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Dilemma and Countermeasures for Digital Governance of Renewable Energy in China under the "Dual Carbon" Goal

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Abstract: Digital technology makes energy systems more dynamic, efficient, reliable and sustainable. Promoting the digital governance of renewable energy is not only a key part of energy transformation, but also an important initiative to cope with the global energy crisis, which provides a new impetus for realizing the goal of net-zero emissions. In order to achieve the "dual-carbon" goal, China has been actively promoting energy reform and enhancing the wide application of digital technologies in the development and utilization of renewable energy. The digital governance system and governance capacity of renewable energy is an important support for the modernization of the national governance system and governance capacity. Although the digital governance of renewable energy in China has better policy support and advantages, the dilemmas it faces are still relatively prominent, including unsound laws and policies, insufficient governance capacity, and security loopholes in digital technology, etc. Therefore, this paper proposes a problem-oriented approach to the digital governance of renewable energy. Therefore, this paper puts forward problem-oriented optimization suggestions to innovate the legal system of renewable energy digital governance, promote the digital transformation of China's renewable energy industry, provide development space for renewable energy digital governance in a diversified mode, and enhance the digital governance capacity by improving the renewable energy security system.

Keywords: "dual carbon" goal; renewable energy; digitalization; governance

1. Introduction

The global energy crisis has sparked unprecedented momentum in renewable energy development, with the world set to add as much renewable energy in the next five years as it has in the past 20. The global energy crisis is driving a dramatic acceleration in renewable energy installations that will nearly double total global capacity growth over the next five years, overtaking coal as the largest source of power generation and helping to keep the possibility of limiting global warming to 1.5°C alive, the International Energy Agency says in a new report. As the world economy enters an era where decarbonization and digitization are superimposed, intertwined, mutually reinforcing and synergistic, digitization has become an important initiative for the world economy to find new momentum. The realization of the "dual-carbon" goal through digitalization is an inevitable requirement for the healthy and sustainable development of all countries' economies, and it is necessary to widely apply digital means in macro policies and micro measures to reduce pollution and carbon emissions. [0] To this end, China has proposed a "dual-carbon" goal - peaking carbon emissions by 2030 and neutralizing carbon emissions by 2060. Under the guidance of the "dual-carbon" goal, China's energy digitalization, intelligence and low-carbonization are accelerating. Carbon neutrality is the core force of digital transformation, and digitalization is the driving force of decarbonization strategy. Entering the new stage of the "14th Five-Year Plan", carbon neutrality navigates the digital transformation, and digitalization empowers the decarbonization strategy.[2] Digital transformation to drive the mode of production, lifestyle and governance changes, promote

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the low-carbon green development of the energy industry, build a safe and efficient energy system has become the development direction of the energy industry.[3]

In recent years, China's renewable energy installed capacity scale and many other indicators to maintain the world's first, for the first time more than the installed capacity of coal-powered electricity, accounting for the proportion of the total installed capacity is close to 50%, reaching about 49.2%. Energy saving and consumption structure optimization has also achieved remarkable results. By 2030, the proportion of non-fossil energy in primary energy consumption will reach about 25%, and the total installed capacity of wind and solar power will reach more than 1.2 billion kilowatts.[4] With the in-depth promotion of clean and low-carbon energy transformation, China will gradually get rid of its dependence on fossil energy. According to the preliminary estimates of relevant research institutions, by 2060, China's non-fossil energy consumption will be increased from the current 16% or so to more than 80%, non-fossil energy power generation will be increased from the current 34% or so to more than 90%, our country will gradually build a non-fossil energy as the main body of the safe and sustainable energy supply system, to achieve the depth of decarbonization of the energy sector. [5]

China's 14th Five-Year Plan proposes the construction of a digital China to help realize the "dual-carbon" goal. The use of digital technology to promote the reduction of pollution and carbon in all areas of society will become a new growth engine for China's economy, and renewable energy, as the source of pollution and carbon reduction, will realize the efficient use of renewable energy through digital technology. Therefore, it is necessary to accelerate the transformation from factor-driven to innovation-driven with the help of digitalization, and form a green governance path with digital as the supporting force.[6] The article analyzes the opportunities and challenges brought about by the interaction between digital technology and renewable energy development, and puts forward relevant suggestions for the digital governance of renewable energy. This paper will be developed from four aspects: the first section discusses the necessity of renewable energy digitization; the second section describes the policies and advantages of China's renewable energy digital governance; the third section analyzes the dilemmas in China's renewable energy digital governance; and the fourth section proposes improvement measures for China's renewable energy digital governance.

2. The necessity of promoting digital governance of renewable energy in China

Renewable energy refers to non-fossil energy sources such as wind, solar, hydro, biomass, geothermal and ocean energy. Renewable energy has become the primary goal of China's current energy transformation with its advantages of renewability, cleanliness and abundant reserves. However, there are a series of problems in the current development of renewable energy in China, and a new driving force is urgently needed, and energy digitization is the way to break the ice. Promoting the integration of digital economy in the energy sector will help renewable energy consumption and accelerate the transition to decarbonization. Therefore, the study of the relationship between the level of digitization and renewable energy development has important theoretical value and practical significance.[7] From the perspective of the characteristics and distribution of the solar, wind, geothermal and biomass energy consumption market, wind energy consumption accounts for the mainstream of the renewable energy consumption market; from the comparison of the total amount of photovoltaic, wind and geothermal power generation installed capacity, the total amount of renewable energy installed capacity shows a sustained high trend; from the point of view of the investment in renewable energy as well as the forecast of the growth of the consumer market, the future development of renewable energy will be centered on the Asia-Pacific region. At the same time, digitalization is both a new driving force for high-quality development and an important path to achieve the dual-carbon goal, and green economic transformation is a fundamental way to high-quality development.

According to the deployment requirements of the Decision of the Central Committee of the Communist Party of China on Several Major Issues on Adhering to and Improving the Socialist System with Chinese Characteristics and Promoting the Modernization of the National Governance System and Governance Capability, the national energy digital governance capacity is an important

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support for the modernization of the national governance system, and promoting the modernization of the energy digital governance capacity and the governance system is the proper meaning of accelerating the high-quality development of energy. The field of energy governance is presenting a new form of intelligence, efficiency, interaction and integration, with the main features of intelligent facilities, diversified integration, symmetrical information, decentralized supply and demand, and open transactions.[8] Accelerating the modernization of the energy governance system and governance capacity will improve the rationality and effectiveness of energy policymaking as a whole and promote the high-quality development of smart energy.[9]

Digital technologies and data have great potential to accelerate the clean energy transformation of the entire energy sector. In recent years, advances in digital technologies and services, falling costs, and ubiquitous connectivity have accelerated the digital transformation of energy, particularly in the electricity network sector. Investments in digital technologies related to electricity grids have grown by more than 50 percent since 2015 and are expected to reach 19 percent of total grid investments by 2023. Investment in electric vehicle charging infrastructure has also increased significantly, doubling in 2022 compared to the previous year.[10] However, policymakers and businesses need to make further efforts to realize the potential of digitization. This includes implementing enabling standards, policies and regulations that prioritize innovation and interoperability while addressing cybersecurity and data privacy risks.[11] In the electricity system, digital technologies can help integrate increasing amounts of variable renewable energy and improve grid reliability, and they can improve energy and material efficiency and reduce emissions. In addition, digital services such as videoconferencing offer low-emission alternatives to travel, while also supporting a behavioral shift toward lower-emission options. [12]

As renewable energy sources gradually become the main source of energy and energy costs decrease, the main bottleneck in energy utilization is how to achieve overall coordination. Digital transformation is by interconnecting digital technologies with the periphery, and the energy internet platform can enable each of us to enjoy cleaner, greener, cheaper and better-quality electricity. [13] Digital technology can empower the development of renewable energy, improve green infrastructure with digital technology, promote the transformation of traditional industries, expand the scale of green investment and stimulate green financial vitality. Energy digital transformation for the transformation and upgrading of the traditional energy industry brings many opportunities: First, it helps the development of the digital economy, bringing new economic growth points for electric power enterprises; second, it promotes the modernization of the governance capacity of energy enterprises, using big data to boost the scientific and efficient decision-making of energy enterprises, optimize services and supervision, and provide customers with more high-quality and convenient energy public services.[14] Third, it provides a new breakthrough for improving the competitiveness of the energy industry. By adopting digital technology, productivity can be increased, costs can be reduced, revenues can be improved, and the competitiveness of the energy industry and enterprises can be enhanced.

3. Policy support and advantages of China's renewable energy digital governance

At present, the world is undergoing a new round of energy revolution and scientific and technological revolution, and the development of renewable energy has become a major strategic direction for global energy transformation and response to climate change. Accelerating the development of renewable energy and the implementation of renewable energy substitution action is a major initiative to promote the energy revolution and build a clean, low-carbon, safe and efficient energy system, an inevitable choice to ensure national energy security, an objective requirement for our country to further promote the construction of ecological civilization and achieve sustainable development, and an important force in building a community of life between human beings and nature, in building a community of destiny for mankind, and in coping with global climate change.[15] Power. To this end, China has issued a number of policies to promote the transformation of renewable energy and enhance the capacity of digital governance.

3.1. Policy support for renewable energy digital governance

China has amended the Renewable Energy Law of the People's Republic of China, which is committed to promoting the development and utilization of renewable energy, increasing energy supply, improving energy structure, ensuring energy security, protecting the environment, and realizing sustainable economic and social development.[16] At the same time, it provides a rule of law guarantee for the development and governance of China's renewable energy industry.

In terms of policy support, in March 2021, the State Council issued the Outline of the Fourteenth Five-Year Plan for the National Economic and Social Development of the People's Republic of China and the Vision 2035, which puts forward the goal of "accelerating digitalization and building a digital China", creating a new advantage in the digital economy, speeding up the pace of building a digital society, improving the level of digital government construction, and creating a good digital ecosystem. government, and create a favorable digital ecosystem.[17] In June 2022, the Guiding Opinions of the State Council on Strengthening the Construction of Digital Government clearly pointed out that strengthening the construction of digital government is an inevitable requirement for leading and driving the development of digital economy and the construction of digital society, creating a good digital ecosystem, and accelerating the development of digitization, and it is also an important initiative to form a new pattern of digital governance and promote the modernization of the national governance system and governance capacity.[18] In February 2023, the CPC Central Committee and the State Council issued the Overall Layout Plan for the Construction of Digital China, proposing to promote the in-depth integration of digital technology and the real economy, and to accelerate the application of digital technological innovation in key areas such as agriculture, industry, finance, education, healthcare, transportation and energy.[19] It will strengthen digitalization capacity building, and promote the interconnection of information system networks, data sharing on demand, and efficient business collaboration.

In terms of energy development, in March 2022, the National Development and Reform Commission (NDRC) released the "14th Five-Year Plan" for a modern energy system, proposing to vigorously develop non-fossil energy sources, enhance the modernization of the energy industry chain, and focus on accelerating the digital and intelligent upgrading of the energy industry.[20] After this, in June 2022, the National Development and Reform Commission issued the "14th Five-Year" Renewable Energy Development Plan, which made more specific arrangements for the development of renewable energy.[21] The National Energy Administration's Opinions on Accelerating the Development of Energy Digitization and Intelligent Development puts forward the important role of digital technology in energy development and the realization of the path, and the integration and development of the energy industry and digital technology is an important engine in the new era to promote the advanced development of China's energy industry foundation and the modernization of the industrial chain.[22] Subsequently, various local governments have introduced digital government construction rules and regulations one after another. In summary, China's laws and policies provide important institutional support for the digital governance of renewable energy, with certain institutional advantages.

3.2. The digital transformation of renewable energy is becoming increasingly mature

The government's energy digital management tools are constantly improving. In today's world, digitalization, networking and intelligence are developing deeply, playing an increasingly important role in promoting economic and social development, promoting the modernization of the national governance system and governance capacity, and meeting the people's growing needs for a better life.[23] As a result, China has made major strategic plans for building a strong network country, digital China and a smart society, emphasizing the need to cultivate new momentum with informatization, promote new development with new momentum, and create new glory with new development. However, digital transformation has become a new kinetic energy for economic growth, especially in the context of energy transformation and global epidemic prevention, enterprises use digital transformation as a new kinetic energy for growth to achieve a substantial increase in the economic efficiency of enterprises. [24] On the basis of the national development of

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digital technology, enterprises give full play to the role of the main market. Energy and power enterprises are market-oriented, the development and application of digital technology for energy and power enterprises and large-scale enterprises to play an important role in strategic transformation, management mode and other aspects.

At this stage, the "industrialization of digital technology" is still in the "concept" stage for the majority of real enterprises. The national digitalization strategy has given rise to new functional missions and digital transformation modes for enterprises. The process of digital change not only reflects resources, innovation, business ecology, business processes and management, and business models, but also involves adaptive changes in organizational structure, corporate culture and governance mechanisms. Therefore, a multi-dimensional and multi-level research perspective can be used to improve the theoretical model and governance path of enterprise digital strategic change in the future.[25] Achieving net-zero emissions is a major challenge, but digitization can ease the pressure for transformation. Moreover, as the world strives to decarbonize its energy systems, the world needs innovative approaches to designing and operating power systems. Without such innovation, growing electrification could lead to increased energy insecurity, unnecessary transmission and distribution losses, and missed opportunities for cost savings for energy consumers and producers.

Digital technologies can build more dynamic, efficient, reliable and sustainable renewable energy systems. For example, the power system of the future will provide electricity at the right time, in the right place, at the lowest cost and with the lowest emissions, in response to forecasted demand. Digital technologies can be applied to a wide range of distributed energy resources, such as energy efficiency, smart demand response, smart electric vehicle charging, building-level energy storage, and distributed solar photovoltaics, all of which are becoming increasingly important. The development and iteration of digital technologies facilitates the flexibility needed to integrate renewable energy generation, and the share of renewable energy in their energy mix is increasing.

3.3. Gradual growth in the share of renewable energy industry development

China released the Strategy for Energy Production and Consumption Revolution (2016-2030), announcing that the power generation from non-fossil energy sources (including nuclear energy and renewable energy sources) will account for about 50% share of the total power generation by 2030, and that the share of non-fossil energy sources in the total energy consumption will exceed 50% by 2030.[26] China's renewable energy to achieve leapfrog development, installed capacity, utilization level, technology and equipment, industrial competitiveness to a new level, has achieved world-renowned achievements for the high-quality development of renewable energy has laid a solid foundation. Specifically manifested as:

Firstly, the scale of development continues to expand. As of the end of 2020, China's renewable energy power generation installed capacity reached 934 million kilowatts, accounting for 42.5% of the total installed capacity of power generation, wind power, photovoltaic power generation, hydropower, biomass power generation installed capacity reached 2.8, 2.5, 34, 0.3 billion kilowatts, for many years ranked first in the world.[27] Secondly, the level of renewable energy utilization has been significantly improved. in 2020, China's total renewable energy utilization reached 680 million tons of standard coal, accounting for 13.6% of total primary energy consumption. Among them, renewable energy power generation capacity of 2.2 trillion kilowatt-hours, accounting for 29.1% of the total power generation capacity, the utilization rate of hydropower, wind power and photovoltaic power generation in major river basins will reach 97%, 97% and 98% respectively, and the non-electricity utilization of renewable energy will be about 50 million tons of standard coal. Thirdly, the technological level of renewable energy is constantly improving. Hydropower has the capability of independent design and manufacturing of megawatt-class hydraulic turbine units, and the design and construction of extra-high dams and large underground caverns are world-leading. Onshore low-wind wind power technology is world-class, and offshore large-capacity wind turbine technology maintains international standards. Photovoltaic technology is rapidly iterating, and has repeatedly set new world records for battery conversion efficiency, with the average conversion

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efficiency of mass-produced monocrystalline silicon and polycrystalline silicon batteries reaching 22.8% and 20.8% respectively. Fourth, the advantages of renewable energy industry continue to strengthen. Hydropower industry has obvious advantages, China has become the backbone of the global hydropower construction. Wind power industry chain is complete, seven wind power machine manufacturing enterprises ranked among the top ten in the world. Photovoltaic industry occupies a dominant position in the world, with polysilicon, silicon wafers, cells and modules accounting for 76%, 96%, 83% and 76% of the global output respectively. The integrated manufacturing of the whole industrial chain has vigorously promoted China's renewable energy equipment manufacturing costs continue to decline, and international competitiveness continues to increase. [28] Compared with the "13th Five-Year Plan" period, the main development goals of renewable energy in the "14th Five-Year Plan" reflect its growing trend (Table 1).

Table 1. Main goals for renewable energy development and utilization in 2025.

Type	Unit	2020	2025	Attribute
1. Renewable energy generation and utilization				
1.1 Renewable Energy Power Consumption Responsibility Weight	%	28.8	33	Expectancy
1.2 Non-hydroelectric Renewable Energy Power Consumption Responsibility Weight	%	11.4	18	Expectancy
1.3 Trillion Kilowatt Hours of Renewable Energy Generation	Trillion kilowatt hours	18	3.3	Expectancy
2. Renewable Energy Non-electrical Utilization	10000 tons		6000	Expectancy
3. Total Renewable Energy Utilization	100 million tons of standard coal	6.8	10	Expectancy

3.4. Digitalization is conducive to promoting renewable energy consumption

The level of digital access essentially reflects the connectivity of the information network between subjects in a region. Emerging information technologies such as big data, cloud computing, and 5G technology are integrated with renewable energy power generators. Each power generation body can establish connections through digital networks, breaking the "information barriers" between regions and power generation bodies, promoting intra-regional connectivity, free and efficient flow of information, and reducing coordination and communication costs. Energy flow and information flow with the help of digital technology to realize interactive integration, network, load, storage coordination and mutual aid, and continue to promote the energy revolution. [29]

First of all, the digital access level is conducive to the improvement of renewable energy industry. Since the "14th Five-Year Plan", the government has issued a series of policies to encourage enterprises to strengthen the construction of digital platforms. The digital platform reflects the degree of development of digitalization within the enterprise and the degree of importance attached to digital transformation, and demonstrates the enterprise's internal digital transformation capabilities.[30] On the one hand, the digital platform can deploy renewable energy production, transmission and consumption through data aggregation and analysis within the enterprise, promote the optimal allocation of renewable energy on a wider scale, and at the same time enhance the level of "observable, measurable, controllable and adjustable" for energy, solve the vulnerability of renewable energy access system, and improve the level of renewable energy consumption. The level of renewable energy consumption. On the other hand, the digital platform breaks the silo structure between enterprises, connects energy producers and users, facilitates the response to the user's personalized needs [31], and prompts the energy production from the previous supply side to the demand side of the transfer, and strengthens the consumption of renewable energy. [32]

In addition, the level of digital application has a positive impact on the development of renewable energy industry. The level of digital construction can reflect the degree of perfection of the infrastructure characteristic of the digital economy, which is based on information networks and integrates emerging digital technologies. [33] For a long time, the energy industry is highly

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dependent on large-scale production equipment, the development of digital technology will introduce intelligent infrastructure construction into the renewable energy industry, the establishment of a smart energy system, increase the proportion of renewable energy power generation, and realize the efficient transformation of the energy structure of decarbonization. The level of digital construction can, to a certain extent, reflect the level of development of the integration of digital resources and the real economy, and the level of reform of the market trading system of the energy industry as a whole. Through the deep integration of digital economic thinking, the renewable energy industry in the digital transformation of the marginal economic benefits brought about by the better. [34]

Implement the "dual carbon" strategy, promote the revolution of energy production and consumption, and establish a clean, low-carbon, safe and efficient energy system. China's energy will enter a new stage of power-centered development, showing the characteristics of energy power, energy integration, energy digitalization. Therefore, we need to be empowered by digital technology, play the role of production factors of data, promote the power prediction of source side and load side, promote the coordination and interaction of source, network, load and storage, and improve the capacity of renewable energy consumption. [35]

4. Constraints on the digital governance of renewable energy in China

Although China has been promoting the energy revolution, the carbon emission problem in China's energy sector is still very prominent, and digital technology faces many dilemmas in promoting renewable energy transformation and governance. For example, the contradiction between the scale development of renewable energy and efficient consumption and utilization is still prominent, the new digital power system urgently needs to accelerate the construction of the new digital power system, the development of non-electricity utilization of renewable energy is relatively lagging behind, and the institutional mechanism for guaranteeing the high-quality development of renewable energy needs to be further improved.

4.1. Renewable energy governance legal norms need to be improved

On the one hand, energy digital governance supporting relevant policies need to be improved, such as intelligent data collection, various types of energy facilities intelligent construction and transformation, there is no unified standard; energy data elements management regulations and norms are missing, data cleaning, rights, classification and hierarchical protection and commercial and other laws and regulations need to be formulated; natural gas intelligent scheduling, energy system governance and cross-industry response to the energy management norms need to be completed energy digital governance. Governance supporting related policies need to be improved, such as data intelligent collection, all types of energy facilities intelligent construction and transformation, there is no unified standard; energy data elements management regulations and norms are missing, data cleaning, rights, classification and grading protection and commercial regulations and systems need to be developed; natural gas intelligent scheduling, energy system governance and cross-industry response to energy management norms need to be completed. On the other hand, the sustainable development of renewable energy, inseparable from the guidance and promotion of the law, "dual-carbon" goal established, so that China's renewable energy is facing a new opportunity for development, the more need to crack the development bottleneck through the innovation of the legal system, and constantly enhance the development of renewable energy scale and level. In fact, each country's renewable energy development motivation and the external situation faced by different, China's renewable energy legal system innovation, should be China's renewable energy development of the real needs of the problem-oriented.

4.2. Insufficient digital governance system and governance capacity of renewable energy

Supply and demand sides, the production chain, the business sector of the energy scheduling requirements are different, the demand is diverse and volatile, to deal with energy emergencies, high

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complexity, low fault tolerance, to ensure that the energy system digital, intelligent operation of the technical level needs to be improved. Energy digital governance exists supporting facilities construction, management and operation costs are high, the transformation experience is insufficient, the value of the difficult to reflect the problems, restricting the development of intelligent energy, need related technological breakthroughs to safeguard economic benefits. The integration of digital technology into the renewable energy industry is insufficient, and technological innovation to promote the development of energy digital governance is limited. The continuous emergence of distributed energy, renewable energy, energy storage and other multifaceted technological innovations has provided technical support for the continuous improvement of energy production and energy supply technologies. Blockchain, artificial intelligence information technology and energy industry in-depth integration, supported by big data, cloud platforms, Internet of Things, intelligent control and other advanced technologies, the integration and application of emerging technologies in the field of energy, the trend of energy intelligence is becoming more and more obvious. Green finance to support the development of renewable energy still has a huge funding gap. [36]

The "double carbon" goal accelerates the promotion of energy decarbonization, intelligent construction. China's energy demand has maintained a high growth rate for a long time, and a variety of intelligent and interactive energy forms such as high proportion of renewable energy, energy storage and electric vehicles are rapidly emerging, which urgently requires the construction of energy digital governance system. China's renewable energy development strategy has put forward higher requirements for energy digital governance capacity. Eastern coastal cities and other energy infrastructure is relatively perfect, energy security supply and mutual aid and mutual protection ability is high, a new generation of information facilities to take the lead in the layout of the network, with energy integration and complementary, intelligent energy development integrated and coordinated development conditions. However, the digital governance capacity of renewable energy in central and western cities is relatively insufficient. There is a big difference between urban and rural renewable energy utilization and its governance, and the rural governance capacity and governance system lags far behind that of urban areas, so it is necessary to coordinate the development of urban and rural areas in the coordinated development of renewable energy digital governance.

4.3. Security concerns exist for renewable energy digital technologies

Digital technology security is an important part of the overall national security concept, and data has become an important productive force. National energy digital governance based on "big cloud, material, mobile intelligence chain" and other technical means, network information and data invasion and leakage risk increases. At present, the application of energy digital governance is mainly within a single market entity and dominated by a single energy variety, and it is difficult to avoid the security problem of data interaction between various entities and regions. In order to realize the energy application scenarios of trans-entity, trans-variety, and trans-region, it is necessary to solve the problem of the difficulty of coordinating the breakthrough of the energy supply pattern and the user's habit of using energy. The digital transformation of the energy industry under the "dual carbon" goal faces challenges such as carbon emission reduction synergy, energy security and data security, data silos, and business models. [37] Digital governance of renewable energy needs to consider the issue of technical security, and security is a prerequisite for development. Energy digital transformation faces the dual challenge of security issues from the digital economy itself superimposed on energy security issues. For one thing, after the energy industry is digitally interconnected, both the energy production side and the user side, once the data security is not effectively protected, its data privacy, especially sensitive data involving trade secrets, intellectual property rights, key business, etc., will face the potential risk of exposure in the network. For another, the energy industry is an important strategic industry of a country, energy security is an important element of national security, and the digital transformation of the energy industry also needs to consider the new challenges facing energy security. [38]

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5. Suggestions for improving China's renewable energy digital governance capacity

Renewable energy digital governance is an important element of China's energy revolution, China's renewable energy development is based on the reality of China's national conditions. First of all, it has become a general consensus of the international community to establish a "dual-carbon" target for addressing climate change. As a responsible big country, China has actively participated in it, which is the top-level design basis for the development of renewable energy in China. Secondly, after more than 40 years of rapid economic development, China is facing relatively severe pressure on environmental protection. The development of renewable energy is to grasp the implementation of "energy conservation and emission reduction", and enhance the ecological environment governance capacity is the realistic need for the development of renewable energy in China. [39]

5.1. Innovative renewable energy digital governance legal system

China's renewable energy legal system innovation should be problem-oriented. The sustainable development of renewable energy cannot be separated from the guidance and promotion of the law, the establishment of the "double carbon" goal, so that China's renewable energy is facing new opportunities for development, but also the need to crack the development bottleneck through the innovation of the legal system, and constantly improve the scale and level of development of renewable energy. In fact, each country's renewable energy development motivation and the external situation faced by different, China's renewable energy legal system innovation, should be China's renewable energy development of the real needs of the problem-oriented.

Above all, improve the renewable energy laws and regulations and policy system. In-depth promotion of renewable energy "management" reform, optimize the management mode, enhance the effectiveness of services, and continuously improve the effectiveness of renewable energy governance. Do a good job of revising the Electricity Law, Renewable Energy Law, Nuclear Power Management Regulations, Electricity Regulation Regulations, etc., and study and draft the Energy Regulation Regulations. Establish a sound energy data management system and strengthen data security governance. It will strengthen the research on new power systems, energy storage, hydrogen energy, pumped storage, CCUS and other standard systems, and accelerate the formulation and revision of standards related to the realization of "dual-carbon" energy.[40] Within the framework of China's current legal system of renewable energy, the institutional response to the development of renewable energy industry is not sufficient, at least the following three aspects of the problem need to be resolved: first, the positioning of the basic driving force for the development of renewable energy industry; second, the output of the renewable energy industry, the problem of the consumption; third, the development of renewable energy industry, the coordination of the position of environmental protection. The existence of the above problems, clear the basic orientation of China's renewable energy legal system innovation. [41]

Furthermore, there is a need to clarify the positioning of renewable energy legislation based on market mechanism. The development of renewable energy is to adhere to the government guidance or market-driven is renewable energy legislation needs to make choices on the basis of the problem. Renewable energy development of the ultimate goal of fossil energy substitution, from the industrial development point of view, this needs to renewable energy industry relative to the fossil energy industry to form a competitive advantage as a prerequisite for the competitive advantage fundamentally depends on the cost advantage. In China's "' 14th Five-Year' Renewable Energy Development Plan" is also clearly put forward, "14th Five-Year" period to vigorously promote the market-oriented development of renewable energy, to achieve "the development of subsidies to support the development of affordable low-cost development by the policy-driven development to market-driven development. policy-driven development to market-driven development". The "14th Five-Year Plan" is a five-year period of transformation, and energy development must seize the opportunity of the low-carbon revolution to promote and complete the market-oriented transformation. China's renewable energy development strategy and policy on the market-oriented development path of choice, determines the future of China's renewable energy legislation and institutional innovation of the basic positioning, purpose and value.

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Last but not least, optimize the institutional structure of renewable energy consumption. China's renewable energy resources development region is relatively concentrated, large-scale, far from the load center, the problem of consumption has been the bottleneck factor restricting the development of China's renewable energy industry, "abandoned wind and light" as a typical renewable energy power consumption problem has not yet been fundamentally resolved. Essentially, the consumption problem is rooted in the renewable energy development link and demand link in the technology-oriented disconnect. Therefore, the optimization of the legal system structure of renewable energy consumption needs to be done:

In the first place, to enhance the stability of energy conversion in the renewable energy development link, it should be promoted through the legal system of functional complementarity. Improve China's renewable energy legislation should increase the utilization of water energy and hydropower development of targeted system design, and increase the development of different types of renewable energy links for multi-energy complementary layout arrangements at the planning level for different types of renewable energy system synergies to lay the foundation.

In another, gradually promote the diversity of renewable energy supply mode, should be distributed energy system promotion system oriented. In view of the inherent decentralization of renewable energy sources, low energy density and other characteristics, distributed energy systems should be developed in accordance with the characteristics of renewable energy sources. It is necessary to establish a matching energy supply and utilization method to promote the diversification of renewable energy supply methods in order to expand the path of renewable energy consumption. Therefore, in the legislative level to improve the system of renewable energy consumption should be to promote distributed energy system as a key area, for distributed energy system development planning, the main types, technical specifications, price composition, incentives, and other issues to form a systematic legal arrangements, for the development of distributed energy system to provide a suitable legal system environment.

What's more, to provide a channel for the docking of renewable energy supply and demand links, the establishment of energy storage system should be the basis. At present, China's "renewable energy law" for the application and development of energy storage has not yet made the corresponding provisions of the future system should be improved at least from two aspects: first, the macro level for the application of energy storage and industrial development planning and coordination arrangements. China's future renewable energy legislation, should increase the layout of the development of the energy storage industry, application mode, system synergistic positioning, industrial incentives, such as special planning, for the continuous development of energy storage technology and industry to build the corresponding legal system environment. Secondly, the cultivation and guidance of the market environment for the development of energy storage industry. Energy storage industry in China is still in the early stages of development, although the development prospects are broad, but the market environment for industrial development is not mature, to be policy, especially the legal system of cultivation and guidance, China's renewable energy legislation should be synergized with the relevant legislation, in order to create a market environment conducive to the development of energy storage industry in the early stage, laying the foundation for the sustainable development of energy storage industry in China.

5.2. Advancing the Digital Transformation of China's Renewable Energy Industry

In recent years, the energy industry has seen rapid digitalization, leading to a shift in many traditional business models. Energy companies continue to look for new ways to operate and interact with customers. The government has taken measures to support the expansion of digital business models, accelerate energy restructuring, optimize resource allocation and spatial distribution, and help transform the energy use structure. Digital business models have great potential in the new energy economy, and digital business models can bring more benefits to consumers.

In the first instance, accelerate the intelligent construction and upgrading of energy infrastructure. Accelerate the construction of provincial energy management digital platforms, promote the integration of digital energy platforms with smart platforms such as city brains, and

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promote the high-quality development of energy digitalization. On the one hand, promote the construction of new coal-fired smart power plants and the intelligent transformation of stock of power plants. Accelerate the intelligent transformation of the national natural gas pipeline network platform, and basically build a national natural gas intelligent pipeline network data platform and intelligent scheduling platform. Accelerate the intelligent transformation of facilities such as stations, gate stations and urban natural gas regulating stations. On the other hand, it will make full use of new-generation information technology, promote the construction of intelligent service and supervision platform for charging infrastructure, create an intelligent charging network of vehicle-pile-grid-internet-multiple value-added services, build a charging data sharing center, and promote charging facilities and service networks with future communities and smart cities. service network and future community, smart city, smart transportation and other integrated development.

In the second place, accelerate the construction of institutions and mechanisms to support new modes and new businesses. Accelerate the introduction of standards and specifications in areas related to energy digital governance, and study and formulate a system of digitalized and intelligent standards and specifications for energy data sharing and opening, energy infrastructure construction and transformation, and oil and gas operation and scheduling. Pilot application scenarios such as energy consumption offset, carbon sink trading and green consumption, establish weighted assessment standards centered on ecological benefits and power quality, and explore market-oriented pricing mechanisms under government guidance. Improve the system rules for energy storage to participate in market-oriented trading. On the one hand, explore the profit mechanism of energy storage based on capacity value, energy value and auxiliary service value, and make it clear that new energy resources configured with energy storage can participate in peak frequency regulation. On the other hand, guide market players to optimize operation and trading strategies by configuring energy storage under real-time tariffs, peak-frequency regulation tariffs, and other quantitative and pricing environments, promote the formation of a market-based pricing mechanism for energy storage, and improve the sharing mechanism for auxiliary services.

In conclusion, digging deeper into the energy big data derived application scenarios, and building application scenarios coordinated between energy and social governance. To serve local social governance, build application scenarios for energy and environmental protection inspections, grassroots community governance, and housing vacancy rates. Develop an energy and environmental protection index and promote the experience of building "environmental protection + electricity" demonstration cities. Formulate energy community index, strengthen the end service perception ability, assist in digging out the weak points of social governance, and open up the "last kilometer" of energy grassroots governance services. Focusing on the future trend of smart energy governance, we will build a platform for the supply and demand of application scenarios, conduct in-depth excavation of energy data-derived scenarios, and establish a dynamic release system for model scenarios. Promote in-depth cooperation between energy enterprises and advantageous Internet enterprises, explore the establishment of "data mine 100+" application scenarios practice area, and help key projects and scenarios of new energy data industry come to fruition.

Accelerate the integration and application of digital, networked and intelligent technologies in the energy and power industry, and promote the integration of the energy revolution and the digital revolution can effectively support the "four revolutions, one cooperation" new energy security strategy in-depth implementation. It analyzes the important role of digitalization in the transformation and upgrading of energy and power from the aspects of digitalization promoting low-carbon development of energy and power, market transformation, industrial chain upgrading, modernization and supervision, and discusses in depth the application scenarios and key issues of digital technology in energy production, consumption, system and technology, etc., and provides references for the initiative of China's energy and power industry to integrate into the new round of scientific and technological and industrial revolutions as well as to accelerate the realization of digitalization and intelligent upgrading. Upgrade. [42]

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5.3. Provide development space for renewable energy digital governance with diversified models

Currently, digitalization is a data-centric ideological, theoretical, methodological and technological architecture system, the essence of which is to ask for productivity from data. For digital transformation, digitalization is the direction and trend, transformation is the path and means, and its essence is a change driven by software and services. [43] The comprehensive energy service model of multi-energy complementarity and optimization and integration is gradually promoted, carrying a variety of energy management platforms to provide integrated solutions for the development of intelligent energy applications. Comprehensive energy companies focusing on clean energy, new energy, and related industries, and comprehensive energy projects with smart integration by energy Internet have gradually formed a scale, vigorously promoting the innovation of energy development models and business models. Emphasis on data integration, technological innovation and talent cultivation in the digital transformation of energy will better enhance the competitiveness of China's export trade by improving the product structure, optimizing the business environment and supporting policy support. [44]

The renewable energy industry should take the initiative to meet the various challenges brought about by the digital economy. First of all, we should focus on the integration of the energy revolution and the digital revolution, the combination of national strategy and enterprise strategy, accelerate the development of digital strategy, lead the development of the industry with digital strategy, coordinate the deployment of digital transformation paths, innovate new modes of digital application, increase the deployment of cloud platforms and "cloud", continue to improve the level of application of big data, industrial Internet and Internet of Things, and build a new digital enterprise. We will continue to improve the application level of big data, industrial internet and internet of things, and build a new type of digitalized enterprise governance system. Secondly, we should take the digital revolution as an opportunity to lead the key core technology innovation, introduce and strengthen open innovation on the basis of strengthening original innovation, give full play to the innovation system with energy enterprises as the main body and the synergy of industry, academia, research and application, strengthen the core technology of software and hardware, and push forward the research and development of key network equipments and intelligent network equipment as well as the industrialization and application of such equipments. Again, strengthen the construction of digital talent team to change the situation of digital talent shortage. Industry associations can hold innovation competitions to promote the use of the competition; energy companies should establish incentive mechanisms for digital talents and strengthen exchanges with science and technology innovation enterprises to form a two-way mechanism for personnel training and empowerment, and provide talent support for industrial digitization and digital industrialization. [45]

Enhance the digital governance capacity of renewable energy through joint participation. The first major problem facing the digital transformation of the energy industry is the lack of basic capabilities, especially those needed to develop and deploy digital tools and applications. The energy industry involves many professions and many roles of industry participants, resulting in complex information systems, multiple data sources, high information barriers among industry participants, high requirements for industry security and stability, and high costs for product customization. As a result, higher requirements are placed on the development and integration capabilities of digital tools in the technology sector. [46] Thus, advancing digital transformation also requires an agile culture within the organization that promotes collaboration, knowledge sharing and the adoption of new ways of working.

5.4. Improve the security guarantee system for renewable energy digital technologies

Improve the data security guarantee system. As the new infrastructure further promotes the coherent integration of the digital and physical worlds, data security risks extend from the digital world to all application scenarios in the physical world. Electricity data involves corporate trade secrets and personal privacy. To this end, it is necessary to strengthen the bottom-line thinking of security, create a large security protection system covering network security, data security,

information security, critical infrastructure security, etc., enhance the ability of deep security defense, and build a three-dimensional security supervision network to protect corporate commercial secrets and customers' personal privacy, prevent leakage of sensitive data and personal information, and achieve zero intrusion at the network boundary.[47]

Strengthen network security awareness, security technology and protection, and comprehensively build energy data security management system. First, strengthen energy data security technology, such as encrypted transmission, access control, data desensitization and other security technologies to enhance network security and network resilience. The second is to formulate and improve energy industry data security related laws and regulations, build energy data security responsibility system, clarify the attribution of security responsibility and the main responsibility of enterprise security, as well as the responsibility of supervision and management at all levels of government; enhance practitioners' awareness of data security, and safeguard energy data and network security. Third, formulate data security standards for the energy industry, establish and improve the energy data elements grading and assessment system, focus on sorting out core data elements, implementing graded protection, and reducing network security maintenance costs. Fourth, strengthen the construction of energy data security early warning capabilities, energy companies in network security defense and data security need to take the initiative, improve situational awareness, testing and evaluation, early warning and disposal capabilities and levels, continuous testing and maintenance and upgrading of security defense systems; in addition, the establishment of a complete emergency response plan system, to achieve closed-loop management, and comprehensively safeguard data security.

Enhance digital governance capabilities and transform the advantages of digital transformation into governance effectiveness. First, establish a modern corporate governance concept based on digital governance. Through the use of modern information technology, it promotes information interoperability, efficient interaction and mutual assistance and trust among different management levels, and strengthens self-supervision and self-management at the grassroots level. We will continue to enrich the application scenarios of digital technology in corporate governance, and implant the concept of "speaking with data" into the minds of decision-makers and managers. Secondly, we focus on the openness and integration of key data resources to realize efficient collaboration through process reengineering. According to the unified data collection and exchange standards, the company promotes the sharing and opening of data resources, interdepartmental data standard docking and system interconnection, and realizes cross-departmental, cross-system, and cross-level efficient collaboration through process reengineering. Thirdly, we will continue to improve governance rules, create a benign digital governance ecosystem, strengthen the sharing of decision-making power, guide subjects at all levels of the enterprise to become part of the governance, and promote the compatibility of the goals of different subjects, as well as provide creative solutions to various types of decision-making problems.[48] Emphasizing the design of institutional frameworks, focusing on sustainable paradigm shifts in the green economy transition agenda, strengthening systemic leadership in digital technology, and improving data governance capabilities are all important initiatives to enhance the digital governance of renewable energy.[49]

6. Conclusion

This paper has systematically sorted out the necessity, status quo, dilemmas and improvement paths of renewable energy digital governance in China. From the above discussion, the following conclusions are drawn: digital transformation contributes to the efficient use of renewable energy, and improving digital governance can promote the realization of China's "dual-carbon" goal. China has introduced a series of relevant laws and policies to provide institutional support for the digital governance of renewable energy, and the digital governance of renewable energy in China has certain advantages. However, there are still many dilemmas and challenges in the digital governance of renewable energy, including the lack of legal norms for renewable energy, the lack of digital governance and governance capacity, and the imperfect security of digital technology, etc. Therefore, it is necessary to put forward a demand-oriented proposal for the digital governance of renewable

energy. Therefore, it is necessary to put forward demand-oriented digital solutions, innovate the legal system of renewable energy, promote the digital transformation of renewable energy, optimize the multiple modes of renewable energy governance and strengthen digital security.

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