Analysis and Countermeasures of China's Energy Structure Including Supply and Demand Sides

Ying He[1,*], Jiarui Huang[1], Qian Zhai[2], Yijun Ji[2]
[1]*College of Environmental Science and Safety Engineering, Tianjin University of Technology, Tianjin, China*
[2]*College of Environmental Science and Engineering, Nankai University, Tianjin, China*
**Corresponding Author.*

Abstract: Optimizing China's energy structure is a crucial path to the goal of carbon emission peaking and carbon neutrality. This article adopts a comparison analysis to study the current energy structure including both supply side and demand side in China. The results show that China's energy structure, originally characterized by heavy coal and heavy industry, has improved dramatically compared to decades ago and to other countries. However, the proportion of raw coal is relatively high, while the proportion of crude oil, natural gas, and other clean energy consumption is relatively low, and the degree of electrification is below the target. Finally, this article proposes countermeasures to address the existing problems in the current energy structure, including strengthening guidance, constructing a new energy pattern, and improving the degree of electrification.

Keywords: Energy Structure; Supply-Demand Sides; Energy Consumption; Carbon Peaking; Carbon Neutrality

1. Introduction

China holds the distinction of being the world's foremost energy producer and, concurrently, the largest consumer of energy on a global scale [1]. Its energy resources play an indispensable role in fuelling the country's economic engine and steering social development. China is currently the world's largest emitter of carbon dioxide, facing enormous pressure to reduce carbon dioxide emissions [2]. To achieve the strategic goals of carbon peak and carbon neutrality, optimizing the both the energy and industrial structures is crucial. It is the main battlefield. [3, 4]. Both developed and developing countries should attach importance to this battle [5]. At the same time, the energy structure affects the high-quality development of China's socio-economic development and the control of environmental pollutants. The aim of this article is to conduct an analysis of China's current energy structure, examine the existing problems and put forward corresponding countermeasures to provide theoretical support for the optimisation of the existing energy structure, including both the supply side and the demand side, at the same time, to contribute to China's dual-carbon goals and high-quality economic development [6, 7]. Based on data from *the China Statistical Yearbook*, *China Energy Statistical Yearbook*, and the International Energy Agency, this article studies the current situation of energy supply and demand in China, along with the current energy structure and its associated challenges. Subsequently, in response to these challenges, the article puts forth strategic countermeasures aimed at advancing the realization of the 'dual-carbon' goal.

2. Analysis of the Current Situation of China's Energy Structure

2.1 Energy Supply Side Situation

The total primary energy production in China reached 42.71 × 10^8tce (tons of standard coal) in 2021, growing at an average annual rate of 10.48% since 2000. China's coal production hit 41.26 × 10^8 t in 2021. Taking into account import, export, and stock changes which stood at 3.23 × 10^8 t, 0.02 × 10^8 t, and -0.40× 10^8 t, respectively the total supply reached 44.06 × 10^8 t. This marks a remarkable increase of 234.04% compared to the 2000 level of 13.19 × 10^8 t. In 2021, the total oil production amounted to 1.99 × 10^8 t, showing minimal

change compared to the levels in 2000. However, the import experienced a substantial fivefold increase, reaching 5.88 × 10^8 t. The production and import volumes of natural gas have grown rapidly, with the total supply increasing from 0.14×10^8t in 2000 to 0.71 ×10^8t in 2021. In 2021, primary electricity, which includes wind power, nuclear power, and hydropower, accounted for 29.27% of the total electricity supply. This was an increase from 2010 when primary electricity only accounted for 20.14% of the total supply. The generation of wind power has increased rapidly. Total imported energy has increased from 1.43 × 10^8tce in 2000 to 12.48 × 10^8tce in 2021. The scale of total energy imports has increased by an order of magnitude and external energy dependence has increased. The share of each energy source on the primary energy supply side in 2021 is shown in Figure 1, and the production and import volumes of the four main energy sources in 2021 are shown in Figure 2.

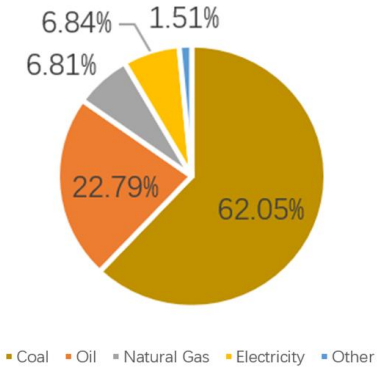

Figure 1. The Proportion of Primary Energy Supply

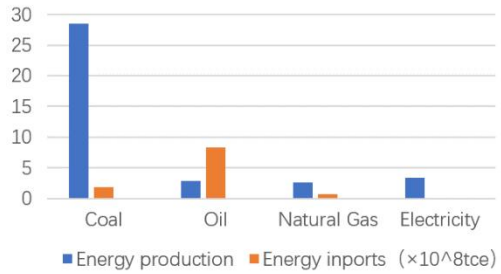

Figure 2. Production and Import Volume in Primary Energy Supply

In the conversion of secondary energy sources, the amount of energy invested in power generation and heating accounts for a large proportion of the overall energy consumption. In 2021, the coal invested in power generation was converted into standard coal consumption, which was approximately 17.14 × 10^8tce, 3.26× 10^8tce coal input for heating, accounting for 48.38% of the total primary energy production, increased by 13.15×10^8tce compared to the coal consumption of thermal power generation in 2000, coal consumption for thermal power increased by 2.62 × 10^8tce.

2.2 Energy Demand Side Situation

In 2021, China's energy consumption reached 52.58×10^8tce. Industrial energy consumption increased by over 24×10^8tce compared to 2000, accounting for 66.28% of total consumption The energy consumption of the residential sector was 6.75×10^8tce, followed by the transportation industry (4.39×10^8tce), other departments (3.18×10^8tce), the wholesale and retail accommodation and catering industry (WRC Industry1.49×10^8tce), agriculture (0.97×10^8tce), and the construction industry (0.96×10^8tce).

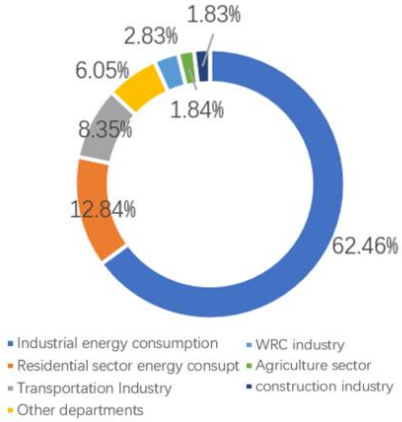

Figure 3. The Proportion of Terminal Sector Energy Consumption

Compared to 2000, the proportion of energy consumption in each industry sector has remained relatively unchanged, with industrial and agricultural sectors decreased by 3.71% and 1.01% respectively; the residential sector and other sectors increased by 1.49% and 1.90% respectively. The growth rate of other departments was less than 1%. The proportion of energy consumption by each terminal department in 2021 is shown in Figure 3.

The amount of electrical energy obtained in the secondary energy conversion process was 10.70×10^8tce, the thermal energy capacity was 2.42×10^8tce, and the total energy consumption supplied to various industries was 39.46× 10^8tce. The share of electricity supply in the total energy demand was 20.35%.

2.3 Comparison of China's Energy

Structure with the Current Situation of Other Countries

In 2021, the proportion of coal in China's energy consumption has decreased to 55%, while the proportion of oil, natural gas, and other low-carbon energy sources has increased to 19%, 9%, and 17%, respectively. Compared to the energy consumption pattern several decades ago, where coal accounted for over 70%, oil and natural gas accounted for less than 20%, and other energy sources accounted for less than 10%, the energy structure has been further optimized. But compared to other developed countries [8], the proportion of coal is still too high. Countries like the United States and Russia have superior natural resource endowments, in which oil and natural gas account for over 70%, with the remaining 10% attributed to coal and 20% to clean energy. France vigorously develops nuclear power through technology, with nuclear power plants producing nearly 40% of the electricity, while Canada develops hydroelectric power technology through its excellent water resources, making hydroelectric power account for 30% of its total electricity. Even for Australia, which is rich in coal resources, its coal consumption accounts for less than 30%. The specific energy structure between China and several developed countries in 2021 is shown in Figure 4.

Compared to other countries, Brazil, Russia, India, and South Africa, which are also BRICS countries [9], have different natural resource endowments. Brazil's dependence on fossil energy is lower than that of the other four countries, and its research and development in the field of biomass energy are relatively leading. With Brazil's abundant hydropower resources, hydropower, and biomass energy consumption accounts for 48%. India and South Africa, like China, rely on fossil fuels and have a relatively high proportion of coal. In 2020, coal consumption accounted for 43.5% and 73% of total energy consumption in both countries; Russia has abundant oil and gas resources, with oil and natural gas consumption accounting for73.6% of total energy consumption, Additionally, Russia is relatively leading in nuclear energy development, with nuclear energy consumption accounting for nearly 70% of renewable energy consumption. The specific energy structure between China and other BRICS countries in 2020 is shown in Figure 5.

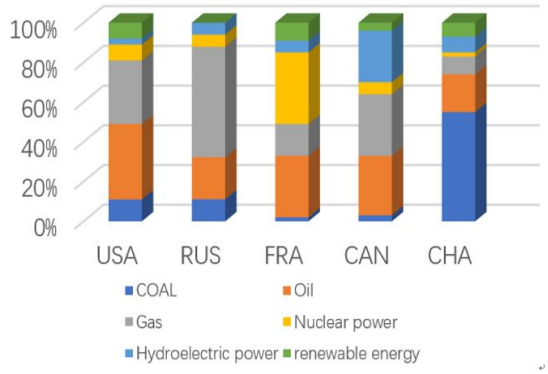

Figure 4. Comparing the Energy Structure of Developed Countries in 2021

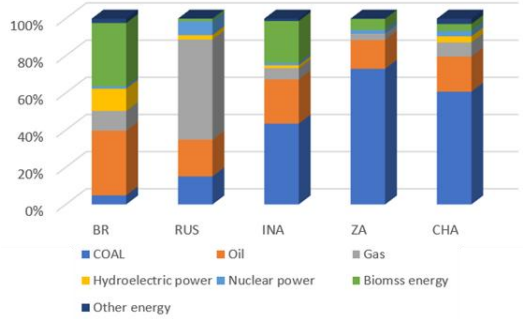

Figure 5. Comparing the Energy Structure of BRICS Countries in 2020

2.4 Problems in China's Energy Structure

Based on the above data and analysis, there are currently four problems in China's energy structure:

(1) From the perspective of energy supply, despite China's efforts to promote clean energy, coal continues to dominate, leading to a series of environmental pollution and carbon emission issues.

(2) China has a relatively low proportion of oil, gas, and clean energy in its energy mix, with a high dependence on imports, especially for oil. The import quantity of oil is approximately three times the production volume.

(3) From the perspective of energy demand, the proportion of electricity generated through secondary energy conversion in various industrial sectors is relatively low in the total consumption. At present, there is a significant gap in the level of electrification compared to 41% and 50% in the Announced Emissions Scenario (APS) and the Net Zero Emissions Scenario (NZE) [10].

(4) Excessive reliance on coal remains a concern, despite some progress in clean energy. There is a need to intensify efforts to promote structural transformation. The relative low

energy utilization efficiency contributes to the issue of energy wastage. Some traditional, high-energy-consuming, and polluting industries, such as steel and cement, still persist, exerting significant pressure on energy demand.

3. Results and Suggestions

This article summarizes and analyzes the energy situation on the supply and demand sides of China, and compares the energy structures of multiple countries. The results show that currently, China's coal supply exceeds 60%, with a total of about 30% for oil and natural gas, and less than 10% for other renewable energy sources. Compared with developed countries, China's energy structure is overly dependent on coal, with a higher proportion of fossil energy production. On the demand side, the high proportion of energy consumed by heavy industry is unavoidable due to the needs of China's economic development. However, in the future, China's economic development goals will continue to shift from rapid development to high-quality development, and this shift is expected to result in an improvement in the energy consumption patterns of the industrial sector on the demand side. Finally, the article proposes three recommendations and outlines specific countermeasures the shortcoming of this article is that it does not establish models or set scenario predictions for future changes in energy structure and energy consumption. Future research can will incorporate scenario settings to simulate the impact of changes in energy structure on carbon emissions.

3.1 Strengthening the "Dual Carbon" Policy to Lead and Stimulate the Optimization of Energy Structure

Based on the current energy structure situation in China, we determine the following optimization and control objectives, including but not limited to: specific values for reducing traditional fossil fuels such as coal, oil, and natural gas on the supply side; Enhance the share of clean energy, including wind, hydro, solar, and nuclear energy, in the overall energy usage Improving energy conversion rate and reducing loss rate in secondary energy conversion; increasing the proportion of electricity used as energy on the demand side. Utilize the direct and indirect impact of the "dual carbon" policy on the energy market, provide direct subsidies or tax reductions to enterprises that use clean energy and develop new technologies, impose fines, and rectify enterprises that still use outdated, high-energy consuming, and high polluting energy, establish a sound carbon emission trading market such as CCER, and indirectly promote energy structure optimization through an "invisible hand". The "dual carbon" policy promotes energy transformation, improves energy efficiency, develops low-carbon technologies, optimizes energy supply chains, and establishes a carbon market system, optimizing energy structure to achieve emission reduction goals and promote sustainable development.

3.2. Building a Pattern of "Coal + Oil and Gas + New Energy" on the Supply Side

Based on the current state of China's energy structure, it is unrealistic to completely eliminate the use of coal in a short period of time. Coal remains an important resource to ensure energy security in various industries in China. Under the guidance of the dual carbon policy, the mid-term goal is to build a tripartite energy pattern of "coal + oil and gas + new energy" around 2035, which is reasonable and feasible. Firstly, it is necessary to improve the utilization efficiency of coal resources by using technologies such as clean coal combustion and CCUS to reduce the carbon emissions. Simultaneously, there should be a gradual reduction in coal usage while improving the comprehensive utilization rate of this resource. Secondly, it is crucial to advance the technology involved in oil and natural gas extraction, steadily enhancing both the output and quality of these valuable resources. For the energy imports, it is essential to achieve trade diversification as far as possible, seizing the development opportunities of the Belt and Road and carrying out more in-depth cooperation in the energy field. What’s more, take both internal and external measures to ensure China's solid energy supply. Finally, we will continue to vigorously develop new energy technologies, invest and expand clean energy infrastructure, develop hydropower, wind energy, solar energy, nuclear energy, etc. according to local conditions, and increase the proportion of new energy in the total energy supply. While the

proportion of new energy is increasing, it is also necessary to strengthen the infrastructure construction of new power systems to improve the safety, flexibility, and intelligence level of the power grid or power system.

3.3 Strengthening Electrification and Reducing Primary Energy Consumption on the Demand Side

To increase the electrification level of end-use energy on the demand side, it is necessary to increase the production of primary electricity and the efficiency of electricity in secondary energy conversion; the improvement of electrification in the industrial and transportation sectors requires continuous innovation and development of energy-saving technologies, industrial processes, and transportation equipment. The improvement of electrification in demand side also requires the construction of new power systems, including the continuous increase of renewable energy installed capacity, the deepening development of clean coal-fired power, the continuous strengthening of cross regional transmission facilities, and the innovation and enhancement of energy storage technology. The government needs to formulate incentive policies, such as reducing electricity costs and providing rewards or subsidies, to promote the electrification at the terminal. Additionally, it is essential to establish relevant standards and regulations to ensure the safety, interoperability, and quality of electrification equipment, thereby enhancing user confidence. A higher proportion of primary energy consumption indicates a heavier energy structure. Given that an important root cause of a heavier energy structure lies in a heavier industrial structure, it is recommended to improve the coordination level between local industrial structure and local energy endowments and environmental capacity.

Acknowledgments

This research was supported by the National Key R&D Program of China (grant number 2018YFC1902303) and the Asia Research Center in Nankai University (grant number AS2113).

References

[1] Fan, D., Driving factors of carbon emissions from energy consumption in China-Based on LMDI-PDA method. China Environmental Science, 2013, 33(9): 1705-1713 (in Chinese)

[2] Qu, B., Liu, C., Exploration of development path of electric energy substitution under energy structure transformation. Power Demand Side Management, 2022, 24(6) (in Chinese)

[3] Huang, S., Wang, J. Y., Short-term strategy and long-term prospect of energy structure optimization under carbon neutrality target. Chemical Industry and Engineering Progress, 2022, 41(11) (in Chinese)

[4] Xia, Y.M., Liu, H. D., Analysis of energy structure, resource endowment conditions and carbon emission reduction path of thermal power generation industry. Coal Processing& Comprehensive Utilization, 2023, 11:90 (in Chinese)

[5] Li, F., Wu, Y. C., Wang, M. C., et al. Empirical study on CO_2 emission, financial development and economic growth of the BRICS countries. Energies, 2021, 14(21): 3-7. (in Chinese)

[6] Liu, Y.H., Wang, W.T., Challenges, Opportunities, and Actions for China to Achieve the "Dual Carbon" Goals. China Population, Resources, and Environment, 2021, 31(9):1-5(in Chinese)

[7] Song, H., The Grey Correlation Analysis of China's Energy Structure and Industrial Structure. Standardization of Engineering Construction, 2020, 7: 69 (in Chinese)

[8] Zheng, H., Xiao, M. X., Medium- and long-term energy demand of China and energy transition pathway toward carbon neutrality. Journal of the Chinese Academy of Sciences, 2021, 36(9): 08-16(in Chinese)

[9] Zheng, H. Z., Wang, H., Wang, J. P., et al. BRICS countries' climate policies, energy structures, and carbon emissions towards carbon neutrality. China population, resources and environment, 2023, 33(6): 67-79. (in Chinese)

[10] IEA, 2023, World Energy Outlook 2023, Paris, https://www.iea.org/reports/world-energy-outlook-2023, License: CC BY 4.0 (report); CC BY NC SA 4.0 (Annex A).

