Investigations and Considerations of the Current Energy Development in Our Country

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Abstract. In order to implement the new strategy of national energy security, carbon peak will be realized during the 15th Five-Year Plan period and strive to basically achieve the strategic goal of carbon neutrality by 2050. A clean, low-carbon, safe and efficient energy system is needed to be built. This paper investigates the primary energy supply and consumption, analyses power generation structure and carbon emissions. Moreover, comparisons with typical carbon peak regions are conducted and foreign advanced experience is learned. To achieve the carbon neutrality, we need to limit the fossil energy use, improve the energy efficiency, develop the renewable energy and increase the terminal electrification rate.

Keywords: carbon peak · carbon neutrality · primary energy supply · terminal electrification rate

1 Introduction

Confronted with energy source constraints and ecological environment deterioration, China has put forward a new energy security strategy of "four revolutions and one cooperation", pointing out the way for energy development in the new era. On September 2020, China pledged to "strive to achieve a carbon peak by 2030 and achieve carbon neutrality by 2060", further clarifying the energy development goal in the new era.

On December 2020, the State Council Information Office of China released "Energy in China's New Era". It states that the essence of high-quality new energy development is to further promote the clean, low-carbon, safe and efficient energy.

In this study, the current primary energy supply and consumption are analyzed while the power generation structure and carbon emission are evaluated. Moreover, comparisons with typical carbon peak regions (the United States, South Korea, Japan and the European Union) are conducted and some advanced experience is learned. The results are significant to the construction of a clean, low-carbon, safe and efficient energy system.

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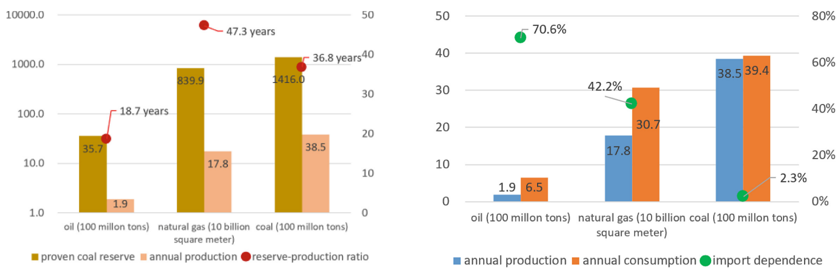

(a) (b)

Fig. 1. The fossil energy situation of China in 2019

2 Current Energy Situation

2.1 Traditional Fossil Energy Supply

The human energy utilization period has roughly experienced the firewood age, the coal age and the oil age. Up to now, traditional fossil energy still plays an important energy role for human beings, and it will act as the stabilizer and ballast in the future energy system.

The oil and natural gas resources in China are relatively scarce. By 2019, the proved reserves of oil and natural gas were 3.57 billion tons and 8.4 trillion cubic meters respectively, with reserve-production ratios of 18.7 and 47.3. They are lower than the world average values of 54.5 and 49.8 [1]. They have great dependence on import, as high as 70.6% and 42.2%.

The coal resource in China is relatively abundant. By 2019, the proven coal reserve was 141.60 billion tons, accounting for 13.2% of the world's total proven coal reserve. However, China has a large amount of coal mining, and the reserve-production ratio is only 36.8, far lower than the world average of 114.0 [2] (Fig. 1).

In terms of energy reserves, the reserve-production ratios of coal and oil are far lower than the world average, and the proved reserves are insufficient. Although the reserve-production ratio of natural gas is close to the world average, its resource is obviously insufficient, considering the growing domestic consumption demand. In the view of import dependence, the output and consumption of coal are close to each other and can basically achieve self-supply, while oil and natural gas have higher import dependences and higher risks of energy supply security.

Therefore, in order to improve the future energy supply and development trend, renewable energy should be first developed. The nuclear power should also be safely developed, and the consumption of fossil energy (e.g., coal, oil and natural gas) should be reduced as much as possible. On the other hand, oil and gas exploration should be enhanced to increase their storage and production. Their supply, storage and marketing system should be constructed to improve the energy supply and security assurance.

2.2 Primary Energy Consumption

In 2019, China's primary energy consumption reached 4.84 billion tce, accounting for 24.3% of the world's total primary energy consumption. Coal accounts for 57.6% in

Table 1. Carbon content per unit energy of each typical energy source

Energy	bituminous coal	oil	Natural gas	electricity
carbon content per unit energy (kg carbon/GJ)	26.2[a]	18.9[a]	15.3[a]	43.7[b]

Note: a source from "Guidelines for the preparation of provincial greenhouse gas inventories" (Development and Reform Office Climate 2011); b carbon emissions per kilowatt-hour are measured as 577.0 g CO2/kWh.

the primary energy consumption, much higher than the world average of 27.0%. The proportions of natural gas, oil and nuclear energy are 7.8%, 19.7% and 2.2% respectively, far lower than the world average of 24.2%, 33.1% and 6.4%. Hydropower accounts for 8.0%, higher than the world average of 4.3% while non-water renewable energy accounts for 4.7%, close to the world average of 5.0%.

In the primary energy consumption, non-water renewable energy, hydropower and nuclear energy basically produce no carbon emission in the process of energy utilization, which can be regarded as zero-carbon energy [3]. The utilization processes of coal, oil and natural gas produce carbon emission. However, the carbon emission of coal is much higher than those of oil and natural gas under the same calorific value. Then the coal is classified as high-carbon energy, while oil and natural gas are classified as low-carbon energy. The carbon content per unit energy of each typical energy source is estimated as shown in Table 1. The carbon content per unit energy of bituminous coal is 1.4 times that of gasoline and 1.7 times that of natural gas respectively.

The primary energy consumption structure determines the carbon emission of primary energy per unit energy. The high proportion of high-carbon energy and low proportion of low-carbon energy in China make the carbon emission per unit of primary energy reaches 69.3 kg CO_2/GJ, equivalent to 2.0 tons of CO_2 per ton standard coal, about 1.2 times of the world average level.

The total primary energy consumption and consumption structure determine the energy carbon emissions. In recent years, China's energy carbon emission is consistent with the primary energy consumption trend, as shown in Fig. 2. The primary energy consumption grows rapidly after China joined the world trade organization (WTO) in 2001, especially coal consumption. From 2014 to 2016, the total energy carbon emission reduced due to the increased use of low-carbon and zero-carbon energy.

2.3 Power Generation Structure

With the rapid development of clean energy, the electricity proportion in the terminal energy consumption is constantly increasing. The modern energy system with electricity as the center and grid as the platform is building up [4].

The total power generation in China has grown rapidly over the past two decades, reaching 7.5 trillion kwh in 2019, accounting for 27.8% of the world's total. Among them, coal power accounted for 64.7%, hydroelectric power accounted for 16.9%, non-water renewable power accounted for 9.8%, nuclear power accounted for 4.6% and gas power accounted for 3.2%. Compared with the world's electricity generation composition,

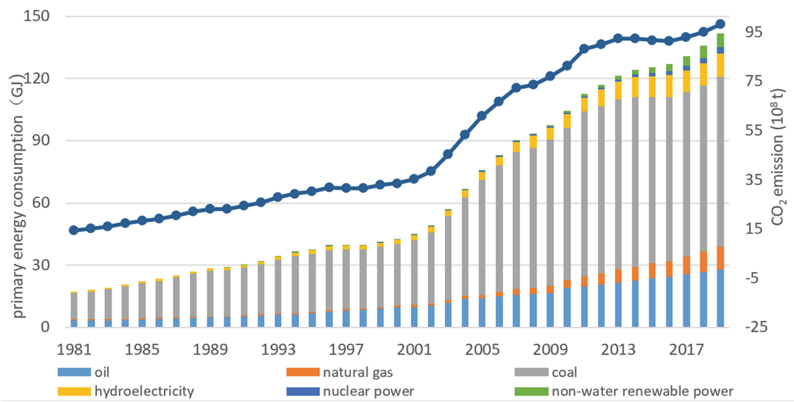

Fig. 2. Primary energy consumption and carbon emission of China

Table 2. Carbon emission of power generation (g CO_2/kwh)

method	gas power generation	Coal power generation	Comprehensive power generation (2019)	Thermal power generation (2019)
Energy	Natural gas	Bituminous coal		
Carbon emission	360.0[a]	857.0[b]	577.0[c]	838.0[c]

Note: Data a takes a gas generating unit in Zhejiang as an example. The average coal consumption of power generation in 2019 is 269.9 g/kWh; Data b Takes a 600000 kW supercritical coal-fired unit in Zhejiang as an example, the average coal consumption for power generation in 2019 is 287.7 g/kWh; Data c is from "Electric Power Industry Annual Development Report 2020". The data of a and b are greatly affected by the type of unit and fuel composition.

China's zero-carbon energy generation was 31.4%, lower than the world average of 36.4%. Its low-carbon energy generation was only 3.2%, far lower than the world average of 26.4%. Moreover, its high-carbon energy generation was far more than the world average.

Power generation composition determines the carbon emission from power generation. The carbon emissions of typical gas, coal and combined average power generation are shown in Table 2. The coal power is about 857.0 g CO_2/kWh, and the natural gas power is about 0.4 times that of coal power. Under the current power generation situation in China, the comprehensive average carbon emission is higher than those of typical natural gas power. However, the carbon emission will decrease steadily with the increase of zero-carbon energy generation in the future.

2.4 Energy Consumption Per Unit of GDP and Energy Carbon Emissions

In 2019, the GDP of our country reached 14.3 trillion US dollars, accounting for 16.3% of the world's total. However, its primary energy consumption and energy carbon emission reached 4.84 billion Tecs and 9.83 billion Tecs respectively, accounting for 24.3% and 28.8% of the world's total, far higher than those of other countries. Meanwhile, the energy consumption and carbon emission per unit of GDP are 3.4 tons of standard coal per 10,000 US dollars and 6.9 tons of carbon dioxide per 10,000 US dollars, far higher than the world average levels. Our energy consumption per unit of GDP and energy carbon emission can be greatly improved in the future.

3 Comparisons with Typical Carbon Peak Regions

In China, carbon peak refers to the peak of CO_2 emissions, while in some other countries, it refers to the peak of greenhouse gas emissions [5]. Four typical regions (the United States, South Korea, Japan and the European Union) have reached a carbon peak according to the BP Statistical Yearbook of World Energy 2020. The total primary energy consumption of the United States and South Korea reached the maximum in 2007 and 2018 respectively, and their CO_2 emissions also peaked. Subsequently, with the overall decline of total primary energy consumption and the increase in the proportion of zero-carbon energy, their total CO_2 emissions gradually decreased. While Japan's total primary energy consumption peaked in 2005, its CO_2 emission reached its peak between 2008 and 2013. In 2011, Japan's CO_2 emission fluctuated upward, which was mainly affected by the Fukushima nuclear accident. The EU's total energy consumption peaked in 2006, but its CO_2 emission peaked before 1990 and greatly declined in recent years, mainly due to the significant increase in zero-carbon energy consumption.

Generally, the total energy consumptions of four areas (the United States, South Korea, Japan and the EU) usually get to the peak and then the CO2 emissions peak. In recent years, the United States mainly reduces the carbon emission by natural gas replacing coal and increased renewable energy. South Korea mainly controls the total primary energy consumption and uses renewable energy to reduce carbon emission. Besides, the EU has achieved a gradual reduction in its total carbon emission by developing renewable energy sources. Japan's renewable resources are limited and its total carbon emission is greatly affected by the Fukushima accident.

For now, the total primary energy consumption in our country is still increasing rapidly, and the total carbon emissions are still on the rise [6]. However, the gradual optimization of the primary energy consumption structure has eased the trend. To achieve the carbon peak, China will not only vigorously promote the development and utilization of zero-carbon energy, but also pay more attention to energy conservation and efficiency, optimize the industrial structure, and control the total amount of primary energy consumption.

4 Conclusion

This study investigates the current primary energy supply and consumption. The power generation structure and carbon emission are evaluated. Moreover, comparisons with typical carbon peak regions are conducted. The conductions and suggestions are as follows.

The reserve-production ratios of coal and oil are far lower than the world average, and the proved reserves are insufficient. The high proportion of high-carbon energy and low proportion of low-carbon energy in China make the carbon emission about 1.2 times of the world average level. The energy consumption and carbon emission per unit of GDP are far higher than the world average levels.

For the energy supply, zero-carbon energy should be first emphasized. The diversified utilizations of solar energy and wind power need to be promoted. The nuclear power should be safely developed while biomass, geothermal and marine energy should be properly developed. Moreover, the low-carbon energy needs to be moderately developed. The exploration and development of oil and gas should be enhanced and the construction of natural gas adjusting peak power stations is encouraged. Finally, the total high-carbon energy consumption should be controlled.

For the energy consumption, it is necessary to further adjust the industrial structure, control the development of energy-intensive industries, adhere to the policy of energy conservation optimization, and curb unreasonable consumption. It is also essential to improve the energy efficiency and terminal electrification rate.

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