“Dual Carbon” Target of Energy Structure Optimization

Subjects: Green & Sustainable Science & Technology
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Exploring the path of energy structure optimization to reduce carbon emissions and achieve a carbon peak has important policy implications for achieving the “Dual Carbon” target.

Keywords: energy structure optimization ; “dual carbon” target ; optimal path

1. Introduction

In 2020, at the 75th UN General Assembly General Debate, China announced its “Dual Carbon” target, specifically to realize carbon peaking by 2030 and carbon neutrality by 2060. Inspired by the “Dual Carbon” target, countries around the world have proposed successively specific requirements and timelines for achieving carbon neutrality, which is regarded as the first-step and crucial solution to address increasingly serious issues from climate change, environment degradation and resource depletion.

The global climate and environment have been suffering negative changes. For about 200 years, human activities have increased carbon emissions rapidly. The record, which remained for nearly 2.5 million years with a carbon dioxide concentration of 280 ppm (parts per million), was broken by a level of 400 ppm in 2015. Research from the World Bank shows that the average annual growth rate of carbon dioxide concentration reached 0.2 ppm at the end of the 1950s. Then, the value raises to 2.2 ppm from 2005 to 2019. Unfortunately, this rapid growth may continue, and the carbon dioxide concentration could reach more than twice as high as the current situation if no measures are adopted. Affected by the rapid growth of carbon emissions, global surface temperatures show a fluctuating upward trend. Data from the Goddard Institute for Space Studies of the National Aeronautics and Space Administration (NASA) point out that average annual surface temperatures rise unstably, and this phenomenon becomes worse and more obvious over time. The average surface temperature added 1.2 ± 0.1 °C in 2020 compared with 1980.

The World Meteorological Organization (WMO) reports that not only did the quantity and concentration of greenhouse gas achieve a new all-time high in 2020, but also 2020 became one of the three warmest years on record. A “Dual Carbon” target is necessary to solve this dilemma. After decades of continuous follow-up and systematic evaluation, the Intergovernmental Panel on Climate Change (IPCC) finds that human activities represented by the large-scale exploitation of fossil fuels are the main reason leading to global warming. A wealth of data further supports this view. Fossil fuels such as oil, natural gas and coal are the most crucial energy consumption products current human activities rely on, and they are also the main contributors of greenhouse gas (such as carbon dioxide and PM2.5) emissions. The Statistical Review of World Energy 2021 reports that the situation is still not optimistic (fossil fuels account for 84.3% of primary energy consumption and carbon emissions because of fossil fuels burning account for 74.67%) except only negative growth caused by COVID-19 in 2020. Therefore, optimizing energy structures seems like a priority in achieving carbon neutrality.

The questions above are worse if turning perspective from worldwide to China. As the world’s largest carbon emitter, China has been suffering serious carbon emissions related to fossil fuel consumption. Also shown in the Statistical Review of World Energy 2021, the growth rate of primary energy consumption in China is not only faster than the worldwide average but also remained positive in 2020 (2.41%) compared with global −4.28%. Not affected by strong shocks from COVID-19, China’s total primary energy consumption accounted for a percentage of global consumption that changed from 20.64% in 2010 to 36.13% in 2020. Under huge regulatory pressure on energy consumption, China’s carbon emissions related to energy account for 30.66% of the world’s total. This is contrary to China’s current development approach. China’s economy is experiencing a transitionary stage from high-speed to high-quality, and promoting the “Dual Carbon” target by optimizing the energy consumption structure strives from three requirements: firstly, strategic needs of national energy security. In 2020, the external dependencies on oil and natural gas of China were 73.5% and 41.3%, respectively, and the structural contradiction between the supply and demand of energy was prominent; Secondly, the environmental carrying capacity of energy resources is facing harm. The limited per capita share of energy resources and relatively fragile ecological environment prove a long-standing, simple and crude development approach that is no longer sustainable; Thirdly, the public has a pressing need. Realizing the "Dual Carbon" target would help address problems such as recent extreme and severe weather and lift the quality of social life. Overall, the "Dual Carbon" target is an essential initiative to solve climate change and accelerate high-quality economic growth in China, and the first priority is to adjust China's energy consumption structure.

Realizing the "Dual Carbon" target is China's focus in future work, the government launched the "1 + N" policy system for the "Dual Carbon" target. The aims of "1" in the "1 + N" policy system, which are respectively known as Opinions on the Complete and Accurate Implementation of the New Development Concept to Realize Carbon Peaking and Carbon Neutrality on 24 October 2021, and Carbon Peaking Action Program by 2030 on 26 October 2021, are that: by 2025, the proportion of non-fossil energy consumption will reach around 20%, energy consumption per unit of GDP will fall by 13.5% compared to 2020, and CO_2 emissions per unit of GDP will fall by 18% compared to 2020; by 2030, the proportion of non-fossil energy consumption will reach around 25%, and CO_2 emissions per unit of GDP will fall by more than 65% compared to 2005, so as to successfully achieve the carbon peak target by 2030. It's not difficult to find that the "Dual Carbon" target is closely associated with energy structure optimization in general planning. Specially studying "N" in "1 + N" policy system, energy structure optimization is repeatedly mentioned: in two, 2021, Guidance on Accelerating the Establishment of Sound Economic System for Green, Low-carbon and Circular Development points out that "…energy resources need to be allocated more rationally and utilized more efficiently, total emissions of major pollutants should continue to be reduced, and carbon emissions intensity aims to be significantly reduced…"; in three, 2021, the 14th 5 Year Plan aimed to strictly control the growth of coal consumption and gradually reduce it during the 15th 5 Year Plan; what is more, "…in 2030, the installed capacity of wind power and solar photovoltaic power generation should reach 1.2 billion kilowatts, build a new power system with new energy as the mainstay, promote industrial electric transportation and improve energy use efficiency…"; on 28 October 2021, China updated its National Determined Contributions (NDCs) before Glasgow Climate Pact on 2 November 2021, and in 11 November 2022, China announced Progress on the Implementation of China's Nationally Determined Contributions (2022), and the measures of carbon reduction also mainly concentrate on energy structure, for example, "…under the requirements of achieving 'Dual Carbon' target, the development and utilization of low-carbon renewable energy industries need to be vigorously developed in order to increase non-fossil energy consumption and promote the sustainable development of the energy industry, and a revolution in energy production and consumption must be promoted…", and "…in order to reduce the level of carbon dioxide emissions, it's necessary to reduce greenhouse gases in human production activities, such as burning less coal or improving the efficiency of coal use, and using more green energy, such as solar, wind, water and nuclear energy…".

To achieve the "Dual Carbon" target, the energy structure urgently needs optimization, which leads us to wonder what is the optimal path to achieve the "Dual Carbon" target from the perspective of optimizing the energy consumption structure. Based on the doubt above, a research framework is established as follows: firstly, this research aims to narrow the research scope for better accuracy. As announced by The State Council of China, the "Dual Carbon" target is divided into two sections: one is to achieve carbon peaking by 2030, and then is to reach carbon neutrality by 2060. Carbon peaking is the basis and prerequisite of carbon neutrality. Therefore, details that are currently available will focus on improving the accuracy for forecasting situation changes from 2024 to 2035, i.e., exploring whether or how carbon peaking can be achieved under existing policies; Secondly, based on the scenario settings of high-speed, middle-speed and low-speed economic growth, a combination of the GM (1,1) Model and the Multiple Linear Regression Model is used to forecast the proportion of secondary industries, the total of the resident population, social fixed-asset investment, and most importantly, the total emissions of carbon dioxide and total consumption of primary energy from 2024 to 2035. Thirdly, for scenarios of nature evolution and lowest carbon emissions, a combination of the Markov Chain Model and Multi-Objective-Programming Model is used to forecast energy consumption structure and resulting carbon emissions from 2024 to 2035 under different scenarios. Finally, the Multiple Attribute Decision-Making Model is used to analyze the feasibility of the "Dual Carbon" target and the optimal path to achieve carbon peaking considering different decision-preference.

2. "Dual Carbon" Target of Energy Structure Optimization

With the gradual completion of industrialization, as a world power responsible for carbon emission reduction, China's carbon emission reduction pressure is increasing day by day, and the problems of inefficient energy use and low investment efficiency in China's secondary industry are gradually coming to the fore [1][2][3]. At present, few previous studies have been conducted in the primary industry, and most of them focus on the decomposition of carbon emission factors and carbon emission estimation, while relatively few previous research have been conducted on the peak path and peak value [4][5][6][7]. Among the tertiary industries, transportation is the main source of carbon emissions [8]. Improving the efficiency of fossil energy use, developing clean energy and improving transportation efficiency can effectively reduce carbon emissions from the transportation industry, thus effectively shortening the time to peak [9][10][11]. Most of China's regional carbon emissions show a significant growth momentum, and provinces such as Shandong, Shanxi and Hebei have a large volume of carbon emissions and a fast-growth trend of carbon emissions [12][13][14][15]. There are obvious regional characteristics that carbon emissions in China are higher in developed eastern provinces than in western provinces and higher in northern industrial provinces than in southern provinces [16][17][18][19]. Previous regional research focused on the more economically developed provinces (regions and cities) such as Beijing, Shanghai and Jiangsu and constructed regional carbon peaking models from factors such as population size, energy structure, investment efficiency and technological innovation [20][21][22][23][24]. The national peak carbon target is not a simple summation of the peak carbon target of each province (region and city) [25][26][27][28] but a reasonable prediction of the national peak carbon time and peak value [29][30][31] and on this basis, the total energy consumption and carbon growth constraint target should be proposed, and the total carbon emission and intensity characteristics of different provinces (regions and cities) should be considered according to local conditions, and the coordinated and integrated development of the whole country should be adhered to [6][9][10][25][28][31][32][33][34][35].

Specifically, previous research related to carbon peaking can be divided into four categories: (1) research industry features. Among the primary industries, China's total carbon emissions from agriculture are on an obvious upward trend [36][37]. Leaving policy guidance, it is difficult for agriculture to achieve the spontaneous transformation of decreasing carbon emissions [35][38]. Policy guidance is needed to further increase the share of renewable energy in its total energy consumption, reduce the total fossil energy consumption and optimize the energy structure to achieve better and faster carbon peaking in the primary industry [20][39][40]. The secondary industry is the main source of carbon emissions in China, and industry and construction occupy a major position in it [41][42]. Research shows that industry and construction can achieve the carbon peak target as scheduled, but the implementation of green policies will lead to longer-term economic losses in related industries [43][44][45]. The cost increase caused by green production and the output loss caused by restricted production are inevitable, and decoupling economic growth from carbon emissions and achieving a win-win situation between green production and economic growth are urgent issues to be solved [2][46][47]. Carbon emissions from transportation are the main source of carbon emissions in the tertiary sector, and the high proportion of fossil energy consumption and large greenhouse gas emissions are long-standing problems in the transportation industry [17][24][48]. Reasonable control of carbon emissions from the transportation industry will strongly promote the process of carbon peaking in China [49]. Combining the characteristics of various modes of transportation to design an efficient multimodal transport structure, reduce the carbon emission intensity of transportation, improve transportation efficiency, and vigorously develop new energy vehicles to adjust the energy consumption structure will promote the process of carbon peaking [3][13][50];

(2) Research regions. Previous research on China's carbon peaking is mainly divided into national peaking research and regional peaking research. From a macro perspective, the national carbon peaking study takes the whole country as a whole to study the factors influencing carbon emissions, peak carbon levels, and carbon peaking pathways [51][52][53]. China's energy consumption level and carbon emissions are mainly influenced by endogenous factors such as GDP, energy structure, energy intensity, population size, industrial structure, and technology level [10][38][42]. Most of the sample literature suggests that through green and low-carbon policy guidance, reducing the proportion of fossil energy consumption, promoting the rationalization and advanced development of industrial structure, actively building green cities, and accelerating the completion of the carbon emission trading market, China's total carbon emissions will slowly rise and reach the inflection point and decline in the short term, and the inflection point will appear earlier than 2030 [4][5][54]. Regional carbon peaking research is conducted for regional and local communities to achieve national carbon peaking [55][56][57]. By reasonably decomposing carbon dioxide emission factors in a specific province and analyzing specific scenarios based on local resource endowment, industrial structure, and humanities, regional carbon peaking research can provide a clear picture of energy consumption, carbon emissions, carbon peaking time, and peak value in different development scenarios [22][24][49][58]. It can effectively identify the potential factors to promote "carbon emission reduction" in the province [12][59];

(3) Research methods. The main research methods in the sample literature are qualitative research, quantitative research, "qualitative + scenario analysis", "quantitative + scenario analysis", and "mixed + scenario analysis". The Japanese scholar Yoichi Kaya established the Kaya constant equation by linking human social activities to carbon emissions and decomposed the factors influencing carbon emissions by the Kaya decomposition method [35][36][49][60]. These methods have been widely used in research related to carbon peaking. Some papers use the Monte Carlo simulation method to simulate scenario analysis, which effectively solves the problem that traditional scenario analysis methods cannot break through static analysis [16][32][36][61]. The environmental Kuznets curve shows that CO_2 emissions will rise and then fall in an inverted "U" shape with economic growth [18][43][44][62]. Some papers use the environmental Kuznets curve model to estimate the time of inflection point of carbon emission changes so as to predict the time of

carbon peak in a certain region [10][47]; some papers use the LEAP (Long-range Energy Alternatives Planning System) model to evaluate the future total carbon emissions, so as to predict the future peak carbon level in China [8][63]. The IPAT (Stochastic Impacts by Regression on Population, Affluence, and Technology) model has the advantage of visualizing the relationship between the environment and various types of human activities [64][65], and the STIRPAT (Stochastic Impacts by Regression on Population, Affluence, and Technology) model is improved on this basis [13][49]. STIRPAT model can effectively solve the drawback of the same driving elasticity factors of the IPAT model. By decomposing the regional or industrial carbon emission impact factors using quantitative analysis, the main drivers of carbon emission can be identified, and then the path of carbon peaking can be simulated by using scenario design, which can effectively study the problems related to carbon peaking [6][15][25][29][50][63];

(4) Research topic. Analyzing previous research, this entry finds that China's carbon peak research is conducted according to the following three aspects: firstly, carbon emission reduction analysis, carbon peak time prediction, carbon peak level and peak path prediction for regions or industries with the theme of "carbon peaking" [41][49][62]. In the analysis of carbon emission reduction, researchers decompose the factors influencing carbon emission in the study area or industry through quantitative analysis and find out the drivers with a strong influence on carbon emission through comparative analysis [25][47][54]. The existing literature on peak time, peak value and peak path uses scenario analysis to build a green model or a technology breakthrough model based on the realistic situation to simulate the carbon emission reduction scenarios, predict the possible peak time and peak value, and find the optimal peak path [6][31][40][43]. The second is the research on the theme of "energy". Fossil energy consumption, new energy development, and energy structure optimization are the focus of energy research in the context of carbon peaking [22][30][64]. Rapid economic development has put forward higher requirements for the development of the energy industry, and in the context of carbon peaking, ecological and environmental protection and resource conservation, new energy technologies have gained wide attention and gradually become an important way to solve environmental problems [1][25][35][57]. Thirdly, the research is carried out on the theme of "climate change". Climate change is the inevitable product of rapid economic development and excessive use of energy [33][52][63]. Since different countries have different resource endowments, economic development models and social development stages, there are many differences in greenhouse gas emissions, energy consumption and energy structures, and only high-quality economic development can solve the resulting carbon emission problems [5][15][40][48].

In summary, many previous studies have been conducted to predict and analyze whether China's carbon emission reduction targets can be achieved. The previous research on China's carbon emission attainment target is broadly classified into three categories from the methodological perspective: the index decomposition method, the scenario analysis method and the system optimization method [9][47][57][66]. Among them, the Kaya and STIRPAT models are used to predict peak carbon emissions based on the exponential decomposition method [35][38]. The LEAP model is widely used in the scenario analysis method. The models based on system optimization models include the MARKAL-MACRO, IPAC and IMAC models [7]. In addition, the Environmental Kuznets Curve (EKC) is also widely used to predict the peak of carbon emissions in China [20][24]. Most of the results suggest that China is well-positioned to achieve peak carbon emissions around 2030 [46][60]. Green et al. constructed an IPAT-based Kaya decomposition model to predict China's future carbon emissions using 2014 and 2015 base data and showed that carbon emissions from energy consumption will peak by 2025 [67]. However, the results obtained by Elzen et al. suggest that it is difficult to reach the peak of carbon emissions by 2030 under the current policies, and the implementation of energy conservation and emission reduction policies must be further strengthened [68]. In addition, some previous research has taken into account economic growth, energy intensity, industrial structure, and urbanization rate to predict that China will reach the peak of carbon emissions between 2030 and 2035 [12][55]. The impact of changes in energy mix on carbon emission peaking has not yet been studied in depth.

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