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Views & Comments

Contemplation on China's Energy-Development Strategies and Initiatives in the Context of Its Carbon Neutrality Goal

Yinao Su [a], Houliang Dai [b], Lichun Kuang [b], Jizhen Liu [c], Dazhao Gu [d], Caineng Zou [b], Haixia Huang [b]

[a] Energy and Mining Engineering Division of the Chinese Academy of Engineering, Beijing 100088, China
[b] China National Petroleum Corporation, Beijing 100007, China
[c] North China Electric Power University, Beijing 102206, China
[d] China Energy Investment Co., Ltd., Beijing 100011, China

1. Introduction

Climate change has become a global nontraditional security challenge, and achieving carbon neutrality is the global trend of the era that will determine the future of humanity [1–5]. So far, more than 137 countries have set goals or pledged to achieve carbon neutrality. In September 2020, China committed itself to peak carbon emissions by 2030 and to achieve carbon neutrality by 2060, in what are known as China's "dual carbon goals" [6].

Carbon dioxide (CO_2) is the primary greenhouse gas (GHG) emitted through human activity, and fossil fuel combustion is the main human activity that emits CO_2. In 2020, energy-related CO_2 emissions accounted for about 87% of total CO_2 emissions [7]. Different energy resource endowments and technological advantages lead to different pathways for low-carbon transition around the world; however, there is a common trend in which coal consumption is being reduced, with oil consumption growth being slowed down, natural gas consumption increasing and the production of renewable energy expanded vigorously. China is the world's largest energy producer, consumer, and CO_2 emitter [8,9], and nearly 88% of China's CO_2 emissions come from the energy system. Thus, achieving carbon neutrality in China requires a rapid and deep transformation of the energy system by relying on improving energy efficiency, cutting coal consumption, and significantly increasing the proportion of clean energy sources [10]. China must leverage the advantages of a new system concentrating nationwide effort and resources on key national undertakings, strengthen government guidance, deepen institutional reform, enhance scientific and technological innovation, and accelerate the green and low-carbon energy consumption transition in order to support the achievement of China's dual carbon goals on schedule [11–14].

2. Energy consumption and carbon emissions in China

China's total energy consumption, CO_2 emissions, and energy consumption per unit of gross domestic product (GDP) are at high levels. According to statistics [9], China surpassed the United States in total energy consumption in 2009 and in CO_2 emissions in 2005, thereby becoming the world's largest energy consumer and CO_2 emitter. In 2020, China's primary energy consumption reached 4.98 billion tonnes of standard coal equivalent, and its CO_2 emissions reached 9.9 billion tonnes, respectively accounting for 26% and 31% of the global totals. Due to objective factors such as China's energy-intensive industrial structure [15], coal-oriented energy mix, and the rigid growth of China's domestic demand, China's energy consumption and carbon emissions per unit of GDP are at high levels. In 2020, China's energy consumption per unit of GDP was 3.4 tonnes of standard coal [9,16], which is 1.5 times greater than the global average and 2–4 times greater than the equivalent value in major developed countries. China's CO_2 emissions per unit of GDP were 6.7 tonnes [9,16], which is 1.8 times greater than the global average and 3–6 times greater than those of major developed countries (Fig. 1). However, China's historical cumulative carbon emissions per capita are lower than the global average and far lower than those of developed countries such as the United States, the United Kingdom, and France [17].

China's energy consumption and CO_2 emissions have gradually reached a plateau. In recent years, as China has been deepening reform comprehensively and promoting high-quality development of economy, the growth of primary energy consumption has been slowed down significantly and the energy mix has been continuously improved. The share of coal consumption has decreased from 70.2% in 2011 to 56.8% in 2020, while the proportion of non-fossil energy has risen from 8.4% in 2011 to 15.9% in 2020. China's CO_2 emissions have gradually reached a plateau. According to statistics [9], from 2014 to 2020, the average annual growth in China's energy consumption was 116 million tonnes of standard coal equivalent, while that of China's CO_2 emissions was 94 million tonnes; these values are much lower than the average annual growth from 2002 to 2013 of 218 million tonnes of standard coal equivalent and 477 million tonnes of CO_2 emissions (Fig. 2). In particular, the proportions of natural gas, nuclear power, hydropower, wind power, and solar PV have risen rapidly in the energy mix [18], whereas the CO_2 emissions per unit of energy consumption increment have decreased from 2.18 tonnes of CO_2 per tonne of standard coal in 2002–2013 to 0.81 tonnes of CO_2 per tonne of standard coal in 2014–2020.

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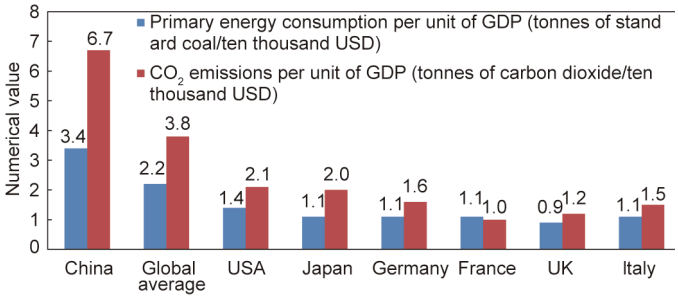

Fig. 1. Energy consumption and CO_2 emissions per unit of GDP of global average and major countries in 2020.

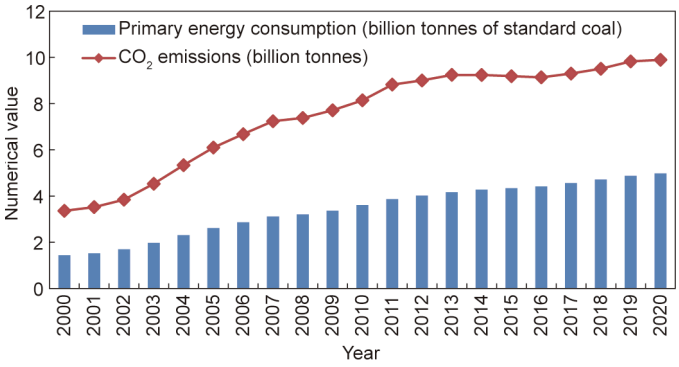

Fig. 2. Trends in energy consumption and CO_2 emissions in China.

There is still a long way to go before China achieves the green and low-carbon transition of its energy structure. It is urgently necessary to promote China's green and low-carbon energy transition as an important channel for implementing the new national energy-security strategy and achieving the goal of carbon neutrality. At present, the transition of China's energy structure presents many difficulties, such as a large proportion of high-carbon energy consumption, strong carbon-emission intensity, major loss of fossil energy assets due to premature abandonment, difficult transformation of resource-based cities, a heavy burden of re-employment of traditional energy industry personnel, and energy technology that lags behind the goal of energy transformation. From its carbon peak to carbon neutrality, China's energy transition has a tighter time schedule and involves heavier tasks in comparison with developed countries or regions such as Europe and the United States. Therefore, it is necessary for China to take an intrinsically Chinese energy transition development path.

3. China's energy-development strategies and initiatives against a backdrop of carbon neutrality

3.1. Strategic thinking

Based on its national conditions and energy resource endowments, China should firmly adhere to energy conservation and efficiency improvement, insist on supply-and-demand coordination, strengthen top-level design of energy transition, and implement projects in energy conservation, decarbonization, innovation, efficiency improvement, emergency response, and support. Efforts should also be made to accelerate the transformation of the energy consumption structure from coal-oriented (with oil, gas, and new energy respectively accounting for less than 20%, while coal accounts for over 50%) to new-energy-oriented (with coal, oil, and gas respectively accounting for less than 20%, while new energy accounts for over 50%). China should also speed up the construction of a clean, low-carbon, safe, and efficient smart energy system, which would underpin efforts to achieve its carbon neutrality goal on schedule [19–22].

3.2. Three stages—To achieve a peak in carbon emissions followed by carbon neutrality, China will have to pass through three stages

3.2.1. 2021–2035: Fossil energy will gradually reach peak level

In this stage, China will accelerate the pace of promoting the clean utilization of coal while cutting its total consumption. At the same time, we should maintain the steady development of oil, rapid development of natural gas, and incremental development of new energy. Meanwhile, more efforts will be made to expand the deployment of mega-tonne-level carbon capture, utilization and storage (CCUS) demonstration projects and the flexible modification of coal power, while the energy storage for fossil fuel energy systems will be mostly completed. In 2035, coal, oil, gas, and non-fossil energy will respectively account for 39.7%, 15.8%, 13.5%, and 31.0% of China's energy mix.

3.2.2. 2036–2050: Replacement of fossil energy with non-fossil energy will be accelerated

During this time period, China will achieve overall breakthroughs in energy conservation and efficiency enhancement. Coal reduction will be accelerated; however, a supply of coal should still be guaranteed for emergency use. We will gradually reduce the oil utilization, steadily expand the utilization of natural gas, and increase the promotion and application of CCUS. Coal power will gradually become a flexible peak-shaving power source. In 2050, coal, oil, gas, and non-fossil energy will respectively account for 15.6%, 11.7%, 13.8%, and 58.9% of the energy mix.

3.2.3. 2051–2060: "Zero-carbon" new energy will gradually dominate the energy mix

In this stage, high-carbon coal and oil will gradually return to being used as chemical raw materials. Low-carbon natural gas will become the best partner for the large-scale utilization of new energy. In addition, large-scale CCUS will be achieved, along with its commercial utilization. Hydrogen energy will be applied on a large scale in sectors that have difficulty in reducing emissions. Smart energy and energy-storage systems will be fully completed. In 2060, coal, oil, gas, and non-fossil energy will respectively account for 7.1%, 7.3%, 12.4%, and 73.2% of the energy mix.

3.3. Six significant systematic projects—Six systematic projects will aid China in moving forward on an intrinsically Chinese energy transition path

3.3.1. Energy-saving projects

China should utilize energy in a conserving and efficient way by raising public awareness of energy conservation, adjusting the industrial structure, upgrading energy-saving technologies, and enhancing energy management. The concept that energy conservation is the top priority must be publicized, while the public mindset must be shifted from "being required to save energy" to "proactively saving." It is also necessary to speed up the phasing out of high-energy-consuming industries and promote the orderly transition and upgrading of the industrial structure. At the same time, China should deepen the integration of new-generation digital technology, information technology, and the energy industry, while promoting energy efficiency through technology innovations. China should also enact and improve laws and regulations on energy conservation and energy efficiency improvement, provide governmental demonstrations, and enforce both rewards and penalties. If the energy consumption per unit of GDP of our country

can reach the global average level of 2020, its annual energy consumption would be able to reduce by 30%.

3.3.2. Decarbonization projects

The energy industry should pioneer in achieving carbon neutrality by means of carbon reduction, utilization, replacement, and storage. Focusing on energy conservation and efficiency, energy efficiency should be enhanced, while the proportion of clean energy should be increased so as to reduce energy consumption per unit of GDP and carbon emissions. Efforts to combine artificial carbon utilization with ecological carbon absorption should be redoubled; CO_2 should be used directly to produce chemicals, and the capacity of the ecology for carbon absorption and sequestration should be enhanced, while simultaneously increasing the scale of such measures. China should also promote the replacement of thermal power with green power—such as solar power, wind power, and hydropower—and increase the replacement of so-called "blue" and "gray" hydrogen with green hydrogen. It is also necessary to give full play to the advantages of the petroleum industry in terms of storage space, technology, and operational experience; vigorously develop negative emission technologies such as CCUS; and take advantage of near-depleted oilfields and gas-field complexes, with the aim of forming an annual storage capacity of more than 1 billion tonnes of CO_2.

3.3.3. Innovation projects

It is necessary to attach importance to the research and development (R&D) of disruptive technologies. China must forge wind and solar power generation and intelligent control technologies based on big data, cloud computing, artificial intelligence, and so forth. The vigorous development of safe, highly efficient and low-cost hydrogen technology is needed [23,24], along with highly efficient, long-lasting, and low-cost advanced energy-storage technology at various scales. It also need to conduct research on small controllable nuclear fusion technology for a faster realization of net zero emissions in energy supply.

3.3.4. Efficiency-promotion projects

China should accelerate the reduction in the amount of fossil fuel burned to provide energy until the fossil energy sources can be mainly used as raw materials for processing. It is necessary to greatly promote the efficiency of energy utilization and improve energy services through measures that include: ① making full use of new-generation digital and intelligent information technology; ② accelerating the construction of multi-energy, complementary, multi-network integration and a two-way responsive smart energy ecosystem with collaborative configurations of source, network, load, and storage; ③ supporting and encouraging all kinds of energy entities to independently access the energy system and participate in energy market transactions in terms of both purchasing and selling.

3.3.5. Emergency projects

It is necessary to increase natural gas storage and give full play to its role as the best partner of low-carbon transition, as a stabilizer for the large-scale utilization of renewable energy, and as a means of ensuring sufficient storage for emergency use. China should maintain a bottom-line reserve of coal as a supply of strategic reserve resources for medium- and long-term emergencies and extreme conditions, while ensuring a necessary proportion of coal-production capacity. It will also be necessary to make full use of digital and intelligent technology to speed up the construction of intrinsically Chinese energy reserves and emergency supply systems.

3.3.6. Supportive projects

China should improve the laws and regulations of the carbon market and build a multi-source, multi-level, and differentiated financial and tax support system. The construction of national carbon-emission trading market should be accelerated, and efforts should be made to establish a domestic and foreign trading system for carbon market access. It is also necessary to explore green finance reform and demonstration zones to encourage financial institutions to participate in carbon market trading and enrich trading products.

4. Conclusions

As the key to achieving peak carbon emissions and carbon neutrality, the energy industry should have a comprehensive understanding of the general trend of the world's energy transition and be fully aware of China's energy resource endowments, which include enriched coal, insufficient oil and gas, and abundant new energy. China should unswervingly follow the path of intrinsically Chinese energy transition and development. To achieve its dual carbon goal on schedule, China needs to give full play to the technological and industrial advantages of PV, wind power, hydropower, and smart grids, and accelerate its energy consumption transition from the old coal-oriented mode to a new-energy-oriented mode.

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