Numerical and Model Analysis of the Development Trend of Renewable Energy in China

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Abstract. At present, the clean and low-carbon energy has become the development trend of all countries. Especially in China, the coal based energy structure not only guarantees the social and economic development of the country, but also causes serious ecological damage, so the energy transformation is imminent. The development of renewable energy is an important choice for energy transformation. This paper uses mathematical model to calculate the overall development trend of China's energy, and then uses diamond model to analyze the macro environment for renewable energy industry, to clarify the basis and challenges for renewable energy industry, so as to provide reference for the formulation of macro policies and industrial.

Introduction

Diamond model through four factors of industry, namely production factors, demand conditions, supporting industries and peer competition, in addition, there are opportunities and government two factors for comprehensive analysis. Using diamond model to analyze renewable energy industry is to analyze the production capacity, market demand, competition with traditional energy and advantages and disadvantages of policy. The diamond model is shown in Figure 1.

Figure 1. Diamond model.

Overall Situation of China's Energy Development

Overall Situation of Energy Structure

In 2018, China's primary energy consumption totaled 4.64 billion standard coal (tce) with electric power accounting for 25.5% of the terminal energy consumption[11]. Non fossil energy accounts for
14.7%; renewable energy accounts for 143.5 million toe, a year-on-year increase of 28.8%, 4.4% of total consumption, and 25.6% of global consumption.

In terms of total amount, China consumed 23.6% of global energy. In terms of per capita, China consumed 96.9 GJ which is 1.28 times the world. In terms of external dependence, the total amount of energy imports reached 970 million tce, with an overall external dependence of 21%, including 70% for oil, 43% for natural gas and 6% for coal. In terms of carbon emissions, 9.429 billion tons, accounting for 27.8% of the total 33.89 billion tons [2][3].

Energy Development Calculation

Mathematical Model and Parameters

Total Energy Consumption. According to the predicted energy consumption intensity coefficient of macro population and GDP, determine the proportion coefficient of energy demand growth, and calculate the total primary energy consumption:

\[ r = \frac{1}{n} \sum_{i=1}^{n} r_i \]  

(1)

Based on the analysis of China's GDP and energy growth rate in the past 30 years, this paper takes \( r = 2.9 \)

Proportion of Energy Sources. Calculate the annual growth value of the proportion of oil, coal, natural gas and non fossil energy in the primary energy since 1978, especially in the past 10 years, get the trend, and adjust the corresponding coefficient according to the total control target of natural gas, coal and non fossil energy. For example:

\[ O = \rho_o \frac{1}{n} \sum_{i=1}^{n} O_i \]  

(2)

\( O, C, G, R \) are the growth rate of oil, coal, natural gas and renewable energy in the proportion of primary energy. \( \rho_o, \rho_c, \rho_g, \) and \( \rho_r \) are the corresponding intensity coefficients. According to the development trend and total amount control of various energy sources in recent years, they are mainly the macro objectives of carbon emission reaching the peak by 2030, coal consumption will reach the peak in 2024, oil will reach the peak in 2029, and natural gas will account for 15% of the total primary energy by 2030. The intensity coefficients are 4.5, 4.5, 3.2 and 2.8 respectively.

Classification Calculation. According to the proportion of energy in each year, the consumption is calculated by the product of the total primary energy in that year. For example:

\[ A_{O(i)} = R_{O(i-1)} \times (1 + O) \times A_i \]  

(3)

\( A_i \) are the consumption of oil, coal, natural gas and renewable energy in the i year; The proportion of oil, coal, natural gas and renewable energy in the primary energy, as shown in Table 1.

| Year | Oil  | Gas  | Coal | Non fossil |
|------|------|------|------|------------|
|      | \( R_O \) | \( R_G \) | \( R_C \) | \( R_R \) |
| 2018 | 19.73% | 6.61% | 58.79% | 14.86% |
| 2030 | 16.68% | 14.54% | 44.42% | 24.40% |

Calculation Results

Under the constraint of carbon emission, prediction results of China's energy development as shown in Table 2. According to the calculation, if the domestic supply is assumed to remain unchanged, the dependence on foreign oil will increase slightly from 70% to 73% and the dependence on foreign gas...
will increase from 43% to 80%. This will be an important challenge to energy security, and in this mode, China's carbon emissions will reach 10.5 billion tons. Enough to see the urgency of developing non fossil energy, not only to meet the incremental requirements, but also to focus on the replacement of stock in the future.

Table 2. Prediction results of China's energy development (million toe).

| Year | Total | Oil  | Gas | Coal | Non fossil |
|------|-------|------|-----|------|------------|
| 2018 | 3243.6| 640  | 214.5| 1907 | 482.1      |
| 2030 | 4273.1| 712.9| 621.3| 1898.3| 1042.7     |

Diamond Model Analysis of Renewable Energy Development

Analysis of Production Factors

The production factors of renewable energy are mainly resource reserves. According to the data of wind farm industry research report of Sansheng consulting from 2019 to 2024, the exploitable onshore wind energy is 253 million kW, and the offshore reserves are 750 million kW totaling 1 billion kW. The theoretical reserve of land solar energy resources in China is 1.86 trillion kW. From the above data, we can see that the reserves of renewable energy in China are enough to meet the development needs, and with the technological progress, the reserves of exploitable technological resources will be further improved.

Demand Factors

From the perspective of China's urgent needs, the demand for renewable energy is very urgent, and the increment is also significant. According to the above analysis, the annual growth rate of wind and solar power generation demand in the next decade will exceed 15% [4].

Looking forward to 2050, considering that the coal consumption will further decline, the hydropower development capacity is limited, and it will basically reach the highest limit by 2030, other renewable energy will not use the possibility of large capacity development in a short time. It can be seen from this that the demand for wind power and solar power in China and even in the world will maintain a high-intensity growth.

Related and Supporting Industries

Wind Power. In recent years, with the support of industrial policies and large-scale project implementation, China's wind power related equipment manufacturing has been at the forefront of the world. In the process of development, the industry concentration has been significantly improved, and the technical level, localization rate and global competitiveness have been greatly improved. In 2016, the capacity of 20 wind turbine manufacturers in China was 173 million kW. In 2016, 2017 and 2018, the annual capacity of wind power is 20.24 million kW, 19.52 million kW and 20.26 million kW. It can be simply inferred that in the next 10 years, the annual construction capacity of wind power is about 25 million kW-35 million kW.

Solar Power Generation. At present, China has established a whole industry chain with international competitiveness in photovoltaic power generation, breaking through the international technical blockade such as polysilicon production, and the output is far away from the first place in the world. In terms of capacity, “The capacity statistics of global PV module enterprises in 2019” has made statistics on the capacity of 88 PV module manufacturers in China, with the module capacity of 178 million kW per year. In 2016, 2017 and 2018, the new capacity of solar power generation was 34.13 million kW, 53.06 million kW and 44.21 million kW respectively. It can also be simply inferred that in the next 10 years, the annual construction capacity of solar power will be about 55 million kW-65 million kW.

Energy Storage Supporting Industry. The inherent characteristics of wind power and solar power generation are instability and intermittence, which is also the main bottleneck hindering the
rapid development of the industry. The direct way to solve this problem is to set up large capacity energy storage devices in the power system, so as to increase the number of wind and solar power access, reduce the system reserve capacity. In recent years, chemical batteries, such as liquid flow batteries and lithium batteries, have developed rapidly. Hydrogen energy has also become an important role in the energy storage market. With the rapid development at home and abroad, hydrogen can be produced by using the low-level electricity of renewable energy. Hydrogen energy can generate electricity, mix natural gas, hydrogen energy transportation, etc. It is expected that hydrogen energy will lead the energy storage in 2030. We will promote the commercialization and industrialization of the region and support the large-scale development of renewable energy. By 2020 and 2030, the extensive promotion of chemical battery energy storage, compressed air energy storage and hydrogen energy will be realized. At that time, the energy storage industry is likely to fully guarantee the large-scale development of wind power and solar power generation.

But, it is also seen that the energy storage industry is still in its infancy, especially the technological innovation and economy still need to be improved. For example, in the United States, all practical batteries plus the batteries of 1 million electric vehicles can only provide 2 hours of electricity for the United States. And even Tesla, the world's largest battery factory, can only store three minutes of electricity a year, equivalent to the annual electricity demand of the United States, and it will take 1000 years to produce 2 days of storage. From a cost perspective, the cost of storing a barrel of oil is less than US $0.50, but the cost of storing equivalent energy in a battery is as high as US $200, which is 400 times the difference.

Power Grid Transmission Industry Support. Solar power generation and wind power have similar volatility, but the regularity of solar power is slightly stronger than wind power. Based on the analysis of wind power access system, it can be seen that most of China's wind power resources are at the end of the power grid in the three north region, while users are concentrated in the load center in the East. In the existing power grid transmission mode, in order to ensure the system security, large-scale access to unstable power supply is a major challenge. But under the idea of Global Energy Internet, the whole network is interconnected and intelligent dispatching can guarantee the large-scale renewable energy to the greatest extent.

Enterprise Strategy, Horizontal Competition Factors

In terms of competition with traditional energy, China's power demand is strong. There is no fierce competition between the development of renewable energy and the development of traditional energy, but there is a large space for substitution. At present, China's power system is transforming from a highly planned power generation form to a market-oriented one, from power distribution to selection based on economic benefits. Economy is the decisive factor of power generation. The Rocky Mountain Institute expects that by 2025, the economy of wind power and solar energy will be fully competitive over coal. Many institutions at home and abroad have predicted the economy of new energy and reached positive conclusions. In fact, by the end of 2018, in Inner Mongolia, Qinghai and other regions with rich scenery resources, the cost of wind power and solar energy has dropped below 0.3 yuan, which is lower than or close to the cost of local coal power. With the rising pressure of fossil fuel price, the competitiveness of renewable energy will continue to improve.

However, it should also be noted that the above economic evaluation of renewable energy is relatively radical and optimistic, only considering the investment and return of the project itself, and then calculating the electricity price. However, in terms of the whole power system, a large number of renewable energy accesses are bound to require supporting thermal power peak shaving, or later energy storage, grid capacity reserve and so on. These costs are quite considerable, that is to say, the total cost is still high, and so it will take a long time to reach the comprehensive parity of the system.

Opportunity

The restriction of ecological environment and the upgrading of macro industrial structure are the fundamental constraints for the development of energy industry. For the development of renewable
energy, at present and in the period of 2030 predicted in this paper, the biggest opportunity lies in the adjustment of industrial structure and supply side reform of the whole society at the national macro level. From extensive economic development to the opportunity to improve the quality of development; from focusing only on economic growth to the opportunity to attach equal importance to economic and ecological environmental protection; from backward production capacity and industrial level to the opportunity to make progress in scientific and technological innovation and industrial level into the world's advanced ranks.

**Government**

In order to speed up the healthy development of renewable energy, our government has issued a large number of documents and regulations on planning, industrial guidance, preferential policies and other aspects, in order to speed up industrial development and scientific development. In terms of supporting facilities, a number of new extra high voltage transmission channels have been planned to increase the power transmission of new energy. At the same time, according to the actual development, scientific assessment, timely restriction on the development of photovoltaic and wind power, guidance on the healthy development of the industry, so that the renewable energy industry will gradually develop from focusing on scale to focusing on efficiency, from focusing on speed to focusing on quality. In the future, with the deepening of the reform of the electricity market, further ensuring the development of clean energy and improving the overall efficiency of the system.

**Summary**

According to the analysis of this paper, renewable energy is the main direction of China's energy structure adjustment. From the study of several dimensions of diamond model, we can see that the macro basis of China's renewable energy development is good, which is conducive to the scientific, healthy and rapid development of the industry. But at the same time, we can see that the development of renewable energy is still insufficient in the aspects of system comprehensiveness and market mechanism. In general, the focus of renewable energy is consumption. Energy policy should focus on three dimensions: reliable supply, reasonable price and environmental friendliness to further promote the healthy development of renewable energy.

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