Evolution of the Energy Mix Transition

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Countries have started to aggressively undertake energy structure transformation strategies in order to reach the objective of carbon neutrality. Both clean and efficient coal energy use and clean energy use will be crucial to the process of changing the energy structure since the two cannot be totally replaced within a short period of time.Therefore, it is worth exploring how the two have an impact on the energy mix transition in the energy transition process. It is also important to see how carbon sentiment affects the various actors involved in the decision-making process.

carbon neutrality energy structure transition low-carbon sentiment

1. Introduction

More fossil fuels are being used as science and technology improve, which is a factor in the rising number of environmental problems. Achieving carbon neutrality has been suggested as a solution to the issue of industrial emissions caused by the use of fossil fuels [1]. These emissions have led to issues like the greenhouse effect. By 2050, it is expected that hundreds of countries will be carbon neutral [2] and a number of them have already incorporated carbon neutrality targets into their legal systems. Many nations have begun the shift from fossil fuels to alternative energy sources. Supporting the transition of the changing shape with the advancement of clean fossil fuels and new fuel technologies is critical. As China's economy expands and its CO_2 emissions increase, so does its standard of living, which drives up energy consumption [3]. According to data, China utilized primary energy equal to 3512.8 million tons of oil in 2020, making up 26.1% of the entire amount of energy consumed worldwide [4]. To accomplish carbon neutrality goals and to handle the numerous socio-economic and environmental concerns involved, regional energy transition strategies have been created to achieve low-carbon and sustainable development. The phrase "energy transition" has been referred to in a variety of ways by academics, including "sustainable energy transition" [3], "low carbon energy transition" [4], and "green energy transition" [5]. As a result, reducing greenhouse gas emissions is essential to reducing global warming, its impacts, and the ensuing socioeconomic and environmental issues. Alternative energy sources have been suggested, including examples include the construction of numerous hydroelectric power plants in the Iberian Peninsula and the continued improvement of wind energy generation in Xinjiang [6][7], the gradual advancement of solar energy storage [8], alternative technologies using materials, such as graphene as batteries [9], microbial fuel cell technology [10], and nuclear fission power systems [11][12], all of which have gradually matured, leading to an increase in the share of clean energy in all electricity. As China's economy expands and its CO_2 emissions increase, so does its standard of living, which drives up energy consumption [13]. According to data, China utilized primary energy equal to 3512.8

million tons of oil in 2020, making up 26.1% of the entire amount of energy consumed worldwide [14], it is anticipated that the carbon neutrality goal would be attained by 2060.

China is the country under the most pressure to reduce its emissions and use of energy. Despite fluctuations in economic growth due to the COVID-19 epidemic, China's electricity and energy consumption were still increasing significantly in 2020 [15]. As the main source of energy for power generation, half of fossil energy consumption comes from coal, but the share of clean energy generation has grown significantly [16]. In 2020, 64.7% of China's total power generation came from coal-fired power generation, with hydro-power generation ranking second and accounting for only 16.9% [14]. The country's level of urbanization is still rising, and the industrial structure's impact on the environment, which depends heavily on the combustion of fossil fuels in all areas, is becoming progressively worse [17]. In recent years, smart mines have also been developed with government regulation, emergency response capabilities, and clean coal technologies [18][19][20], which can operate in low-carbon and in a clean manner while achieving energy conservation [21]. Although green energy sources, such as wind, tidal, and biomass fuels, have relatively little environmental impact, they have the drawback of being unstable and intermittent in their supply [7], which raises the possibility of energy security risk events and jeopardizes the security of the energy supply. This indicates that the use of fossil energy, represented by coal resources, currently dominates the whole energy cycle and is unlikely to alter very soon [22]. Due to technology and other circumstances, the development of new energy applications and development in China is uneven. For example, the development of solar energy, hydrogen energy, and other clean energy sources is still at a very early stage. Due to this, clean energy and coal have been in a constant state of competition, with the latter unable to fully replace the former for an extended length of time. However, clean energy research and utilization have allowed for the safe and effective use of coal. Therefore, coordinating the development of both coal energy and clean energy within the framework of carbon neutrality is a key part of the energy structure change that needs to be dealt with.

2. Progress of Energy Structure Transformation Research

Analysis of energy strategy games has begun. In order to capture the drivers of the energy transition and in order to simulate and discuss the evolutionary process and evolutionary stabilization strategies to support the development of hydrogen-powered vehicles and solar photovoltaic hydrogen production, Wang et al. [23] analyzed a partnership consisting of an investment company, hydrogen-powered vehicle users, and solar photovoltaic power plants. To replicate and explain the evolutionary process, Wang et al. [24] proposed a partnership of carbon exchange, solar power plants, and coal-fired thermal power plants. Hou et al. [25] proposed a new conceptual model, the institutional economic-technical behavioral framework, to synthesize the similarities and differences in energy transitions in various nations. The German energy transition plan is significant as a framework for fostering the growth of renewable energy, as per Gao et al. [26] 's comprehensive analysis of several strategies for boosting renewable energy during the energy transition. In order to investigate whether the relationship between the government and the public can encourage manufacturers to adopt low-carbon technologies by examining the interaction effects between various stakeholders, Chen et al. [27] developed a three-way game model between the government, manufacturers, and the public under carbon taxes and subsidies. In order to study how financial penalties impact players' tactics and the evolutionary process of optimizing financial penalties, Chang et al. [28] developed a mixed strategy game model and an evolutionary game model for regulators and conventional energy corporations. The application of game theory has been well proven in the study of energy transition, and the theory of evolutionary games can explain how different strategic decisions may have an influence on the entire energy transition system.

3. Application of Evolutionary Games in Energy Structure Transformation

Evolutionary game theory offers a reasonable analytical framework, given that energy structural transformation is a gradual and ongoing process rather than a sudden change that occurs only once. Many academics have conducted pertinent studies on energy transitions using this evolutionary game framework. In a three-way evolutionary game model that included regulators, energy companies, and whistleblowers, Yang et al. [29] discovered a substantial association between the likelihood of a whistleblower, the likelihood of active management by energy companies, and the likelihood of rigorous monitoring. Zhao et al. [30] analyzed the behavioral strategies of generators in connection to renewable energy and the influence of important institutional characteristics on the dynamic evolutionary process of generators. According to Qiao and Yin [31], who used an evolutionary game model based on psychological perceptions, strategic choices made by consumers and companies are essential to the effective implementation of the energy transition. In order to study two different types of power generation enterprises, Liu et al. [32] used an evolutionary game approach and a numerical simulation method of scenario analysis to study two different types of power generation enterprises. In order to deal with the complex relationship between the Chinese government, thermal power producers, and grid companies, Shang et al. [33] used a system dynamic (SD)-based evolutionary game. They came to the conclusion that the Chinese government must strictly enforce the renewable portfolio standard in order to promote green and low-carbon upgrading of energy and electricity (RPS). By examining the many actions each decision-maker in the process takes, these studies have concentrated on how the entire decision-making system changes to support the transition in the energy mix. However, are decision-making processes in government agencies and energy users entirely rational? It is unknown if additional factors have any role in their decision-making.

4. Progress in Emotion-Rrelated Research

Nevertheless, research has shown that psychological preferences and feelings have an effect on decision-makers' inclinations and decisions, both in terms of long-term direction and contingency influences [34][35]. As an example, negative emotional states can have a direct impact on risk-taking behavior and decision-making [36]. Since decision-makers are limited in their rationality, in their behavioral choices, and have limited access to information, which can reveal different preferences and subsequently different emotions, emotions play a significant role in decision-making [37]. Decision-makers have varied psychological preferences and risk attitudes as a result of their differing values, interests, and contingent emotions [38]. Both government regulators and energy users experience emotions as a result, and these feelings can further affect their choices. The emotional attitudes of the participants in the energy structure transition towards the transition will have a significant impact on policy practices. However, the traditional evolutionary game does not take into account the psychological preferences and emotions of each player, so further improvement and refinement are required. The rank-dependent expected utility (RDEU) theory and evolutionary games have been merged. To create a co-evolutionary game model of shared manufacturing quality innovation with multi-subject involvement and examine how emotions impact quality improvement motivation, Zhang et al. [39] merged the RDEU theory with evolutionary game theory. To create an RDEU game model for various sectors, Ni et al. [40] merged game theory with the RDEU theory. They came to the conclusion that different emotional states and intensities impact evolutionary outcomes and evolutionary speed. Emotions are less often taken into account as an influencing element in research pertaining to the evolution of energy transitions, however. As a result, this research takes the impact of each game subject's low-carbon sentiment into account and builds an evolutionary game model that takes carbon sentiment into account using the RDEU theory. The mutual synergistic development of coal energy and clean energy is translated into the question of the impact of the share of coal and clean energy in the energy structure transformation on the energy structure transformation based on the issue of the share of coal and clean energy in the integrated energy consumption. Government regulators and energy consumers won't always act rationally in the face of energy structural transformation. In order to promote the efficient use of coal energy, the quick development of clean energy, and new advancements in energy structural transformation, the researchers must first understand the effects that various emotions will have on people's decision-making and behavior, as well as on energy structural transformation.

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