Measuring China’s Energy and Power Development Based on Mathematical Models

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Abstract. From the spontaneous use of natural energy by humans to the conscious use of fossil energy after the industrial revolution and the energy use that is currently entering the stage of intelligence, energy plays an important role in promoting and promoting human progress and social development. Simultaneously, due to the massive development of fossil energy, serious ecological damage has been caused, and it has threatened human survival. Clean energy and low carbon have become the development strategies of all countries in the world. Based on the advantages of resources, China has formed a coal-based energy structure. While ensuring China's social and economic development, energy has also produced serious pollution. In particular, carbon emissions have ranked first in the world for many years, accounting for 28% of the global total in 2018. The pressure to reduce emissions is huge, and energy transformation is imminent. This paper analyzes China's energy status and challenges, predicts China's energy development trends in 2030 based on numerical values, and quantifies the development space of various energy sources.

1. Introduction

When Robert C. Allen studied why the first industrial revolution broke out in the UK, from an economic point of view, the British high-income system was one of the main reasons for the promotion, and the energy industry has made tremendous contributions. Because at that time, coal had replaced wood as an emerging energy source, and the UK had the cheapest coal resources in the world at that time, which became an important foundation for the steam engine industry. Therefore, machine industrialization has significant economic benefits compared to expensive labor costs. This directly promoted the outbreak of the industrial revolution [1]. From this perspective and the second industrial revolution driven by electricity, energy plays an important role in promoting social development and change. In recent years, research on energy structure adjustment at home and abroad has emerged in an endless stream. Most of them are aimed at the necessity, urgency and feasibility of large-scale development of renewable energy, and basically draw more positive conclusions. Focusing on sustainable development, Passa Dasgupta has demonstrated from the perspective of economics and concluded that considering the impact of ecology on human development, the current $9 consumption can be abandoned for the next dollar [2]. That is to say, from an economic point of view, human beings should take measures against environmental pollution and ecological damage as soon as possible, and energy structure transformation is an important content. Undoubtedly, the direction of energy transformation is to accelerate the development of low-carbon and renewable energy. This paper quantifies the development trend of various types of energy in 2030 based on the specific quantity of energy development in China.
2. China's energy development status

2.1. Current status of energy development
In 2018, China's primary energy consumption totaled 4.64 billion tons of standard coal (tce), which consumed 23.6% of the total global energy. Non-fossil energy accounts for 14.7%; from a per capita perspective, China is 96.9 GJ in 2018, which is 1.28 times the world average, but only 32.9% of the US. Carbon emissions reached 9.429 billion tons, accounting for 27.8% of the world [3].

2.2. Current status of power development
In 2018, China's power installed capacity is close to 1.9 billion kW, including 1.14 billion kW of thermal power; 350 million kW of hydropower; 180 million kW of wind power; 175 million kW of solar energy; and 44.66 million kW of nuclear power. In 2018, the total power generation is 699.3 billion kWh, of which thermal power is 493.1 billion kWh; hydropower is 123.29 billion kWh; nuclear power is 294.4 billion kWh; wind power is 366 billion kWh; solar energy is 177.5 billion kWh.

3. China's energy industry challenges

3.1. Resource constraints are increasingly prominent
China's coal, natural gas and oil reserves are only 38, 37.6 and 18.7 years, respectively, the overall dependence on energy is 21%, oil is 70%, natural gas is 43%, coal is 6% [4]. The pressure of emission reduction is huge, the development of coal power is limited, and the total hydropower is 500 million kW. The Fukushima accident affects the development of nuclear power. Renewable energy is difficult to become the main force in the short term. The rigid demand for industrialization and electrification continues to increase, and the gap in total energy demand will further increase. Resource constraints have become increasingly prominent.

3.2. Increased ecological environment constraints
From the perspective of carbon emissions, large-scale fossil energy consumption has led to a large amount of greenhouse gas emissions since industrialization. The concentration of carbon dioxide has increased from 280ppm before the industrial revolution to the current 380ppm, which has increased the global average temperature by 0.74°C in the past 100 years. More than 70% of greenhouse gas emissions are attributed to fossil fuel combustion. Of course, China is the world's largest carbon emitter. Since 2000, China's emissions have increased by about 45% of the total global increase. In 2009, the Chinese government proposed the emission reduction target for 2020, but it is estimated that the installed capacity of nuclear power will be 80 million kW at that time. However, due to the serious impact of the Fukushima nuclear accident, China’s nuclear power has entered a wait-and-see period. The current installed capacity is only 4466. Ten thousand kW is only half of the target, which is bound to cause huge pressure on China's emission reduction targets. At the same time, fossil energy is also in the process of internal trade. In recent years, China's coal control has achieved stage results, but carbon emissions have increased in 2017 and 2018, mainly because the growth of oil consumption offset the positive effect of coal reduction. In 2018, oil accounted for 18% of consumption, and the intensity of consumption increased year by year. If not controlled, the greenhouse gas emissions of oil consumption and the impact on air and water pollution will become increasingly serious.

3.3. Technological innovation needs to be improved
For a long time, the problem of China's energy and energy industry is not strong. The main performance is weak basic research, backward technology at the cutting edge, and some key core technologies, equipment and materials rely on imports for a long time, and the original innovation capability is insufficient. In 2018, China's energy consumption per unit of GDP is 1.49 times that of the world, and it is 2.14 times that of the United States. China consumes 23.6% of the world's energy and produces 15.9% of the world's GDP. The overall energy efficiency is low.
4. Estimation of the number of energy development in China in 2030

4.1. Total amount
From 2005 to 2013, China's GDP grew at an average annual rate of 10.2%, energy consumption elasticity was 0.59, GDP annual growth rate was 6.9% in 2013-2018, and energy consumption elasticity was 0.32. By examining the empirical data for the past 30 years, the average annual energy consumption elasticity is 2.9. According to the process of gradually reducing GDP growth from 6.5% to 3-5% in the next 10 years, and taking into account factors such as lower energy consumption, the growth rate of energy consumption will decrease year by year on the basis of 2018, decreasing by 0.15 from the current 3.3%. The percentage increase will be 1.5% by 2030.

4.2. Oil
"China's total oil consumption peak and control program research" is expected to reach 720 million tons of oil consumption in China by 2025, and 600 million tons in 2035. Investigate the proportion of oil in total consumption in the past 10 years, from 21.50% in 2009 to 19.75% in 2018, with an average annual reduction of 0.06%. On this basis, adjust the oil coefficient by 4.5 times to determine the oil to 2030. In the proportion of primary energy, this paper estimates that oil consumption will reach a peak of 713 million tons of oil equivalent by 2029.

4.3. Natural gas
Investigate the proportion of natural gas in total consumption in the past 10 years, from 2% in 2009 to 6.5% in 2018, with an average annual growth rate of 0.15%. In recent years, the growth rate of natural gas has accelerated, and the macro target is 2030. In the year, natural gas accounted for 15% of the total consumption, so it was adjusted by 4.5 times the intensity coefficient to determine the proportion of natural gas in primary energy by 2030, with an average annual growth rate of 7%.

4.4. Coal
As far as coal is concerned, China's current consumption is about 4 billion tons. By the end of 2018, the country's fully-developed coal mine capacity is 3.5 billion tons/year, and the coal mine capacity under construction is 1.03 billion tons/year. Considering the situation of small construction and construction, it is estimated that China Coal production capacity will be 4.8 billion tons / year, and most institutions expect China's coal consumption peak to be 4.2-4.3 billion tons / year, which is about 7% more than the current total consumption. Investigate the proportion of coal in the past 10 years, from 70.6% in 2009 to 59% in 2018, with an average annual decrease of 0.37%.

4.5. Non-fossil energy
Non-fossil energy sources include hydropower, nuclear and wind power, and solar energy. Looking at the development trend in the past 10 years, the proportion of energy consumption has increased from 5.9% in 2009 to 14.7%, with an average annual growth rate of 0.28%. In recent years, renewable energy has developed rapidly, taking into account non-fossil energy in 2030. In the macro target of 20% of total energy consumption, the coefficient is adjusted by 2.8, and it is predicted that non-fossil energy accounts for 24.4% in 2030.

4.6. Carbon emission
For the calculation of carbon emission using a simple model, it is roughly calculated according to the corresponding relationship between the growth ratio of fossil energy and carbon emissions. Use the 2010 data and the 2018 data to average. Carbon emissions increased by 16.3% from 2010 to 2018, while fossil energy increased by 21%. Based on the increase in carbon emissions, the growth rate of fossil energy was 77.3%. In 2030, fossil energy increased by 17% compared with 2018, relative carbon. The emission increase is 13%, and the calculated carbon emissions will reach 10.67 billion tons.
4.7. Forecast of energy development

According to the model, by 2030, China's total energy consumption will be 4.273 million tons of oil equivalent (toe), or 6.11 billion tons of standard coal, an increase of 35%, of which fossil energy will increase by 17% and non-fossil energy by 116%. Table 1 shows.

| Table 1. China's energy development forecast results | Million tons of oil equivalent |
|---------------------------------------------------|-------------------------------|
| **years** | Total amount | oil | natural gas | coal | Non-fossil |
| 2018 | 3243.6 | 640 | 214.5 | 1907 | 482.1 |
| Percentage in 2018 | 100% | 19.73% | 6.61% | 58.79% | 14.86% |
| 2030 | 4273.1 | 712.9 | 621.3 | 1898.3 | 1042.7 |
| Percentage in 2030 | 100% | 16.68% | 14.54% | 44.42% | 24.40% |
| Compared to the growth rate of 2018 | 35.2% | 11.39% | 189.63% | -0.46% | 116.28% |

5. Estimation of the number of power development in China in 2030

5.1. Non-fossil energy generation forecast

China's total power generation in 2018 is 699.4 billion kWh. Considering that 4.4 TWh can be generated in a modern power plant with a capacity of 1 million toe, the proportion of power generation to the total primary energy consumption is 49%, of which non-fossil energy the power generation is 200.7 billion kWh. The total non-fossil energy power generation in 2030 is 457.8 billion kWh. The calculation is shown in Table 2.

| Table 2. Prediction results of non-fossil energy generation | Billion kWh |
|----------------------------------------------------------|-------------|
| Power generation form | Historical average annual growth rate | 2018Year | 2030Year | Forecast annual growth factor | Increase |
| Total amount | 9.3% | 2121 | 45878 | 4.84% | 76.35% |
| Hydropower | 10.7% | 1232 | 17578.2 | 3.00% | 42.58% |
| Nuclear | 29.6% | 2944 | 8614.7 | 9.4% | 192.6% |
| Wind | 24.3% | 3660 | 13255.8 | 11.32% | 262.18% |
| Solar energy | 87.4% | 1775 | 6428.7 | 11.32% | 262.18% |

5.2. Forecast total power generation and thermal power generation in 2030

Analysis of the relationship between China's total energy consumption and power generation, according to the trend of a certain coefficient, combined with the above analysis of the total energy consumption to predict power generation. In the past 10 years, the proportion of China's power generation to total energy consumption has increased by 1.4%. The inertia prediction can be made according to this coefficient. As a result, by 2030, power generation will account for 64% of total energy consumption. In the case of power generation, thermal power generation requires a 50% growth rate, which is inconsistent with the current overall situation, that is, the strength factor needs to be reduced. Comprehensive coal production and sales in China is estimated to be thermal power development, which is about 7% higher than the current total consumption. Therefore, thermal power is also increased by a small percentage, with an average annual growth rate of 0.5%. By 2030, thermal
power generation will be 522.6 billion kWh, an increase 6%, the corresponding total power generation is 981.4 billion kWh. It can be seen that by 2030, the total power generation accounted for 52% of energy consumption, with an average annual growth rate of 0.3%, much lower than the average increase of 1.4% in the previous decade. Compared with 64%, the gap is 2 trillion kWh, which is equivalent to the annual renewable energy generation in 2018.

It can be seen that renewable energy still has some shortcomings in meeting power growth. It can also be seen that even if the total power generation reaches about 10 trillion kWh, the per capita electricity consumption reaches 7 thousand kWh, which is still only half of the current per capita electricity consumption level in the United States. As shown in Table 3.

| Table 3. Power generation measurement model | Billion kWh |
|-------------------------------------------|-------------|
| 2018Year | 2018 ratio | 2030Year | 2030 ratio | Increment | Annual increase |
| Total amount | 69940 | 100.00% | 98144.6 | 100.00% | 40.33% | 2.86% |
| Hydropower | 12329 | 17.63% | 17578.2 | 17.91% | 42.58% | 3.00% |
| Thermal power | 49231 | 70.39% | 52267.5 | 53.26% | 6.17% | 0.50% |
| Nuclear | 2944 | 4.21% | 8614.7 | 8.78% | 192.62% | 9.36% |
| Wind | 3660 | 5.23% | 13255.8 | 13.51% | 262.18% | 11.32% |
| Solar energy | 1775 | 2.54% | 6428.7 | 6.55% | 262.18% | 11.32% |

5.3. Installed capacity forecast

The installed capacity is mainly based on different types of power generation characteristics and utilization efficiency, and the power generation capacity is reversed. In 2018, the utilization hours of nuclear power equipment were 7184 hours; the thermal power was 4477 hours; the hydropower was 3613 hours; the wind power utilization hours were 2095 hours; and the solar energy was 1212 hours. According to the power generation amount, the equipment utilization rate is considered to push back the installed capacity.

6. Conclusion

Based on the numerical basis, this paper predicts China's energy development and power development trends. It can be seen that the incremental growth of renewable energy sources is more than 10% per year. Even so, energy and especially power demand cannot be met. Moreover, the current large-scale access to wind power and solar power into the power grid has some obstacles in the absence of mature industries such as energy storage. From the perspective of economy, although the economics of wind power and solar energy projects have basically reached the conditions of affordable Internet access, if the whole system is considered to be equipped with energy storage, system additional backup, peaking unit cost, etc., the overall economic efficiency of the system. It is still too early to reach parity online. As for carbon emissions, China is still facing tremendous pressure, and the path of decarbonization is difficult.

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