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Historical Evolution, Stage Characteristics and Suggestions on China's Low-Carbon Energy Policies

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Abstract: Energy serves as a fundamental material foundation for economic and social development. The low-carbon energy transition is a critical measure for China to achieve the "Dual Carbon" goal, advance ecological civilization construction, and ensure energy security. Along with economic growth and energy structure adjustment, China's low-carbon energy policies have been gradually improved, forming a comprehensive policy system covering energy production, consumption, technology and institutional mechanisms. This paper sorts out the development course of China's low-carbon energy policies, dividing it into four stages: initial germination, preliminary development, rapid advancement and in-depth improvement. By summarizing the core characteristics of policies at each stage, analyzing existing problems in policy implementation, and combining the requirements for high-quality energy development in the new era, this paper puts forward targeted policy suggestions.

Keywords: Low-carbon Energy; Energy Policy; Dual Carbon Goals.

1. Introduction

(1)Research Background

Climate change has become one of the most pressing challenges facing the international community [1]. Reducing greenhouse gas emissions and promoting the low-carbon transition of energy systems have become a global consensus. As the world's largest developing country and a major energy producer and consumer, China has long been plagued by high carbon emissions, severe environmental pollution and rising external energy dependence due to its coal-dominated energy structure. To address global climate change and break resource and environmental constraints, a low-carbon development model targeting carbon neutrality has become China's strategic direction[2]. China has explicitly set the goals of peaking carbon dioxide emissions before 2030 and achieving carbon neutrality before 2060, integrating low-carbon energy development into the overall layout of the new national energy security strategy and ecological civilization construction.

Low-carbon energy policies provide essential institutional support for guiding energy structure transformation, regulating energy development and utilization, and boosting low-carbon technological innovation. Since the reform and opening-up, China has issued a series of laws and regulations, planning outlines, industrial policies and incentive measures based on its national conditions and global energy trends, steadily driving the energy system to shift from high-carbon to low-carbon and from extensive to efficient. Policies differ significantly in objectives, tools and priorities across development stages. A systematic review of the historical evolution, stage characteristics, existing problems and optimization paths of low-carbon energy policies carries important theoretical value and practical significance for perfecting the policy system, enhancing implementation effectiveness and steadily advancing energy transition.

(2)Research Significance

Theoretical Significance:Sorting out the historical evolution of China's low-carbon energy policies enriches theoretical research on energy policies and climate governance in China. Combined with stage characteristics and implementation effects, this paper constructs an analytical framework for low-carbon energy policies suitable for China's national conditions, providing a theoretical reference for subsequent academic studies.

Practical Significance:Developing low-carbon energy is an important approach for China to alleviate the contradiction between energy supply and demand and curb environmental pollution, as well as an inevitable choice to implement the Scientific Outlook on Development and accelerate new industrialization[3]. Accurately identifying shortcomings in current low-carbon energy policies and proposing targeted optimization paths helps improve policy synergy, pertinence and operability, thus promoting continuous optimization of energy structure and steady improvement of energy efficiency. Meanwhile, it supports China in achieving the Dual Carbon goals as scheduled, safeguarding national energy security and advancing the comprehensive green transition of economic and social development.

2. Core Concepts and Theoretical Basis

(1)Definition of Core Concepts

Definition of Core Concepts Low-Carbon Energy:Low-carbon energy refers to environmentally friendly energy forms with low greenhouse gas emission intensity and high energy efficiency in development, production and utilization. It mainly includes renewable and clean energy such as hydropower, wind power, solar energy, biomass energy, nuclear energy and geothermal energy, as well as low-carbon utilization of fossil energy including clean and efficient coal utilization and efficient oil and gas development. The core of low-carbon energy is to replace traditional high-carbon fossil energy, reduce the carbon emission intensity of the energy system, and realize the coordinated development of energy development and ecological environment protection.

Low-Carbon Energy Policy: Low-carbon energy policies are a set of policies formulated by the state to promote the low-carbon transition of energy systems, achieve carbon emission reduction targets and ensure sustainable energy

development, including laws and regulations, development plans, industrial policies, fiscal and taxation policies, technological policies and regulatory policies. By combining government guidance and market regulation, these policies optimize energy structure and improve energy efficiency to realize coordinated development of energy, economy and environment.

(2)Theoretical Basis

Sustainable Development Theory :Sustainable development theory emphasizes meeting present needs without compromising the ability of future generations to meet their own needs, pursuing coordinated development of economy, society and environment. Handling the relationship between human and nature, and between people is the support of sustainable development [4].

Energy Transition Theory:Energy transition refers to the process of replacing traditional fossil fuels such as coal, oil and natural gas with new energy sources and technologies at global, national or local levels, substantially reducing greenhouse gas emissions [5]. The theory points out that human society has undergone two major energy structure transitions from firewood to coal, and from coal to oil and gas, and is now moving toward the third transition dominated by renewable energy.

Externality Theory:Externality means an economic subject exerts an external impact on another, which cannot be traded through market prices [6]. Carbon emissions and environmental pollution in energy production and consumption generate negative externalities, while R&D of low-carbon energy technologies and renewable energy development produce positive externalities. Relying solely on market mechanisms fails to achieve optimal resource allocation. Low-carbon energy policies correct externality problems in the energy sector through fiscal subsidies, administrative regulations and market transactions, accelerating the growth of the low-carbon energy industry.

3. Historical Evolution of China's Low-Carbon Energy Policies

The evolution of China's low-carbon energy policies is deeply bound to economic development stages, energy strategy adjustment, ecological civilization construction and participation in global climate governance. According to policy objectives, core measures and priorities, it can be divided into four stages.

(1)Initial Exploration of Energy Conservation and Environmental Protection

In the early reform and opening-up period, rapid economic growth drove soaring energy demand. Large-scale development and utilization of fossil fuels such as coal led to energy shortages and environmental pollution. At this stage, China did not explicitly put forward the concept of "low-carbon energy", and policies focused on energy conservation and environmental pollution control.

In terms of energy conservation, China established the energy policy of "stressing both development and conservation, with conservation as the priority" in 1980, and issued policies such as the Interim Regulations on Energy Conservation Management, taking energy conservation as a key measure to ease energy shortages. For renewable energy, the government began to value the development of traditional clean energy such as hydropower and rural biomass energy, introducing supportive policies for small hydropower and promoting rural biogas projects to solve rural energy shortages. In environmental regulation, the Environmental Protection Law was formally enacted in 1989, imposing restrictions on pollutant emissions in energy development and integrating energy development with environmental protection.

Overall, low-carbon energy policies at this stage were fragmented and auxiliary, with the core goal of ensuring energy supply and mitigating industrial pollution. A systematic low-carbon development concept had not been formed; policies were weak in intensity and limited in coverage, and low-carbon energy development was in a spontaneous exploration stage.

(2) Large-Scale Startup of Renewable Energy and Promotion of Energy Conservation and Emission Reduction

After joining the WTO, China's economy entered a period of rapid growth, accompanied by fast expansion of heavy and chemical industries, sharp growth in total energy consumption and a high proportion of coal consumption. Carbon emissions and environmental pollution became increasingly prominent, and China formally participated in global climate governance, facing growing pressure for carbon emission reduction. At this stage, policies shifted to the large-scale development of renewable energy and systematic promotion of energy conservation and emission reduction, and the low-carbon energy policy system was initially established.

Legally, the Renewable Energy Law came into force in 2006, clarifying the strategic status of renewable energy and establishing systems such as full guaranteed purchase and fiscal subsidies, providing legal protection for the development of wind power, photovoltaic, biomass energy and other new energy sources. The Energy Conservation Law was revised to strengthen the binding mechanism of energy conservation. For energy conservation and emission reduction, the 11th Five-Year Plan set the mandatory target of reducing energy consumption per unit of GDP by about 20% for the first time, and implemented an assessment system for energy conservation and emission reduction responsibility. In renewable energy development, supportive policies and feed-in tariff subsidies for wind power and photovoltaic industries were issued, driving rapid growth in installed capacity. Internationally, China pledged at the 2009 Copenhagen Climate Conference to cut carbon dioxide emissions per unit of GDP by 40%-45% by 2020 from the 2005 level and raise the share of non-fossil fuels in primary energy consumption to about 15%, specifying low-carbon energy development goals.

At this stage, low-carbon energy policies evolved from fragmentation to systematization, with administrative regulation as the core tool. Driven by energy conservation, emission reduction and renewable energy support, low-carbon energy development entered an institutionalized and large-scale initial stage.

(3)Energy Structure Optimization and Proposal of the Dual Carbon Goals

Since the 18th National Congress of the Communist Party of China, China has incorporated ecological civilization construction into the Five-in-One overall layout [7], making energy transition the core task of ecological civilization construction. With accelerated global climate governance, China's low-carbon energy policies entered a stage of rapid advancement and comprehensive deepening, with a constantly improved policy system and significantly

accelerated energy structure optimization.

Strategically, the 12th and 13th Five-Year Plans continuously strengthened mandatory targets for energy consumption intensity and carbon emission intensity, and set goals for raising the share of non-fossil energy consumption. In 2014, General Secretary Xi Jinping proposed the new energy security strategy of "Four Revolutions and One Cooperation", pointing out the direction for low-carbon energy development [8]. In September 2020, China formally announced the goals of peaking carbon emissions before 2030 and achieving carbon neutrality before 2060, elevating low-carbon energy transition to a core national strategy. In policy tools, the model shifted from single administrative control to coordinated administration, market and fiscal measures: the national carbon emission trading market was piloted, using market mechanisms to promote carbon emission reduction. Feed-in tariff adjustment policies for photovoltaic and wind power were introduced, guiding the new energy industry to shift from policy subsidies to market-oriented development. Industrially, China ranked first globally in installed wind and photovoltaic capacity; renewable power costs dropped substantially; hydropower and nuclear power developed steadily; and new energy vehicles, energy storage and other industries rose rapidly.

At this stage, low-carbon energy policies featured clearer objectives and more diversified tools, covering the whole chain of energy production, consumption and technology. The low-carbon transition of energy accelerated significantly, laying a solid foundation for achieving the Dual Carbon goals.

(4) Systematic Layout Under the Guidance of the Dual Carbon Goals

After the proposal of the Dual Carbon goals, China's low-carbon energy policies entered a deepening stage with improved top-level design and cross-sector coordinated promotion. Centering on the "1+N" policy system for peaking carbon emissions and achieving carbon neutrality, a systematic, standardized and efficient low-carbon energy policy system has been built.

In top-level design, the Opinions on Fully, Accurately and Comprehensively Implementing the New Development Philosophy to Do a Good Job in Carbon Peaking and Carbon Neutrality and the Action Plan for Carbon Peaking Before 2030 were issued, clarifying the overall objectives and key tasks of low-carbon energy development. Carbon peaking implementation plans for energy, industry, transportation, construction and other sectors were formulated, forming a multi-sector coordinated policy pattern. For energy structure adjustment, large-scale wind and photovoltaic bases were vigorously developed to speed up renewable energy replacement. New coal-fired power projects were strictly controlled, and the "three-linkage transformations" of energy saving, carbon reduction, flexibility and heating supply for coal-fired power were promoted[9]. In institutional reform, energy system reform was deepened to remove institutional barriers restricting low-carbon energy development; the shift from dual control of energy consumption to dual control of carbon emissions was strengthened to improve policy accuracy [10]. In international cooperation, global green and low-carbon energy cooperation was deepened, green energy projects under the Belt and Road Initiative were promoted, and active participation in global climate and energy governance was enhanced.

At present, China's low-carbon energy policies have been systematically upgraded around the Dual Carbon goals, paying more attention to advancing in an orderly manner and coordinated promotion, balancing energy security, economic development and low-carbon transition. The policy system is more mature and the implementation path is clearer.

4. Stage Characteristics of China's Low-Carbon Energy Policies

(1)Initial Germination Stage: Fragmented Policies Centered on Energy Supply Guarantee

Policy objectives were single, aiming to alleviate energy shortages in the early reform and opening-up period and conduct end-of-pipe treatment of industrial pollution, without forming low-carbon or carbon emission reduction concepts. Low-carbon energy only served as a supplement to energy supply. Policies were dominated by interim regulations and departmental rules, lacking special and systematic laws and regulations, with limited coverage focusing on specific fields such as energy conservation and rural clean energy. Policy tools were mainly administrative instructions and planning guidance, without fiscal, market or other incentives. Low-carbon energy development relied primarily on preliminary government guidance, with a complete absence of market-oriented mechanisms. Low-carbon energy was dominated by traditional clean energy such as hydropower and rural biogas; new energy such as wind power and photovoltaic was in technological exploration, playing an auxiliary and supplementary role in the energy system.

(2)Preliminary Development Stage: Systematic Policies With Administrative Control as the Main Tool

Policy objectives became clear, with quantified indicators such as energy consumption intensity and renewable energy share defined around national energy conservation, emission reduction and international carbon reduction commitments. Low-carbon energy development goals shifted from ambiguity to clarity. Centered on the Renewable Energy Law and the Energy Conservation Law, supported by industrial plans and fiscal subsidy policies, a preliminary legal-plus-policy system was formed, covering renewable energy, energy-saving renovation and other fields.

(3) Rapid Advancement Stage: Diversified Policies Balancing Transition and Energy Security

The single administrative control model was broken, and a diversified policy tool mix was formed with administrative regulations, fiscal subsidies, market pilots and technical support, with market mechanisms gradually functioning. Policy priorities shifted from simple energy conservation to energy structure adjustment, vigorously developing renewable energy and promoting clean utilization of fossil energy, leading to a continuous decline in the share of coal consumption. R&D investment in cutting-edge technologies and core equipment for low-carbon energy was increased, promoting technological breakthroughs, cost reduction and core competitiveness of the new energy industry.

(4) In-Depth Improvement Stage: Systematic Policies Led by the Dual Carbon Goals

Centering on the "1+N" policy system for carbon peaking and carbon neutrality, a cross-department, cross-sector and cross-regional coordinated policy system was established, with significantly improved policy pertinence and systematization. Market mechanisms played a leading role: the national carbon market, green power and green certificate trading were fully promoted; direct subsidies for new energy were gradually reduced to drive market-oriented and

sustainable development of the low-carbon energy industry. Adhering to the principle of "building before abolishing", China vigorously developed low-carbon energy while ensuring stable energy supply, promoting the optimal combination of traditional and new energy, and balancing low-carbon transition and energy security. Policies covered the whole chain of energy production, transmission, consumption, storage and technology, coordinating power system reform, industrial transformation and consumption upgrading to promote an all-round low-carbon transition of the energy system. Based on domestic energy transition practices, China actively integrated into global climate governance, promoted international cooperation in low-carbon energy technologies, industries and standards, demonstrating its responsibility as a major country.

5. Existing Problems in the Implementation of China's Low-Carbon Energy Policies

(1)Insufficient Policy Coordination and Poor Linkage Between Sectors and Regions

Lack of coordination among scattered policies and supporting systems has seriously weakened the legal effect of energy policies [11]. Economically and technologically advanced eastern regions enjoy strong policy support and effective implementation of low-carbon energy development. Central and western regions are rich in resources but lack supporting policies and technical foundations, facing prominent problems of renewable energy accommodation and outward transmission, leading to a wide regional gap in low-carbon energy development. Policies for new energy power generation, energy storage, transmission and power consumption are poorly linked; the construction of new power systems lags behind new energy development, and problems of new energy accommodation and grid connection have not been fully solved.

(2) Imperfect Market Mechanisms and Low Marketization of Policies

The national carbon market covers limited industries with low trading activity and low carbon prices, failing to fully exert its incentive and restrictive effects on carbon emission reduction. Carbon trading, green certificate and green power trading mechanisms are poorly connected, suffering from double counting and market segmentation. In terms of market pricing, government pricing and administrative intervention still exist in some low-carbon energy fields, and the renewable energy power pricing mechanism cannot fully reflect market supply and demand. The environmental cost of fossil fuels has not been fully internalized, and incentives for low-carbon transformation of high-carbon energy are insufficient.

(3)Weak Technological Innovation Support and Shortcomings in Core Technologies

China's insufficient R&D accumulation and high barriers in low-carbon energy technologies result in slow transformation of investment into productivity and even limited effects [12]. Part of core components and high-end materials in wind power, photovoltaic, energy storage and other fields rely on imports; R&D of cutting-edge technologies such as CCUS, hydrogen storage and transportation, and advanced nuclear power lags behind developed countries. Technological R&D in universities and research institutes is disconnected from enterprise practical needs and industrial applications, leading to a low transformation rate of low-carbon technological achievements. The technological innovation incentive mechanism is imperfect, weakening enterprises' endogenous motivation for innovation. It is difficult to promote mature low-carbon technologies in small and medium-sized enterprises and traditional high-energy-consuming industries due to insufficient technological renovation funds and inadequate policy guidance, limiting the popularization of low-carbon technologies.

(4)Lack of a Linkage Mechanism Between Traditional and Low-Carbon Energy

China's coal-dominated energy structure is difficult to change in the short term. Some policies promote low-carbon transition in a "one-size-fits-all" manner while ignoring the supporting role of traditional energy, leading to poor connection between coal power withdrawal and new energy replacement, and causing energy supply fluctuations in some regions.

6. Research Suggestions

(1)Improve the Policy Coordination System and Strengthen Support

First, establish a national-level coordination agency for low-carbon energy policies to unify policy standards, coordinate implementation and resolve inter-departmental conflicts, realizing deep integration of energy, environmental protection, industrial and technological policies and avoiding policy fragmentation. Second, formulate differentiated policies according to resource endowments and economic levels of eastern, central and western regions: strengthen support for renewable energy outward transmission channels and accommodation facilities in central and western regions, and encourage technology and capital transfer from eastern to central and western regions to promote coordinated regional development of low-carbon energy. Third, for mature energy projects such as hydropower and solar photovoltaic, focus on building demonstration projects while exploring more efficient development technologies[13]. Fourth, set up special support funds to promote low-carbon energy development, and improve the management system of these funds to institutionalize and standardize fund utilization, management and performance assessment[14].

(2) Improve Market-Oriented Mechanisms and Stimulate Market Players' Vitality

First, gradually expand the industry coverage of the national carbon market, improve carbon emission accounting and quota allocation mechanisms, enhance trading activity, promote the connection between the carbon market and green certificate and green power trading, and establish a unified low-carbon energy market trading system to give full play to the market's incentive role in carbon emission reduction. Second, The essence of enhancing the market competitiveness of low-carbon energy lies in achieving price equilibrium between high-carbon and low-carbon energy sources[15]. deepen energy price reform, promote market-oriented formation of renewable energy power prices, gradually cancel unreasonable administrative intervention, incorporate the environmental cost of fossil fuels into the pricing system, raise the cost of high-carbon energy use and force energy structure transformation. Third, improve green financial policies, introduce special policies for green credit, green bonds and green funds, and encourage financial institutions to increase financial support for low-carbon

energy projects [16].

(3)Strengthen Technological Innovation Drive and Make Up for Shortcomings in Core Technologies

Launch national-level R&D programs for low-carbon energy technologies, focusing on core technologies such as energy storage, CCUS, hydrogen energy, advanced nuclear power and high-end new energy equipment to break foreign monopolies. Build an industry-university-research-application integrated innovation system to deepen integration between technological R&D and industrial application. Meanwhile, increase tax reductions and R&D subsidies for enterprises' low-carbon technology innovation, encourage enterprises to raise innovation input, establish platforms for low-carbon technology achievement transformation, improve transformation efficiency and promote large-scale application of mature technologies.

(4) Optimize Industrial Structure and Ensure Transition Security

Developing low-carbon energy requires industrial restructuring and low-carbon policies for agriculture, industry and service sectors [17]. Improve the linkage policy between traditional and low-carbon energy, and gradually optimize fossil energy production capacity on the basis of safe and reliable replacement by new energy to boost industrial development and integrate upstream and downstream resources [18]. Furthermore, introduce special support policies for low-carbon transformation of traditional energy enterprises, encourage them to develop new energy, energy storage, CCUS and other industries, promote integrated development of traditional and low-carbon energy and realize a smooth transition.

7. Conclusion

Based on the analysis of the development stages and characteristics of low-carbon energy policies, this paper summarizes existing problems and puts forward corresponding suggestions.

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