Study on the Regional High Quality Development of Energy

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Abstract. Clean and low-carbon are overall goals of high quality development of energy. Regional development approaches should be chosen according to local situations. Taking Jiangsu Province as an example, this paper focuses on the regional high quality development of energy. The development status and characteristics of energy in Jiangsu are analysed. The amount of energy consumption is large. Coal is the dominating source of energy. Energy cleanliness is already high. A large amount of energy is moving in from other provinces or countries. According to these characteristics, some suggestions on the regional high quality development of energy in Jiangsu are given. Take multiple measures simultaneously to achieve low-carbon energy. Encourage energy cascade utilization to achieve high-efficiency energy. Develop comprehensive energy service to achieve cost-effective energy. The results are also helpful for making energy development plans in other places.

1. Introduction

Energy is an important material foundation for human living and development. For a long time in the past, with the rapid increasing of energy demands and carbon emissions, here comes the carbon emissions and air pollution problems. In this situation, global energy development is undergoing a transformation. Clean and low-carbon energy is a new trend, which is also an ultimate goal of high-quality energy development. Every province should choose the appropriate method according to the characteristics of energy using, supply conditions, and the positions in the national energy flows. Jiangsu Province is one of the most economically developed provinces in China. It should take the lead in achieving high-quality energy development. Jiangsu Province has a large volume of industry, the proportion of heavy chemical industries is high, the energy resources endowment are poor, and is at the end in the country’s energy flow. Based on the actual situation of Jiangsu Province, this paper studies on the regional high quality development of energy. The results are also helpful for other provinces.

2. Status and characteristics of the energy development in Jiangsu Province

2.1. The amount of energy consumption is large

Jiangsu has a large energy consumption volume. In 2017, the energy consumption in Jiangsu was 314.3 million tons of coal equivalent[1], which increases 1.2% compared to 2016[2]. The total energy consumption ranked third in China only after Shandong and Guangdong. In 2017, Jiangsu's coal consumption was 266.2 million tons, which ranked the fifth in China; coke consumption was 40.71 million tons, which ranked the second in China; crude oil consumption was 38.66 million tons, which ranked the fourth in China; refined oil (gasoline, kerosene, and diesel) consumption was 20,500 tons,
which ranked the fourth in China; natural gas consumption was 23.8 billion cubic meters, which ranked the first in China; total electricity consumption was 580.8 billion kilowatt-hours[3], which ranked the second in China.

Energy status reflect the economic status. In 2018, Jiangsu’s GDP was 929.5 billion yuan[4], which ranked the second in China only after Guangdong Province. The added value of the secondary industry was 4,124.9 billion yuan[4], which ranked the first in China. Energy serves for the economy. Under the great uncertainties of the international economic environment, the importance of Jiangsu’s healthy developing economy is obviously there for the whole country’s economy to operate within a reasonable range. The high-quality development of energy should be helpful to the entity economy, therefore, it would be inappropriate to increase energy price.

2.2. Coal is the dominating source of energy
According to the primary energy structure of Jiangsu in 2017, coal consumption accounted for about 66%, oil consumption accounted for about 15%, natural gas consumption accounted for about 10%, and non-fossil energy consumption accounted for about 10%. The comparisons of primary energy consumption structures of Jiangsu, China, Zhejiang and Guangdong are shown in Figure 1. It is obvious that the proportion of coal consumption in Jiangsu is relatively high, which is about 6 percentage points higher than the national average level, and it is also different from Zhejiang and Guangdong, where there are similar industry developing level.

The energy consumption structure is relevant to the industrial structure. Jiangsu has a large amount of heavy industry. In 2018, the production of pig iron was 67.96 million tons, which ranked the second in China[4]; the production of cement was 14.17 million tons, which ranked the second in China[4]; the generation of coal-fired power was 371.1 billion kilowatt hours, ranking the third in China[5]. These are the main reasons for the high proportion of coal consumption. It is difficult to change this regional industrial structure in a short time. Therefore, it is necessary to adapt to the current situation of Jiangsu's high proportion of energy consumption coal, rather than force changing it.

2.3. Energy cleanliness is already high
According to the estimation, in 2018, approximately 71% of the consumed coal in Jiangsu was used by the power generation industry (including coal for heat supply in cogeneration), 15% was used for coking, and 12% was directly consumed by industry (used in iron blast furnaces, cement kilns, etc., which are difficult to be replaced by other fuels), and only about 1% was used for scattered burning and small boilers. Non-fossil energy does not generate emissions. Natural gas combustion generates few pollutants. Pollutant emissions from coal-fired power generation have reached a level similar to that of gas-fired power generation[6]. Therefore, we define the ratio of the total sum of natural gas, non-fossil energy, and coal used in power generation (including cogeneration) to the total energy consumption as the energy clean utilization rate.
\[ \alpha = \left[ c_{\text{gas}} \cdot k_{\text{gas}} + c_{\text{non-fossil}} + c_{\text{elec-coal}} \cdot b \right] / c_{\text{total}} \times 100\% \]  
\hspace{1cm} (1)

Where \( \alpha \) is the energy clean utilization rate, dimensionless; \( c_{\text{gas}} \) is the natural gas consumption, 100 million m\(^3\); \( k_{\text{gas}} \) is the natural gas discount coefficient, = 133,000 tce / 100 million m\(^3\); \( c_{\text{non-fossil}} \) is non-fossil energy consumption (Fossil energy production and net transfer of non-fossil power), 10,000 tce; \( c_{\text{elec-coal}} \) is coal power consumption (including local coal power generation and net moving in of coal power), 100 million kWh; \( b \) is unit coal consumption for power generation, gce / kWh; \( c_{\text{total}} \) is the total energy consumption, 10,000 tce.

According to the estimation, in 2018, the energy clean utilization rate was about 66% in Jiangsu, which was 11 percentage points higher than the national average level. Energy consumption has reached a high level in terms of cleanliness, and the next step of development should focus on low carbon emission.

2.4. A large amount of energy is moving in

The energy resource endowment in Jiangsu Province is poor. Local energy production is quite low, and at the same time, the energy demand is high, which result in a large number of external energy (including imports from other countries and moving in from other provinces). In 2017, the primary energy production in Jiangsu is about 26.56 million tons of coal equivalent, which could only meet 8% of local consumption, of which 12.78 million tons were mined raw coal, which could only meet about 5% of local consumption. In terms of secondary energy, Jiangsu generated 488.5 billion kWh of electricity, and received 92.3 billion kWh of electricity from other provinces. A large amount of external energy results in high-energy costs and more uncontrollable factors (such as natural gas shortages in winter). Therefore, for the high-quality energy development, Jiangsu should pay more attention to energy conservation and full utilization.

3. Thoughts on high-quality energy development in Jiangsu Province

3.1. Take multiple measures simultaneously to achieve low-carbon energy

Low-carbon development is a major trend in global energy development, and is an important direction for high-quality energy development. According to the energy development situation of the whole country and Jiangsu Province, it is suitable to take the development path that places equal emphasis on non-fossil and natural gas, and equal emphasis on both inside and outside the province.

Non-fossil energy endowments are limited in Jiangsu. The terrain of Jiangsu Province is flat and there are no large-scale conventional hydropower resources. Tianwan site is the unique nuclear power plant in Jiangsu's coastal. Wind and solar resources in Jiangsu are ordinary, and land resources are precious at present. Large-scale development of wind and solar power is difficult, as they are under pressure from land usage and ecological protection factors. According to calculations, if only take local primary electricity, non-electricity non-fossils, and established external calls into account, without consideration of new external electricity, the proportion of non-fossil energy consumption in Jiangsu in 2025 will be about 17%, which is lower than the national average in 2025 (about 18%). Therefore, to further increase the proportion of non-fossil energy consumption, Jiangsu should focus on increasing the amount of non-fossil energy imported from the other provinces. Currently, there are three main sources of possible non-fossil power: Southwest hydropower, Fujian nuclear power, and Northwest wind and solar power. No matter which path is chosen, it will involve inter-provincial power transmission, which needs to be combined with the national grid development plan.

Natural gas is a high-quality energy source and its price is relatively high. To expand natural gas consumption, we must identify the main areas where natural gas could replaces coal. According to estimates, about 70% of natural gas consumption in Jiangsu was used for power generation and heating in 2018, about 10% was used for residential consumption and the tertiary industry, and about 20% was used for manufacturing (glass, ceramics, etc.) and other fields, as shown in Figure 2. Natural gas must give priority to people's livelihood, and then followed by industrial production. Although the gas consumption of residential consumption, tertiary industry, and manufacturing, the gas consumption will
all increase in the future. Since it accounts for a relatively small portion in the consumption structure, it is expected that the future increase will be limited. Power generation and heating are the most suitable areas for natural gas to replace coal. Gas-fired cogeneration will be the main growth point for large-scale development of natural gas consumption.

![Figure 2. Natural gas consumption structure of Jiangsu in 2018.](image)

Natural gas resources are scarce in Jiangsu, and Jiangsu relies on pipeline gas transfer from other provinces and offshore LNG imports. Natural gas transferred from other provinces mainly comes from the West-to-East Gas Transmission and the Sichuan-to-East Gas Transmission, and Jiangsu is at the end of the pipeline. As shown in Figure 2, between 2015 and 2017, natural gas outflows from the West-East Gas Pipeline and Sichuan-East Gas Source (Xinjiang, Sichuan, and Chongqing) increased by 29.3 billion cubic meters, which has an average annual growth rate of 29%. However, natural gas received by Jiangsu increased by only 2.6 billion cubic meters, with an average annual growth rate of 9% during the same period [1,2,7]. The increase in the amount of external gas received by the pipeline in Jiangsu is much lower than the increase in the amount of gas delivered outside the production area, mainly due to the increase in natural gas consumption in various places along the way (Gansu, Ningxia, Shaanxi, Shanxi, Henan, Anhui, Hubei, Jiangxi and other provinces). Judging from the production of gas sources and the consumption of various places along the route, during the 15th Five-Year Plan period, there will be an inflection point in the pipeline gas supply. After that, the pipeline's natural gas intake will gradually decrease. To cope with this situation, Jiangsu should pay attention to the development of LNG. As of 2018, the total receiving capacity of all LNG receiving stations in Jiangsu Province was only 7.1 million tons. In order to improve the future natural gas supply guarantee capacity, LNG should be developed rapidly during the 14th Five-Year Plan period, and preliminary research needs to add more than 8 million tons of receiving capacity.

3.2. Encourage energy cascade utilization to achieve high-efficiency energy

Saving resources is one of China's basic national policy, and saving energy is an important social awareness in the world. Improving energy efficiency can save energy resources and is an important part of high-quality energy development. Cascade utilization is an effective method of efficient energy use. Cogeneration is a typical energy cascade utilization, and it can be used to replace industrial boilers especially in Jiangsu Province. Cogeneration units can be divided into gas-fired cogeneration and coal-fired cogeneration. It is estimated that the industrial boilers consumed approximately 4.5 billion cubic meters of natural gas in Jiangsu in 2018, and provided approximately 160 million mega joules of heat. Assuming using gas-fired combined heat and power units (parameter selection of thermoelectric units refer to reference [8, 9]) to replace these gas-fired boilers for industrial heating, it will consume about 10 billion cubic meters of natural gas and generate about 45 billion kilowatt-hours of electricity. According to the statistics of the China Electricity Council, the coal consumption for power supply in Jiangsu Province is 292.5 gce / kWh, and the line loss rate is 3.31% [5]. Using gas-fired cogeneration units in industrial parks instead of gas-fired boilers can reduce electricity purchases from the power grid by about 46 billion kilowatt-hours and reduce power generation coal by about 13.5 million tons of coal.
equivalent. After the replacement, the total energy consumption for heating and power generation decreased by approximately 6.2 million tons of standard coal, and the total carbon dioxide emissions decreased by approximately 25 million tons, as shown in Table 1.

Table 1. Comparison of energy consumption before and after the replacement of gas boilers by gas co-generators.

| Heating plan                     | Before replacement | After replacement |
|----------------------------------|--------------------|-------------------|
| Gas used by boilers / 100 Mm³    | 45                 | 0                 |
| Gas used by co-generators / 100 Mm³ | 0                  | 100               |
| Coal used by grid power generation / 10 ktce | 1350               | 0                 |
| Total energy consumption / 10 ktce | 1950               | 1330              |
| Total CO₂ Emission / 10 kt       | 4700               | 2200              |

3.3. Develop comprehensive energy service to achieve cost-effective energy

In August 2016, the State Council issued the “Work Plan for Reducing the Cost of Entity Economy Enterprises”, which took reducing the cost of energy used by enterprises as a key task of “cost reduction” reforms. Jiangsu has a well-developed entity economy. In order to promote the development of private enterprises, it is even more important to reduce their energy costs. Replacing coal with natural gas will increase fuel costs. In order to achieve the goal of reducing energy consumption costs in the context of rising fuel costs, reforms in systems and mechanisms are needed to rationalize the distribution of benefits in all aspects.

The development of comprehensive energy services in industrial parks[10] will be helpful to improve the economics of energy supply and reduce the cost of energy used by enterprises. The comprehensive energy service provider supplies multiple sources of energy such as electricity, gas, heat, and cold at the same time. It is suitable to use energy cascades such as cogeneration to improve energy efficiency and reduce fuel costs. Light industry is well-developed in Jiangsu. Taking the textile industry as an example, the thermoelectricity ratio of this industry is about 0.8[1]. Four energy supply methods to meet industrial heat demand and part of power demand are considered, including coal-fired boiler, gas-fired boiler, coal-fired back pressure, and gas-fired co-generator, and the remaining power demand could be satisfied by purchasing electricity from the grid. The comparison is shown in Table 2. According to the China Thermal Coal Price Index from the National Development and Reform Commission's Price Monitoring Center, the price of thermal coal of 5000 kcal / kg in Jiangsu is 536 yuan / ton[11], which is equivalent to 750 yuan / tce. A survey of an industrial park in Nanjing shows that the price of natural gas is about 2.4 yuan/cubic meter, and the price of electricity is about 0.61 yuan/kWh. The boiler operation cost refers to reference[12], and the cost of cogeneration operation is calculated based on actual project experience.

Table 2. Comparison of four energy supply plan.

| Energy supply plan                                  | Coal boiler | Gas boiler | Coal backpressure | Gas co-generator |
|-----------------------------------------------------|-------------|------------|-------------------|------------------|
| Heat demand / GJ                                     | 0.8         | 0.8        | 0                 | 0                |
| Electricity demand / kWh                             | 278         | 278        | 278               | 278              |
| Total energy consumption / kgce                       | 123         | 114        | 109               | 83               |
| Total CO₂ Emission / kg                              | 340         | 280        | 300               | 160              |
| Total cost / yuan                                    | 219         | 233        | 181               | 198              |
Total energy consumption (including fuel consumption and coal consumption for electricity purchase), total cost (including fuel cost, operating cost, and electricity purchase cost), total carbon dioxide emissions (including fuel emissions and coal consumption for electricity purchase) of the four heating schemes are compared in Figure 3 (relative value of 100% for coal-fired boilers). Replacing a coal-fired boiler with a gas-fired boiler can reduce the total energy consumption by about 7% and reduce the carbon emissions by about 17%, but it will increase the cost of energy by about 7% of the enterprise. Replacing a coal-fired boiler with a coal-fired back-pressure unit can reduce total energy consumption and carbon emissions by about 11%, while reducing the cost of energy used by enterprises by about 17%. Replacing a coal-fired boiler with a gas-fired cogeneration unit can reduce the total energy consumption by about 32% and reduce the carbon emissions by about 55%, while reducing the cost of energy used by enterprises by about 10% at the same time. Comprehensively considered, the gas-fired cogeneration scheme is better.

In addition, comprehensive energy service providers can also switch energy types according to the needs. Achieving multi-energy complementary coordination and optimization, and reduce costs are important goals[13]. And the comprehensive energy service provider collects energy costs uniformly, which reduces labour costs and time costs compared to traditional sub-sector charges, and also reduces energy supply costs.

4. Conclusion
This paper uses Jiangsu Province as an example, and focuses on the high-quality development of local energy. The current situation and characteristics of energy development in Jiangsu are analyzed. First, the energy consumption of Jiangsu is large and the economy scale is big. The energy supply should not affect the development of the entity economy development. Second, the energy consumption structure of Jiangsu Province is dominated by coal, which is determined by its industrial structure. It is necessary to adapt to the current situation of Jiangsu's high proportion of energy consumption coal, rather than force changing it. Third, the cleanliness of energy consumption in Jiangsu Province is already high, and the next stage should mainly focus on the low-carbon targets. Fourth, the energy resource endowment in Jiangsu Province is poor. It imports a large number of external energy and the prices are high, so it is even more important to save energy.

Therefore, some thinking of high-quality energy development in Jiangsu Province were put forward. First, multiple measures should be taken simultaneously to achieve low-carbon energy, and focus on both non-fossil and natural gas, and relies on both inside and outside the province. While fully tapping the potential of non-fossil energy in the province, consideration should also be given to transferring non-fossil power from outside the province. From the demand side, power generation and heat supply should be the main areas for natural gas to replace coal; and from the supply side, more LNG receiving stations should be built to ensure natural gas supply. Second, encourage energy cascade utilization to achieve high-efficiency energy. Cogeneration is an effective means of cascade utilization of energy and should
be supported. Using gas-fired cogeneration units to replace gas-fired boilers to supply energy to industrial parks has significant energy saving and emission reduction effects. Third, develop comprehensive energy service to achieve cost-effective energy. Reforming in the system can achieve the goal of reducing the cost of energy supply in the context of rising fuel costs. The results are also helpful for making energy development plans in other places.

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