 1: Intelligent bottom-turning furnace plant of a state-owned metallurgical enterprise*

#### *4.1.1 Background and objectives.*

With the in-depth implementation of the "dual carbon" strategy, a state-owned metallurgical enterprise actively responded to the country's call and decided to carry out intelligent transformation of its core production facility, the rotary hearth furnace, aiming to achieve production through the deep integration of big data and AI technology. Precise control of the process, effective reduction of energy consumption and significant improvement of environmental protection indicators. The goal of this project is to create a modern metallurgical production demonstration base integrating high efficiency, green and intelligence.

#### *4.1.2 Technology applications*

Production process optimization: Use big data analysis technology to monitor and analyze various parameters in the rotary hearth furnace production process in real time, and identify key factors that affect production efficiency. Subsequently, AI algorithms are used to intelligently schedule and optimize the production process to ensure that all production links are closely connected, reduce waiting time and ineffective operations, thereby significantly improving production efficiency.

Energy consumption management: Establish an energy consumption monitoring and prediction model, use big data to collect equipment operating status, production load and other data, and combine AI algorithms to conduct energy consumption analysis and prediction. By intelligently adjusting production parameters and optimizing energy distribution strategies, we can achieve refined management of energy consumption and effectively reduce energy consumption in the production process.

Environmental monitoring: Deploy environmental monitoring equipment, collect emission data in real time, and use AI technology to conduct in-depth analysis of the data. By establishing an emission early warning system, potential environmental pollution problems can be discovered and dealt with in a timely manner to ensure that production activities comply with environmental protection standards. At the same time, big data analysis technology is used to evaluate the impact of different production plans on the environment, providing scientific basis for formulating more environmentally friendly production strategies.

#### *4.1.3 Effectiveness of implementation.*

After the construction and operation of the intelligent rotary hearth furnace factory, the company has achieved a significant increase in production efficiency, a significant reduction in energy consumption per unit product, and environmental protection indicators have also reached industry-leading levels. In addition, intelligent transformation also improves the stability and reliability of the production process, reduces failure rates and maintenance costs, and brings significant economic and social benefits to enterprises.

### *4.2 Case 2: Green Supply Chain Collaborative Management Platform*

#### *4.2.1 Platform construction*

In order to promote the low-carbon transformation of the entire supply chain, the state-owned

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metallurgical enterprise has teamed up with a number of upstream and downstream enterprises to jointly build a green supply chain collaborative management platform based on big data and AI. The platform integrates functional modules such as supply chain management, carbon emission monitoring, data analysis and decision support, and realizes real-time sharing and transparent management of carbon emission data in each link of the supply chain.

#### *4.2.2 Technology applications*

On the platform, enterprises upstream and downstream of the supply chain can upload their carbon emission data in real time, forming a complete carbon emission data chain. These data are encrypted to ensure data security and privacy protection. At the same time, the platform provides data visualization tools to help enterprises visualize their own carbon emissions and those of the entire supply chain.

Transparent management: Use AI technology to analyze and mine data to reveal the carbon emission correlation and impact between various links in the supply chain. By building a carbon emission responsibility traceability system, we can clarify the emission reduction responsibilities and contributions of each link and promote collaborative emission reduction among supply chain companies.

Decision-making support: Based on the results of big data analysis, the platform provides supply chain enterprises with personalized emission reduction suggestions and optimization plans. By simulating the implementation effects of different emission reduction strategies, the platform helps enterprises assess the costs and benefits of emission reduction and formulate scientific and reasonable emission reduction plans.

#### *4.2.3 Implementation effects.*

The establishment of a green supply chain collaborative management platform has effectively promoted the low-carbon transformation of the overall supply chain. Through data sharing and transparent management, supply chain companies can collaborate more closely and have clearer emissions reduction responsibilities. At the same time, the decision support function provided by the platform helps enterprises formulate more scientific and reasonable emission reduction plans, reduces emission reduction costs, and improves emission reduction effects. Ultimately, the overall carbon emissions of the supply chain were effectively reduced and environmental performance significantly improved.

## 5. Challenges and recommendations for countermeasures

### *5.1 Data quality and security*

Challenge: In the process of empowering low-carbon production processes with big data and AI, data is the core driving force. However, data quality issues (such as missing data, errors, inconsistencies, etc.) will directly affect the accuracy and reliability of analysis results. At the same time, data security is also an issue that cannot be ignored, involving data leakage risks in corporate confidentiality, user privacy and other aspects.

Suggestions for countermeasures: Strengthening data security management: Establishing a perfect data security management system, including data encryption, access control, audit tracking and other measures, to ensure the security of data in the process of collection, processing, storage and transmission.

Improvement of data quality: Strict data quality standards have been formulated, and technical means such as data cleansing, calibration and integration have been adopted to improve the completeness, accuracy and consistency of data. At the same time, a data quality monitoring mechanism has been established to regularly assess and improve data quality.

Cultivate data awareness: Strengthen the data awareness education of enterprise employees, raise the importance of data quality and security, and form a good atmosphere for all staff to participate in data quality management.

### *5.2 Technology integration and innovation*

Challenge: The integrated application of big data and AI technology requires interdisciplinary knowledge reserves and innovation capabilities. At present, insufficient technological integration and

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insufficient innovation capabilities are important factors restricting the optimization of low-carbon production processes.

Countermeasures and suggestions: Increase R&D investment: Enterprises should increase R&D investment in big data and AI technology to support technological innovation and integrated applications. By establishing special funds and cooperating with universities and scientific research institutions, we attract outstanding talents and resources and promote technological breakthroughs.

Cultivating complex talents: Strengthening the training of interdisciplinary talents, encouraging employees to learn new technologies and new knowledge, and improving their comprehensive quality and innovation ability. At the same time, establish incentive mechanisms to attract and retain professionals with interdisciplinary backgrounds.

Promote technological innovation practices: Encourage enterprises to carry out technological innovation practices, apply big data and AI technology to actual production processes, and form technological achievements with independent intellectual property rights through continuous trial and error and optimization.

### *5.3 Policy and standards support*

Challenge: The policies, regulations and standard systems related to low-carbon production are not yet perfect and lack unified guidance and norms[7]. This has led to the problem of policy uncertainty and non-uniformity of standards faced by enterprises in carrying out low-carbon technological innovation.

Suggestions for countermeasures: Improvement of policies and regulations: The government should speed up the improvement of policies and regulations related to low-carbon production, clarify the responsibilities and obligations of enterprises to reduce emissions, and provide policy support and incentives. At the same time, it should strengthen the supervision and evaluation of policy implementation to ensure the effective implementation of policies.

Formulation of unified standards: Establish a unified system of standards related to low-carbon production, including standards for carbon emission accounting, energy-saving and emission reduction technology assessment, and green product certification. Through the formulation and implementation of standards, enterprises will be guided to standardize their production behaviors and enhance the level of low-carbon production.

Strengthening international cooperation: Strengthening cooperation and exchanges with the international community, drawing on international advanced experience and technological achievements, and promoting the internationalization of low-carbon production standards. At the same time, we will actively participate in the formulation and revision of international standards, so as to enhance our country's voice and influence in the field of international low-carbon production.

## 6. Conclusions and outlook

### *6.1 Conclusion*

In the innovative practice of low-carbon production processes in state-owned metallurgical enterprises, big data and AI technology have played an immeasurable role. First of all, they provide strong technical support for enterprises' carbon emission monitoring and management. Through real-time data collection and analysis, they achieve refined management in the production process and precise control of carbon emissions. This not only greatly improves production efficiency, but also effectively reduces energy consumption and emission levels, laying a solid foundation for the company's green development.

Secondly, the integrated application of big data and AI technology promotes the optimization and upgrading of metallurgical production processes. Through in-depth mining and analysis of production data by intelligent algorithms, companies can promptly discover and solve bottlenecks in production and realize intelligent transformation of production processes. This not only improves the overall competitiveness of the company, but also sets an example for the industry's low-carbon transformation.

In addition, big data and AI technology have also promoted the construction and development of green supply chains. By building a green supply chain collaborative management platform based on big

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data, companies can grasp the carbon emissions of each link in the supply chain in real time and promote the low-carbon transformation of the overall supply chain. This not only helps companies achieve their own carbon neutrality goals, but also contributes to promoting green and sustainable development of the entire industry.

### *6.2 Looking ahead*

Looking to the future, with the continuous advancement of technology and the deepening of its application, the role of big data and AI technology in the low-carbon transformation of the metallurgical industry will become more prominent. In order to continue to promote this process, we make the following suggestions:

1) Strengthen technology research and development and innovation: Continue to increase investment in research and development in the fields of big data and AI technology, and promote technological innovation and integrated applications. Encourage cooperation and exchanges between enterprises, universities and scientific research institutions to jointly overcome technical problems and promote the overall improvement of the industry's technical level.

2) Improvement of policy and standard system: The Government should further improve the policy, regulations and standard system related to low-carbon production, so as to provide clear guidance and norms for the low-carbon transformation of enterprises. At the same time, it should strengthen the supervision and evaluation of the implementation of policies to ensure the effective implementation of policies.

3) Strengthen talent training and introduction: Pay attention to the training and introduction of interdisciplinary talents to provide strong talent support for the application of big data and AI technology in the metallurgical industry. By strengthening education and training and establishing incentive mechanisms, we will attract more outstanding talents to devote themselves to the low-carbon transformation of the metallurgical industry.

4) Promote industry cooperation and sharing: Strengthen the construction of cooperation and sharing mechanisms within the industry, and promote the widespread application and popularization of big data and AI technology in the metallurgical industry. Promote the common progress and development of the entire industry by building an industry communication platform and sharing technological achievements.

### *6.3 Emphasizing the responsibility and accountability of State-owned metallurgical enterprises*

State-owned metallurgical enterprises have an important responsibility in realizing the goal of carbon neutrality. As the industry leaders and front-runners, state-owned metallurgical enterprises should actively respond to the national call and take the initiative to undertake the important task of low-carbon transformation. By strengthening technological innovation, optimizing production processes and promoting the construction of green supply chain and other measures, they can continuously improve their low-carbon production capacity and level. At the same time, it should also play an active role in demonstrating and leading the whole industry in the direction of low-carbon, green and sustainable development. Only in this way can we contribute China's strength and wisdom to the realization of global carbon neutrality.

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