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Research on China's Energy Development Strategy under Carbon Neutrality

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Research on China’s Energy Development Strategy under Carbon Neutrality

Abstract

China has pledged to reach peak carbon dioxide emission by 2030, and carbon neutrality by 2060 at the Seventy-Fifth Session of the United Nations General Assembly in 2020. As the largest energy consumer and emitter of greenhouse gases, carbon peak and carbon neutrality targets have posed a high requirement for China's sustainable development of energy and economy. In recent years, even though the growth rate of China's energy consumption has decreased, and carbon dioxide emissions gradually enter the plateau, fossil fuels still supply more than 80% of the energy consumption in China. Besides learning from the adjustment of energy consumption structure in developed countries, it is worth discussing in-depth about the change of the strategic path of energy transition and how to advance energy transition under carbon peak and carbon neutrality targets, the strategic goals in China's economic and social developments. It is also an important action in China's energy revolution. Furthermore, it is an important step to achieve the development of civilization. China needs to keep working on how to reduce carbon emission, to find the optimal strategic path, and to reach the equilibrium between carbon dioxide emission reduction and economic development in the fields of electrical engineering, industry, civil engineering, and agriculture along the path towards carbon neutrality.

Keywords

carbon peak; carbon neutrality; carbon emission reduction; energy consumption structure; trend prediction; strategic path

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Research on China's Energy Development Strategy under Carbon Neutrality

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Abstract: China has pledged to reach peak carbon dioxide emission by 2030, and carbon neutrality by 2060 at the 75th Session of the United Nations General Assembly in 2020. As the largest energy consumer and emitter of greenhouse gases, carbon peak and carbon neutrality targets have posed a high requirement for China's sustainable development of energy and economy. In recent years, even though the growth rate of China's energy consumption has decreased, and carbon dioxide emissions gradually enter the plateau, fossil fuels still supply more than 80% of the energy consumption in China. Besides learning from the adjustment of energy consumption structure in developed countries, it is worth discussing in depth the change of the strategic path of energy transition and how to advance energy transition under carbon peak and carbon neutrality targets, the strategic goals in China's economic and social developments. It is also an important action in China's energy revolution. Furthermore, it is an important step to achieve the development of civilization. China needs to keep working on how to reduce carbon emission, find the optimal strategic path, and reach the equilibrium between carbon dioxide emission reduction and economic development in the fields of electrical engineering, industry, civil engineering, and agriculture along the path towards carbon neutrality. **DOI:** 10.16418/j.issn.1000-3045.20210727001-en

Keywords: carbon peak; carbon neutrality; carbon emission reduction; energy consumption structure; trend prediction; strategic path

Chinese President Xi Jinping stated China's aim to peak carbon dioxide emissions before 2030 and achieve carbon neutrality before 2060 at the general debate of the 75th session of the UN General Assembly on September 22, 2020. It is an extensive and profound systematic reform in the economy and society to achieve carbon peak and carbon neutrality, which needs to be incorporated into the general layout of the ecological and cultural construction. Carbon neutrality is a strategic goal for economic and social development in China as well as an important measure to push forward the energy revolution and fulfill the elevation of civilization [1].

1 Trends in energy consumption and carbon emissions in China

Energy transition is of top priority for the fulfillment of carbon neutrality. As the largest energy consumer and carbon dioxide emitter worldwide, China faces an evident contradiction between economic growth and environmental protection. It imposes new challenges on China's shift toward a green low-carbon energy structure to reach carbon neutrality in short term. Therefore, it is necessary to expedite industry restructuring and energy structure transition and formulate pathways to implement carbon neutrality in line with the resource endowment and national conditions of China.

As the largest energy consumer and carbon dioxide emitter, China has far higher energy consumption and carbon emissions per unit of gross domestic product (GDP) than developed countries, while the historical cumulative carbon emissions per capita are much lower due to the lagging Chinese economy. In 2020, the gross energy consumption in China was 4.98 billion tons of standard coal. Carbon dioxide emissions related to energy was approximately 9.9 billion tons, i.e., 30.9% of the total global emissions, which tops the world list and even beats the sum of the US (13.9%), India (7.2%), and Russia (4.5%). Meanwhile, the energy consumption and carbon emissions per unit of GDP for China in 2020 were 3.4 tons of standard coal and 6.7 tons of carbon dioxide per 10,000 US dollars, respectively, which are evidently higher than the world average and that of developed countries such as the US, Japan, Germany, France, and the UK (Figure 1). When it comes to the historical cumulative carbon emissions per capita, China recorded around 164 tons of carbon dioxide per capita, below the world average (214 tons) and far below the US (1,232 tons), the UK (925 tons), and France (521 tons) ①.

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① BP Statistical Review of World Energy.

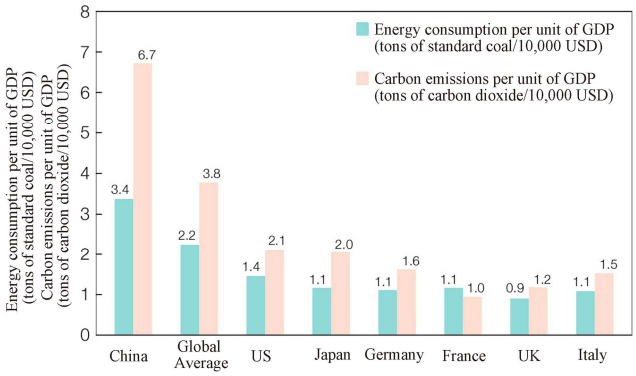

Figure 1 Energy consumption and carbon dioxide emissions per unit of GDP of major countries in 2020

Data source: National Bureau of Statistics *Statistical Communiqué of the People's Republic of China on the 2020 National Economic and Social Development*.

According to statistics on energy, the total energy consumption of China has been increasing since 1980, with a modest rise from 1980 to 2001 and a rapid growth from 2002 to 2013 but a markedly slowed growth rate from 2013 to 2020, bringing the overall energy consumption and carbon emissions to a plateau (Figure 2) [2]. The energy consumption structure of China is still dominated by fossil fuels, including coal, petroleum, and natural gas, and coal consumption accounts for more than half. In recent years, the structure of energy consumption in China has been increasingly optimized, and the annual coal consumption in the past decade is maintained at 2.8 billion tons of standard coal. The ever-decreasing percentage of coal consumption [3] is reduced from 68.5% in 2000 to 56.8% in 2020. Consumption of clean energy (natural gas + non-fossil energy) accounts for a continuously larger percentage [4], from 9.5% in 2000 to 24.3% in 2020. Among the total energy consumption of 4.98 billion tons of standard coal in 2020 in China, coal, petroleum, natural gas, and non-fossil energy make up 56.8%, 18.9%, 8.6%, and 15.7%, respectively (Figure 3).

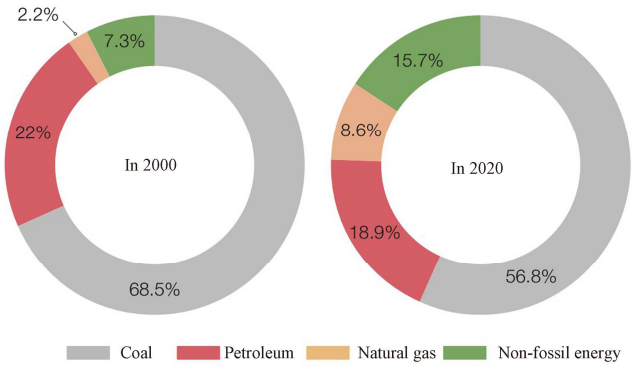

Figure 3 Comparison chart of the proportion of energy consumption types in China of 2000 and 2020

Data source: National Bureau of Statistics *Statistical Communiqué of the People's Republic of China on the 2020 National Economic and Social Development*.

The industrial sectors are a major source of energy consumption and carbon emissions in China. Six sectors (electric power, steel, cement, aluminum smelting, petrochemicals, and coal-to-chemicals) and two fields (transportation and construction) jointly contribute to more than 90% of carbon emissions (Figure 4). In the countries with high carbon emissions, the dominant contributor is the electric power sector, except for the US where transportation accounts for the largest share of carbon emissions. Priority should be given to the rapid development and substitution of natural gas and non-fossil energy, thereby optimizing Chinese energy structure and accelerating energy transition [5]. It is necessary to conduct thorough research on pathways, measures, and policy [7] for containing carbon emissions, targeting those sectors with top emissions of carbon dioxide in China.

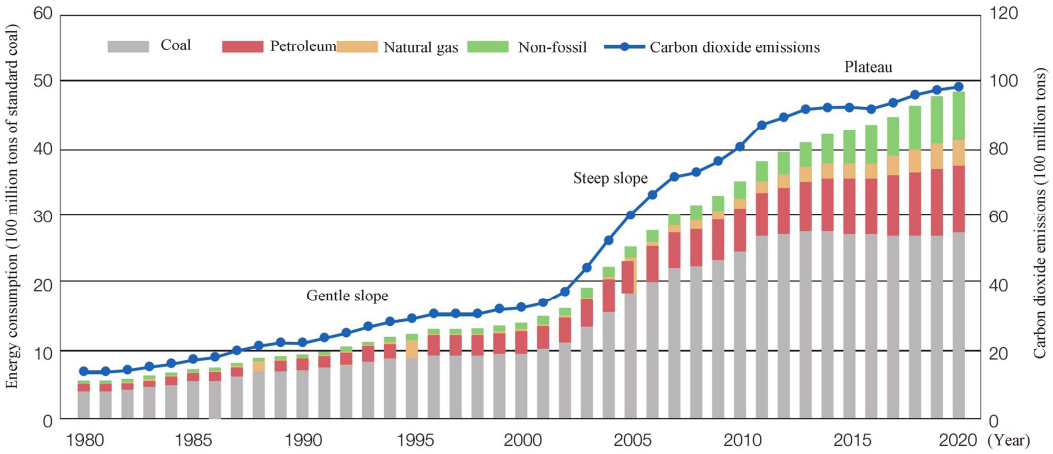

Figure 2 Trends of energy consumption and carbon dioxide emissions in China from 1980 to 2020 [2]

Data source: 2021 BP Energy Statistics and National Bureau of Statistics *Statistical Communiqué of the People's Republic of China on the 2020 National Economic and Social Development*.

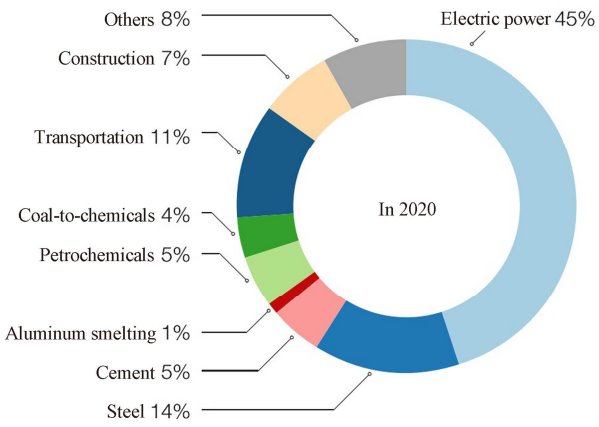

Figure 4 Proportion of direct carbon dioxide emissions from energy consumption by industry in China in 2020

Data source: *China Energy Statistical Yearbook 2020*.

2 What the strategies for carbon peak and carbon neutrality in developed countries mean to China

(1) The main challenge facing China is the short time from carbon peak to carbon neutrality. Countries push forward carbon neutrality at different paces, and 132 countries/regions have prescribed their time to carbon neutrality[①]. In terms of time points, most countries have proposed to reach carbon neutrality by 2050 [6]. In terms of time span, the average time from carbon peak to carbon neutrality for those countries is over 50 years. Since China is still undergoing industrialization and urbanization, its primary energy consumption is in an ascending trend, and so are carbon emissions. The time span from carbon peak to carbon neutrality is 30 years as announced by China, while it is 60–70 years pledged by the European Union (EU), more than double that of China. This heralds that the goal of carbon neutrality cannot be accomplished for China without arduous efforts, surprising speed, or high efficiency. Meanwhile, China should not directly copy the models of carbon neutrality in other countries but come up with pathways to implement carbon neutrality in line with the resource endowment and national conditions of China through extensive investigation and analysis.

(2) From the experience of Japan and the US, the dominant pathway to carbon emission reduction is to control the total energy consumption and optimize energy structure [8]. For most European countries, the US, and Japan that have completed industrialization, their energy-intensive industries have phased out or been transferred, thereby leaving economic growth essentially decoupled with energy demand, and most countries have achieved carbon peak. In Japan, the total energy consumption and carbon emissions have been mitigated through energy conservation and improved energy efficiency. Japan's energy consumption peaked as early as 1996; afterward carbon emissions were still increasing due to increased coal consumption. From 2008 to 2020, coal consumption flattened and petroleum consumption greatly dropped, while more renewable energy was consumed, thus leading to rapidly reduced carbon dioxide emissions. The US accomplished a steady energy consumption and obviously decreased carbon emissions by promoting natural gas and renewable energy [9]. The US energy consumption has been maintained stable for a long time after peaking in 2005, and natural gas and renewable energy can substantially replace coal [10]. From 2005 to 2020, the percentage of natural gas consumption rose from 23% to 34%, and that of renewable energy consumption from 1% to 7%. It is estimated the substitution of natural gas and renewable energy for coal cut emissions by roughly 750 million tons of carbon dioxide, about 82% of the cumulative decrease in carbon emissions in the US.

(3) Different resource endowments and technological advantages in countries determine their pathways for a shift to clean and low-carbon energy. The US is abundant in coal, petroleum, and natural gas. In spite of its huge consumption, high production of energy can guarantee self-sufficiency, which determines the path for transition to clean and low-carbon energy is to boost natural gas and renewable energy. The EU lacks coal, petroleum, and natural gas. Owing to large energy consumption and low production, its fossil energy is highly dependent on imports, which results in promoting non-fossil energy as the path for a shift to clean and low-carbon energy. For instance, "abandoning coal, increasing gas, and boosting renewable energy" is adopted as the carbon-reducing path in the UK, and the years from 1965 to 2020 have witnessed a decrease of 56% in the percentage of coal consumption, an increase of 14% in the percentage of natural gas consumption, and an increase of 13% in the percentage of renewable energy. "Boosting renewable energy while ensuring nuclear energy as the foundation" is adopted as the carbon-reducing path in France, making nuclear energy account for 37% and the share of renewable energy increase by 6%. "Abandoning coal and nuclear and boosting renewable energy" is adopted as the carbon-reducing path in Germany, with the consumption of coal and nuclear energy decreased by 45% and 6% respectively and the consumption of renewable energy increased by 16%. Similar to China in resource endowment, India is rich in coal but scarce in oil and gas. Therefore, it is an arduous task for India to accomplish energy transition in a short term. The only feasible path for low-carbon transition will be what suits their national conditions. Experience from other countries demonstrates that a practical option for China to achieve carbon neutrality is to

① Among them, 2 countries have reached carbon neutrality and 120 countries/regions will reach carbon neutrality by 2050. Carbon neutrality is explicitly targeted at the legal level in 6 countries, at the legislative level in 6 countries, and at the level of national policy in 20 countries.

push forward efficient and clean utilization of coal, expedite substitution of clean energy, and promote renewable energy and natural gas.

3 Prediction of future total energy consumption and peak in China

(1) Prediction of total primary energy consumption for China. Simulated analyses of predictions by different institutions [(3)] show that China's primary energy consumption will reach a peak at 5.29–6.14 billion tons of standard coal around 2030 [(4)], with an annual average of 5.57 billion tons. After peaking it will undergo a downturn shortly [11]. It is projected via comprehensive interpretation that China's primary energy consumption will reach a peak at 5.6 billion tons of standard coal around 2030, and potentially decline to about 4.5 billion tons of standard coal in 2060 (Figure 5).

(2) Prediction of the time to carbon peak and the peak value for China. Comparison of predictions of the time to carbon peak and carbon emissions in eight carbon neutral scenarios (Figure 6) shows that China's peak carbon emissions

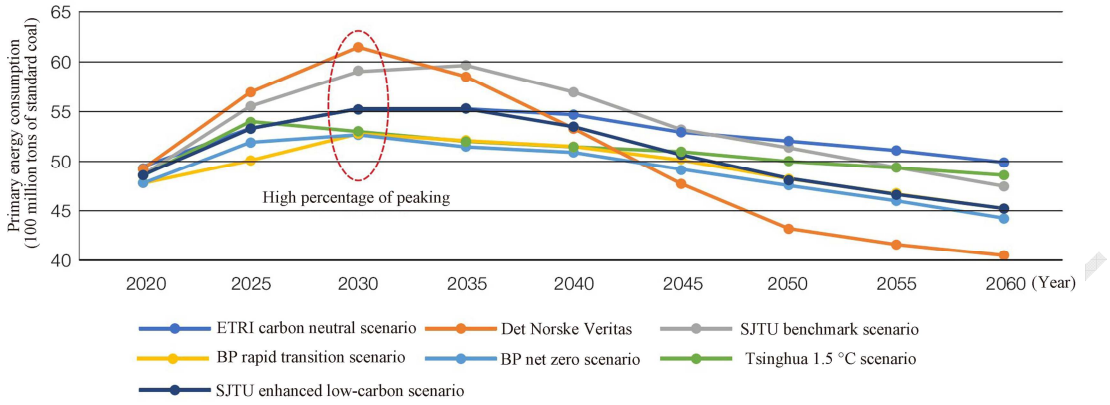

Figure 5 Comparison of primary energy consumption forecast for carbon neutral scenarios in China

Data source: CNPC Economics & Technology Research Institute (ETRI), *2050 World and China Energy Outlook* (2020 edition); *AFRY Thinkpiece: Implications of China's proposed 2060 carbon neutrality*; Det Norske Veritas, *2020 Energy Transition Outlook, Greater China Regional Forecast*; BP, *Energy Outlook 2020*; Institute of Climate Change and Sustainable Development, Tsinghua University, *China's Long-term Low-carbon Development Strategies and Pathways: Comprehensive Report*; Shanghai Jiao Tong University (SJTU), *Energy Strategy 2035 Special Report* sponsored by Chinese Academy of Engineering Grant for Key Consulting.

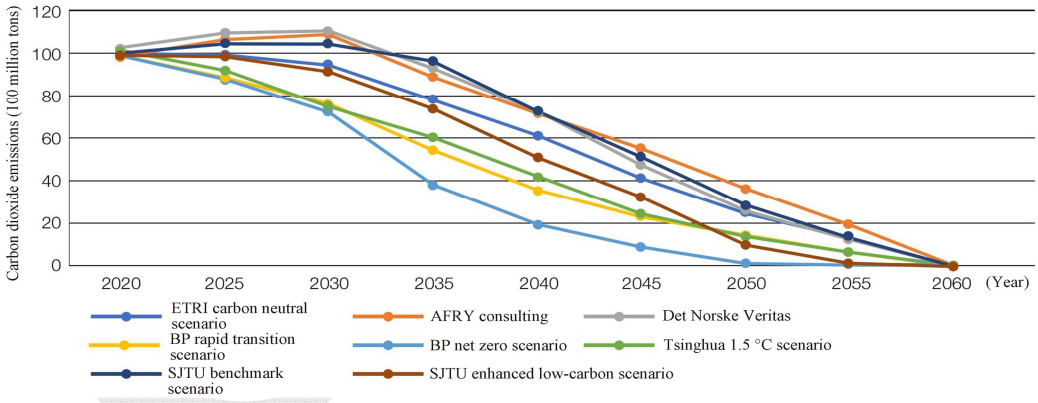

Figure 6 Comparison of carbon emission predictions for eight carbon neutral scenarios in China

From the investigation of 33 predictions of China's total primary energy consumption by 14 institutions worldwide, a total of 21 reasonable scenarios were screened out by comprehensive interpretation considering various factors. Among them, eight scenarios (CNPC Economics & Technology Research Institute, AFRY (Bayley Engineering Design Consulting Co. Ltd.) Consulting, Det Norske Veritas, BP rapid transition scenario, BP net zero scenario, Tsinghua 1.5 °C scenario, Shanghai Jiao Tong University benchmark scenario, and Shanghai Jiao Tong University enhanced low-carbon scenario) can achieve carbon neutrality, and these data resulted from analyses of eight scenarios that can achieve carbon neutrality.

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② International Energy Agency. World Energy Outlook 2020. https://www.iea.org/

are approximately 10.3 billion tons on average. It will decline after peaking with an average annual reduction of 250 million tons as required. It is projected via comprehensive interpretation that China's carbon emissions will peak between 2025 and 2030 and potentially reach carbon neutrality between 2055 and 2060 [①].

(3) Structure of energy consumption and carbon emissions in China under carbon neutrality. Based on the comprehensive prediction in eight carbon neutral scenarios, this study recommends the scenario of "boosting natural gas." This also considers a number of advantages of natural gas, including abundance in natural gas resources, carbon emissions from natural gas being less than half those from coal with equal calorific value, power generation from natural gas serving as flexible and efficient peaking plants, and support for the development of renewable energy from natural gas. In this scenario, coal consumption is projected to peak before 2025, followed by a continuous decrease, down to about 43% in 2030 and 4.7% in 2060. Petroleum consumption is projected to peak at about 730 million tons between 2025 and 2030, and then drop to 200 million tons or so in 2060 which accounts for 6.4%. Natural gas consumption is projected to peak at roughly 680 billion cubic meters [②] between 2035 and 2040 and then fall to 600 billion cubic meters [③] in 2060 which accounts for 17.6%. Consumption of non-fossil energy will make up an increasingly large share, predicted above 25% [④] in 2030 and at 71.3% in 2060.

4 Measures and suggestions to facilitate carbon neutrality

Carbon neutrality is the strategic goal for the development of Chinese economy and society and an important measure to advance energy revolution in China. Moreover, it is an important grip for the development of civilization. Achieving carbon neutrality will certainly give rise to a profound systematic reform in the economy and society as well as new technologies, new industries, new transportation, new buildings, new energy, and new ways of development. Furthermore, China's economy and society will be continuously driven forward, thereby realizing sustainable development and progress in the economy, energy, environment, and climate. To accomplish carbon neutrality, China should make constant efforts to reduce carbon emissions while working out optimal strategic paths in electric power, industry, construction, agriculture, and other fields, so as to achieve carbon reduction in parallel with economic development [12]. Seven measures or suggestions are proposed in this study.

(1) A top-level design for carbon neutrality should be formulated. Carbon neutrality is pertaining to all respects of economic and social development. China should form a scheme for the implementation of carbon neutrality as soon as possible, set milestone targets for controlling gross carbon emissions, and specify region-wise and sector-wise responsibilities. It is necessary to sign letters of responsibility on the goal of carbon peak and carbon neutrality with provinces (including autonomous regions and municipalities) and leading state-owned enterprises and prescribe their respective tasks. Additionally, China should enforce process management and performance assessment, and actively exert unified coordination at the national level [13]. Laws in response to climate change have been passed in the UK, Japan, Mexico, the EU, the Republic of Korea, the Philippines, the state of California in the US, etc. Given that legislation has become an important grip for major countries and regions to tackle climate change, it is advisable for China to initiate legislation on carbon peak and carbon neutrality in a timely manner.

(2) We should encompass the establishment of demonstration zones in the long-term national strategies on carbon neutrality. For China, the goal of carbon neutrality needs to be reached as anticipated, and meanwhile, carbon emission reduction should be achieved without compromising economic development. In particular, the steady and sustainable development of the coal industry and oil/gas industry is significant to economic development and societal stability at the regional level. Western China is home to the petrochemical industry as well as the largest base for the coal-to-chemicals industry. For example, the annual carbon dioxide emissions in Xinjiang are 580 million tons, 80% of which is contributed by coal. Under the constraint of carbon neutrality, the energy industry will be left with the only option, i.e., clean and low-carbon development, which is also an urgent need. The following suggestions are put forward. Home to the vital infrastructures such as gas transmission from west to east and power transmission from west to east, western China has considerable carbon emissions; alongside its output of clean energy, measures should be taken to refund the carbon credit to western China. At the same time, carbon source and carbon sink are well-matched in Xinjiang, a unique edge for advancing carbon capture, utilization and storage (CCUS) in favor of carbon emission reduction. In view of that, it is advisable to include the establishment of demonstration zones in the long-term national strategies for carbon neutrality and orient carbon neutrality-related technologies and industries to

[①] Institute of Climate Change and Sustainable Development, Tsinghua University. China'sLong-term Low-carbon Development Strategies and Pathways: Comprehensive Report.

[②] Institute of Energy, Environment and Economy, Tsinghua University. Analysis of low-carbon energy transition scenarios under the 2060 carbon neutrality target, 2020.

[③] CNPC Economics & Technology Research Institute, 2050 World and China Energy Outlook (2020 edition).

[④] Zhang XL. Analysis of low-carbon energy transition scenarios under the 2060 carbon neutrality target, Institute of Energy, Environment and Economy, Tsinghua University, 2020.

recyclable development. Considering Xinjiang's strategic position, resource endowment, environmental carrying capacity, and technological advantages of local industries, it is favorable to set up national demonstration zones for carbon neutrality, where how to boost the output of carbon dioxide flooding is to be solved, and paradigm projects on carbon neutrality will be established. Furthermore, green and low-carbon paths will be explored for such high-carbon industries as energy and chemical engineering, so as to facilitate high-quality development of the economy and society in Xinjiang as well as fulfillment of carbon neutrality for China.

(3) Efforts should be made to promote efficient and clean utilization of coal and high-quality development. Advancing efficient and clean utilization of coal can effectively control carbon dioxide emissions. Around 50% of coal consumption in China is used to generate electricity. Therefore, clean and efficient power generation from burning coal is crucial to efficient and clean utilization of coal. We can make use of the strong complement between coal and renewable energy for power generation in an optimized way. Therefore, instability in power generation from renewable energy can be prevented, and its capacity for carbon neutrality can be utilized to reduce carbon emissions for coal-fired power generation. In addition, underground coal gasification is another important approach to clean utilization, which is likely to revolutionize the exploitation and utilization of mid-deep coal, thus mitigating negative impacts on the environment during coal exploitation and usage [14].

(4) Oil and gas companies are expected to scheme the development of new energy while ensuring national energy security. Carbon neutrality in the oil/gas sectors needs unified consideration in the context of national energy security, particularly oil/gas security. We can stimulate increased production of conventional gas, make breakthroughs in the exploration and development of unconventional gas, and enhance the facilitating role of natural gas in low-carbon transition and carbon neutrality. Meanwhile, under the premise that China's energy security is guaranteed, with ever-maturing emission reduction technologies via new energy, oil/gas companies can push forward new energy business at a faster pace and actively foster the ability to develop new energy, as carbon emissions enter the plateau and rapid decline [15]. It is feasible to provide solutions to carbon dioxide emissions from coal and electric power enterprises through the offerings in carbon dioxide conversion and storage. Moreover, oil/gas companies ought to focus on the research and development of low-cost technologies and ensure steady development of new energy business by taking advantage of both innovativeness and cost-effectiveness of low-carbon technologies with emphasis on lowering cost [16].

(5) We can expand the applications of CCUS technology. Greater efforts need to be taken to make technological breakthroughs in carbon dioxide flooding and carbon sequestration and promote mature technology-based industries. Since CCUS is under exploration and in the early stage of application, its fundamental research and technologies have yet to be full-fledged. ① Fundamental research is to be conducted on unified coordination between development and utilization of oil and gas resources and carbon neutrality, with focuses on the study of mid- and long-term trends in economic development as well as scenario analysis and path simulation of future energy demand and trends in carbon dioxide emissions. ② Key technologies for carbon capture, isolation, transportation, utilization, storage, and monitoring are to be unraveled. We can optimize the arrangement of carbon source and carbon sink, lay out pipelines dedicated to carbon dioxide transmission ahead of time, and comprehensively assess the performance of carbon dioxide flooding and carbon sequestration. ③ A new generation of CCUS technology with low cost, low energy consumption, and low water consumption needs to be pre-deployed and intensively integrated with digital technology and renewable energy like wind and solar energy, in order to largely increase the ratio of carbon dioxide utilization and sequestration in its full life cycle.

(6) It is recommended to obtain government guidance and support from policies in revenue, taxation, and finance. Policy support is indispensable for the large-scale application of CCUS technology. In particular, government guidance and policy support are more needed in the early stage of large-scale promotion and application. ① Hence, under the thrust by the government, an "enterprise–locality–enterprise" communication mechanism should be established for integrated development of the industries including petroleum, chemical engineering, coal-to-chemicals, and coal-fired power generation. Cross-enterprise coordination and cooperation mechanisms are to be established to coordinate benefit distribution between enterprises, break the impasse in corporate cooperation, and form an integrated carbon capture–transmission–sequestration (utilization) mode. ② Tax and treasury policies should be enacted to support CCUS in accordance with China's national conditions with reference to the US Code Section 45Q (Credit for Carbon Oxide Sequestration) [①], in order to form a healthy cycle that can improve efficiency and bring in investment. ③ Drawing on national and local platforms for carbon trading, carbon dioxide can be traded on the market, leading to the scale-up and commercial operation of CCUS programs.

(7) We can promote "carbon negative initiatives" such as building nursery and carbon sequestration forests. Enterprises should be encouraged to build nursery and carbon sequestration forests as part of "carbon negative initiatives," which will make room for carbon emission reduction during the operation of demonstration zones. With carbon neutrality

[①] US Department of Treasury and Internal Revenue Service. US Code Section §45Q. Credit for Carbon Oxide Sequestration, Jan. 15th, 2021.

targeted and carbon trading market pushed forward, carbon assets will become rare resources. The following suggestions are given. ① It is favorable to conduct a complete survey on carbon sources in the demonstration zones and drive effective arrangements of resources based on the carbon market. ② Energy enterprises are encouraged to build nursery and carbon sequestration forests, expand the principal part of the afforestation projects like ecological shelter forests, and initiate the construction of "green mines and green operating zones," thereby achieving green development alongside increased carbon sink. ③ We can call upon enterprises to purchase carbon credit from the designated regions under rural revitalization, so as to drive green development in those regions.

5 Conclusions

Carbon peak and carbon neutrality is a pivotal strategic decision made by the Central Committee of the Party and the State Council of the PRC. It manifests the establishment of ecological civilization centered at green low-carbon development, new expectation for a better life by the Chinese people, and inherent demand for high-quality, innovative, and sustainable development at a new stage. In line with China's radical interests, carbon neutrality ought to be embraced by all regions and industries. As the largest energy consumer and carbon dioxide emitter, China can make reference to the practices by developed countries in restructuring energy consumption and reducing carbon emissions, in an attempt to achieve carbon neutrality. Efforts can be made to expedite energy transition while working out optimal strategic paths in electric power, industry, construction, agriculture, and other fields, and we can achieve carbon reduction without compromising economic development.

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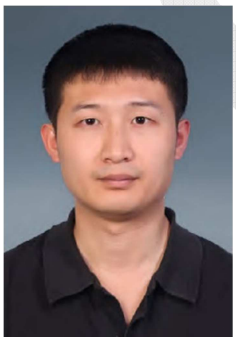

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