Study of the Development of Low-Carbon Energy in Beijing

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Abstract. As in recent years Beijing has stuck to the new concept of development with the supply-side structural reform as the main thread, its socioeconomic growth has ushered in a new pattern revolving around the strategic positioning of the capital city. Meanwhile, the energy demand and supporting task of megacities have become more complicated and diverse and raised higher requirements for energy development. By drawing urban carbon emission charts, this article conducts an in-depth analysis of the carbon emissions of Beijing in 2017 largely in light of the supply side and the consumer end. The results show that total carbon emissions of Beijing are on the decrease, mainly because Beijing has continuously optimized its energy structure with a significantly increased proportion of clean energy, energetically developed renewable energies and continued to increase the rate of comprehensive energy utilization.

Keywords. Low-carbon energy; carbon flow diagram; energy consumption; carbon emission.

1. Introduction
The rapid growth of the global economy has a growing demand for energy. As the Paris Agreement was signed, various countries attach increasing importance to carbon emission reduction. For China, the largest energy producer and consumer in the world, how to make energy production and consumption low-carbon has become a problem that the government focuses on studying and solving. The coming years is a critical stage for the transformation of Chinese energy development and a crucial period concerning whether China can fulfill its commitment by 2030. Beijing, as the political, cultural, international exchange and technological innovation center in China, has grown economically rapidly in recent years, and its demand for energy continues to grow. While maintaining economic growth, Beijing had made a long-term commitment to energy conservation and emission reduction, the energy consumption of gross output value in “ten-thousand-yuan” areas experienced 5.4% average annual decline, ranking No. 1 in terms of energy conservation and emission reduction in the country, as Beijing leads the country in low-carbon energy has. However, one the one hand, the air quality issue in recent years has posed a more severe challenge to the energy development of Beijing; on the other hand, Beijing, as the capital of China, has the responsibility and obligation to set a higher low-carbon development goal. Thus, how to achieve low-carbon development of Beijing, guarantee energy security and supply and solve environmental problems brought by fossil energy consumption and reduce CO2 emissions become important research topics.

As for studies on low-carbon energy development, Chinese and foreign scholars perform studies mainly from the perspectives of energy efficiency, energy structure and carbon emission. Tian et al. [1] analyzed the current situation of green and low-carbon development in the Beijing-Tianjin-Hebei region, and proposed to increase the efficiency of energy utilization and set up an optimized green and
low-carbon energy supply system. Wang [2] argues that a low-carbon energy structure and a higher rate of energy utilization are the most critical factors for Beijing to achieve low-carbon development. Li and Xian [3] employed the grey system model to forecast and analyze carbon emissions of each industry in Beijing, and discussed the choice of low-carbon development path of Beijing. Besides, Li et al. [4] used carbon flow diagram to analyze the characteristics of the changes in Chinese carbon flow from 2008 to 2012, and proposed to customize carbon emission policies to different end consumers.

2. Formatting the Title, Authors and Affiliations

The calculation methods about carbon source and carbon sink in references were used to calculate carbon emissions produced by breathe carbon source [5], waste carbon source [6] and industrial product carbon source [7], and calculate carbon sinks of forest, grassland, cultivated land and wetland [8]. The calculation of the carbon emissions of fossil energy based on energy flow diagram [10, 11], and consulted the 2006 IPCC Guidelines for National Greenhouse Gas Inventories, primary energy carbon emissions can be figured out by multiplying different kinds of energy consumed by carbon emission coefficient. The coefficients of the carbon emissions of different kinds of energy are as shown in table 1. Based on the above calculation data, the carbon flow diagram could be drawn [12-14].

| Name of energy         | Carbon emission coefficient | Unit     |
|------------------------|----------------------------|----------|
| Raw coal               | 1.9003                     | kg-\text{CO}_2/kg |
| Coke                   | 2.864                      | kg-\text{CO}_2/kg |
| Crude oil              | 3.022                      | kg-\text{CO}_2/kg |
| Fuel oil               | 3.175                      | kg-\text{CO}_2/kg |
| Gasoline               | 2.926                      | kg-\text{CO}_2/kg |
| Kerosene               | 3.026                      | kg-\text{CO}_2/kg |
| Diesel oil             | 3.104                      | kg-\text{CO}_2/kg |
| Liquefied petroleum gas| 3.104                      | kg-\text{CO}_2/kg |
| Refinery dry gas       | 3.02                       | kg-\text{CO}_2/kg |
| Natural gas            | 2.164                      | kg-\text{CO}_2/m^3 |

3. Analysis of the Carbon Flow Diagram in 2017

The carbon flow diagram of Beijing in 2017 is shown as figure 1. In 2017, the total carbon sink of forest, grassland, cultivated land and wetland of Beijing reached 26.873 million tons, and is total carbon emissions was 151.89 million tons, among which primary energy carbon emissions was 133.96 million tons, net carbon emissions was 68.51 million tons.

In light of the supply side, the carbon emissions produced by coal, natural gas, and crude oil and its products were 46.3392 million, 35.6787 million and 51.9413 million tons, accounting for 30.51%, 23.49% and 34.20% of total carbon emissions respectively. Among them, coal and crude oil as well as its products were bigger carbon emitters, carbon emissions produced by natural gas was the least, the proportion of natural gas to the total carbon emissions was obviously lower than that of natural gas to energy consumption.

In light of end-use sector, transportation & warehousing and the service industry produce more carbon emissions, as they emitted 44.7608 million and 36.4563 million tons respectively, accounting for 29.47% and 24% of total emissions. In the transportation and warehousing sector, carbon emissions produced by crude oil and its products was 39.734 million tons, taking up 88.77% of the total carbon emissions of the whole sector. In the agriculture, construction and construction sector and the service industry, carbon emissions produced by coal were 13.929 and 23.259 million tons,
accounting for 45.80% and 63.80% of the carbon emissions of the whole sector respectively. In living consumption of residents, due to the differences in energy consumption structure, there were large rural-urban disparities in carbon emissions, as urban emissions was 17.4967 million and rural emissions was 4.8301 million tons. Furthermore, carbon emissions produced by natural gas were all from cities, and 2.283 million tons of carbon emissions produced by coal were from rural areas.

To sum up, it has continued to increase the consumption of natural gas, replace coal, crude oil and its products with clean energy in the agriculture, industry and construction sector and the service industry and the lives of rural residents, and implement targeted policies to reduce carbon emissions.

Figure 1. The carbon flow diagram of Beijing in 2017.

4. Low-Carbon Development of Beijing

Reviewing the development of energy economy of Beijing from 2009 to 2017, based on the analysis of carbon flow diagram data, this article discusses the low-carbon development of Beijing from three aspects, namely the structural adjustment of energy supply side, industrial structure optimization and carbon emission reduction.

4.1. Structural Adjustment of the Energy Supply Side

During “the 12th Five-Year Plan” period, Beijing energetically advanced coal reduction and the construction of clean energy facilities, and gasified four coal-fired thermal power plants in the city. In particular, after the State Council released Air Pollution Prevention and Control Action Plan in 2013, Beijing successively shut down Datang Gaojing, Jinneng Thermal Power and Shenhua Guohua Coal-fired Power Plant, carried out the project of “turning coal into clean energy”, successfully replaced scattered coal for civil use with clean energy, and the six districts and southern plain areas became basically “coal-free”. Meanwhile, projects such as distributed photovoltaic power generation, concentrated heating with ground source heat pump, electricity generation through waste incineration, and wind power and hydropower are constructed, and renewable energies are fully exploited and used. The energy composition of Beijing in 2009 is as shown in figure 2, 52.5% were coal products, 31.7%
were crude oil and other oil products, natural gas and renewable energy accounted for 12.9% and 2.9% respectively; in 2017, the proportion of coal products decreased by 26.8%, natural gas increased to 31.8%, crude oil and other oil products was 33.8%, and the proportion of renewable energy rose to 7.6%. The changes in the types of energy supplied from 2009 to 2017 are closely related to the supply structure adjustment of “coal reduction, gasification and using renewable energy”, and carbon emission reduction has achieved remarkable success.

![Figure 2. Energy structure chart of Beijing in 2009, 2013 and 2017.](image)

### 4.2. Industrial Structure Optimization

In recent years, Beijing vigorously transferred non-capital functions, sped up the construction of “cutting-edge” economic structure, changed from “pursuing growth by gathering resources” to “seeking growth by transferring functions”, constantly optimized its industrial structure, and upgraded and transformed end-use sector to achieve low carbon emission. Moreover, it has continued to advance the transformation and upgrade of agriculture, downsized the production of traditional agriculture, accelerated the growth of urban agriculture like sightseeing agriculture and folk tourism, and constantly increased the electrification level of agricultural production. Meanwhile, it controlled increments and transferred stocks, exercised strict control over entry barrier to industry; 1992 manufacturers and polluting enterprises were shut down and exited from 2013 to 2017, and a total of 594 specialized markets and logistics centers were evacuated. Meanwhile, the transfer of public services like education and health care was advanced in an orderly manner. Besides, Beijing also energetically grew the new generation of information technology, integrated circuit, new materials and other cutting-edge industries to drive clean energy consumption.

In 2009, 49.46 million tons of standard coal were consumed by various end-use industries, agriculture, industry and the building industry accounted for 36.89%, the service industry 21.64%, transportation and warehousing 29.50%, urban residents 8.22%, rural residents 3.75%; in 2017, the consumption of standard coal increased to 52.76 million tons, agriculture, industry and the building industry decreased to 20.93%, the service industry grew to 23.45%, transportation and warehousing increased to 38.91%, urban residents rose to 12.79%, rural residents increased to 3.92%. The decrement and intensive socio-economic development have yielded significant results, energy consumed by agriculture, industry and the building industry decreased quickly, transportation & warehousing and the service industry became two big energy consumers.

In terms of the energy consumption of various end-use industries, the energy structure of agriculture, industry and the building industry has changed from traditional coal to clean energy featuring gas and electricity, the proportion of coal consumption decreased from 34.1% in 2009 to 4.9% in 2017, and electricity and oil products were main energies for final consumption. A higher level of agricultural electrification and the intensive development of cutting-edge industries are the main reasons behind the rapid optimization of the energy structure. In the energy structure of the service industry, natural gas and electricity occupy the highest proportions, as the service industry was transformed and upgraded and increased the proportion of clean energy, as a result, the proportion of
energy consumed by coal production only took up 0.2% in 2017 and the proportion of electricity consumption rose quickly. Over 90% of energy for transportation and warehousing were from crude oil and oil products. In 2017, as the capacity of major airlines like Air China and Capital Airlines increased, energy consumption of air transportation grew rapidly, and energy consumption of transportation and warehousing increased by 28.95% than 2009. Energy consumed by residents has experienced rapid growth. Main energies consumed are natural gas, heat and electric power, as rural residents still take coal as primary energy for consumption. As Beijing implemented the policy of “turning coal into gas”, the proportion of natural gas rose, and it should start to use clean energy like biomass and natural gas to completely replace coal in the future.

4.3. Carbon Emission Reduction

Figure 3 shows that the total carbon emissions of Beijing in 2017 was 151.89 million tons, and the total carbon emissions achieved negative growth with the average annual growth rate of -0.9% under pressure from the growth of both energy consumption and GDP. If only net carbon emission is taken into account, then the decline will be greater and the average annual decline will be 4.5%.

In terms of the types of energy emitting carbon dioxide, 90% of carbon emissions of Beijing were produced by primary energy consumption. In 2017, natural gas consumption accounted for 31.81% of the total consumption, but the carbon emissions of natural gas accounted for 23.5% of the total carbon emissions, while primary energy carbon emissions took up 26%. In 2017, Beijing’s electricity output and heat output both increased when compared with that in 2009, yet carbon emissions produced decreased accordingly, mainly because the consumption proportion of natural gas rose markedly, which indicates that energetically developing natural gas plays an important role in low carbon emission reduction.

In terms of end-use carbon emission sector, the biggest carbon emitters in 2009 were agriculture, industry and the building industry, the biggest carbon emitter in 2013 was the service industry, and transportation and warehousing was the biggest carbon emitter in 2017. The primary reason behind the changes is that power consumption occupied the highest proportion in the energy structure of the service industry, and generating the same amount of electricity need to consume primary energy twice over, so the higher the proportion of electricity, the bigger the numerical value of carbon emissions, as a result, the service industry was the largest carbon emitter in 2013. On the other hand, from 2013 to 2017, Beijing transformed power plants through gasification, more use of natural gas made electricity-
induced carbon emissions decrease, and lowered the overall carbon emissions of the service industry, so the changes in carbon emissions of end-use sector is closely bound up with the path of the adjustment of energy structure.

5. Conclusions
On the whole, the industrial structure of Beijing is dominated by the tertiary industry, natural gas has become the second largest energy consumer, and the proportion of consumption also rises year by year. Transportation & warehousing and the service industry are big carbon emitters. Constantly optimizing industrial structure and energy consumption structure is essential for Beijing to reduce carbon emissions. From 2009 to 2017, Beijing adopted compressed coal and coal products, increased the supply of clean energy, and achieved low-carbon development and carbon emission reduction from the source of the supply side. Besides, it continued to optimize the industrial structure, promote the growth of “cutting-edge” industries, and curtail carbon emissions of the three main industries. Meanwhile, it continued to increase the efficiency of energy utilization, reduced energy consumption per unit, and achieved low carbon emission.

Moreover, it continued to advance the supply of clean energy and tapped into the potential of the utilization of renewable energies. Currently, Beijing increases the proportion of natural gas and electricity, continues to innovate the energy management model, and increases the efficiency of energy conversion. With “Internet+” technique, Beijing promoted traditional energy and renewable energy, distributed energy and city heat supply system, and integrative development of power grid. In addition, it has developed the intelligent management model of the supply side and demand side of energy, advanced the integration and complementation between central urban areas and neighboring areas of Beijing in energy use, and achieved informatization, refinement and intelligentization of the energy management system.

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