Under the Dual-Carbon Strategy: Opportunities and Challenges in the Green Digital and Intelligent Transformation of the Energy and Power Supply Chain

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Abstract. With the proposal of the "double carbon" goal, the energy and power industry has ushered in new opportunities and challenges. On the one hand, green transformation requires development in a cleaner and more efficient direction to reduce dependence on traditional fossil energy. Its supply chain needs to be adapted to the production and supply of clean energy technologies and equipment. On the other hand, with the development of new technologies, the energy and power industry will adopt more digitalization and IoT technologies to improve efficiency and management. Its supply chain needs to integrate new technologies, establish a digital supply network, realize intelligent supply and warehousing, and follow the path of sustainable development. In short, under the background of "dual carbon", the supply chain of the energy and power industry is facing certain opportunities and challenges, and it is necessary to adjust its development strategy in a timely manner and follow the path of green, digital and intelligent development.

Keywords: Energy and power industry; Supply chain; Double carbon; Energy Transition.

1 Introduction

In the context of moving towards the "3060" dual-carbon development goal, China has clearer requirements for accelerating the development of the digital economy, green transformation, and promoting the high-quality development of the green supply chain. The energy and power industry is a key support for the development of modern society, and in the context of dual carbon, achieving green and low-carbon development has become an important goal of the industry. With the continuous development of science and technology, digitalization and intelligence have become important engines to promote the transformation and upgrading of the energy and power industry. The supply chain is an important link in the operation of the energy and power industry, and the key to the development of green digital intelligence also lies in the continuous optimization and collaboration of the supply chain.

K. Zhang et al. (eds.), *Proceedings of the 5th International Conference on Economic Management and Big Data Application (ICEMBDA 2024)*, Advances in Economics, Business and Management Research 313,
https://doi.org/10.2991/978-94-6463-638-3_40

2 Analysis of the Current Situation of Carbon Emissions and Electricity Composition

Since 2006, China has been the world's largest carbon emitter. According to the "2023 Carbon Dioxide Emissions Report" released by IEA [1], global carbon dioxide emissions in 2023 will be 37.4 billion tons, an increase of 1.1% over the previous year, while China's carbon dioxide emissions will be 12.6 billion tons, an increase of about 4% over the previous year. This increase reflects the increase in China's energy demand after the restart of economic activity, and the fact that clean energy growth is not enough to fully offset the impact of the increase in traditional fossil energy consumption.

As shown in Figure 1, the absolute amount of global energy carbon emissions is still on the rise. China stated that it will increase its nationally determined contributions, adopt more powerful policies and measures, strive to peak carbon dioxide emissions before 2030, and strive to achieve carbon neutrality before 2060.

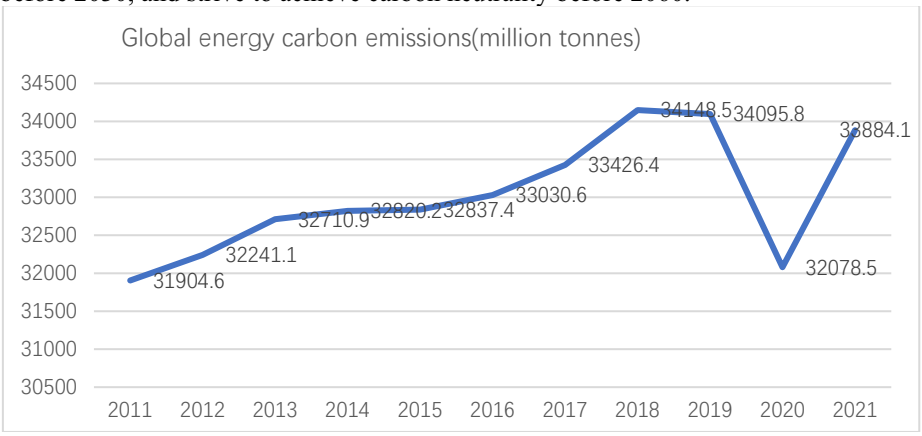

Fig. 1. Global energy carbon emissions

A. Strong growth of carbon dioxide emissions in the global power industry

Global data shows that global electricity demand grew by 2.7%, and despite a 2.0% decline in carbon intensity in the power generation sector, CO2 emissions grew first globally in absolute terms, rising by 1.8%, or 261 million tonnes.

B. New development trends of China's power industry

First, solar power generation has suddenly emerged. According to data from the National Energy Administration of China [2], as of the end of 2023, the cumulative installed power generation capacity of China's power industry is approximately 2.92 billion kilowatts, including 1.39 billion kilowatts of thermal power, 420 million kilowatts of hydropower, 56.9 million kilowatts of nuclear power, 441 million kilowatts of wind power, and 690 million kilowatts of solar power. 90 million kilowatts, accounting for 47.6%, 14.4%, 1.9%, 15.1%, and 20.9% respectively. Among them, the largest year-on-year increases were solar power generation (a year-on-year increase of 55.2%) and wind power (a year-on-year increase of 20.7%). Second, low-carbon green trans-

formation has achieved remarkable results. According to the data released by the China Electricity Council [3], the installed capacity of non-fossil energy power generation accounted for nearly 50% of the total installed capacity, the full-scale non-fossil energy power generation increased by 8.7% over the previous year, and the power investment increased by 13.3% over the previous year. Investment in fossil energy power generation accounted for power investment reached 87.7%. Third, the power industry also continues to promote the application of new energy to optimize the power supply structure. In 2023, the total installed capacity of newly put into operation and the installed capacity of non-fossil energy power generation will reach a new high [4], of which the newly added installed capacity of non-fossil energy power generation will reach 180 million kilowatts, the grid-connected wind power will reach 430 million kilowatts, and the grid-connected solar power generation will reach 490 million kilowatts. The installed capacity of solar power generation and wind power will exceed the installed capacity of hydropower for the first time in 2023, which also fully demonstrates the overall planning of new energy power generation in the power industry and further guides the coordination and connection between upstream and downstream supply chain.

3 Analysis of the Current Situation of Supply Chain Structure in the Energy and Power Industry

The power supply chain can be divided into four major links: power generation, transmission, transformation, distribution, and electricity consumption. Among them, power generation is mainly for the production of electric energy, and the node is the power generation enterprise; Transmission, transformation, and distribution refer to the transportation and distribution process of electric energy, and the node is the power grid company; The electricity consumption link mainly involves electric energy users, that is, end consumers. It can be seen that in the power supply chain, power grid enterprises undertake the upstream and drive the downstream, and form a power supply and demand network with power generation enterprises and terminal power users [5], thus forming a point power main supply chain. In addition, the operation of the supply chain also involves external participants, such as suppliers, national and local governments, industry and environmental protection organizations, etc.

Generally speaking, promoting the construction and development of the supply chain in the energy and power industry is a major systematic project, and it is also a common consideration of comprehensive commercial value, environmental value, technical value and other factors. During the construction process, comprehensive attention must be paid to all parties in the supply chain. In response to the demands of stakeholders, relevant suggestions should be obtained in a timely manner through upstream and downstream collaboration and communication, and respond and improve to ensure a smooth supply chain, enhance the resilience of the supply chain, continuously improve the level of green and digital transformation of the supply chain, and ultimately maximize the environmental benefits of all parties.

4 Opportunities and Challenges for Supply Chain Development in the Energy and Power Industry

"Carbon peaking" and "carbon neutrality" are major measures to coordinate various tasks, and the development of all walks of life is involved. As an important area for the realization of the "double carbon" goal, the energy and power industry's low-carbon development has a positive effect on the realization of my country's "double carbon" goal [6]. Under the background of "double carbon", the green digital and intelligent transformation of the supply chain of the energy and power industry has made certain progress, but it also faces some opportunities and challenges, as follows:

A. Opportunity Analysis

The development opportunities of the supply chain of the energy and power industry mainly come from factors such as energy transformation, policy support, and technological innovation.

1) Energy transition

Energy activities are the most important source of carbon emissions, and the transformation and upgrading of the energy industry has also become the focus of my country's carbon peaking, carbon neutrality goals implementation and path selection. The "double carbon" goal has put forward new and higher requirements for the transformation of my country's energy industry. On the one hand, the energy industry is required to be guided by improving quality and efficiency, transform the extensive development mode of high investment, high consumption and low efficiency for a long time, and effectively promote quality change and efficiency change; On the other hand, the energy industry is required to be green and low-carbon oriented, promote pollution reduction and carbon reduction in an all-round way from different energy varieties, from the upper, middle and lower reaches of the industrial chain, from all links of production, supply, storage, transportation and marketing, and strengthen green industries such as clean energy, energy conservation and environmental protection, so as to help achieve the goal of carbon peak and carbon neutrality [7]. Energy transition is an important opportunity to promote the development of the supply chain in the energy and power industry.

2) Policy support

Since the 18th National Congress of the Communist Party of China, the Party Central Committee and the State Council represented by have attached great importance to the development of my country's supply chain. At the 2016 Central Work Conference, pointed out that "it is necessary to promote the formation of a network system of professional division of labor and collaboration between large, medium and small enterprises, and form a complete and efficient industrial supply chain." Premier proposed at the 2016 Central Economic Work Conference that "the use of information networks and other modern technologies promote changes in production management and marketing models, Reshape the industrial chain, supply chain and value chain, transform and upgrade the traditional kinetic energy, and make it full of vitality and vitality. " In the report of the 19th National Congress of the Communist Party of China, pointed out that we should promote the deep integration of the Internet, big data, artificial intelligence and the real economy, and cultivate new growth points and form new

kinetic energy in the fields of mid-to-high-end consumption, innovation leadership, green and low-carbon, sharing economy, modern supply chain and human capital services. The report of the 20th National Congress of the Communist Party of China also proposed that "efforts should be made to improve the resilience and safety level of the industrial and supply chains" [8].

The possible economic benefits of policy implementation include reducing energy consumption and material costs, improving the response speed and flexibility of supply chain, and thus enhancing the market competitiveness of enterprises. The environmental benefits are reflected in reducing greenhouse gas emissions, reducing pollutant emissions and improving resource recycling, which helps to cope with climate change and environmental degradation.

3) Technological innovation

Technological innovation is an important driving force for the development of the supply chain in the energy and power industry. With the development of emerging technologies such as information technology and the Internet of Things, the supply chain can improve operational efficiency and flexibility through digitalization, automation and intelligence, and can have an impact from multiple channels such as technical effects, human capital effects, and structural effects. This enables enterprises to realize the greening and digital intelligence of the entire life cycle of product design, product manufacturing, upstream and downstream supply chain, recycling and other links. Compared with traditional technology, digital intelligence technology itself has high technological content and small impact on the ecological environment. It can reduce enterprise pollution emissions while improving enterprise production efficiency and product quality, thus promoting the green and low-carbon transformation of supply chain [9].

Digital intelligence technology is widely and profoundly used in supply chain management, which can significantly improve efficiency, reduce costs and optimize decision-making. Specifically, digital intelligence technology can use AI and big data to analyze suppliers' reliability, cost and delivery time in procurement and supply chain management, analyze historical procurement data and supplier performance through machine learning models, and predict future suppliers' performance and risk; In the production planning and control link, the Internet of Things (IoT) and AI are used for real-time production monitoring and intelligent scheduling, production line data is collected through sensors, AI algorithms are used for real-time analysis, and production plans are automatically adjusted to cope with demand changes; In the inventory management process, AI models can be used to predict inventory demand in combination with sales forecasts, seasonal changes and supply chain fluctuations to achieve intelligent replenishment; In the logistics and distribution link, by analyzing historical logistics data and real-time road conditions, the AI system can dynamically adjust the distribution route to reduce transportation time and cost.

Through the application of digital intelligent technology, it can not only realize the automation and intelligence of the supply chain, but also bring deeper insight and optimization to supply chain management, and promote the development of the supply chain in a more efficient, flexible and sustainable direction.

B. Challenge analysis

However, the energy and power industry supply chain also faces some challenges. First, intensified market competition has led to increased supply chain cost pressure. Supply chains need to improve operational efficiency, optimize resource allocation, and control costs to cope with the pressures of price competition and supply chain integration. Green digital intelligent supply chain integrates green environmental protection and digital technologies into supply chain management to achieve an environmentally friendly, resource-efficient and cost-optimized supply chain model. This kind of supply chain can help enterprises gain an advantage in market competition. By improving the transparency, response speed and sustainability of the supply chain, it can enhance customer trust and loyalty, while reducing operating costs and environmental risks. Secondly, the international development of the energy and power industry and geopolitical factors have an impact on the supply chain. The uncertainty of international trade and geopolitics brings supply chain instability and risks. In addition, due to the application of new technologies and new equipment, the supply chain needs to face problems such as rapid technological updates and unbalanced supply and demand of new energy equipment.

5 Exploration of the Path of Digital Intelligence Technology Empowering the Development of Green Supply Chain-Taking Big Data Technology as an Example

Green digital and intelligent development has become an inevitable choice for enterprises to develop high-quality and achieve the "double carbon" goal, and the emergence of digital and intelligent technology provides solutions to solve the problems faced in the green transformation of the supply chain, thereby enabling enterprises to achieve product design[10]. The entire life cycle of design, product manufacturing, upstream and downstream supply chain, recycling and other links is green and digitally intelligent. The emergence and gradual maturity of big data technology provide methods and paths for the green, digital and intelligent development of the supply chain of the energy and power industry.

A. "5V" characteristics of big data technology

In December, 2012, British scholar Victor Mayer-Schoenberg put forward the concept of "big data" in his book "The Age of Big Data", arguing that "big data" refers to massive, high-growth and diversified information assets that need new processing models to have stronger decision-making power, insight and process optimization capabilities.

As for the characteristics of big data, the "5V" characteristics of big data proposed by IBM are highly recognized by the industry[11], as shown in Figure 2.

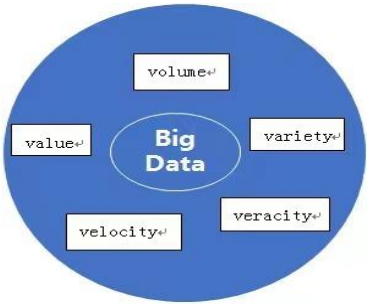

Fig. 2. "5V" characteristics of big data

1) Large data volume. In terms of measurement units, the unit of large data volume is at least P (1 000 terabytes), and may even reach EB (1 million terabytes) or ZB (1 billion terabytes). The large amount of data makes the process of data acquisition, storage and calculation change greatly.

2)Variety of data types and data sources. Data types include structured, semi-structured and unstructured data, and data sources include network logs, audio, video, pictures, geographical location information, etc. Diversified data types require higher processing capabilities.

3) Low value density (value). Low data value is relatively large data volume, which puts forward higher requirements for data value mining.

4) High speed (velocity). Data grows rapidly and requires high timeliness. For example, the recommendation algorithm mentioned later in this book requires real-time recommendation.

5) veracity. The accuracy and reliability of the data, that is, the quality of the data.

At present, with the advent of the era of big data, the green and low-carbon transformation of the supply chain is deeply rooted in the hearts of the people, and catching the express train of big data has become an inevitable trend for enterprises to promote the development and innovation of the supply chain. The U.S. government is the first country in the world to elevate "big data" from commercial behavior to national strategic awareness, and regards the innovative application of big data and the talent pool of future data scientists as important measures at the level of national awareness. As a global leader in big data applications, China has many Internet giants and is constantly seeking breakthroughs in core technologies. It can be seen that in the era of big data, it is very important to integrate big data technology innovation into the development and construction of green transformation of supply chain[12].

B. Application of big data technology in the supply chain of energy and power industry

In the supply chain, the application of big data involves various aspects, as shown in figure 3, including the following:

1) Environmental data analysis. Energy and power companies can collect and analyze environmental data through big data technology to understand the impact of their companies on the environment. Enterprises can also analyze the environmental protection situation of suppliers through big data technology, understand their environ-

mental protection capabilities and levels, select suitable suppliers, and reduce environmental pollution.

2) Energy consumption data management. Big data technology can monitor energy consumption in production, transportation and management, identify peak periods of electricity consumption, optimize energy consumption, and reduce energy consumption and emissions[13].

3) Waste management. Big data technology can improve the reuse rate of waste by identifying the type and quantity of waste generated in the production process, sorting and recycling waste, thereby reducing the pollution of waste to the environmen.

4) Logistics optimization. Big data technology can optimize logistics, reduce the return journey, repeated distribution and no-load transportation of goods, optimize logistics routes to reduce transportation losses, and reduce energy consumption and emissions.

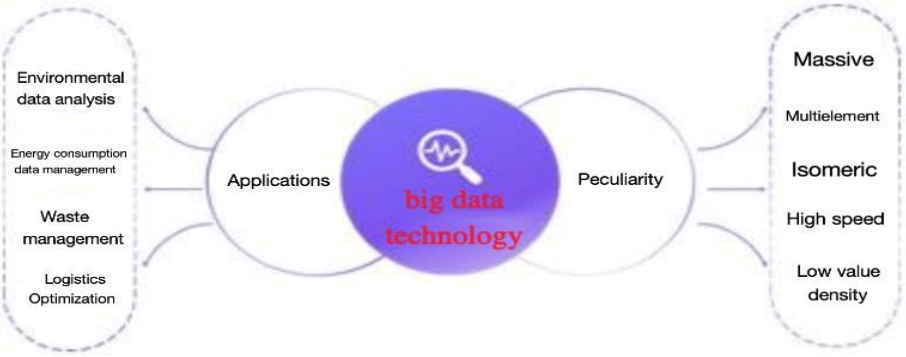

Fig. 3. Application of big data technology in supply chain

C.Smart supply chain management

Green digital and intelligent development has become an inevitable choice for enterprises to develop high-quality and achieve the "double carbon" goal, and the emergence of digital and intelligent technology provides opportunities to solve the problems faced in the green transformation of the supply chain, thereby enabling enterprises to achieve product design, The entire life cycle of product manufacturing, upstream and downstream supply chain, recycling and other links is green and digital.

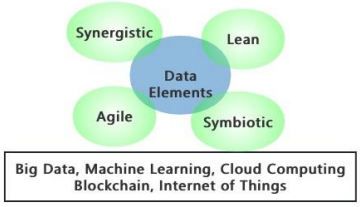

Fig. 4. Smart supply chain management architecture

As shown in figure 4, Smart supply chain management is based on new digital and intelligent information technology, integrating information technology and supply chain management to achieve a high degree of intelligence in the supply chain system. Its basic ideas are embodied in four aspects: agile, synergistic, lean and symbiotic. The essence of this theory is to introduce data elements into the supply chain, use emerging technologies such as big data, machine learning, cloud computing, blockchain, and Internet of Things to realize digital and intelligent decision-making, promote network collaboration among various node enterprises, reduce supply chain uncertainty in the operation process, and realize innovation in supply chain management.

6 Conclusion

To sum up, the development opportunities and challenges of the supply chain of the energy and power industry coexist. Supply chains can improve efficiency and flexibility by adapting to trends in energy transition and technological innovation, while also responding to risks such as market competition and geopolitics. Big data technology provides strong support for the implementation of supply chain management in the energy and power industry. Through the application of big data technology, enterprises can better understand the green transformation of their own supply chain and the environmental protection capabilities of suppliers, so as to optimize and manage, reduce environmental pollution and achieve sustainable development.

Research results of the project "Economic Value Assessment and High-quality Development Path Research of Forest Carbon Sinks in Northwest Sichuan Ecological Demonstration Zone" (Project No.: CXBSTJJ202417) of the "Northwest Sichuan Ecological Economic Development Research Center of Sichuan University for Nationalities" key research base of philosophy and social sciences in Ganzi Prefecture

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